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Technical Writer Review:		
Name: H van Graan		Date: 30/03/2026
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Name: B Engelsman		Date: 30/03/2026
Eskom NSS Technical Lead Acceptance:		
Name: M van Zyl		Date: 2026-03-31
Eskom NSS Employer's Agent Acceptance:		31-03-2026
Name: I Sekoko		Date:

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AMENDMENT RECORD			
Rev	**Draft**	**Date**	**Description**
0		April 2015	New section. Thyspunt Site Safety Report compiled in support of Eskom's Nuclear Installation Site Licence for the Thyspunt site.
0a		January 2025	Section updated to address NNR and Eskom comments.
0b		March 2026	Section updated to correct minor editorial issues.

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Executive Summary

The site was first identified as a potential site for establishment of a nuclear installation(s) in the 1980s and limited geohydrological site work in the form of, *inter alia*, drilling and yield testing was carried out by the Atomic Energy Corporation of South Africa Ltd. Although providing useful background information, this work was not of sufficient detail to compile this Site Safety Report (SSR) and so an additional comprehensive desk study, fieldwork programme, data analysis and ongoing monitoring covering geohydrology was implemented by Eskom Holdings in October 2007. This culminated in the submission of Rev 0 of the Thyspunt SSR (TSSR) in 2015. In line with the requirements of the National Nuclear Regulator (NNR), SSRs must be regularly updated and this revision contains the latest monitoring, hydrocensus and climatic data and also addresses NNR comments on Rev 0.

The purpose of ***Section 5.11*** is to present the baseline geohydrological characteristics of the site and surrounding area (mainly quaternary catchment K80F and the adjacent parts of K90E and K90D) in order to investigate the acceptability of the site for the safety of a nuclear installation(s), through all stages of its development. This was done through a combination of the following activities:

- review of available information;
- hydrocensuses within a 5 km radius of the site in 2007, 2017 and 2024;
- surface geophysics to assist with borehole siting;
- drilling of 38 new boreholes and equipping as monitoring wells;
- yield and packer testing to obtain hydraulic parameters;
- formulation of a conceptual model and then numerical flow modelling, including predicting scenarios such as dewatering requirements, groundwater supply, water level response to climatic extremes and sea level rise.
- ongoing groundwater level and quality monitoring.

Based on the results and knowledge gained to date, the following key conclusions are drawn (with reference to the site unless otherwise stated):

- There are two aquifers present, the upper intergranular Algoa Aquifer and the underlying fractured-rock Table Mountain Group (TMG) Aquifer. The former is a major aquifer and has a basal, discontinuous cobble layer up to 6 m thick that is highly transmissive.

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- Groundwater levels are relatively shallow in the illustrative footprint areas, i.e. 4.8 to 10.2 m bgl, being deeper in some elevated dune areas further inland, i.e. 21.55 to 22.45 m bgl;

- Groundwater flow is generally in a southerly to southeasterly direction towards the Indian Ocean.

- High rainfall events show insignificant and delayed effects on groundwater levels due to overflow into wetlands, the highly absorptive capacity of the Algoa Aquifer sands and efficient drainage properties of the underlying cobble layer.

- The extremely wet year of 2012 resulted in groundwater levels in the monitoring boreholes reaching their highest levels since commencement of monitoring in February 2008 up until February 2024. Groundwater levels measured in 2012 at Algoa Aquifer monitoring boreholes ranges from 0.25 m bgl at THY-MR15 to 21.35 m bgl at THY-MR5. At Algoa Aquifer monitoring boreholes closest to the Nuclear-1 footprint groundwater levels in 2012 ranged from 2.22 m bgl at THY-MR11 to 21.35 m bgl at THY-MR5.

- Similarly, during 2012 highest groundwater levels measured in the TMG Aquifer monitoring boreholes ranged from 0.16 m bgl at THY-RP1 to 13.53 m bgl at THY-RP5-M1. At TMG Aquifer monitoring boreholes near the Nuclear-1 footprint 2012 groundwater levels ranged from 4.28 m bgl at THY-RP12 to 6.80 m bgl at THY-RP11, whilst at THY-RP9 close to the coast the 2012 groundwater level was 2.93 m bgl.

- The 2017-2018 “extremely dry” years resulted in a groundwater level decline of *c*.6.2 to *c*.7.7 m at Algoa Aquifer monitoring boreholes equipped with data recorders and are located inland from the coast and footprint. At Algoa Aquifer monitoring boreholes equipped with data recorders nearer to the coast and the Langefonteinvlei, the groundwater level decline ranges from *c*.1.1 to *c*.5.0 m.

- At inland TMG Aquifer monitoring boreholes equipped with data recorders the “extremely dry” groundwater level decline ranges from *c*.2.2 to *c*.10.2 m, whilst at those near the coast the decline ranges from *c*.1.9 to *c*.3.9 m.

- Groundwater quality is moderate to good with electrical conductivity mostly below 150 mS/m and the groundwater is slightly acidic to alkaline and of a mixed NaCl and $Ca(HCO_3)_2$ type. Provision for corrosion resistant materials should be made for all subsurface installations.

- Extensive use is made of groundwater in the region, with the towns of Oyster Bay, Humansdorp and St. Francis Bay all being supplied from this resource.

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- Numerical flow simulation of the site water balance indicates that approximately 30 ℓ/s could be abstracted from the combined site aquifers for supply during initial construction activities prior to commissioning of a desalination plant. This assumes “dry” climatic conditions.

- The thick saturated and unconsolidated sediments of the Algoa Aquifer will require dewatering prior to excavations for nuclear installation foundations.

- Estimates for potential inflows to a nuclear installation excavation of 20 m depth for the illustrative footprint varies from 21 ℓ/s to 25 ℓ/s, the latter taking into account the effects of sea level rise by 2134. However, it is likely that construction will take place closer to 2034 than 2134 and so *c*.22 ℓ/s is the more likely value. Experience indicates that actual volumes required to be pumped for dewatering could be about 30 per cent higher, but still within an easily manageable range.

- Numerical model simulation of a 1.76 m to 3.28 m (2134) rise in sea level indicates a 0.8 m rise in groundwater level to a maximum distance of 350 m inland. This rise can be managed using appropriate groundwater control measures and poses no additional significant risk to a nuclear installation(s).

- Contaminant transport modelling indicates that a liquid leak from the nuclear installation would be confined to the Nuclear-1 footprint. Groundwater monitoring would detect such an event and remedial action would be taken to contain contamination.

- Groundwater level and quality monitoring since mid-2008 has not shown any concerning or anomalous trends that could affect nuclear safety, apart from the need to allow for corrosive conditions below the water table.

Although the investigation and monitoring period has been relatively short, the conceptual and numerical models are considered robust and adequate to provide a realistic representation of geohydrological conditions at the site. There are therefore no significant uncertainties in this respect. Monitoring will continue and the numerical flow model will be updated if new data indicate significant deviations from established trends. With respect to geohydrology, the site is therefore considered to be suitable for safe establishment of a nuclear installation(s).

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5.11 GEOHYDROLOGY

5.11.1 Introduction

The site was first identified as a potential site for establishment of a nuclear installation(s) in the 1980s (Atomic Energy Corporation, 1986) and limited geohydrological site work in the form of, *inter alia*, drilling and yield testing was carried out by the Atomic Energy Corporation (AEC) of South Africa Ltd. Although providing useful background information, this work was not of sufficient detail to compile this Site Safety Report (SSR) and so an additional comprehensive desk study, fieldwork programme, data analysis and ongoing monitoring covering geohydrology was implemented by Eskom Holdings (further referred to as Eskom) in October 2007. This culminated in the submission of Rev 0 of the Thyspunt SSR (TSSR) in 2015. In line with the requirements of the National Nuclear Regulator (NNR) (Department of Energy, 2011), SSRs must be regularly updated and this revision contains the latest monitoring, hydrocensus and climatic data and also addresses NNR comments on Rev 0. The numerical modelling scenarios have also been updated.

Drawing 5.11.1 shows the site boundaries, enveloping footprint and Nuclear-1 footprint (see ***Chapter 3***, Overview of Planned Activities) in the context of the local and regional physiographic setting, including quaternary catchments. The Nuclear-1 footprint represents the probable site for the nuclear terrace where the nuclear reactors and main auxiliary buildings would be situated. The viewpoints for photographs illustrating aspects of the site are also shown.

The results of the meteorological (see ***Section 5.8***, Meteorology), hydrological (see ***Section 5.10***, Hydrology and Hydraulics), geological (see ***Section 5.13***, Geology) and geotechnical (see ***Section 5.15***, Geotechnical Characterisation) studies were also taken into consideration in the preparation of this section. Close liaison was maintained with the specialists carrying out these parallel studies to ensure commonality of approach and data use where appropriate, to avoid duplication of work and ensure agreement on areas of joint interest, e.g. borehole siting.

5.11.2 Purpose and Scope

The purpose of ***Section 5.11*** is to present the baseline geohydrological characteristics of the site and surrounding area (mainly quaternary catchment K80F and the adjacent parts of K90E and K90D) in order to

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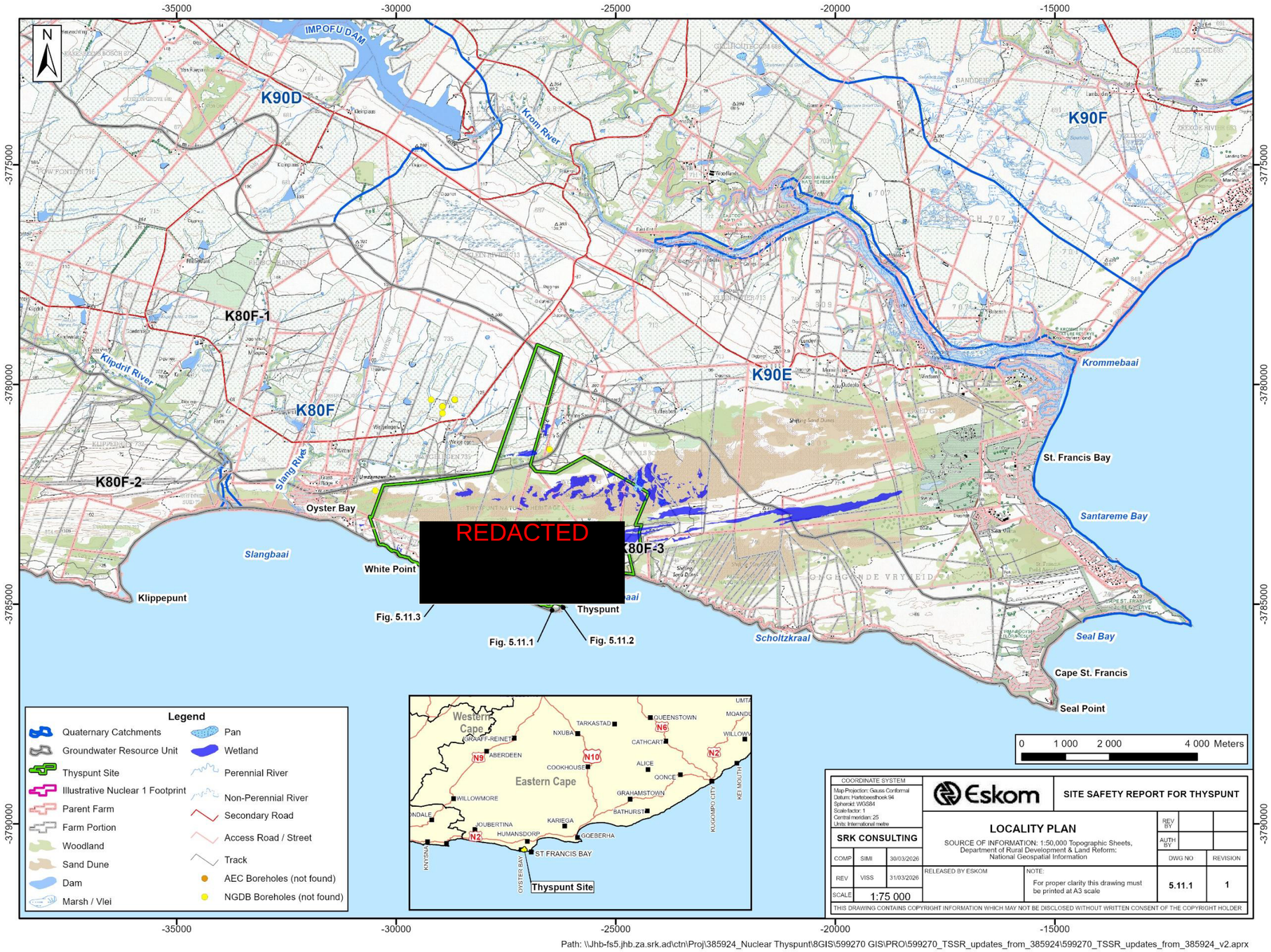
investigate the acceptability of the site for the safety of a nuclear installation(s), through all stages of its development. This is done through detailed data analysis and numerical groundwater flow modelling, including scenario modelling, e.g. of foundation dewatering. More specifically this section of this SSR presents:

- aquifers and their hydraulic properties;
- groundwater flow paths;
- groundwater levels and fluctuations;
- ambient groundwater quality;
- existing groundwater use;
- conceptual groundwater control requirements for the construction and operational phases;
- modelled future changes in the baseline geohydrological system with climate change, including definition of “wet” and “dry” periods, extreme rainfall and predicted sea level rise;
- ongoing and future monitoring requirements and measures;
- management of any uncertainties.

The activities carried out as part of the evaluation of the site and the results achieved are presented in detail in the appendices to this section. These appendices provide the quality assurance record for key decisions and methodologies used and provide the back-up for the data presented herein. The investigation was carried out at the subregional (quaternary catchment) and site-specific scale, as described in more detail below.

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5.11.3 Regulatory Framework

The only national regulations specifically relevant to a geohydrological investigation for an SSR are The Regulations on Licensing of Sites for New Nuclear Installations (National Nuclear Regulator, 2006). However, geohydrology/groundwater are not specifically mentioned, and the relevance of these regulations is in the use of data from ***Section 5.11*** to inform sections of ***Chapter 6*** (Evaluation of External Events) and ***Chapter 7*** (Potential Radiological Impact on the Public and the Environment).

5.11.4 Requirements Documents and Guidelines

The above regulations are not specific in terms of geohydrology and so the references listed below were used to guide the site investigation in terms of the scope of work required:

National and International

- RG-0011: Interim Guide for the Siting of Nuclear Facilities, Rev 0 (Regulator, 2016)
- RG-0016: Guidance on the Verification and Validation of Evaluation and Calculation Models used in Safety and Design Analyses (National Nuclear Regulator, 2016);
- Eskom's Technical Specification for Site Safety Reports, NSIP01388 (Rev 2). Section 5.11: Geohydrology (Eskom, 2022); This document incorporates guidelines and safety requirements of the International Atomic Energy Agency and United States Nuclear Regulatory Commission, as listed below, but these references are not cited again herein;
- United States Nuclear Regulatory Commission (US NRC), NUREG-0800, Section 2.4.12 Groundwater. Rev 3 (United States Nuclear Regulatory Commission, 2007);
- US NRC, Regulatory Guide 1.132, Site Investigations for Nuclear Power Plants, Rev 2 (United States Nuclear Regulatory Commission, 2003);
- International Atomic Energy Agency (IAEA) Safety Guide No. NS-G-3.6, Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants (International Atomic Energy Agency, 2004);
- IAEA Safety Standard Series Report, Specific Safety Requirements No.

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SSR-1, Site Evaluation for Nuclear Installations (International Atomic Energy Agency, 2019);

- IAEA Safety Guide No. NS-G-3-2, Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluations for Nuclear Power Plants (International Atomic Energy Agency, 2002). Sections 3.7 to 3.11 deal with surface and groundwater monitoring and sections 3.24 to 3.39 deal with groundwater considerations or data required to classify the groundwater regime.

5.11.5 Approach to Evaluation

The approach to the investigation followed the requirements set out in Section 5.11 of Eskom's Technical Specification for SSRs (Eskom, 2022), viz:

- **Desk study**: detailed review and collation of available information (see list of references); interpretation of air photographs and satellite imagery; georeferencing of data; liaison with geotechnical and geology/seismic consultants; site reconnaissance; selection of provisional exploratory borehole sites; liaison with Eskom Nuclear Sites Team; formulation of Project Quality Plan, Risk Assessment, Health and Safety Plan, Method Statement, Quality Control Plan and client approval thereof; drawing-up tenders for drilling, test pumping and packer testing, advertising, adjudication and award; appointment of a health and safety consultant to oversee the safe execution of site work;

- **Field work**: hydrocensuses in 2007, 2017 and 2024; selection and verification of new borehole sites in consultation with Eskom and the geological, seismic and geotechnical specialists; selection and verification of drilling techniques; drilling of exploratory/test/monitoring boreholes; down-hole camera surveys; test pumping; packer testing; tracer tests (where suitable conditions exist); chemical, isotope and radiological analysis of water samples; sorption tests on soil samples; set-up and servicing of a monitoring network;

- **Data analysis**: determination of aquifer parameters; input of all data into a geographical information system (GIS), construction of 3D and 2D conceptual geohydrological models; selection of a suitable software code for numerical modelling; numerical flow and scenario modelling, including climatic extremes.

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- **Reporting**: writing this section of this SSR[1].

This investigation comprised:

- review of available information (see list of references) and in particular reports, maps and data of the AEC (relevant data are incorporated into this SSR section), Council for Geoscience (CGS) and the Department of Water Affairs and Forestry[2] (DWAF), e.g. hydrogeological map and borehole information from the National Groundwater Archive (NGA) (see ***Appendix 5.11.A***);

- field surveys in late 2007, August 2017 and February 2024 of all accessible boreholes and springs within a 5 km radius of the site centroid (see ***Drawing 5.11.3*** and ***Appendix 5.11.B***) - Boreholes from the AEC investigation (Atomic Energy Corporation, 1986) could not be located in the field due mainly to burial by mobile sand dunes and growth of dense vegetation.

- surface geophysics, site reconnaissance and discussions with the CGS, SSR geotechnical consultants and Eskom Nuclear Sites in support of the location of exploratory, test and monitoring boreholes (see ***Appendix 5.11.C***) - The heterogeneous nature of the geological formations/aquifers meant that the use of a computer programme to aid in the siting of boreholes was inappropriate.

- drilling of 38 new boreholes within the site boundaries, concentrating on the enveloping footprint area[3] and two illustrative nuclear footprint areas close to the coastline, as originally provided by Eskom (see ***Drawing 5.11.3*** and ***Appendix 5.11.D***) - Boreholes drilled by the mud-rotary method (generally used for unconsolidated sand profiles) are labelled THY-MR1, 2 etc. and those drilled by the rotary percussion method (usually used for hard-rock profiles) are labelled THY-RP1, 2 etc. The extensive drilling programme carried out for the geotechnical investigation (see ***Section 5.15***) was also taken into account.

[1] This SSR was developed with the data available up until February 2024. SSR borehole monitoring was stopped in May 2009 and was re-initiated in April 2011, whereafter it continued until September 2013, when it was stopped again. Borehole monitoring was again re-initiated in August 2017 until January 2019 when it was stopped until the latest monitoring re-initiated in December 2023. The latest monitoring data have been included in this update of this SSR.

[2] DWAF is used for references up to 2009 after which the department was renamed the Department of Water Affairs – DWA and since May 2014 has been known as the Department of Water and Sanitation - DWS

[3] Provisional area where the nuclear installation(s) and auxiliary infrastructure are likely to be located. Initially, two illustrative footprints were provided by Eskom, however, for this update of the TSSR Eskom provided one.

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- implementation of a testing programme including yield tests, down-hole camera survey, packer testing and one tracer test on selected exploratory boreholes to obtain information on aquifer hydraulic properties of the site (see ***Appendix 5.11.E***);

- laboratory testing[4], including macro, trace, isotope[5] and radionuclide analyses to determine chemical, age and origin characteristics of the groundwater in the hydrocensus and exploratory boreholes (see ***Appendices 5.11.F***, ***5.11.G*** and ***5.11.H***);

- adsorption testing, to determine the partition coefficient of certain radionuclide species within the Algoa Aquifer calcareous sands at different pH values to give an indication of retardation of such species within the aquifer (see ***Appendix 5.11.I***);

- numerical flow modelling to simulate scenarios such as dewatering of the nuclear installation foundations and groundwater control measures (see ***Appendix 5.11.J***), including under climatic extremes and predicted sea level rise;

- initial (for this SSR) and ongoing monitoring programme to provide baseline groundwater level and quality data (see ***Appendices 5.11.F***, ***5.11.G*** and ***5.11.H***).

The results of the above activities were used for numerical flow modelling to simulate scenarios such as dewatering of the nuclear installation foundations, fluctuations in groundwater levels and groundwater control measures (see ***Appendix 5.11.J***). These are the key site nuclear safety issues from a geohydrological perspective. The main sources of information used in compilation of this section are referenced in the text and listed under ***Subsection 5.11.12***. The geohydrology is first discussed at the regional scale and then the site-specific scale.

5.11.6 Regional Geohydrology

5.11.6.1 Geology

The geology of the area is shown in ***Drawing 5.11.2*** and incorporates input from SSR ***Section 5.13***.

The site and surrounding catchments are underlain by rocks of the Table

[4] Monitoring data up until February 2024 included in the Appendices.

[5] Isotope monitoring only conducted on samples collected during the 2007 hydrocensus.

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Mountain Group (TMG) and Bokkeveld Group (Geological Survey of South Africa, 1991), with varying cover of younger mostly unconsolidated sediments of the Algoa Group. The site itself is underlain by quartzitic sandstone and subordinate siltstone and shale of the Skurweberg and Goudini formations (Nardouw Subgroup) of the TMG with outcrops of hard grey quartzitic sandstone with interbedded black siltstone (see ***Figure 5.11.1***) along the coast. These rocks have been eroded to form a wave-cut platform. The harder quartzitic sandstones of the Peninsula Formation occur in the northern part of the site, separated from the Nardouw Subgroup by black carbonaceous shales of the Cedarberg Formation. This is a thin marker bed, the hydrogeological significance of which is discussed in ***Subsection 5.11.6.2***.

The Algoa Group, which comprises the Nanaga and Alexandria formations, occurs from west of Oyster Bay along the coast and then northeast towards Jeffreys Bay (see ***Drawing 5.11.2***). The Nanaga Formation is composed of partly to wholly consolidated aeolian sand or aeolianite dune rock, which is calcareous due to the presence of numerous shell fragments. The Nanaga sands are white to yellow in colour; fine to medium grained and can reach thicknesses of up to 250 m in the region. The Nanaga sands are partly consolidated and contain lenses and beds of calcrete.

The basal Alexandria Formation comprises a coarse conglomerate of pebbles/cobbles, shell fragments and sand and is up to 6 m in thickness, but discontinuous. Mobile aeolian sand dunes occur along the coastline between the site and Sea Vista as far as 4 km inland. The dune orientation is slightly north of east-west. These Tertiary and Quaternary-age deposits unconformably overlie the Bokkeveld and TMG rocks.

The more resistant sandstones form rocky promontories interspersed with sandy beaches where less resistant rocks have been eroded away. ***Figure 5.11.2*** shows part of the Thyspunt promontory looking towards the sandy beach of Thysbaai. A similar scene is shown in ***Figure 5.11.3***, a view from White Point looking southeast and showing the wave-cut platform in the foreground and vegetated dunes in the background.

Regionally, the Bokkeveld and TMG rocks strike in a northwest to southeast direction and show well developed smaller folds along the outer limbs of the large-scale open anticlinal and synclinal folds. An anticline occurs in the Peninsula Formation between the Kouga River and the site and a syncline occurs just offshore and to the south of the site. Several extensive faults occur to the south, east and west of the site. Other smaller-scale faults, approximately north-south striking, occur at irregular intervals, e.g.:

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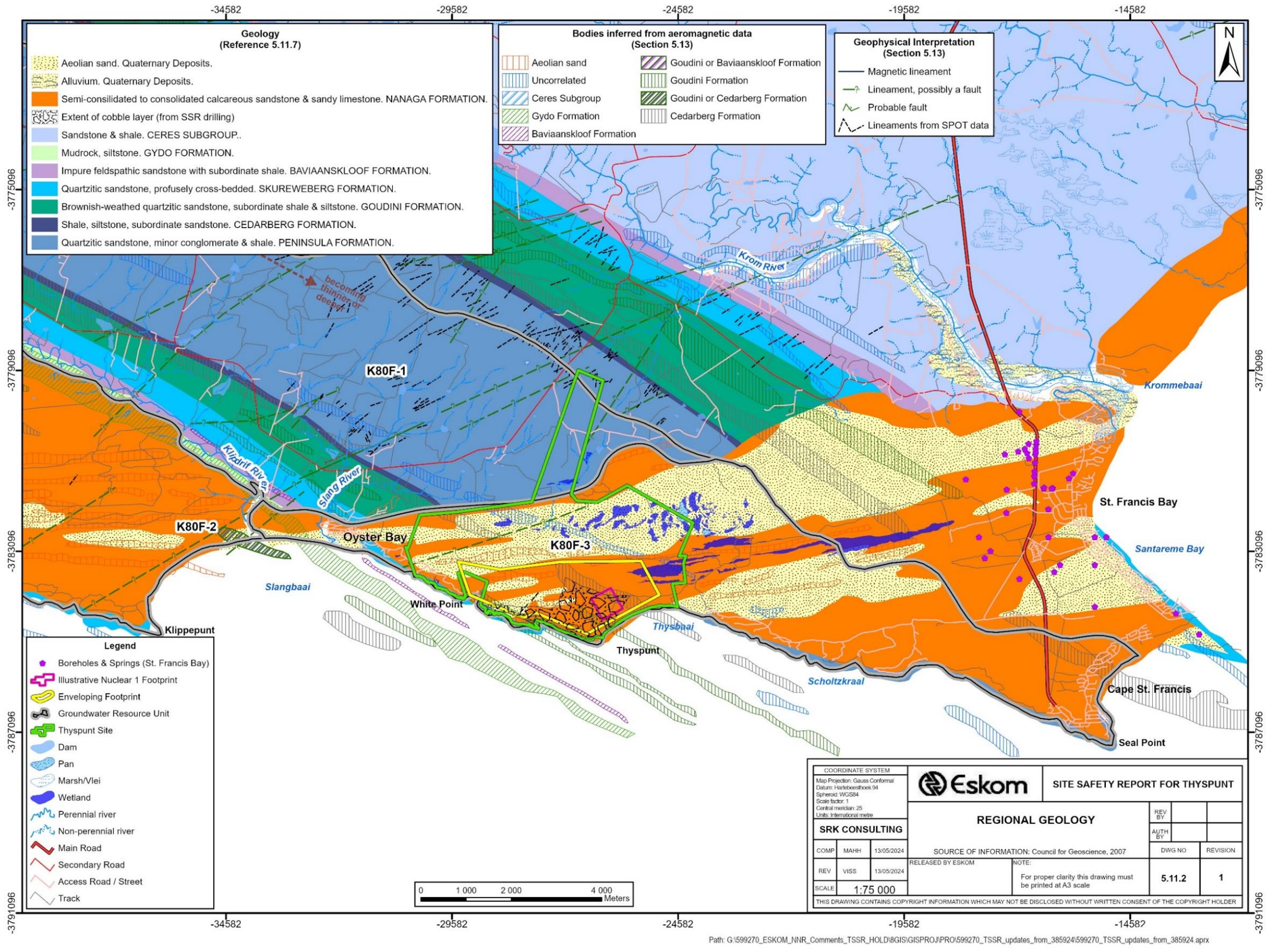
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- to the southeast – 1 km from Cape St. Francis at De Hoek (De Hoek Fault);
- to the west – Tony's Bay, Klipdrif and Morgans Bay faults.

A detailed description of the geology of the site and surrounding area is presented in ***Section 5.13***.

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Figure 5.11.1
Interbedded Siltstone Horizon on Thyspunt Beach

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Figure 5.11.2
View of Thysbaai from Thyspunt, Facing East



Figure 5.11.3
View from near White Point, Facing Southeast

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5.11.6.2 Aquifer Types

The bedrock mainly consists of TMG sandstones which can be classified as secondary or fractured-rock type aquifers. Groundwater flow and storage takes place within secondary openings in the rocks formed by joints, faults and fractures. For the purpose of this SSR, the secondary aquifer associated with these rocks is called the TMG Aquifer. The Bokkeveld Group rocks are essentially non-aquifers in the study area. The bedrock is covered by superficial deposits of varying thickness and lithology.

The superficial deposits of the Algoa Group are classified as a primary or intergranular aquifer. Groundwater flow and storage takes place within the original pore spaces between constituent grains. The upper boundary of the aquifer is the water table and these aquifers are therefore unconfined. For the purpose of this SSR, the primary aquifer is called the Algoa Aquifer.

The groundwater regime surrounding the site as of 1998 is detailed in the DWAF 1:500 000 scale Hydrogeological[6] Map (Meyer, et al., 1998) and accompanying booklet (Meyer, P S, 1998) . The DWAF aquifer classification is shown in ***Drawing 5.11.4***. It should be noted that this drawing indicates the surficial occurrence of these aquifers; The TMG Aquifer extends beneath the Algoa Aquifer to the coastline and beyond. The regional information obtained from the DWAF map has subsequently been updated and more specific information added to this SSR as a result of the site geohydrological and geotechnical drilling programmes implemented from late-2007 to mid-2008, and early-2010. An example of this is the generally higher yields obtained from the SSR boreholes (e.g. see ***Table 5.11.8***) than indicated by the regional aquifer classification in the Hydrogeological Map Series 3324 Port Elizabeth (Meyer, et al., 1998) as shown in ***Drawing 5.11.4***.

On the basis of the review of available information (main references as given above and in the following subsections), and additional work carried out for this SSR, the following regional characteristics pertain to the fractured rock aquifer associated with the TMG:

- A network of joints and fractures control the infiltration, recharge, storage and movement of groundwater in the competent and brittle TMG, with deep fracture extensions providing for deep groundwater circulation.

- Groundwater levels in the TMG Aquifer are between approximately 0+

[6] DWAF terminology – hydrogeology and geohydrology are broadly equivalent terms.

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(artesian) at the coast to 14 m below ground level (m bgl) to the north of the site.

- Average sustainable borehole yields range from 0.5 to 2 ℓ/s, but higher yields, of >5 ℓ/s, can be obtained from discrete fractures.
- Springs are common in the TMG and are fault or lithologically controlled by impeding layers, such as shales/siltstones of the Cedarberg Formation and possibly such layers within the Nardouw Subgroup.
- Springs are also common along the coast and occur from the base of the Algoa Formation, above the TMG, where the groundwater flows into the ocean.
- Recharge occurs in relatively high rainfall areas located at higher elevations of exposed rock to the northwest, the Kareedouw Mountains, where between 9 to 12 per cent infiltration of precipitation is estimated to occur (this study), but higher recharge rates are possible, especially in the areas of TMG exposure in the mountains to the northwest of the site. This recharge enters the site area via throughflow along the northwest-southeast strike of the TMG rocks.
- On a regional scale, this aquifer is classified as a minor aquifer of moderate vulnerability (Parsons, 1995).
- Groundwater flow direction is predominantly to the south and east, with flow from higher elevation and discharging into the Indian Ocean.
- Groundwater flow from higher elevations around the Krom River occurs towards the river, then southeast towards the ocean.

On the basis of the DWAF information and this SSR work the following regional characteristics pertain to the Algoa Aquifer:

- The Algoa Group is classified as a major aquifer of high vulnerability (Parsons, 1995).
- Groundwater flow occurs mainly in the basal Alexandria Formation conglomerate which shows variable thickness (up to 6 m) and is discontinuous.
- Groundwater storage occurs mainly in the sands and aeolianite, with saturated thickness of up to 21 m in the areas covered by this SSR drilling.

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- Recharge percolates rapidly through the highly porous, fine sandy and calcareous material to the base of the Algoa Aquifer, where rapid flow occurs in the basal conglomerate, which acts as a drain, and along the contact with the underlying TMG rocks (Meyer, P S, 1998). The groundwater emerges as seeps or commonly occurring springs at sea-level and from within the dune fields.

- A series of wetlands occurs in the eastern parts of the site which are in hydraulic connectivity with the Algoa Aquifer.

- Build-up of groundwater levels is unlikely to occur because of the high porosity and hydraulic conductivity of the above formations and overflow into the wetlands.

- Groundwater flow direction is to the south with discharge along the beaches and rocky outcrop into the ocean and to the southeast into the Sand River Aquifer. Some localised groundwater flow also occurs in westerly and easterly directions, possibly along channels between the dunes with subsequent southerly flow towards the ocean.

- Borehole yields are typically <0.5 ℓ/s and groundwater levels at between 2 and 25 m bgl. However, borehole yields from the basal conglomerate can be in the order of 10 to 15 ℓ/s.

5.11.6.3 Regional Groundwater Recharge

The study area was evaluated by subdividing it into Groundwater Resource Units (GRUs) based on geological and geohydrological considerations (see ***Drawing 5.11.4***). These units represent areas where the broad geohydrological characteristics, i.e. groundwater occurrence and quality, hydraulic properties, flow regime and aquifer boundary conditions, are considered to be similar. Three such GRUs have thus been delineated, viz:

- K80F-1: TMG Aquifer only;

- K80F-2: Algoa Aquifer overlying TMG Aquifer;

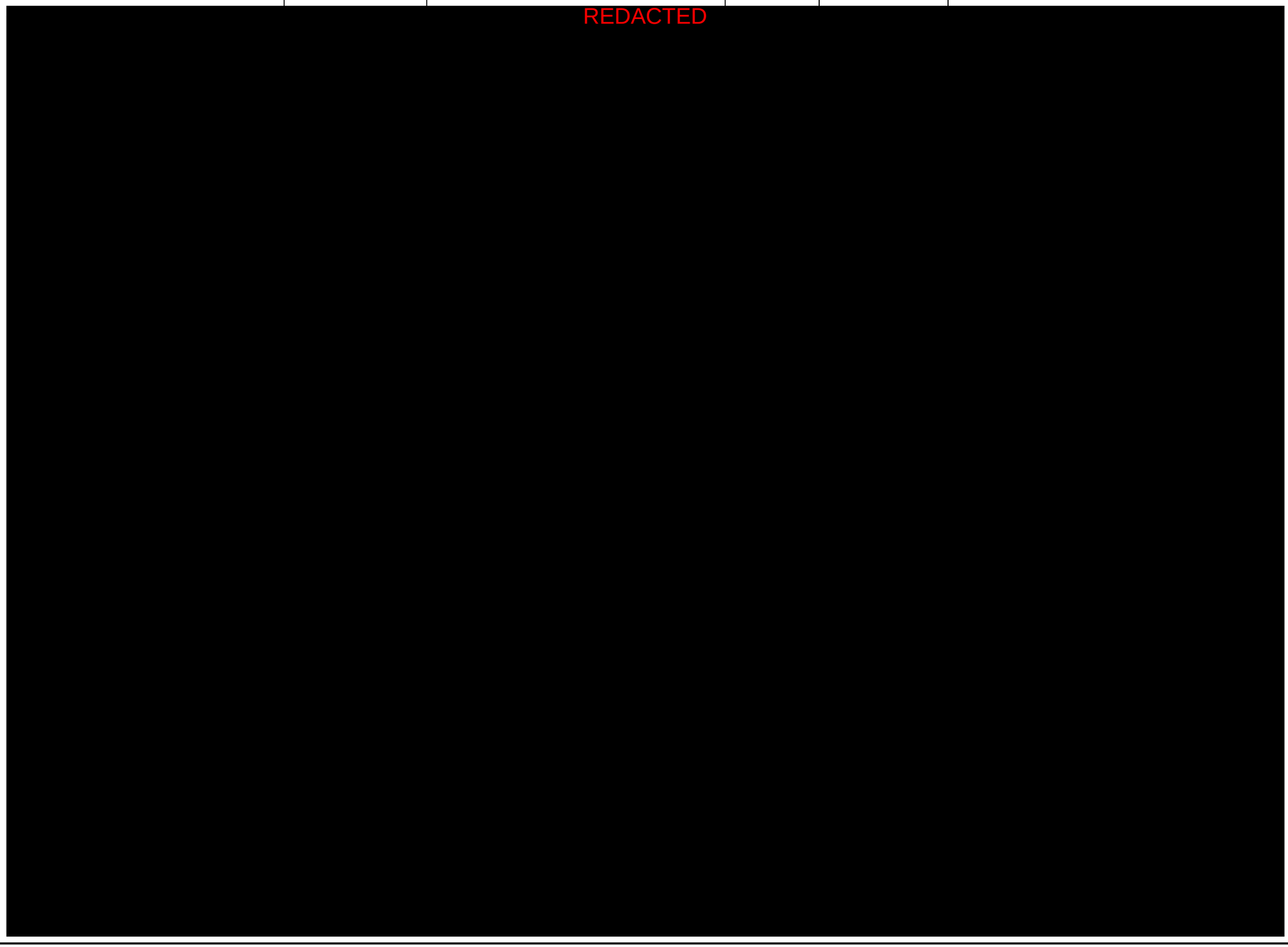
- K80F-3: Algoa Aquifer overlying TMG Aquifer with important wetlands - Most of the site and the enveloping footprint are located in this GRU.

More details on these GRUs are given in ***Table 5.11.1*** below.

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For the site evaluation purposes and this SSR, aquifer recharge refers to the amount of rainwater that infiltrates into the vadose zone (i.e. the unsaturated zone above the water table where interstices contain a combination of air and water) and then actually passes into the underlying aquifer, i.e. effective recharge.

The average effective recharge in the study area has been estimated by the widely used Maxey-Eakin grid-based GIS modelling technique (Maxey & Eakin, 1949). A 20 x 20 m grid of variable recharge rate or factor (R_f) was derived from the mean annual precipitation (MAP) data set, as follows:

R_f = [MAP (mm) / 10 000]

An empirical precipitation-recharge relationship was developed by Maxey-Eakin (Maxey & Eakin, 1949) from mass-balance estimates for basins in southern Nevada. The premise is that as annual precipitation increases with increasing altitude, so does the percentage of precipitation contributing to groundwater recharge. Using this relationship Maxey-Eakin assumed that no recharge occurs where mean annual precipitation is less than about 200 mm. The method ignores differences in lithology, soils, climate, vegetation and topography. For this investigation the Maxey-Eakin method was refined to be more sensitive to additional recharge indicators as described below:

- A 20 x 20 m run-off factor (S_f) grid was derived from a percentage slope grid (calculated from 20 x 20 m digital elevation model), as follows:

  S_f = [100 – slope per cent] / 100

- A 20 x 20 m lithology factor (L_f) grid was derived to take into account the variable recharge rates with the various lithological units.

- A 20 x 20 m river factor (RIV_r) grid was derived by buffering the perennial and non-perennial rivers by 250 and 150 m, respectively, and assigning factors of 1.2 and 1.1 to the buffered zones, respectively.

- A 20 x 20 m fault factor (F_f) grid was derived by buffering the faults by 250 m and assigning a factor of 1.2 to the buffered areas.

- A 20 x 20 m mean annual effective recharge or R_e (mm) grid was derived for the study area as follows:

  R_e (mm) = MAP x R_f x S_f x L_f x RIV_f x F_f

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The above approach has been used extensively by consultants in South Africa on a number of geohydrological projects with substantiated results (e.g. (Department of Water Affairs and Forestry, 2005)), and is recognised by the DWS as an acceptable methodology for estimating recharge. The altitude/precipitation relationship described above for the arid Nevada- type climate is applicable to the coastal environment of the site and further inland.

In ***Section 5.8***, the precipitation records of the Cape St. Francis weather station from 1985 to 2023 were used to define “wet” and “dry” periods. Five “extremely dry” years (1989, 2004, 2005, 2017 and 2018) were noted with two “extremely wet” years (1997 and 2012). “Near normal” rain years account for 33 per cent (13 years) of the historical period, followed by “very wet” years (18 per cent, i.e., 7 years), “severely dry” years and “extremely dry” years (14 per cent, i.e., 5 years), and “moderately dry” years (10 per cent, i.e., 4 years). “Moderately wet” and “extremely wet” years account for 8 per cent (3 years each) and 5 per cent (2 years), respectively. The methodology is described comprehensively in ***Section 5.8***.

Recharge estimates thus obtained range between 7.1 (dry years) and 11.7 Mm^3/a (wet years) with an estimated mean of 9.3 Mm^3/a, which equates to an average recharge of about 11 per cent of the MAP. This correlates well with previous studies carried out on the K80F quaternary catchment (Maclear, 2003). The variability of the mean annual groundwater recharge within the GRUs, as derived using the refined Maxey-Eakin approach described above, is summarised in ***Table 5.11.1*** and illustrated in ***Drawing 5.11.4***. It should be noted that recharge to the TMG Aquifer in K80F-1 reaches the site via throughflow along the northwest-southeast strike of these rocks from the areas of exposure in the Kareedouw Mountains to the northwest.

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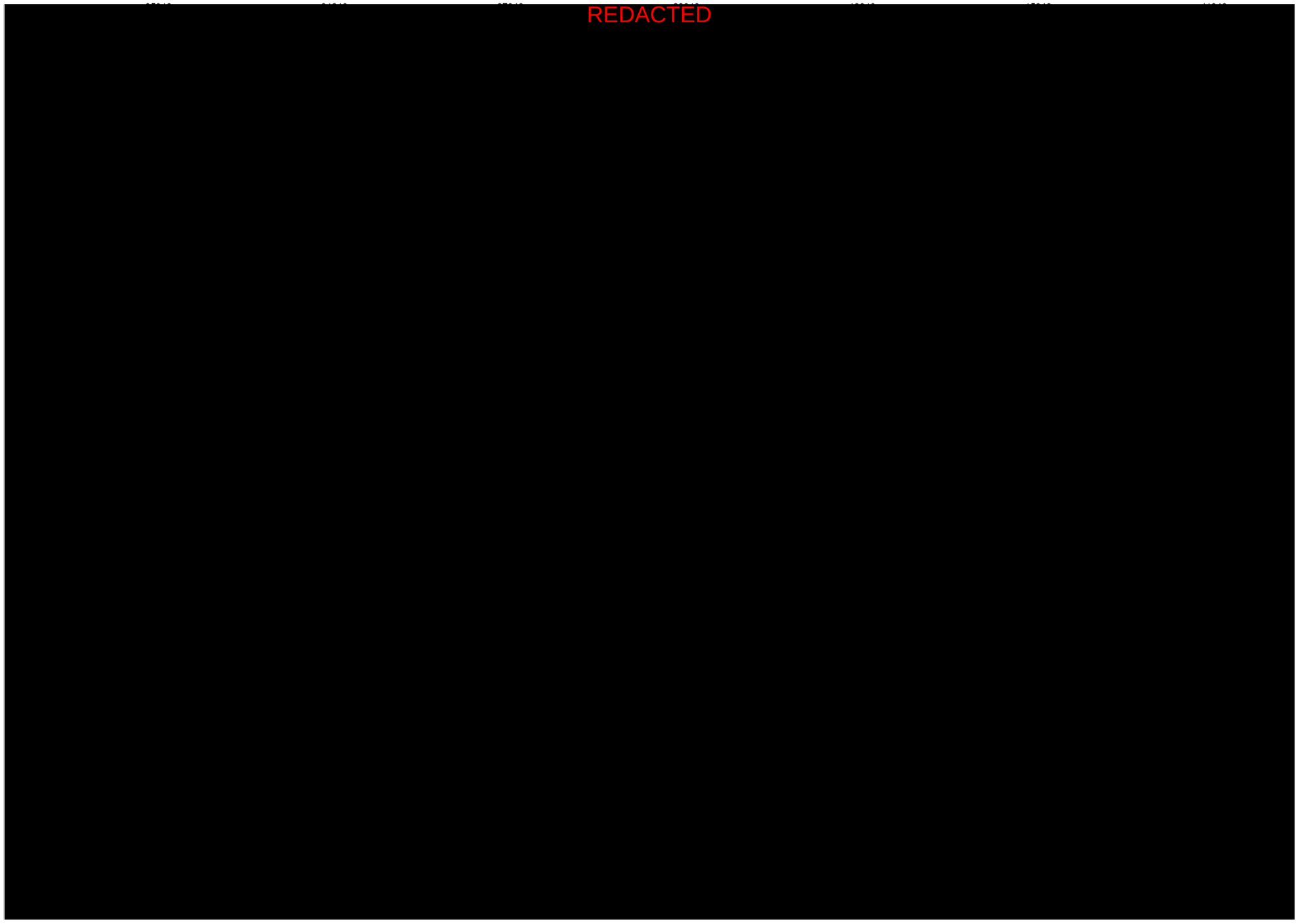
Table 5.11.1
Mean Annual Effective Recharge from Rainfall

Groundwater Resource Unit	Area (m^2)	MAP (mm)	Recharge Factor (%)	Average		"Dry" Conditions		"Wet" Conditions	
				Mean Annual Recharge (m^3/a)	Mean Annual Recharge (mm/a)	Mean Annual Recharge (m^3/a)	Mean Annual Recharge (mm/a)	Mean Annual Recharge (m^3/a)	Mean Annual Recharge (mm/a)
K80F-1	111 185 778	362	11.7	4 716 256	42	3 561 936	32	5 870 565	53
K80F-2	69 688 085	366	11.5	2 941 952	42	2 245 803	32	3 646 290	52
K80F-3	43 132 717	403	9.5	1 657 704	38	1 334 992	31	2 154 216	50
TOTAL	**224 006 580**			**9 315 255**		**7 142 732**		**11 671 070**	

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5.11.6.4 Groundwater Levels

Access for water level measurements in the boreholes identified during the 2007, 2017 and 2024 hydrocensuses (see ***Drawing 5.11.3***) was fairly limited as most were equipped with borehole pumps. During the 2007 hydrocensus, only eleven boreholes were accessible for water level measurement, and all of these are drilled into the TMG Aquifer. Groundwater levels in these boreholes in December 2007 ranged from artesian to 7.0 m bgl, i.e. relatively shallow. The majority of the hydrocensus boreholes are drilled into the TMG Aquifer (24) with only three boreholes drilled into the Algoa Aquifer. The higher number of TMG Aquifer boreholes is attributed to accessibility, with most properties being developed on areas directly underlain by these rocks. Of the 18 boreholes identified during the August 2017 hydrocensus, six boreholes were accessible for water level measured whilst pumps prevented measurements at the rest. Groundwater levels in these boreholes in August 2017 ranged from 3.80 to 11.57 m bgl, i.e. a decline from those measured in December 2007. Similarly, of the 26 boreholes identified during the February 2024 hydrocensus, 11 boreholes were accessible for water level measurement. Groundwater levels in these boreholes in February 2024 ranged from 1.30 to 47.33 m bgl.

Eleven springs/wetland seeps were also identified in December 2007 where the water flows from dunes or wetlands at ground level, mainly along the coast. These springs flow from the base of the Algoa Group, above the TMG. Five springs were identified in August 2017 and one in February 2024.

Rainfall data for the Cape St. Francis weather station indicates that the period preceding the 2007 hydrocensus was relatively dry and the period 2012 to 2022 constituted a drought. This means that groundwater levels measured during the 2007 hydrocensus and early site monitoring and 2024 hydrocensus are relatively low.

Direction of Groundwater Flow

Composite groundwater level contours were constructed for the study area using groundwater levels from the Algoa and TMG aquifers. Groundwater elevations in metres above mean sea level (m amsl) were derived from the surveyed collar elevation (using a hand-held Global Positioning System instrument) for hydrocensus boreholes and the measured depth to groundwater (***Drawing 5.11.6***). These measurements span an approximate fifteen-year period covering the 2007, 2017 and 2024 hydrocensuses, the SSR drilling and groundwater monitoring, i.e. late-2007 to February 2024. These contours indicate the following:

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- Groundwater flow generally follows the topographic gradient.
- The overall flow direction is in a southerly direction with local flow in a southeasterly direction closer to the coastline.
- Groundwater elevations and flow directions in the two aquifers are broadly similar.
- Contours are relatively evenly spaced indicating relatively uniform aquifer thickness and/or transmissivity/hydraulic conductivity.

5.11.6.5 Groundwater Quality

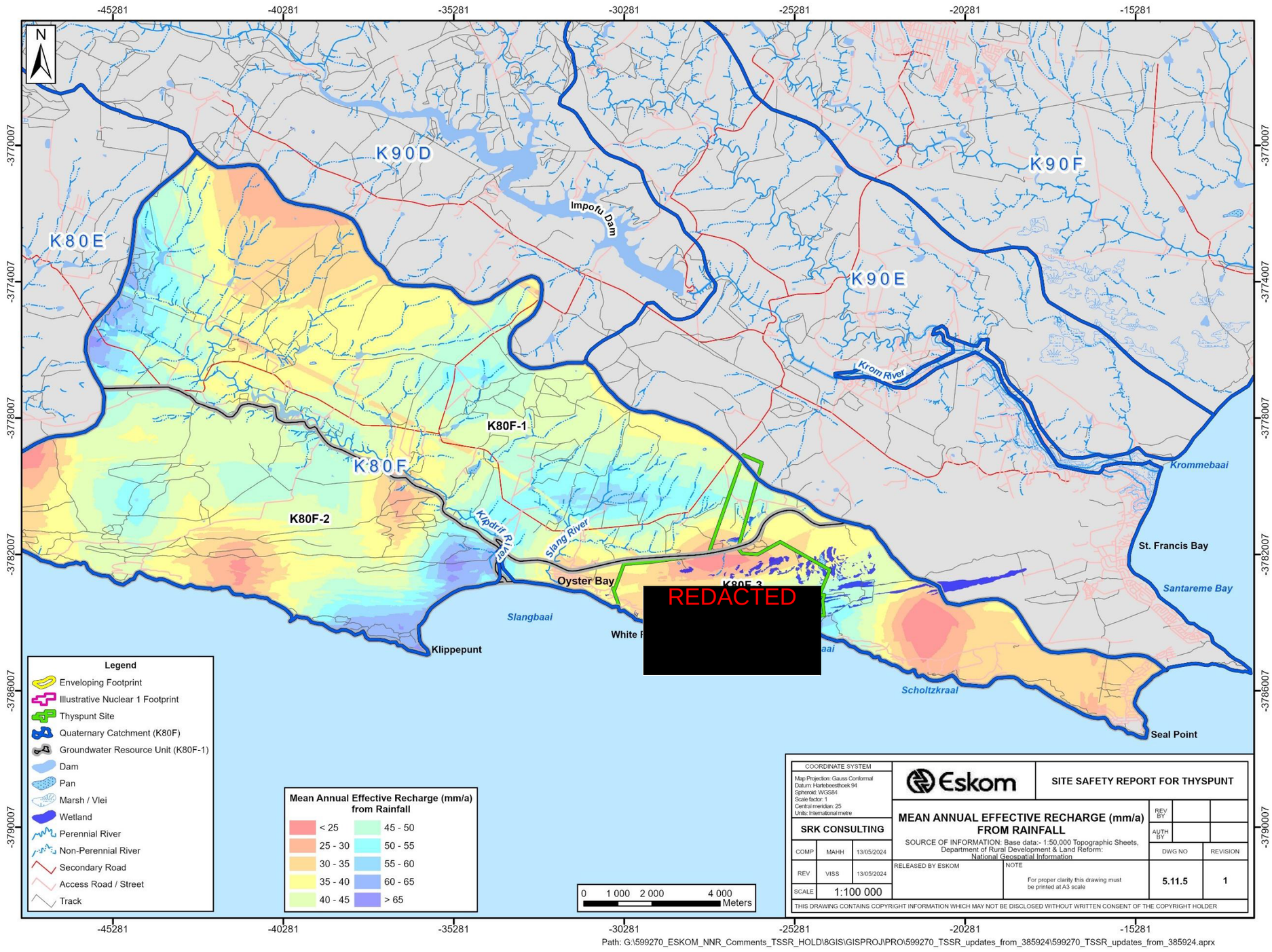
The regional groundwater quality in terms of electrical conductivity (EC) is shown in ***Drawing 5.11.7***, which is taken from the DWAF hydrogeological map, sheet 3324 (Meyer, et al., 1998). This indicates that EC at the site and in a 3 km-wide belt inland from the coast is likely to be in the range 70 to 300 mS/m. Further inland the EC associated with the TMG Aquifer is <70 mS/m, indicating proximity to the main recharge zone of the mountains in this area.

A summary of groundwater macro-chemistry from accessible boreholes during the 2007, 2017 and 2024 hydrocensuses is given in ***Table 5.11.2*** (see also ***Appendix 5.11.F***).

The hydrocensus analyses confirm the data of the regional groundwater quality map in terms of EC. The hydrocensus EC data ranges from 35 to 92 mS/m for the TMG aquifer and 78 to 161 mS/m for the Algoa Aquifer. A borehole tapping both the Algoa and TMG aquifers shows an EC of 147 mS/m. Lower EC groundwater (EC <70 mS/m) is, in general, associated with outcropping TMG rocks to the north of the hydrocensus area. The EC from the spring which supplies water to the village of Oyster Bay was measured at 82 mS/m during the 2007 hydrocensus and 84 mS/m in 2017. This spring's EC was not measured during the 2024 hydrocensus as water was being abstracted from a shallow borehole next to the spring, of which the EC was measured as 135 mS/m.

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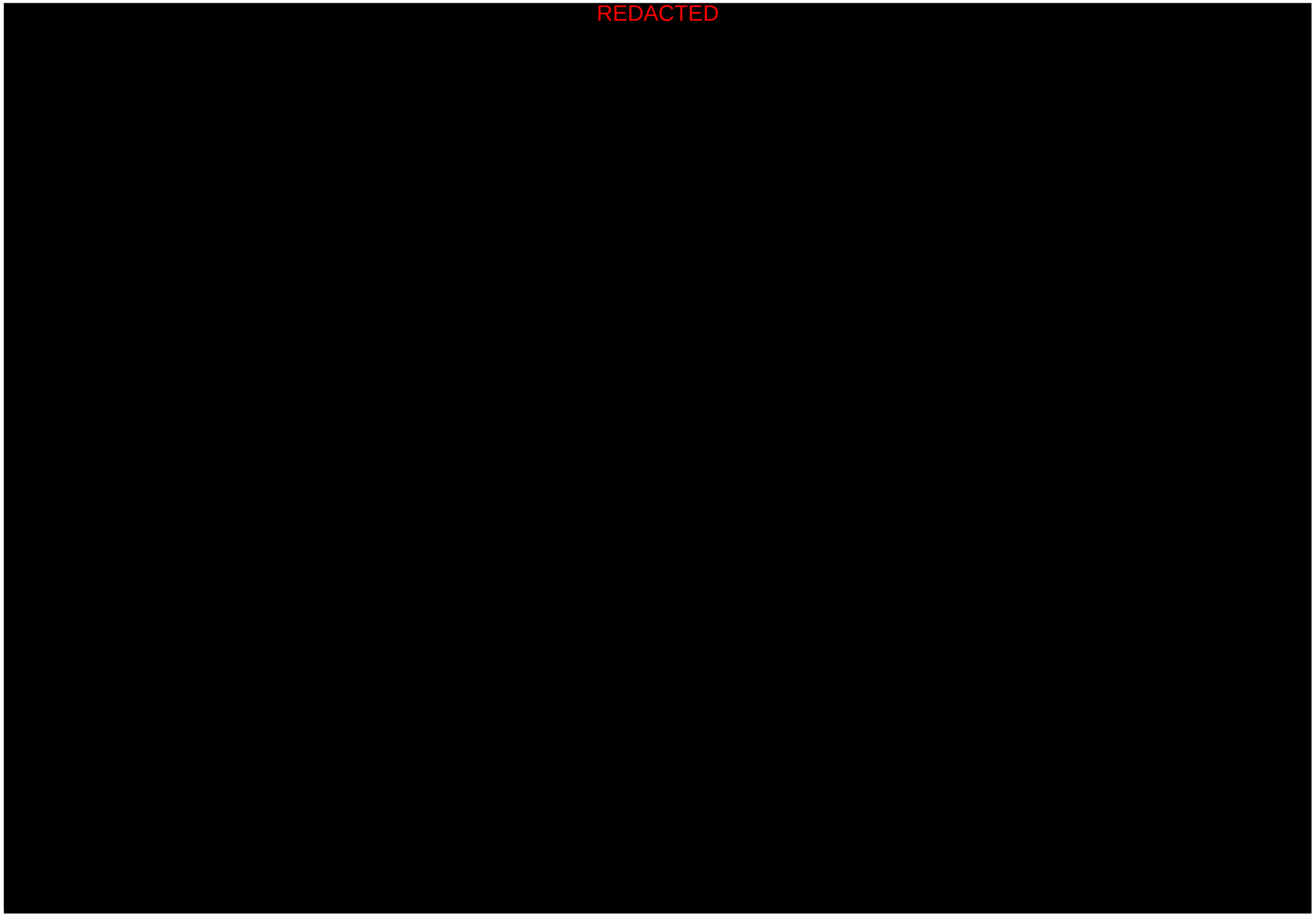


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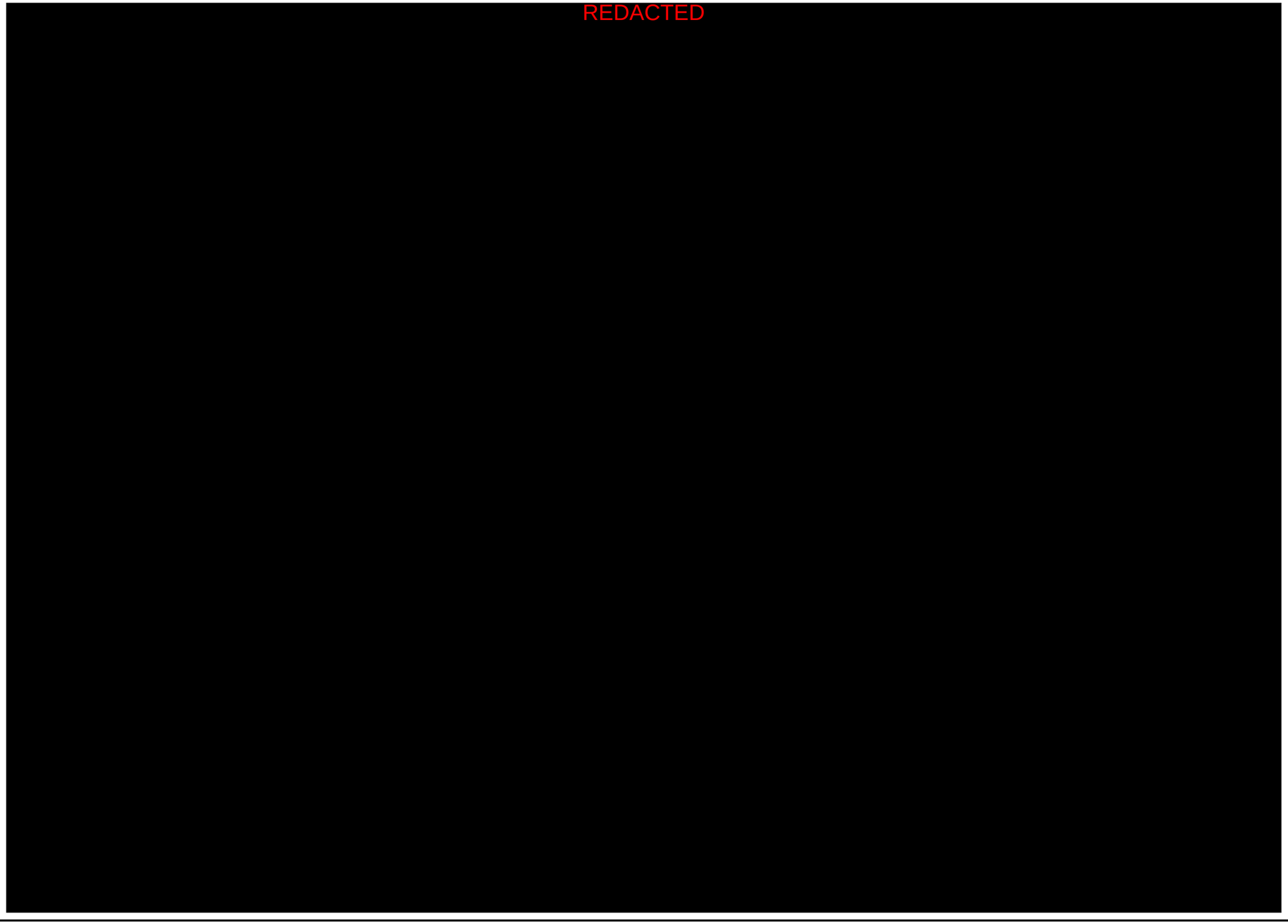
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Table 5.11.2
Chemical Analyses: 2007, 2017 and 2024 Hydrocensus Samples

Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	Ortho-Phosphate (as P)	pH**	EC***
Charly Wood	Algoa	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	193.8	20.3	227.3	2.1	257	439	179.2	<0.045	0.50	na	<0.02	7.9	220
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cilliers 2	Algoa +TMG	Dec-07	16.6	31.9	278.7	1.4	217	381	38.3	1.4000	<0.10	0.06	0.03	6.2	147
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cilliers 3	TMG	Dec-07	14.0	5.5	43.9	<1.0	40	73	2.3	0.0300	<0.10	0.60	<0.03	8.6	35
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Gerber 3	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	34	14.3	84	2.6	31	168	61	<0.05	0.30	NA	<0.03	6.1	75
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Gerber 4	TMG	Dec-07	31.2	16.5	78.2	4.4	54	167	34.0	0.0050	<0.10	0.04	<0.03	6.7	71
		Aug-17	9.6	9.0	62.4	1.4	16	186	17.2	0.50	0.30	NA	<0.03	6.0	46
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Grassridge	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	Done	54.9	367.9	29.9	46	634	121.6	4.77	<0.3	NA	<0.02	6.2	253
GRUN 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	53.2	14.8	85.5	5.5	175	154	5.0	0.385	0.40	NA	<0.02	7.7	85
		Feb-24	49.8	12.3	58.9	7.7	194	100	8.1	0.226	<0.30	NA	<0.02	7.0	74

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Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	Ortho-Phosphate (as P)	pH**	EC***
GWA_OB2_2017	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	23.6	29.6	166.6	20.3	132	307	3.7	<0.045	<0.3	NA	<0.02	7.9	129
KKLSP	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	111.8	12.4	62.2	1.8	264	116	20.1	<0.045	0.50	NA	<0.02	8.1	91
		Feb-24	67.3	11.7	112.6	6.4	202	170	42.6	<0.045	<0.3	NA	0.134	7.54	102.8
Langefonteinvlei 1	Algoa	Dec-07	107.2	11.1	49.9	1.5	294	82	6.1	<0.0025	0.16	0.07	<0.03	8.3	78
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Langefonteinvlei 2	Algoa	Dec-07	137.1	20.9	138.3	2.7	321	224	89.2	<0.0025	0.22	0.10	<0.03	7.5	138
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MANS (Witbank Huis)	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	12.6	18.0	140.4	1.0	13	260	32.9	0.475	0.30	NA	<0.02	6.7	95
		Feb-24	13.8	23.1	146.3	1.4	26	296	32.4	<0.045	<0.3	NA	<0.02	6.3	114
Milagro 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	12.1	11.7	92.3	6.6	36	150	16.8	<0.045	<0.3	NA	<0.02	6.4	63
Milagro 2	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	14.6	18.2	119.1	1.4	20	229	23.3	2.35	<0.3	NA	<0.02	6.2	90
Municipal BH 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	74.2	13.1	119.1	5.7	184	186	43.4	0.565	0.5	NA	<0.02	7.6	105
		Feb-24	125.1	18.2	117.8	2.8	278	237	38.9	<0.045	<0.3	NA	<0.02	7.7	135

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Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	Ortho-Phosphate (as P)	pH**	EC***
Municipal Spring 1	Algoa	Dec-07	103.5	11.8	54.9	1.1	267	105	13.3	<0.0025	0.19	0.04	0.03	8.2	82
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oeloff 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	17.6	23.5	177.7	1.1	23	340	29.2	0.973	0.40	NA	<0.02	6.6	121
		Feb-24	14.7	20.3	154.4	1.5	36	304	27.0	0.70	<0.3	NA	<0.02	6.4	117
Oeloff 2	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	16.0	26.8	192.8	0.7	16	373	27.1	1.538	0.30	NA	0.10	6.3	131
		Feb-24	20.8	38.3	245.3	1.1	30	459	28.6	1.65	<0.3	NA	<0.02	6.3	172
Oeloff 3	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	80.0	14.3	74.4	0.7	168	144	32.3	0.452	0.50	NA	<0.02	8.0	86
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oyster Bay Spring 1	Algoa	Dec-07	119.2	20.1	214.9	3.9	255	330	57.9	0.073	0.14	0.04	0.03	8.0	161
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oyster Bay Spring 3	Algoa	Dec-07	95.0	14.9	121.9	2.4	230	203	40.0	0.770	0.15	0.05	0.05	8.4	114
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oyster Bay Spring 6	Algoa	Dec-07	93.1	14.3	114.3	2.3	206	206	39.6	0.917	0.16	0.04	0.07	8.2	109
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oyster Bay Spring 7	Algoa	Dec-07	84.1	12.7	90.5	2.2	163	163	31.8	0.908	0.15	0.07	0.06	8.3	92
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

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Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	Ortho-Phosphate (as P)	pH**	EC***
Oyster Bay Spring 8	Algoa	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	151.5	49.2	394.7	10.0	232	778	111.8	<0.045	0.50	NA	<0.02	8.1	310
		Feb-24	130.5	35.2	311.4	8.4	276	534	69.2	0.20	<0.3	NA	<0.02	7.9	236
Pebbler	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	40.6	18.4	133.8	4.2	136	227	16.2	0.407	0.50	NA	<0.02	8.2	103
		Feb-24	125.4	17.0	104.4	3.4	304	195	50.9	<0.045	<0.3	NA	<0.02	7.7	127
Pennisands 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	16.8	19.7	141.5	1.2	21	269	27	2.490	0.30	NA	<0.02	6.7	100
		Feb-24	22.0	26.8	158.2	4.8	30	370	29.2	11.18	<0.3	NA	<0.02	6.4	150
Pennisands 2A	TMG	Dec-07	10.7	15.6	104.5	1.0	12	181	25.4	4.643	<0.10	0.04	0.06	6.0	63
		Aug-17	14.9	20.0	126	1.5	12	238	21.9	6.560	0.30	NA	0.09	6.1	91
		Feb-24	17.3	24.9	130.8	2.5	28	263	24.4	10.52	<0.3	NA	<0.02	6.3	109
RD1		Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	7.9	8.5	68.0	11.0	50	121	16.4	0.20	<0.3	NA	0.04	6.6	57
Strydom 1	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	14.4	17.3	138.3	1.4	27	253	25.8	0.790	0.40	NA	<0.02	6.4	94
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Strydom 3	TMG	Dec-07	3.3	7.6	53.5	<1.0	9	93	19.3	0.040	<0.10	0.04	<0.03	5.9	37
		Aug-17	6.2	12.4	77.6	1.6	4	151	13.1	2.260	0.30	NA	0.09	6.1	56
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Strydom 5	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	13.0	16.6	130.8	1.6	40	241	24.3	0.16	<0.3	NA	<0.02	6.4	98

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Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	Ortho-Phosphate (as P)	pH**	EC***
Strydom 6	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	11.4	15.1	123.5	1.3	38	223	22.3	<0.045	<0.3	NA	<0.02	6.4	91
Strydom 7	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	10.1	19.2	130.1	1.2	26	257	23.3	1.36	<0.3	NA	<0.02	6.2	100
Strydom 9	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	14.4	15.2	154.7	2.0	62	285	9.4	<0.045	<0.3	NA	<0.02	6.7	111
Vulindlela 1	TMG	Dec-07	7.0	10.4	68.2	5.4	18	119	29.9	0.217	<0.10	0.04	<0.03	6.8	51
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Vulindlela 4	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	20.6	23.2	187.0	2.3	36	332	36.8	<0.045	<0.3	NA	<0.02	6.3	128
Vulindlela 5	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	21.4	25.4	176.9	5.5	38	332	35.7	2.65	<0.3	NA	<0.02	6.3	129
Welgelegen 2	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	7.4	11.9	97.4	0.6	11	160	19.7	5.750	0.30	NA	<0.02	6.5	65
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Welgelegen3	TMG	Dec-07	7.7	12.5	96.7	<1.0	15	167	24.5	0.592	<0.10	0.10	<0.03	6.6	66
		Aug-17	7.9	10.7	95.2	0.8	13	162	18.9	2.850	0.30	NA	<0.02	6.3	64
		Feb-24	8.5	13.2	97.2	1.0	28	165	20.0	6.88	<0.3	NA	<0.02	7.4	76

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Borehole Number	Aquifer	Hydro-census	Determinand*												
			Ca	**Mg**	**Na**	**K**	**Alkalinity** (as $CaCO_3$)	**Cl**	**SO_4**	**NO_3** (as N)	**F**	**NH_4** (as N)	**Ortho-Phosphate** (as P)	**pH****	**EC*****
Welgelegen 5	TMG	Dec-07	4.1	10.9	83.0	<1.0	10	147	26.4	0.6500	<0.10	0.05	<0.03	6.0	56
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Welgelegen 6	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Feb-24	3.2	7.5	53.2	0.8	18	93	16.0	<0.045	<0.3	NA	<0.02	6.1	42
Bedwell (378 Tuna)	TMG	Dec-07	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
		Aug-17	146.7	24.6	145.8	3.0	308	293	45.5	1.360	0.40	NA	<0.02	7.7	156
		Feb-24	146.4	24.8	149.4	4.1	350	315	55.7	0.91	<0.3	NA	<0.02	8.0	174

ns[7] = not sampled
NA = Not Analysed

* all determinands in mg/ℓ apart from:
**pH value at 22°C
***EC measured in mS/m at 25°C

[7] Boreholes were indicated as not sampled (ns) for various reasons e.g., a broken pump, the borehole has collapsed, or it was drilled after a specific hydrocensus,

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A trilinear Piper Diagram of water samples taken during the three hydrocensuses is shown for TMG Aquifer samples in ***Figure 5.11.4***. and Algoa Aquifer samples in ***Figure 5.11.5***. All the groundwater samples have a dominant NaCl character, which is typical for coastal environments.

Chemical characteristics of groundwater from the different aquifers in the area can be summarised as follows:

- TMG Aquifer - predominantly NaCl-type and acidic to neutral pH, with the exception of Cilliers 3, which has an anomalous pH of 8.6;
- Algoa Aquifer - mixed-type with high concentration of $Ca(HCO_3)_2$ and neutral to alkaline pH[8].

The samples from springs in the Algoa Aquifer show a trend towards higher concentration of $Ca(HCO_3)_2$ compared with the groundwater from boreholes in the TMG Aquifer, as would be expected given the shell-bearing and calcareous nature of the former aquifer.

[8] $(HCO_3)_2$ is the stable ion in the pH range found in the study area; However, $CaCO_3$ is the standard unit for reporting laboratory analyses for alkalinity.

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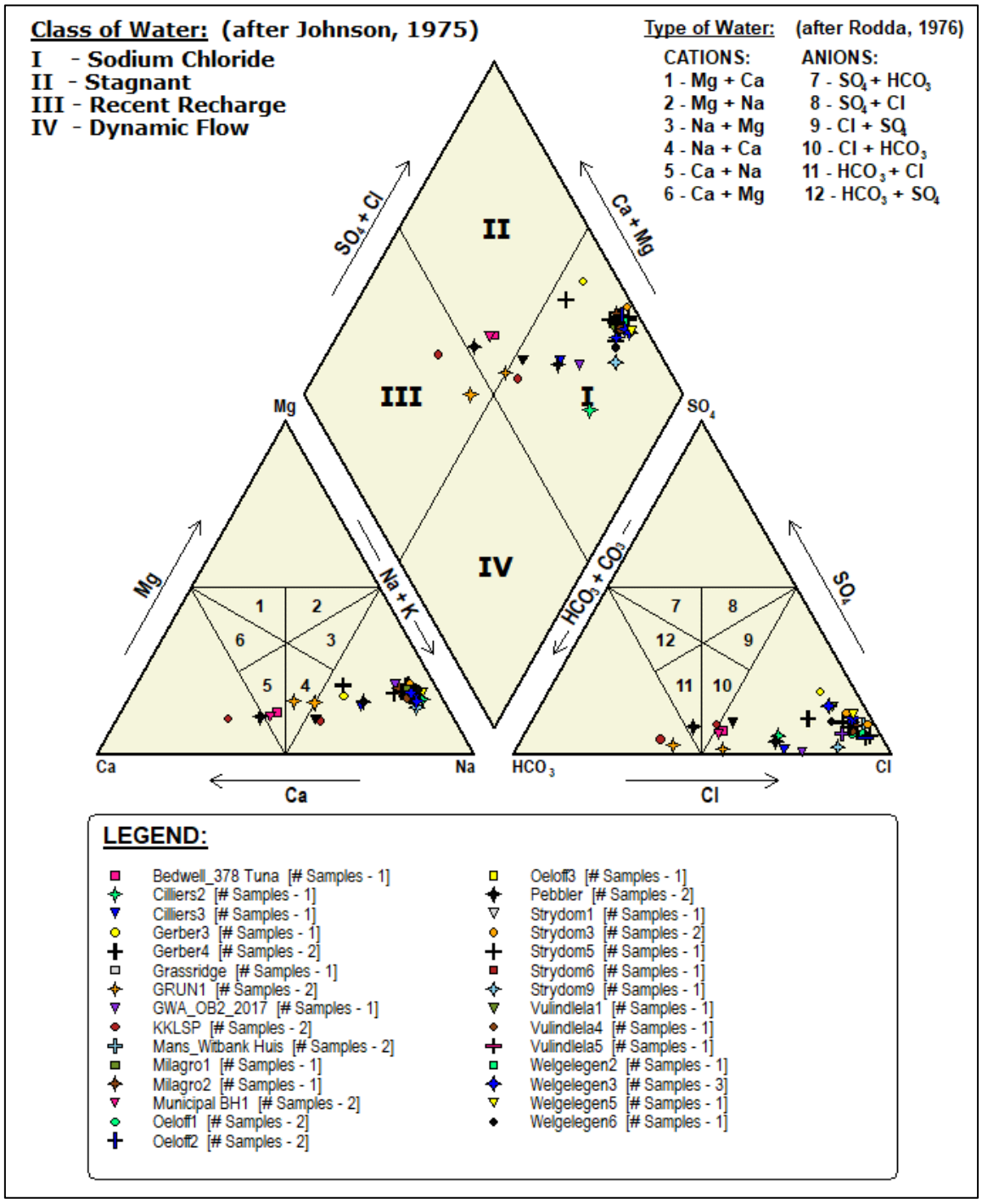


Figure 5.11.4
Piper Diagram: 2007, 2017 and 2024 Hydrocensuses TMG Samples

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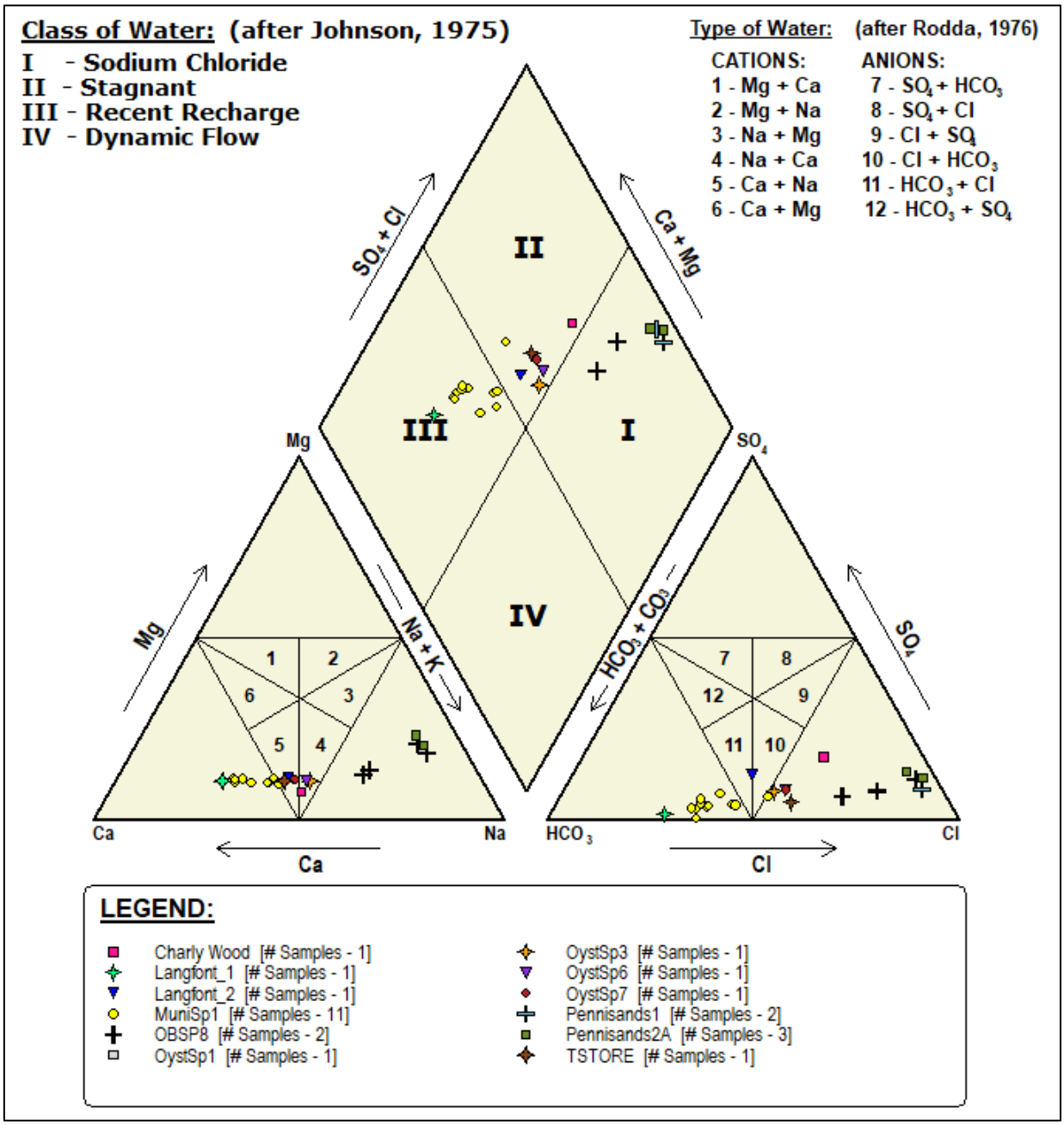


Figure 5.11.5
Piper Diagram: 2007, 2017 and 2024 Hydrocensuses Algoa Samples

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Radionuclide analyses (standard suite for assessment of domestic water radiological quality) of water samples taken during the 2007 and 2017 hydrocensuses were conducted by the Nuclear Energy Corporation of South Africa (Necsa). Results of these analyses are presented in ***Table 5.11.3***, ***Table 5.11.4*** and ***Table 5.11.5***. *Note: Results of water samples collected during the 2024 hydrocensus and submitted to Necsa were still outstanding during compilation of this report*.

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Table 5.11.3
Radionuclide Analyses: March 2008 Hydrocensus Samples

Sample ID	U-238			Co-60			I-131			Cs-137			Total α Activity			Total β Activity		
	mBq/ℓ*	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
Cilliers 2	4.85	1.98	2.2	<MDA		3 500	<MDA		2 800	<MDA		2 900	-86	300	1 000	3 000	250	710
Cilliers 3	11.40	3.20	6.6	<MDA		2 270	<MDA		2 500	<MDA		3 400	-100	210	720	1 430	220	690
Gerber4	5.60	2.40	5.8	<MDA		3 200	<MDA		10 000	<MDA		3 100	53	230	780	1 030	220	700
Langefonteinvlei 1	4.76	1.80	1.8	<MDA		2 900	<MDA		3 600	<MDA		3 200	-100	250	830	855	218	700
Langefonteinvlei 2	21.90	4.00	2.0	<MDA		3 100	<MDA		3 900	<MDA		3 100	-64	290	960	775	220	710
Muni sp 1	13.10	3.80	8.1	<MDA		2 900	<MDA		4 200	<MDA		3 200	-140	250	840	540	220	700
Oyster Bay Spring 1	9.73	2.81	2.2	<MDA		3 000	<MDA		4 500	<MDA		3 200	-130	300	1 000	836	221	710
Oyster Bay Spring 3	7.14	1.98	1.5	<MDA		3 200	<MDA		4 100	<MDA		3 000	-1.3	280	930	540	220	710
Oyster Bay Spring 6	8.03	2.23	1.7	<MDA		3 000	<MDA		4 400	<MDA		3 400	-42	270	910	380	220	710
Oyster Bay Spring 7	7.01	1.81	1.3	<MDA		2 800	<MDA		4 200	<MDA		3 000	-79	260	860	450	210	700
Pennisands 2A	1.20	0.86	1.7	<MDA		2 700	<MDA		4 600	<MDA		3 300	30	240	790	360	210	700
Strydom3	8.30	3.30	8.5	<MDA		3 100	<MDA		4 200	<MDA		3 100	-6	210	720	867	215	690
Vulindlela 1	9.68	3.41	8.2	<MDA		3 200	<MDA		11 000	<MDA		3 500	15	230	780	270	210	700
Welgelegen 3	6.55	2.32	2.2	<MDA		2 600	<MDA		4 900	<MDA		3 200	4.6	240	790	220	210	700
Welgelegen 5	1.50	1.80	6.9	<MDA		3 000	<MDA		3 200	<MDA		3 200	4.6	230	770	2 710	240	700

MDA = minimum detectable activity concentration (@ 95 % confidence level) *Unit used by lab for reporting

1θ = reported uncertainty from counting statistics

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Table 5.11.4
Radionuclide Analyses: November 2008 Hydrocensus Samples

Sample ID	Ra-226			Ra-223			Ra-224			Total α activity			Total β activity		
	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
Cilliers 2	12.9	1.9	2.4	9.61	2.51	4.0	3.3	1.60	4.1	-140	370	200	-170	290	970
Welgelegen 5	3.10	0.97	1.9	0.89	1.3	4.3	0.57	0.57	1.5	1 140	180	560	855	173	550

MDA = minimum detectable activity concentration (@ 95 % confidence level) *Unit used by lab for reporting

1θ = reported uncertainty from counting statistics

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Table 5.11.5
Radionuclide Analyses: August 2017 Hydrocensus Samples

Sample ID	Ra-226			Ra-224			Ra-223			Gross α			Gross β		
	Value	Unc	**MDA**	Value	Unc	**MDA**	Value	Unc	**MDA**	Value	Unc	**MDA**	Value	Unc	**MDA**
BEDWELL (378 TUNA)	73.1	4.7	2.7	14.0	3.0	4.4	-6.4	3.3	3.1	190.0	93.0	300.0	350.0	140.0	460.0
CHARLYWOOD	2.9	1.9	6.2	2.9	1.7	2.6	0.2	1.3	3.0	333.0	107.0	320.0	30.0	140.0	460.0
GERBER 3	103.0	6.0	4.3	19.6	4.1	5.6	-8.5	4.5	6.3	150.0	58.0	180.0	510.0	140.0	450.0
GERBER4	57.7	4.5	2.5	11.9	3.4	7.6	-0.7	3.4	3.4	82.0	46.0	150.0	350.0	140.0	440.0
GRUN 1	9.6	2.5	4.9	6.4	5.4	19.0	0.2	2.1	7.6	-11.0	48.0	170.0	220.0	140.0	450.0
KKLSP	2.5	0.9	1.0	<MDA	-	3.7	1.8	1.8	2.2	-43.0	55.0	200.0	170.0	140.0	450.0
MANS	60.0	5.3	6.7	10.6	3.3	6.3	-5.5	3.6	3.0	62.0	57.0	190.0	98.0	130.0	450.0
MUNICIPAL BH	67.7	5.4	3.8	4.7	3.1	10.0	-5.4	4.0	6.8	180.0	71.0	220.0	497.0	141.0	450.0
OELOFF 1	54.2	4.3	3.5	6.1	2.0	1.8	-5.2	2.9	1.9	89.0	66.0	220.0	220.0	140.0	450.0
OELOFF 2	33.1	4.3	4.0	2.3	3.2	12.0	3.5	3.6	5.4	52.0	65.0	220.0	63.0	140.0	450.0
OELOFF 3	4.4	1.8	4.5	-1.0	2.7	12.0	-1.6	1.8	8.1	23.0	57.0	200.0	44.0	130.0	450.0
OYSTERBAY SPRING	11.1	3.6	8.7	3.5	2.5	4.7	-1.0	2.3	4.7	-4.9	120.0	420.0	500.0	146.0	470.0
PEBBLER	12.0	2.1	1.0	1.5	1.5	3.9	-6.4	2.8	2.3	-13.0	58.0	210.0	74.0	130.0	450.0
PENNISANDS 1	45.7	5.2	6.5	16.9	4.6	8.3	-0.4	4.2	9.4	120.0	59.0	190.0	130.0	140.0	450.0
PENNISANDS 2	90.1	5.7	4.9	24.2	4.2	2.0	-2.8	4.2	2.4	89.0	55.0	180.0	260.0	140.0	450.0
STRYDOM 1	48.0	4.9	5.0	2.9	1.7	2.6	-7.5	3.0	2.7	35.0	58.0	200.0	95.0	140.0	450.0
STRYDOM 3	2.6	1.1	2.7	4.5	3.5	12.0	0.9	0.9	3.1	32.0	45.0	160.0	42.0	130.0	440.0
TSTORE	3.5	1.4	3.4	3.2	1.9	5.6	1.2	1.3	3.8	6.5	62.0	220.0	5.3	130.0	450.0
WELGELEGEN 2	20.6	3.5	4.9	13.3	4.1	8.2	2.3	2.9	5.5	90.0	50.0	160.0	270.0	140.0	440.0
WELGELEGEN 3	15.5	2.3	3.3	7.4	2.6	2.5	0.5	1.1	1.2	79.0	49.0	160.0	170.0	130.0	440.0

1. If a measured value (Value column) was recorded, it is reported if the value is less than the minimum detectable activity concentration (MDA column) or even if the value is negative. In the case where a value could not be obtained, a less than MDA ("< MDA") will be indicated.
2. The reported uncertainty (Unc. column) is quoted at 1 sigma (or coverage factor k = 1). The uncertainty is calculated mainly from counting statistics and it is not the standard deviation obtained from replicate measurements. No uncertainty value is reported if a less than MDA ("< MDA") is indicated in the Value column.
3. The minimum detectable activity concentration (MDA column) is calculated with a 95% confidence level.

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5.11.6.6 Stable Isotopes and Tritium

Fifteen water samples taken during the 2007 hydrocensus were submitted for deuterium/hydrogen (D/H), Oxygen-18/Oxygen-16 (O-18/O-16) and tritium (H-3) analysis. These results assist in the assessment of the origin and recharge of groundwater. The results of these analyses are presented in ***Table 5.11.6***.

Table 5.11.6
Stable Isotope and Tritium Analyses: 2007 Hydrocensus Samples

Borehole ID	Aquifer	δ D (‰)*	δO-18 (‰)	Tritium (T.U.)	
Cilliers 2	TMG + Algoa	-22.9	-5.29	1.3	±0.2
Cilliers 3	TMG	-18.1	-4.70	1.3	±0.2
Gerber 4	TMG	-22.2	-5.00	0.7	±0.2
Langefonteinvlei 1	Algoa	-15.9	-3.92	1.5	±0.3
Langefonteinvlei 2	Algoa	-19.0	-4.04	2.0	±0.3
Municipal Spring 1	Algoa	-22.8	-5.03	2.3	±0.3
Oyster Bay Spring 1	Algoa	-19.5	-4.71	1.8	±0.3
Oyster Bay Spring 3	Algoa	-19.7	-4.81	1.3	±0.3
Oyster Bay Spring 6	Algoa	-19.8	-4.62	1.4	±0.3
Oyster Bay Spring 7	Algoa	-19.4	-4.72	1.4	±0.3
Pennisands 2A	TMG	-22.7	-5.25	1.6	±0.3
Strydom 3	TMG	-27.0	-5.57	1.5	±0.2
Vulindlela 1	TMG	-20.3	-4.78	1.7	±0.3
Welgelegen 3	TMG	-22.6	-5.18	2.4	±0.3
Welgelegen 5	TMG	-29.5	-6.05	1.5	±0.3

* ‰ – per mil is the ratio of stable isotope mass D/H or O-18/O-16 atomic weight and mol fractions per thousand. The ‘minus’ sign indicates that the sample is depleted in that isotope.

Isotopes of hydrogen and oxygen are ideal geochemical tracers of groundwater since their concentrations are not subject to change due to interaction with the aquifer. Once underground and removed from zones of evaporation, the isotope ratios are conserved/stable and are only affected by mixing with other media. Groundwater in the saturated zone thus has an isotopic composition corresponding to the mean isotopic composition of

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infiltration in the area. This may differ slightly from the mean isotopic precipitation due to the fact that not all precipitation throughout the year infiltrates in the same proportion (Craig, 1961).

Figure 5.11.6 presents a plot of δO-18 vs. δD (measured with respect to standard mean ocean water, SMOW[9]) relative to the Global Meteoric Water Line (GMWL[10]) (Craig, 1961) for the 2007 hydrocensus boreholes.

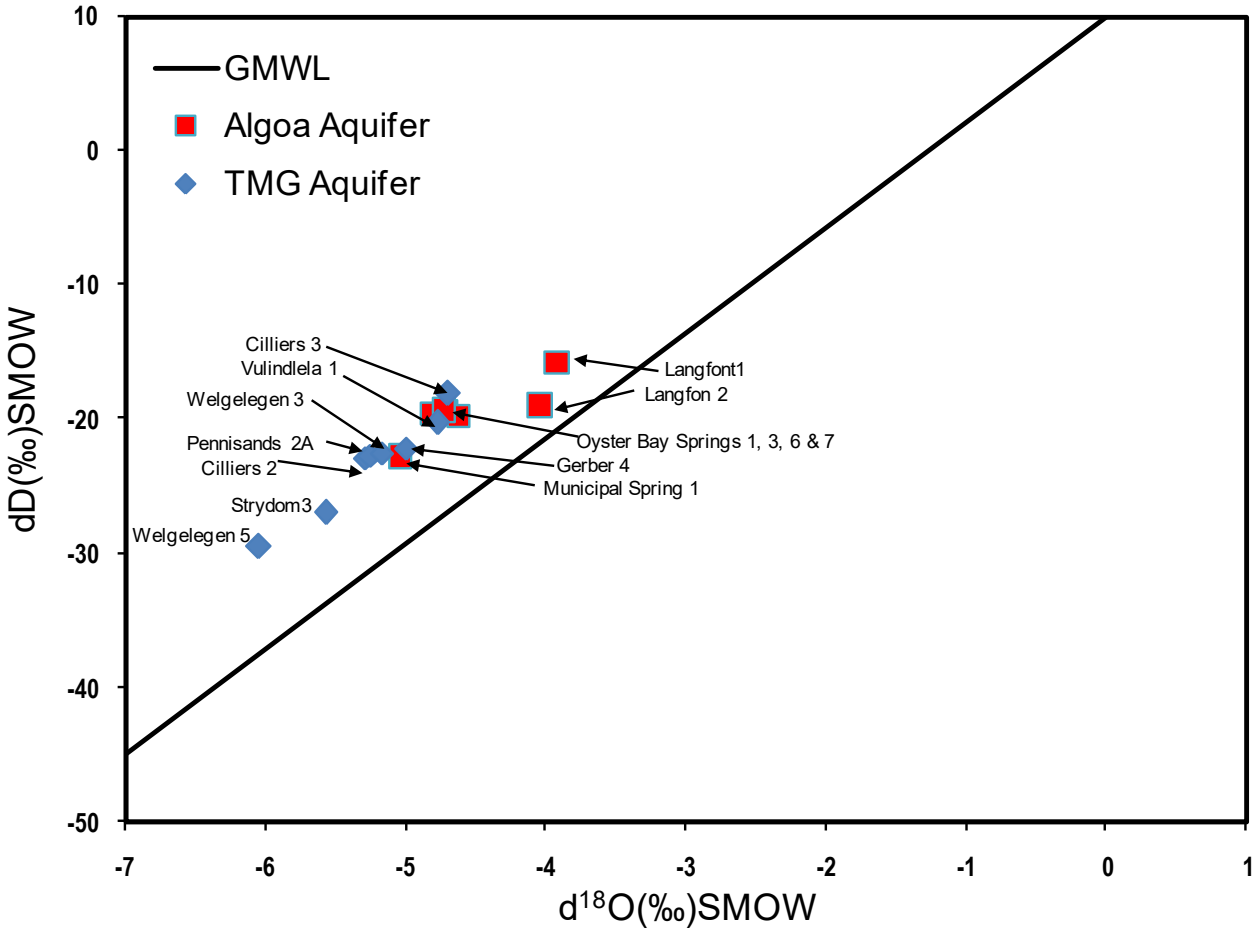


Figure 5.11.6
δO-18 versus δD: 2007 Hydrocensus Samples

[9] SMOW: Standard mean ocean water, an international reference standard used to determine the oxygen and hydrogen isotopic content of water.
[10] GMWL – δD and δO-18 content of rainwater from sampling sites around the world lie along a straight line known as the Global Meteoric Water Line.

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The 2007 hydrocensus samples in ***Figure 5.11.6*** plot on a line approximately parallel to and just above the GMWL. This trend of data indicates normal precipitation and recharge processes at the site and surrounding area. Samples Langefonteinvlei 1 and Langefonteinvlei 2 plot closer to the GMWL as these samples are from a wetland with considerably more direct rainwater influence than the other spring and groundwater samples.

Tritium Analysis

The tritium content of groundwater can provide a qualitative indication of recharge. There are two main sources of H-3 in groundwater. Tritium is naturally produced at low levels in the upper part of the atmosphere (about 10 to 20 km above the earth's surface) when cosmic rays collide with air molecules (cosmogenic processes). Tritium has also been produced from the atmospheric testing of hydrogen (atomic) bombs that began at the end of 1952 (nuclear fallout-produced), with the release of atmospheric H-3 peaking in 1963. Tritium concentrations are given as tritium units (TU) where 1 TU = 1xH-3 atom to $1x10^{18}$ H-1 atoms.

Tritium has a half-life of 12.3 years. This radioactive isotope of hydrogen was present in rainwater at a maximum concentration in 1965 and levels have been declining worldwide since then. Tritium is found in trace amounts in groundwater throughout the world and H-3 in groundwater is not significantly affected by chemical processes. The most important use of H-3 is in distinguishing between water that entered an aquifer prior to 1952 (i.e. pre-nuclear weapons testing) and water that was in contact with the atmosphere after 1952. Pre-1952 groundwater contains H-3 that is not detectable by normal procedures while post-1952 groundwater will contain detectable to relatively high levels of H-3. Tritium concentrations in groundwater have been interpreted as follows (Mazor, 1991):

- groundwater with zero H-3 (in practice, <0.5 TU) has a pre-1952 age;
- groundwater with H-3 concentration >10 TU has a post-1952 age;
- groundwater with H-3 concentration between 0.5 and 10 TU represents a mixture of pre-1952 and post-1952 groundwater.

Shallow groundwater H-3 values reflect the local average precipitation values but are modified to some extent by selective recharge and fractionation processes that may alter the H-3 values of the precipitation before the water reaches the saturated zone. These processes include evaporation of rain during infiltration, selective recharge (e.g. only from

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major storms), interception of rainwater by vegetation, exchange of infiltrating water with atmospheric vapour, and various post-depositional processes (e.g., evaporation during infiltration). Isotopic fractionation during evaporation is mainly a function of ambient humidity. During light rains the H-3 concentration is representative of the moisture at lower levels, while during moderate or heavy rains the exchange at lower levels is insignificant. Re-evaporated water has nearly the same H-3 concentration as the original precipitation. In contrast, precipitation falling on the ocean and other deep bodies of water is rapidly mixed within a zone of about 75 m, and the concentration of H-3 in evaporated water is reduced.

Once H-3 is deposited on the ground, the most rapid loss occurs from surface run-off or direct evaporation from the surfaces of vegetation, standing pools and from the soil surface. Some of the water that recharges the groundwater moves so slowly that the H-3 associated with the fraction of precipitation is effectively lost from circulation due to the relatively short half-life of H-3 (Mazor, 1991) .

The H-3 data shown in ***Table 5.11.6*** indicate values between 1.3 to 2.4 TU for both Algoa and TMG aquifer 2007 hydrocensus samples. These values indicate a mixture of pre- and post-1952 groundwater for all samples. Sample Gerber 4 shows a low H-3 value of 0.7 TU and may therefore represent predominantly pre-1952 groundwater in this TMG Aquifer sample.

5.11.6.7 Groundwater Use

Detailed hydrocensuses of an approximate 5 km zone surrounding the Nuclear-1 footprint were conducted in December 2007, October 2017 and February 2024. ***Table 5.11.7*** provides a summary of the boreholes and springs identified which are shown in ***Drawing 5.11.3***.

This survey showed that groundwater is used extensively for both agricultural (irrigation and stock watering) and domestic purposes. The town of Oyster Bay relies solely on groundwater (spring and borehole) for domestic water supply (see ***Section 5.12***). The spring feeding the town reservoir is located in the dune field to the northeast of the town. This spring also feeds a wetland and is pumped to the main storage reservoir. The borehole (municipal BH on ***Drawing 5.11.3***, screened in the Algoa Aquifer) is located within the northeast part of the town.

There are also a number of municipal, domestic water supply boreholes and wellfields further afield at St. Francis Bay and Humansdorp, mainly tapping the TMG Aquifer.

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In most cases, the 2024 EC readings are the highest, which may be a function of increased groundwater abstraction and the drought/wet period climatic cycles between 2007 and 2024.

Domestic Use

During the hydrocensuses several prominent springs/seeps were identified along the coast that originate from the base of the Algoa Aquifer. Some of these springs supplied water to the holiday houses (now vacated) located on the site.

The most prominent flowing spring is located at the Langefonteinvlei to the northeast of Eskom's property and flows out of the northern sand dunes (about 2 ℓ/s) to the west and emerges as a stream at White Point. This water was formerly used for domestic purposes at the three houses on the farm Buffelsbosch 742.

The most prominent spring along the coast occurs just south of the Nuclear-1 footprint (Spring 4) and has a small weir installed. According to information provided by landowners adjacent to the site, most of the springs flow throughout the year with a noticeable increase in yield following significant rainfall events. Monitoring of springs since late-2007 supports this statement and indicates on-site recharge is taking place.

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[11] Boreholes where measurements were not possible are indicated as nm.

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Wetlands

Wetland ecosystems are described briefly here as they are intimately linked to the site groundwater regime and form an important part of the K80F-3 GRU. More detailed discussion is included in ***Section 5.3*** (Ecology) of this SSR. Wetland ecosystems at the site include the following (see ***Drawing 5.11.3***):

- Largely pristine, seasonal dune-slack wetlands occur within the lower-lying areas of the mobile dune field. These wetlands are fed by groundwater and increase in size during winter.
- Valley bottom wetlands occur in the area north of the mobile dunes and east of the Langefonteinvlei, from where they drain in an easterly direction.
- The Langefonteinvlei comprises two large permanently saturated, vegetated hillslope seeps, located in the northeastern part of the site, on the southern edge of the large mobile dune field. The wetland is fed primarily by groundwater. While throughflows are believed to be predominantly in a north-south direction, a deep organic base that has developed throughout much of the wetland results in perching of surface flows. Thus, during wetter periods, surface flows in the wetland are believed to be largely topographically driven, with flow across the wetland in a roughly east-west direction. The westward edge of the wetlands is, however, unusually abrupt, with virtually no transitional area of seasonal wetland.
- Along the coast, numerous freshwater seeps emerge onto the rocky shores at the contact with the Algoa Aquifer. These are largely unimpacted and form extensive zones of fresh water at the marine interface.

5.11.7 Site Specific Description of Aquifers

There are two aquifers present at the site, viz.:

- Aquifer 1: Algoa Aquifer (upper, primary intergranular);
- Aquifer 2: TMG Aquifer (basal, fractured-rock).

The distribution of these aquifers is presented in ***Drawing 5.11.4*** along with the main points of groundwater withdrawal and discharge as of December 2007. The Algoa Aquifer overlies the fractured TMG Aquifer at

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the site and the latter extends out into the Indian Ocean. A 3D conceptual model and cross-section are also presented in ***Subsection 5.11.8*** and in ***Drawing 5.11.10*** and ***Figure 5.11.28***, respectively.

5.11.7.1 Aquifer 1: Primary Intergranular Algoa Aquifer

A schematic section through the site is shown in ***Figure 5.11.28*** under the conceptual model discussed in ***Subsection 5.11.8***.

The detailed SSR geohydrological study at the site has revealed evidence that the intergranular Algoa Aquifer can be classified as a major aquifer in this area. This aquifer unit comprises minor soils, mainly of Tertiary-age, calcareous aeolian sands and aeolianite of the Nanaga Formation (partly consolidated). These overlie a significant, but discontinuous, sand, shell and cobble layer (Alexandria Formation) which itself unconformably overlies the TMG rocks.

On site, the thickness of the aeolian sand varies from 1 to 2 m along the coast to >50 m in the topographically higher-lying dune areas. The dune field to the north of the site comprises dunes reaching in excess of 100 m amsl. Several layers of calcretised and consolidated aeolianite were encountered within the Nanaga Formation during drilling operations. These aeolianite beds occur below the aeolian sands and vegetated dunes. They are also visible as outcrop below the coastal dunes and as consolidated, eroded outcrop overlying the wave-cut TMG platform along the coast.

The cobble layer at the base of the Algoa Group varies widely in thickness ranging from <1 m close to the coast to a maximum of 6 m in the area around THY-MR11 (the THY prefix is dropped on the Drawings to avoid clutter). It comprises well rounded quartzite and sandstone (10 to about 150 mm diameter) cobbles, fine to coarse sand and shells. The presence of the shelly material indicates that the cobble layer is most likely a marine deposit rather than a palaeochannel associated with a former river course. The presence of sand within the cobble interstices and as layers within the conglomerate indicates that the Algoa Aquifer is bi-modal. The sand and cobble parts of the aquifer will have significantly different hydraulic properties.

Hydraulic Properties

The hydraulic properties of the Algoa Aquifer in specific areas of the site were determined by pump tests and a tracer test. Details of locations and set-ups of tested boreholes with their associated observation borehole are given in ***Appendix 5.11.E***. Parameters obtained from the AEC reports are given in brackets below, although it is difficult to relate these figures to

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specific aquifers. Regional refinement of these properties was performed through numerical modelling and is discussed in ***Subsection 5.11.8***. Hydraulic properties can be summarised as follows:

- transmissivity ranges from 3 to 430 m^2/day, the latter value being from the cobble layer (AEC 8.64 to 17.25 m^2/day);
- hydraulic conductivity varies from 0.67 to 140 m/day, the latter being from the cobble layer (AEC: 86 m/day);
- specific yield varies from 6 per cent in the cobbles to 30 per cent in the sand (AEC: 2 to 20 per cent);
- flow velocity in the Algoa Aquifer (cobble layer and aeolian sand combined) was calculated to be 0.86 m/d;
- flow velocity in the cobble layer, based on one tracer test, was calculated to be 7 m/d - This is a very high value but is proportionate to the highly transmissive nature and low storativity of this layer.

A summary of the hydraulic parameters for the Algoa Aquifer is presented in ***Table 5.11.8***. These are further discussed in the numerical flow modelling section (see ***Subsection 5.11.8***) and the specialist modelling report (***Appendix 5.11.J***).

Borehole Yields

Boreholes drilled into the Algoa Aquifer had high airlift yields ranging from 5 to 10 ℓ/s, especially where the basal cobble layer is well developed. In comparison, boreholes which only intersected the fine-grained sand had much lower airlift yields, ranging from 0.1 to 0.8 ℓ/s. Yield testing of the latter boreholes, however, showed that larger volumes of water are obtainable from pumping. For example, borehole THY-MR2 was pumped at 5 ℓ/s during the step-drawdown test without achieving significant drawdown (estimated to represent 23 per cent of the available resource). However, these high yields could not be sustained during the constant discharge test, due to the ingress of fine sand into the borehole and pumping equipment. Boreholes with aeolian sands, as well as the cobble layer, show moderate to high yields (from 2 to 5 ℓ/s).

Sustainable abstraction rates from boreholes were calculated by using the FC, Cooper-Jacob and Theis methods (Van Tonder, et al., 2002). Rates range from <1.0 to 2.0 ℓ/s in the aeolian sands, 2.0 ℓ/s in the combination of aeolian sands and cobble layer and 9.5 ℓ/s in the cobble layer.

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Table 5.11.8
Summary of the Algoa Aquifer Hydraulic Parameters

Borehole Number	Transmissivity T (m^2/d)	Specific Yield Sy (%)	Saturated Thickness (m)	Calculated Hydraulic Conductivity K (m/day)	Assumed Porosity (%)	Max Test Yield (ℓ/s)	Potential Sustainable Yield (ℓ/s)	Comments
THY-MR1	3	30%	2.0	2	30	0.2	0.05	Thin Algoa Aquifer represented (12 m thick)
THY-MR2	66	5%	25.0	3	30	4.5	2.0	Sustainable yield using FC, Cooper-Jacob & Theis methods**
THY-MR3	n/a	n/a	0.0	n/a	n/a	0.0	n/a	Borehole dry, water table not intersected at end of borehole 55 m
THY-MR4	nt	nt	12.6	nt	30	0.4	0.05	Low yielding borehole
THY-MR5	83	23%	12.9	6.5	30	2.6	1.5	Ingress of sand during the pump test prevented pumping at rates. Sustainable yield using FC, Cooper-Jacob & Theis methods.
THY-MR6	243	30%	15.6	15	30	2.2	2.0	Ingress of sand prevented pumping at higher rates. Sustainable yield using FC non-linear method, T & S values therefore unreliable
THY-MR7	nt	nt	1.5	nt	nt	nt	nt	Yield too low to pump test
THY-MR8	nt	nt	0.6	nt	nt	nt	nt	Yield too low to pump test
THY-MR9	nt	nt	2.2	nt	nt	nt	nt	Yield too low to pump test
THY-MR10	nt	nt	0.0	nt	nt	Dry	nt	Borehole dry, very thin (2 m thick) Algoa Aquifer intersected
THY-MR11*	430	6%	3.0	140	6	9.5	9.5	Distance – drawdown method – cobble layer aquifer only
THY-MR11-M1	nt	nt	16.3	nt	nt	nt	nt	Monitoring borehole

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Borehole Number	**Transmissivity T** (m^2/d)	**Specific Yield Sy** (%)	**Saturated Thickness** (m)	**Calculated Hydraulic Conductivity K** (m/day)	**Assumed Porosity** (%)	**Max Test Yield** (ℓ/s)	**Potential Sustainable Yield** (ℓ/s)	**Comments**
THY-MR11-M2	nt	nt	16.2	nt	nt	nt	nt	Monitoring borehole
THY-MR11-M3	nt	nt	18.9	nt	nt	nt	nt	Monitoring borehole
THY-MR12	nt	nt	16.5	nt	nt	nt	nt	Borehole for cobble layer delineation
THY-MR14	nt	nt	21.3	nt	nt	nt	nt	Borehole for water level information in dunes
THY-MR15	nt	nt	22.5	nt	nt	nt	nt	Borehole for water level information in dunes
THY-RP7	10	0.5%	11.0	0.7	30	0.5	0.1	Algoa Aquifer of sand and cobbles
THY-RP16	nt	nt	20.0	nt	nt	nt	nt	Algoa Aquifer of sand and cobbles
Average	**80**	**18%**		**5.5**	**30**	**1.7**	**0.95**	
Median	**66**	**23%**		**2.7**	**30**	**1.4**	**0.80**	

* Not included in average/median calculations; ** see Appendix 5.11.E; nt = Not tested

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Groundwater Levels

Groundwater levels measured in boreholes tapping the Algoa Aquifer are shown in ***Table 5.11.9***. These are for various periods as indicated in the monitoring status column of this table. Levels are generally deeper in areas of higher elevation, except for THY-MR14 and THY-MR15, which are located within the dune-slack wetlands, within the mobile dune field[12]. Water level fluctuations observed at monitoring boreholes near the site and north of the site (e.g. THY-MR4, -MR5, -MR11-M1, -WBMR1 and -WBMR3) are generally between 5 and 6 m. The reason for this large variation is associated with a water level decline observed after an "extremely wet" rainfall year in 2012 to "extremely dry" rainfall years in 2017 and 2018 (***Subsection 5.11.6.3***). Lesser water level variations of 1.0 to 3.5 m are observed at boreholes east of the site near the Langefonteinvlei wetlands (e.g. (THY-WBMR2, -WBMR4, -WBMR5, -WBMR6 and -MR12). The exception is THY-WBMR3, which is directly downstream of the Langefonteinvlei, where a variation of 5.1 m is observed. Water levels in areas influenced by or close to wetlands are discussed in detail in the wetlands subsection below.

[12] THY-MR14 and -MR15 were covered by sand dunes in Oct-13 and Jun-11 respectively, whereafter continuation of monitoring here was not possible.

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Table 5.11.9
Groundwater Levels for SSR Algoa Aquifer Boreholes (Dipmeter & Data Logger Sources)

Borehole No.	Depth (m)	Surface Elevation (m amsl)	Water Level Minimum (m bgl)	Water Level Maximum (m bgl)	Water Level Average (m bgl)	Water Level Variation (m)	Monitoring Status
THY-MR1	12.0	28.87	8.58	8.60	8.60	0.02	Nonessential BH – No Monitoring since May-08
THY-MR2	42.0	51.45	16.59	18.95	17.777	2.36	Nonessential BH – No Monitoring since May-13
THY-MR3	55.0	76.60	Dry	Dry	Dry	n/a	Dry BH – No Monitoring
THY-MR4	35.0	44.58	18.74	25.59	22.33	6.85	Monthly Feb to May-08. Bi-annually Jun-11 to May13; Aug-17 to Jan-19 and dipmeter 20-Feb-24.
THY-MR5	38.0	42.71	21.35	27.50	24.553	6.15	Monthly Feb to May-08. Hourly by logger Sep-08 to Jan-19 and dipmeter 20-Feb-24.
THY-MR6	21.0	17.68	2.77	8.24	5.01	5.47	Nonessential BH – No Monitoring since May-13
THY-MR7	12.0	16.97	9.36	10.67	10.08	1.31	Nonessential BH – No Monitoring since May-13
THY-MR8	9.0	17.38	7.50	8.45	8.06	0.95	Nonessential BH – No Monitoring since May-13
THY-MR9	8.0	11.38	4.87	6.22	5.60	1.35	Nonessential BH – No Monitoring since May-13
THY-MR10	2.0	6.69	Dry	Dry	Dry	n/a	Dry BH – No Monitoring
THY-MR11	21.0	17.21	2.22	7.93	6.12	5.71	Monthly Feb to May-08. Hourly by logger Sep-08 to May-13
THY-MR11-M1	21.0	17.58	1.42	8.25	5.87	6.83	Hourly by logger Sep-12 to Jan-19; Dipmeter 20-Feb-24.
THY-MR11-M2	21.0	17.19	2.31	7.70	4.36	5.39	Nonessential BH – No Monitoring since May-13
THY-MR11-M3	24.0	17.37	2.41	7.80	4.34	5.39	Nonessential BH – No Monitoring since May-13
THY-MR12	22.0	21.15	12.58	15.27	14.19	2.69	Monthly Feb-10 to Sep-13; Biannually Aug-17 to Oct-18 and Feb-24
THY-MR14	24.3	77.24	0.35	1.87	1.24	1.52	Hourly by logger May-12 to Oct-13 whereafter covered by sand dunes

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Borehole No.	Depth (m)	Surface Elevation (m amsl)	Water Level Minimum (m bgl)	Water Level Maximum (m bgl)	Water Level Average (m bgl)	Water Level Variation (m)	Monitoring Status
THY-MR15	30.0	83.15	0.25	2.65	2.03	2.40	Hourly by logger Feb-10 to Jun-11 whereafter covered by sand dunes
THY-RP7	31.0	18.47	10.34	10.53	10.48	0.19	Nonessential BH – No Monitoring since May-13
THY-RP16	49.0	23.78	7.04	12.39	10.47	5.35	Nonessential BH – No Monitoring since May-13
THY-WBMR1	20.0	36.99	8.79	16.47	13.79	7.68	Hourly by logger Feb-10 to Jan-19
THY-WBMR2	16.4	58.79	9.27	13.31	10.33	4.03	Hourly by logger Feb-10 to Sep-13
THY-WBMR3	16.8	55.21	8.98	14.01	10.54	5.03	Hourly by logger Feb-10 to Jan-19 and by dipmeter on 20-Feb-24
THY-WBMR4	16.0	68.46	2.64	3.69	3.26	1.05	Hourly by logger Feb-10 to Sep-13
THY-WBMR5	18.0	83.66	0.92	3.35	2.14	2.43	Hourly by logger Feb-10 to Jan-19 and by dipmeter on 20-Feb-24
THY-WBMR6	36.0	90.69	18.46	22.21	21.04	3.75	Hourly by logger Feb-10 to Jan-19 and by dipmeter on 20-Feb-24

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Hydrographs of groundwater levels monitored by means of continuous data loggers in THY-MR5, -MR11, -MR11-M1, -WBMR1, -WBMR3, -WBMR5 and THY-WBMR6 are shown in ***Figure 5.11.7*** to ***Figure 5.11.13*** , respectively. Most of the graphs show groundwater levels from May 2008, or February 2010 until February 2024 and rainfall measured at the Cape St. Francis meteorological station. The graphs for THY-MR5 and THY-MR11[13], which are located central and northwest of the Nuclear-1 footprint, show an initial small rise after monitoring started, followed by a sharp decline until mid-2011 whereafter a "very wet" rainfall year in 2011 and an "extremely wet" rainfall year in 2012 (***Subsection 5.11.6.3***) resulted in a steady increase that peaked during the last half of 2013. Thereafter, due to "extremely dry" rainfall years in 2017 and 2018, a steady drop in the groundwater levels of *c*.6 m is observed until the last measurements in February 2024. Similar drops of just less than 7 m are also observed at THY-MR4[14] and THY WBMR1. These large water level declines are ascribed to the "extremely dry" rainfall years described in ***Sub-section 5.11.6.3*** and in TSSR ***Section 5.8***.

In comparison, the monitoring boreholes east of the Nuclear-1 footprint around the Langefonteinvlei wetlands shows much smaller drops of between *c*.2.0 to *c*.3.5 m over the "extremely dry" rainfall years. Groundwater levels here also show considerably more variation and reaction to rainfall events. This is related to the buffering capacity of the wetland and rapid throughflow from the recharge zone associated with unvegetated dune belt occurring just north of the wetlands.

The graphs show a steady but small drop in groundwater level of about 0.2 m during the monitoring period of mid-June to early September 2008. A small rise of water level occurred from September 2008 to February 2009 with a steady (0.35 to 1.50 m) decline to November 2009. Two high rainfall events occurred between October-December 2008 and one in June 2009. A minor rise of the water level occurred after the 2008 events but no corresponding rise in water level occurred after the June 2009 event, thus indicating that the Algoa Aquifer has a large absorbative capacity for infiltration and that high rainfall events do not appear to be likely to cause a critical rise in local groundwater levels that could affect site safety. This is considered to be due to the following site characteristics:

- overflow of excess groundwater into the Langefonteinvlei;

[13] Monitoring was continued here in May 2013 and the Level Logger moved to the nearby THY-MR11-M1.

[14] Graph not included.

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- the high storage and therefore absorbative capacity of the aeolian sands;

- the highly transmissive nature of the basal conglomerate, which acts as a 'drainage blanket' rapidly transporting excess groundwater out of the system, to discharge in the coastal seeps and springs.

Therefore, there appears to be a 'threshold' level above which groundwater levels do not rise. This is similar to the hypothesis put forward to explain groundwater responses in the Rawsonville-Goudini primary aquifer near Worcester (Bureau de Recherches Geologiques et Minieres, 1976).

Groundwater levels and interpolated contours for the site and surrounding area are shown in ***Drawing 5.11.8***. The contours indicate that the main groundwater flow direction for the Algoa Aquifer is in a southerly to southeasterly direction, i.e. towards the coast.

Water level data obtained from SSR monitoring boreholes during the test pumping suggest connectivity between the boreholes located mainly in a west to east direction. Drawdowns of between 0.1 and 1.5 m were observed over distances varying between 5 to 150 m during the test pumping programme.

Apart from the influence of rainfall recharge on groundwater levels, certain man-made features associated with the nuclear installation(s), such as the effects of the proposed storm water retention ponds, could influence groundwater levels. However, the effect of the ponds (see ***Section 5.10***) on local groundwater levels is likely to be minimal since these ponds will be lined, there will be relatively small volumes of surface water run-off created during storm events (small catchments) and because of the high absorptive absorbative capacity of the Algoa Aquifer, as previously discussed.

It is predicted that global warming will cause an increase in sea levels worldwide. Modelling of potential sea level rise at the site has indicated (see ***Section 5.9***, Oceanography and Coastal Engineering) a possible rise of about 1.76 m to 3.28 m over the next 100 years. The possible impact of this sea level rise on site groundwater levels is covered in ***Subsection 5.11.8***. Any rise in temperature will not have a significant impact on groundwater beyond increasing evapotranspiration, which will have a far lesser impact than sea level rise and "wet" and "dry" periods. Surface evaporation from the wetlands may increase with higher temperatures.

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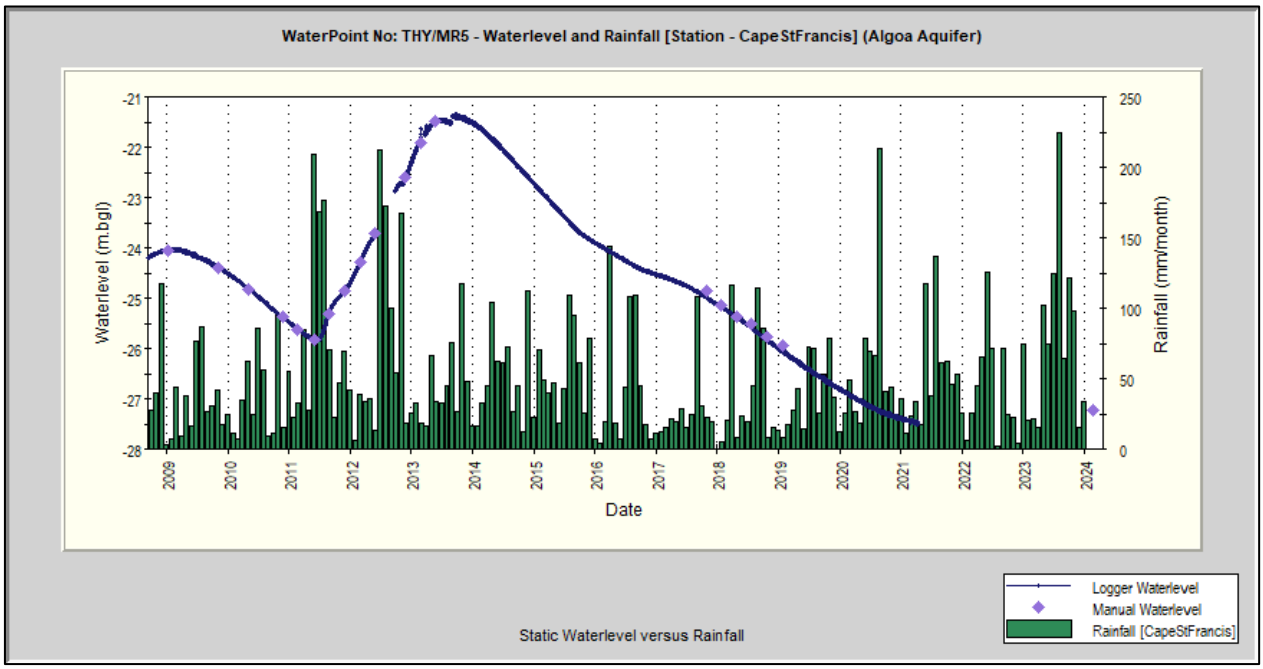


Figure 5.11.7
Hydrograph: THY-MR5 (Algoa Aquifer)

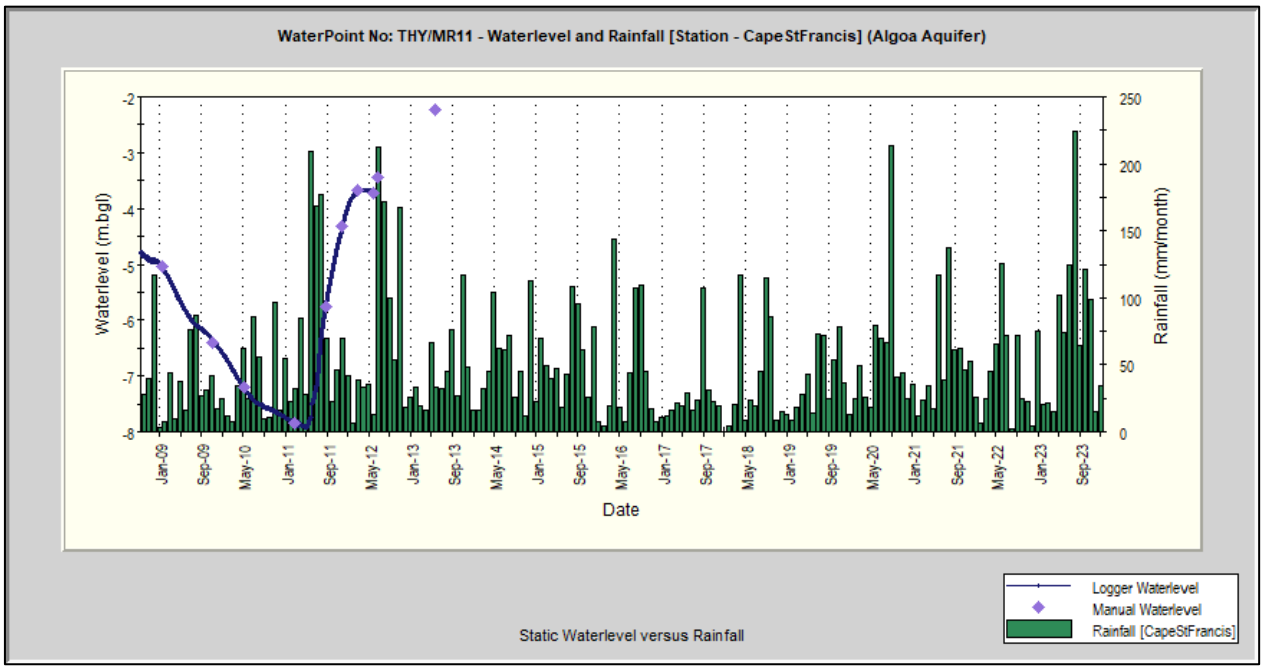


Figure 5.11.8
Hydrograph: THY-MR11 (Algoa Aquifer)

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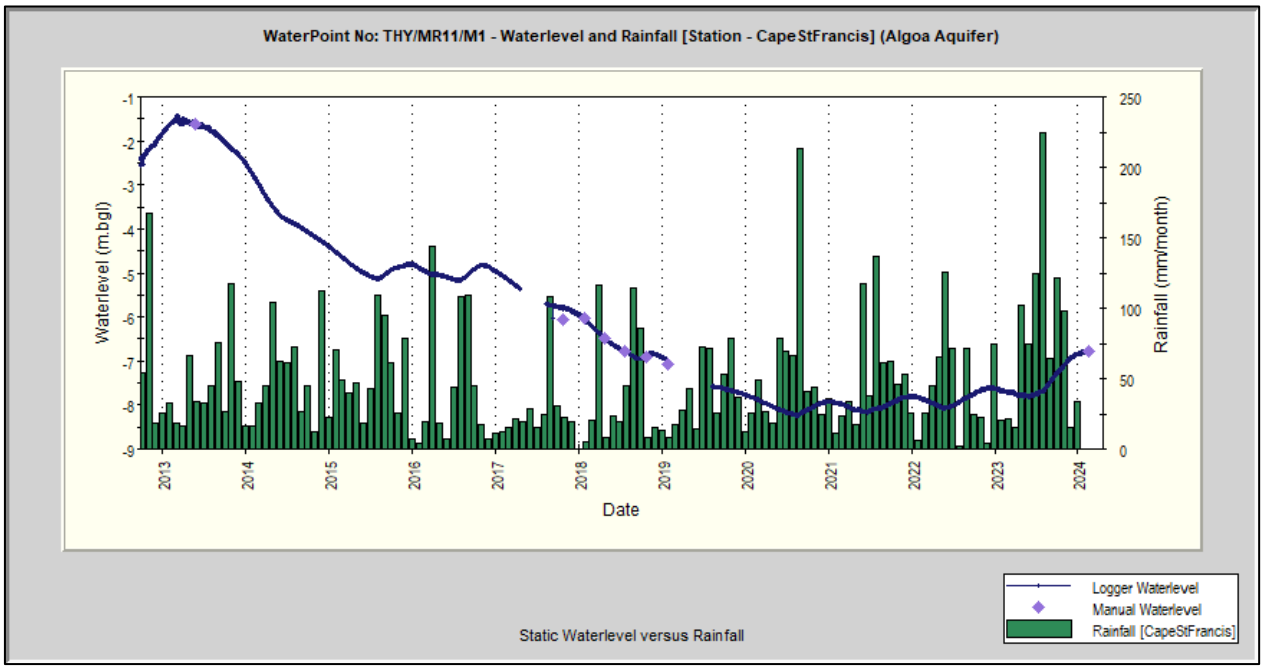


Figure 5.11.9
Hydrograph: THY-MR11-M1 (Algoa Aquifer)

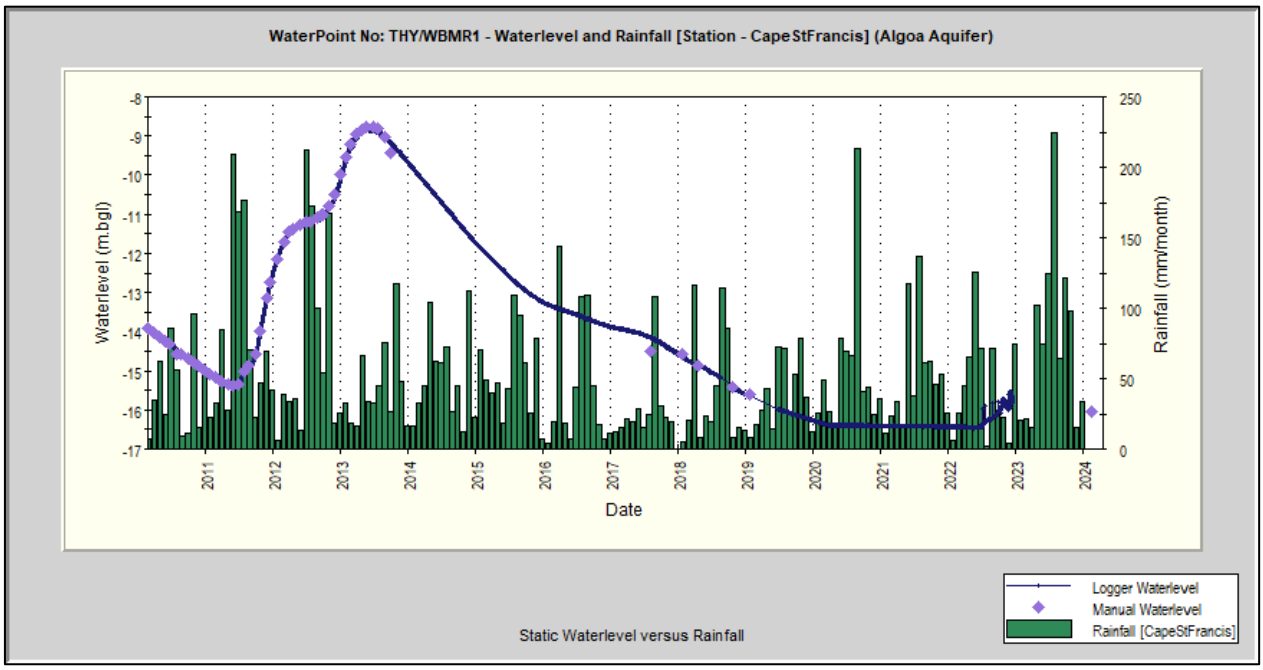


Figure 5.11.10
Hydrograph: THY-WBMR1 (Algoa Aquifer)

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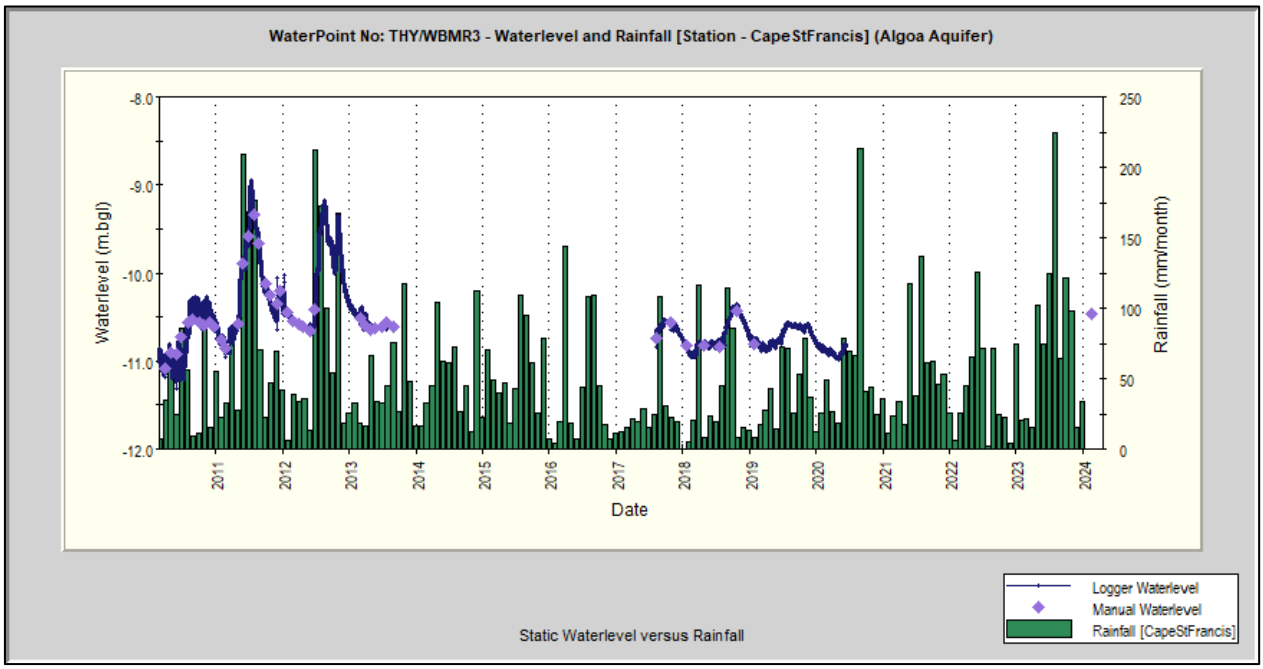


Figure 5.11.11
Hydrograph: THY-WBMR3 (Algoa Aquifer)

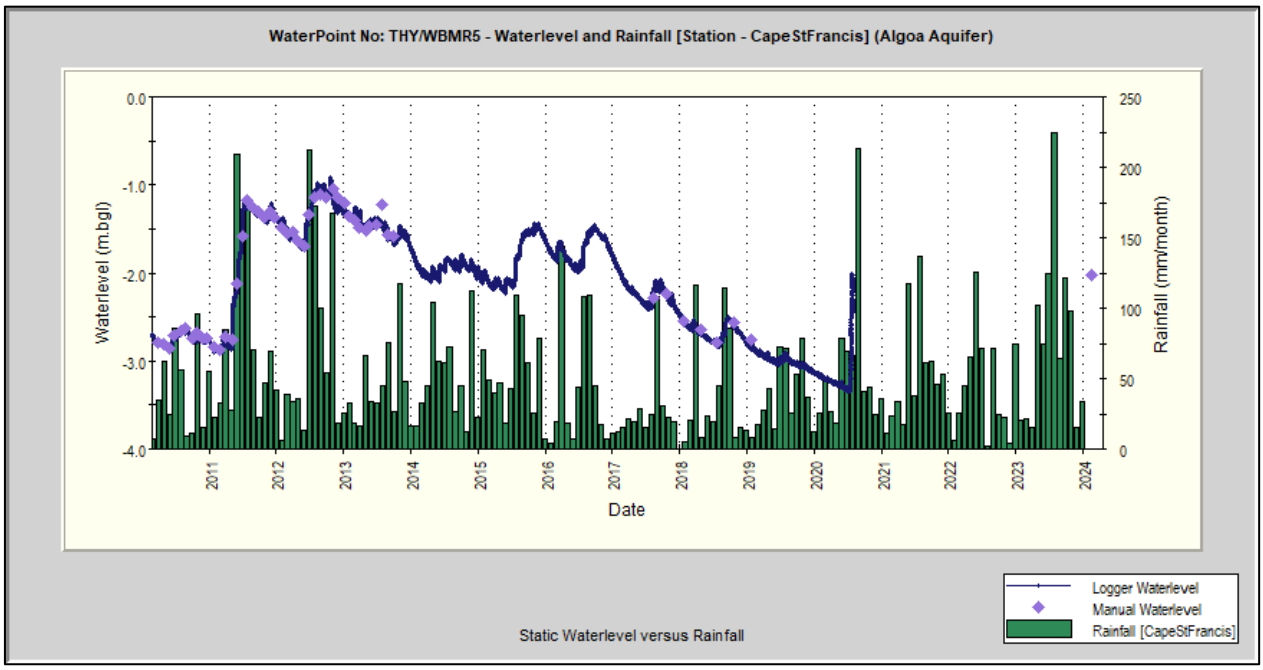


Figure 5.11.12
Hydrograph: THY-WBMR5 (Algoa Aquifer)

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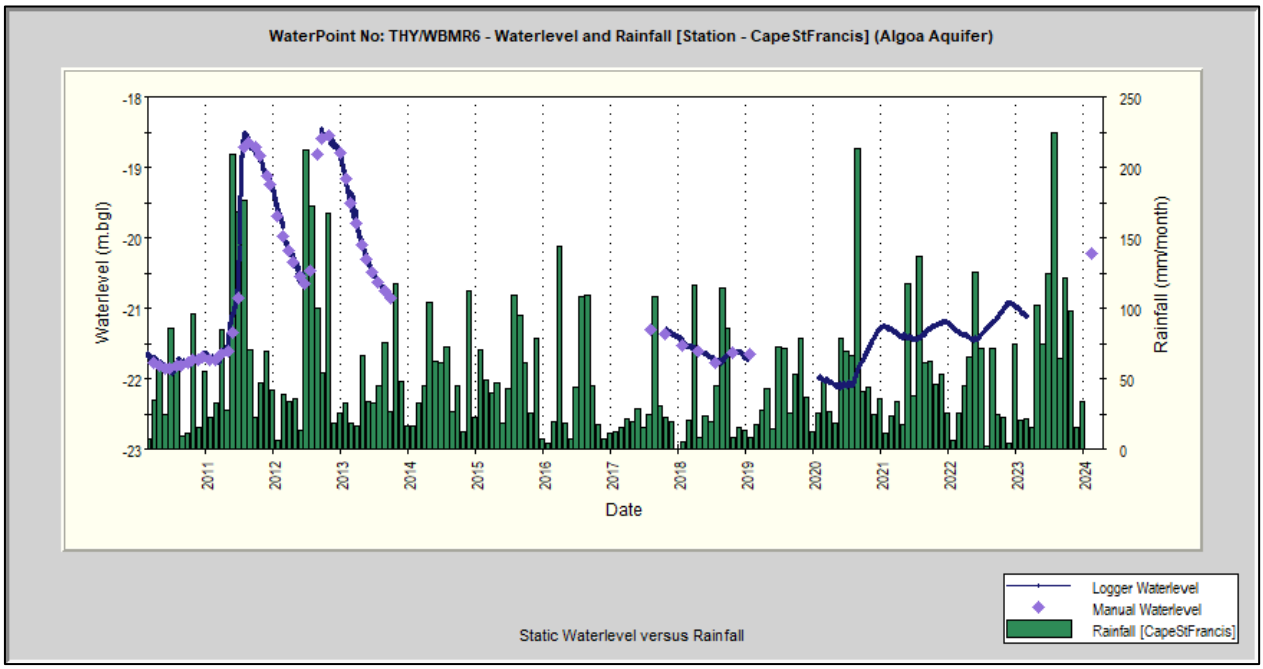
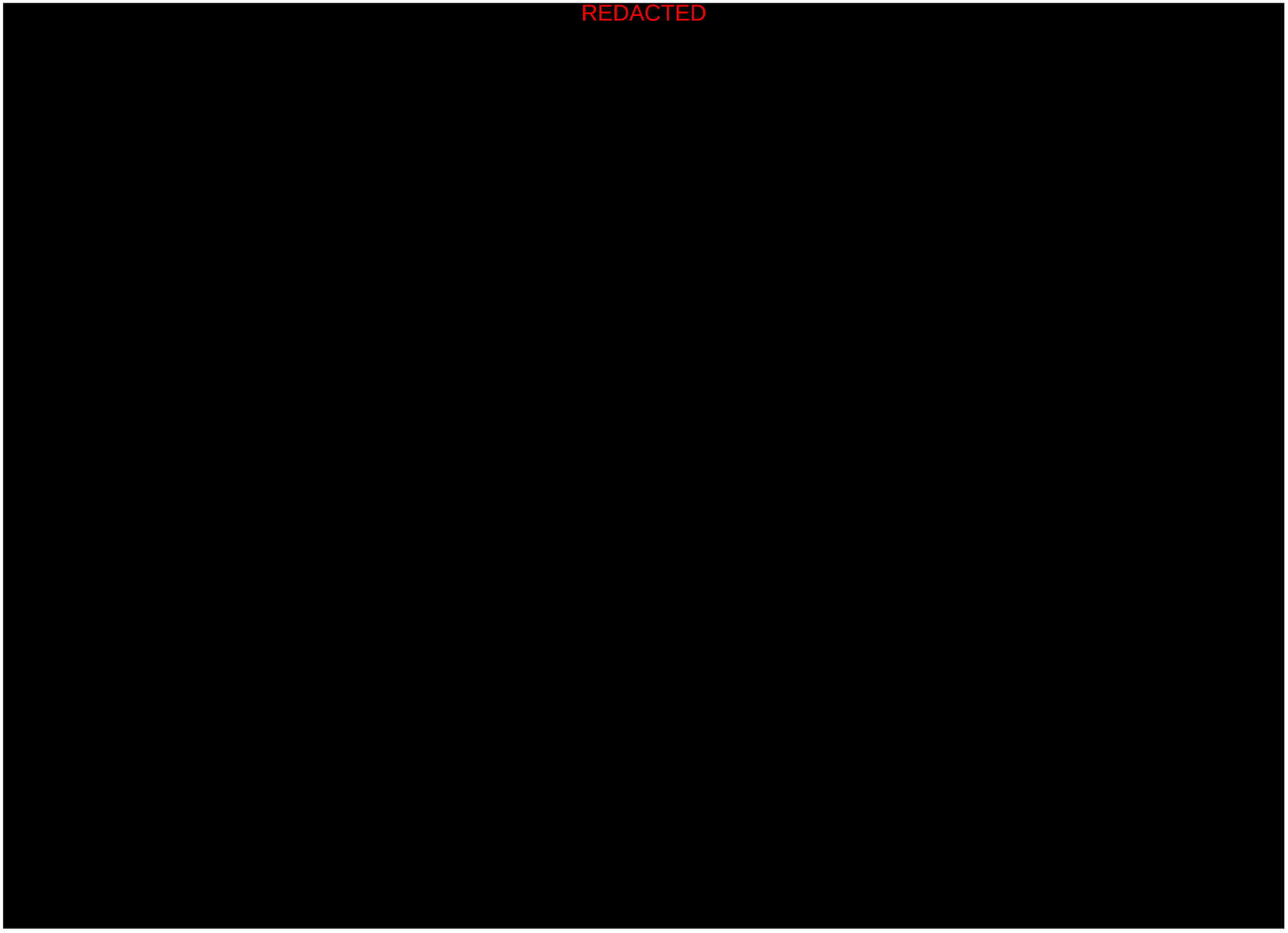


Figure 5.11.13
Hydrograph: THY-WBMR6 (Algoa Aquifer)

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Groundwater Quality

Measured EC values varied from 51 to 82 mS/m and pH values were neutral to alkaline, ranging from 7.1 to 7.9. Down-hole EC and pH profile logs were run in the yield-tested SSR boreholes, i.e. those listed in ***Table 5.11.10***. A graphical example of the results of such a down-hole log is shown in ***Figure 5.11.14*** (see ***Appendix 5.11.D*** for the rest of the borehole logs). In most of the boreholes the EC increases slightly with depth, by approximately 9 mS/m, the pH decreases by approximately 0.3 pH units and the temperature decreases by approximately 0.2ºC. These are all considered to be normal trends in a relatively shallow coastal aquifer environment.

There is no indication of the freshwater-saline water interface zone that should theoretically be present at the coast, as none of the boreholes have been drilled deep enough to intersect this zone. This interface zone appears to be deeper than the zone of potential impact of the nuclear installation(s). The fresh/saline water interface in an aquifer can be estimated by using the Ghyben-Hertzberg relationship (Verrjuit, 1968), which states that the depth of interface (in m) is equal to the height of water level in m amsl x 40. The groundwater level in the Nuclear-1 footprint area is about 6 to 9 m amsl, which means that the interface is at about 240 to 360 m bgl in this area, and therefore below the base of the Algoa Aquifer and top of the solid bedrock that the nuclear installation(s) will be founded on. It is therefore not of concern with respect to the nuclear installation foundations.

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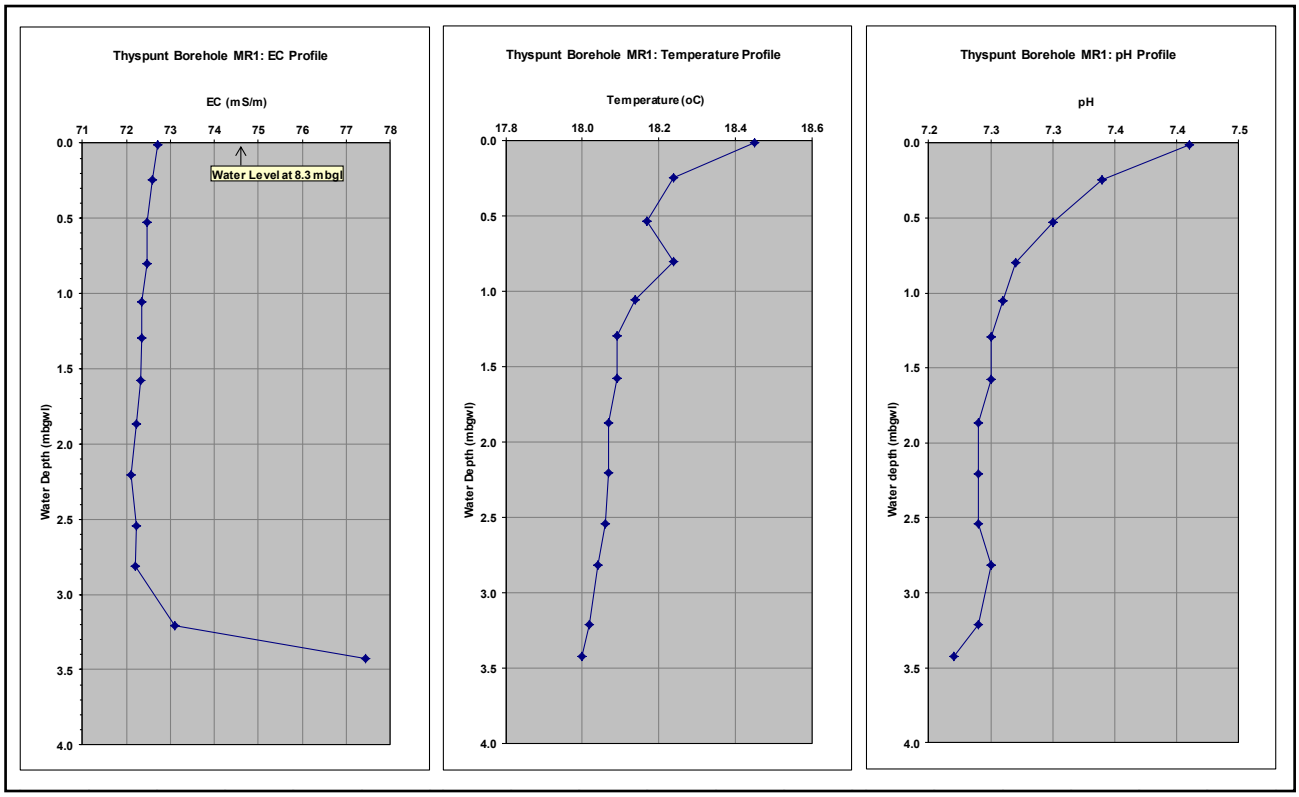


Figure 5.11.14
Down-hole EC, pH and Temperature Logs for Borehole THY-MR1

Piper Diagrams of water samples taken from selected SSR boreholes in the Algoa Aquifer are shown in ***Figure 5.11.15***. The plots show a dominant $Ca(HCO_3)_2$ character, which is indicative of recent recharge (<*c*.30 years).

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Table 5.11.10
Chemical Analyses Summary of Cations: Algoa Aquifer Boreholes

Borehole ID	Ca (mg/ℓ)			Mg (mg/ℓ)			Na (mg/ℓ)			K (mg/ℓ)			Alkalinity as $CaCO_3$ (mg/ℓ)		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
THY_MR02	88	88	88	10	10	10	53	53	53	2.2	2.2	2.2	203	203	203
THY_MR04	70	116	93	9	12	11	46	88	56	1.0	1.0	1.6	184	249	211
THY_MR05	95	95	95	10	10	10	60	60	60	2.6	2.6	2.6	221	221	221
THY_MR06	88	88	88	8	8	8	54	54	54	2.4	2.4	2.4	249	249	249
THY_MR12	91	163	129	9	15	12	24	81	66	<0.1	0.6	2.6	273	462	353
THY_MR15	52	99	79	4	74	11	16	37	26	1.2	1.2	1.7	186	236	219
THY_RP07	70	103	83	8	937	241	51	59	54	1.3	1.3	2.7	200	229	211
THY_RP08	94	129	112	16	26	22	166	266	210	4.0	4.0	5.0	184	277	239
THY_RP12	64	113	89	7	10	9	44	104	54	0.8	0.8	1.6	133	254	206
THY_RP13	101	234	160	7	46	38	53	489	344	1.7	1.7	10.6	218	240	234
THY_RP14	78	107	88	11	16	13	71	80	74	2.2	2.2	3.4	208	225	218
THY_RP16	103	103	103	9	9	9	58	58	58	1.8	1.8	1.8	276	276	276
THY_WBMR1	66	223	97	6	16	10	18	137	56	0.9	0.9	2.3	173	441	229
THY_WBMR2	106	154	129	8	13	10	42	83	71	0.4	0.4	1.5	279	416	324
THY_WBMR3	80	190	124	8	21	13	22	166	104	<0.1	0.6	2.1	253	500	325
THY_WBMR4	67	146	111	6	12	9	34	74	48	0.3	0.3	1.5	229	366	291
THY_WBMR5	88	154	112	7	14	9	39	76	57	<0.1	0.2	0.9	255	389	305
THY_WBMR6	74	141	95	14	20	17	46	87	70	0.4	0.4	1.2	238	391	295

Values less than the Laboratory's detection limit excluded.

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Table 5.11.11
Chemical Analyses Summary of Anions A: Algoa Aquifer Boreholes

Borehole ID	Cl (mg/ℓ)			SO_4 (mg/ℓ)			NO_3 as N (mg/ℓ)			F (mg/ℓ)		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
THY_MR02	86	86	86	26.7	**26.7**	26.7	0.91	0.91	0.91	1.00	1.00	1.00
THY_MR04	67	142	102	21.0	**50.0**	30.8	0.20	3.40	1.30	0.10	0.40	0.24
THY_MR05	96	96	96	23.7	**23.7**	23.7	0.46	0.46	0.46	0.20	0.20	0.20
THY_MR06	89	89	89	18.7	**18.7**	18.7	0.43	0.43	0.43	0.20	0.20	0.20
THY_MR12	81	136	109	1.1	**92.0**	12.0	0.09	1.10	0.36	0.10	0.50	0.28
THY_MR15	37	63	46	1.9	**16.6**	6.1	0.10	4.00	0.96	0.10	0.10	0.10
THY_RP07	78	95	86	22.0	**27.0**	25.3	0.47	6.30	2.22	0.10	0.20	0.18
THY_RP08	272	473	374	41.7	**123.0**	65.2	0.15	1.30	0.66	0.01	0.20	0.14
THY_RP12	27	115	91	8.0	**35.2**	24.9	0.09	1.13	0.28	0.10	0.40	0.22
THY_RP13	89	853	670	33.2	**118.0**	90.3	0.27	14.50	6.31	0.10	0.20	0.19
THY_RP14	29	125	93	1.4	**30.0**	20.5	1.40	3.70	2.50	0.10	0.20	0.15
THY_RP16	95	95	95	33.2	**33.2**	33.2	0.25	0.25	0.25	0.20	0.20	0.20
THY_WBMR1	41	261	102	2.4	**82.0**	25.8	0.20	13.10	2.08	0.10	0.60	0.24
THY_WBMR2	101	139	122	0.7	**32.0**	11.7	0.10	2.00	0.47	0.30	0.30	0.30
THY_WBMR3	60	251	164	3.7	**49.0**	26.3	0.09	2.20	0.48	0.30	0.60	0.42
THY_WBMR4	59	135	79	0.2	**33.0**	9.8	0.10	1.20	0.24	0.20	0.20	0.20
THY_WBMR5	69	99	88	0.2	**19.6**	3.1	0.10	5.00	0.72	0.20	0.60	0.34
THY_WBMR6	91	124	110	0.2	**20.0**	4.8	0.10	1.30	0.41	0.20	0.60	0.38
Values less than Laboratory's detection limit excluded.												

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Table 5.11.12
Chemical Analyses Summary of Anions B: Algoa Aquifer Boreholes

Borehole ID	NH_4 (mg/ℓ)			PO_4 (mg/ℓ)		
	Min.	Max.	Average	Min.	Max.	Average
THY_MR02	0.05	0.05	0.05	0.10	0.10	0.10
THY_MR04	0.23	0.23	0.23	0.14	0.14	0.14
THY_MR05	0.04	0.04	0.04	0.10	0.10	0.10
THY_MR06	0.02	0.02	0.02	0.04	0.04	0.04
THY_MR12	0.10	6.30	1.15	0.17	0.31	0.25
THY_MR15	NA	NA	NA	NA	NA	NA
THY_RP07	0.12	0.12	0.12	0.12	1.90	0.79
THY_RP08	0.01	0.01	0.01	0.14	2.40	1.27
THY_RP12	NA	NA	NA	0.18	4.30	2.24
THY_RP13	0.01	0.01	0.01	0.11	2.90	1.67
THY_RP14	NA	NA	NA	2.50	2.50	2.50
THY_RP16	0.01	0.01	0.01	0.14	0.14	0.14
THY_WBMR1	0.10	0.20	0.15	0.11	14.27	5.34
THY_WBMR2	0.10	0.60	0.22	NA	NA	NA
THY_WBMR3	0.10	1.10	0.31	NA	NA	NA
THY_WBMR4	0.20	2.00	0.82	NA	NA	NA
THY_WBMR5	0.10	1.50	0.33	0.31	0.56	0.42
THY_WBMR6	0.10	1.50	0.34	NA	NA	NA
NA – Not Analysed						

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Table 5.11.13
Chemical Analyses Summary of EC, pH, Fe & Mn: Algoa Aquifer Boreholes

Borehole ID	EC (mS/m)			pH			Mn (mg/ℓ)			Fe (mg/ℓ)		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
THY_MR02	72	72	72	7.6	7.6	7.6	0.039	0.039	0.039	0.039	0.039	0.039
THY_MR04	69	94	78	7.1	8.4	7.9	0.002	0.050	0.033	0.002	0.059	0.028
THY_MR05	78	78	78	7.8	7.8	7.8	0.039	0.039	0.039	0.039	0.039	0.039
THY_MR06	76	76	76	8.0	8.0	8.0	0.039	0.039	0.039	0.039	0.039	0.039
THY_MR12	61	127	99	6.0	8.3	7.5	0.003	0.090	0.035	0.019	0.039	0.026
THY_MR15	43	70	60	7.7	8.3	8.0	NA	NA	NA	NA	NA	NA
THY_RP07	68	72	70	6.6	8.3	7.6	0.039	0.050	0.045	0.039	0.600	0.230
THY_RP08	143	215	171	6.9	8.0	7.7	0.008	0.039	0.024	0.039	0.129	0.084
THY_RP12	66	89	76	6.1	8.3	7.6	0.002	0.209	0.078	0.008	0.189	0.053
THY_RP13	76	287	252	6.5	8.2	7.6	0.039	0.039	0.039	0.003	0.109	0.051
THY_RP14	83	93	87	7.7	8.2	7.9	0.050	0.050	0.050	0.030	0.100	0.065
THY_RP16	78	78	78	8.0	8.0	8.0	0.039	0.039	0.039	0.039	0.039	0.039
THY_WBMR1	47	129	81	5.6	8.4	7.3	0.001	0.037	0.012	0.001	1.380	0.341
THY_WBMR2	78	121	99	6.0	8.4	7.4	NA	NA	NA	NA	NA	NA
THY_WBMR3	61	160	116	5.9	8.3	7.4	0.009	0.046	0.028	0.001	2.877	1.338
THY_WBMR4	57	108	79	6.2	8.4	7.5	NA	NA	NA	NA	NA	NA
THY_WBMR5	66	103	84	6.2	8.5	7.5	0.006	0.030	0.022	0.003	0.959	0.338
THY_WBMR6	71	107	88	5.9	8.4	7.3	0.037	0.043	0.039	3.641	3.796	3.735
Values less than the Laboratory's detection limit excluded. NA – Not Analysed												

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The Langelier Saturation Indices representing the Algoa Aquifer vary from 0.40 to 1.04, indicating that this groundwater is likely to cause scaling rather than being corrosive. Sulfate, which corrodes ordinary concrete when present in concentrations >200 mg/ℓ, ranges from 18 to 34 mg/ℓ and the corrosion risk is therefore considered to be low.

Radionuclide analyses of water samples from SSR boreholes were conducted in order to determine baseline levels. The results of these analyses are presented in ***Table 5.11.14***.

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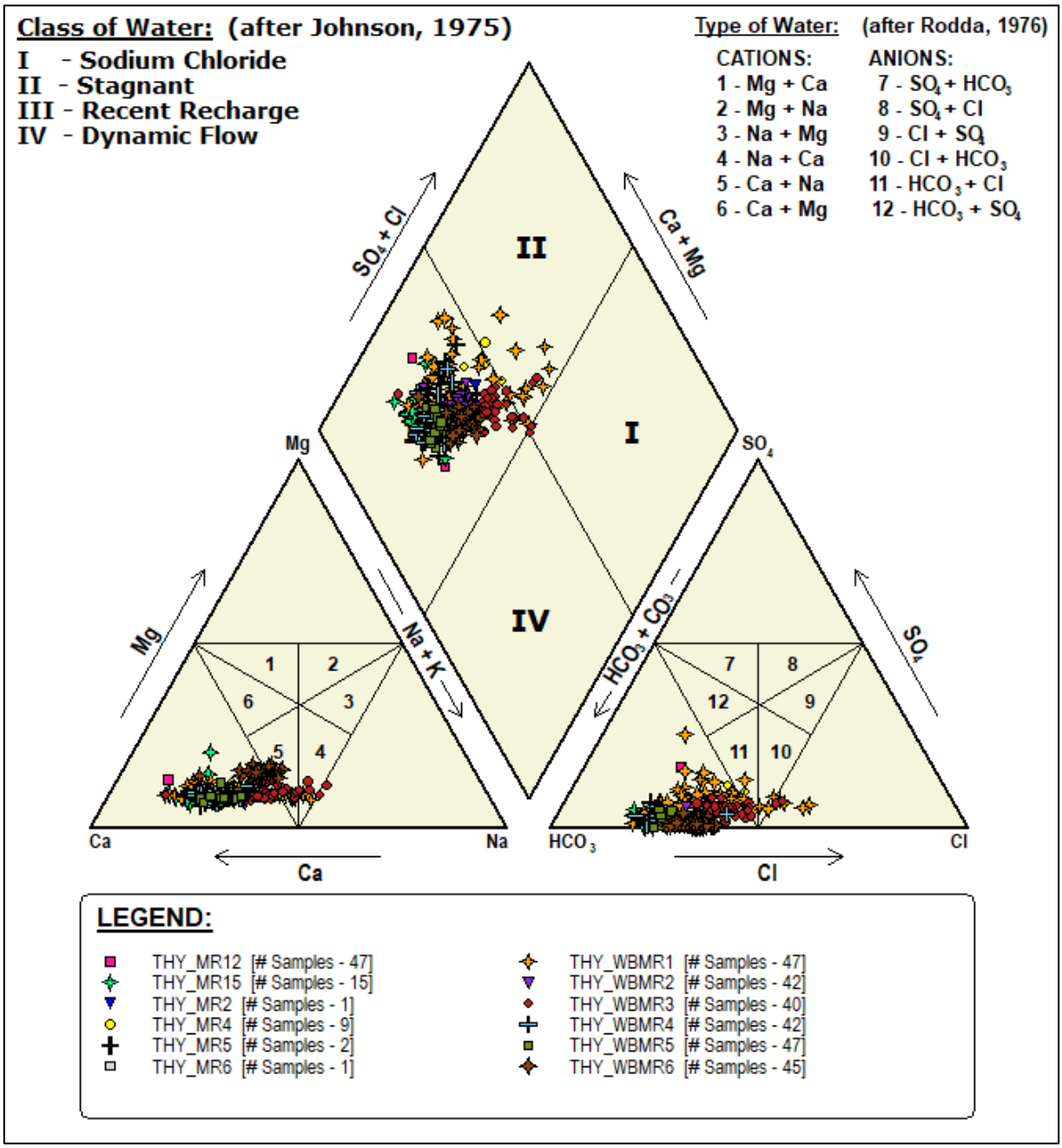


Figure 5.11.15
Piper Diagram of Samples from the Algoa Aquifer Boreholes

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Table 5.11.14
Radionuclide Analyses: Algoa Aquifer

Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
April 2008 Drilling Sampling																														
THY-MR2	29.6	8.8	17	122	17	21	1.37	0.41	0.77	29	7.8	84	10	4.6	11	2.9	2.1	4	NA	NA	NA	NA	NA	NA	-48	200	670	230	270	890
THY-MR5	72.4	13.6	18	134	18	6.5	3.33	0.63	0.82	57	14.4	36	12	6.1	16	8.6	6.1	20	NA	NA	NA	NA	NA	NA	-240	200	690	210	270	890
THY-MR6	18	8.7	24	43.7	10.8	7.1	0.85	0.4	1.1	42	11	77	16.5	7	16	11.9	4.4	9.7	NA	NA	NA	NA	NA	NA	-290	220	730	220	270	890
THY-RP7	27.1	6.9	12	60.9	10.2	12	1.25	0.32	0.54	18	6.4	86	45.8	11	20	26.7	6.6	11	NA	NA	NA	NA	NA	NA	-270	210	710	-96	270	890
THY-RP16	20	9.	26	52.4	12.2	7.6	0.9	0.43	1.2	290	49	100	42.4	10.5	13	19.4	6.8	16	NA	NA	NA	NA	NA	NA	-350	260	890	280	270	900
June 2008 Monitoring																														
THY-SP7	7.05	2.64	6.5	30.7	4.9	6.5	0.32	0.12	0.3	110	29	180	77.2	23.4	48	30.9	12.6	14	5.03	1.2	2.2	5.03	1.29	2.2	-43	140	480	360	180	580
THY-RP7	8.88	2.68	2.2	18.2	4	5.9	0.41	0.12	0.1	124	24	59	10	7.1	20	21.5	6.0	4.5	1.9	0.82	2	1.9	0.82	2	-74	130	450	150	180	580
November 2008 Monitoring																														
THY-SP7	9.27	1.89	1	11.6	2.3	3.6	0.43	0.09	0.048	55	9.6	14	4.59	1.66	3.8	3.78	1.26	1.1	5.02	1.15	1.8	-1	0.74	2.8	230	340	1100	971	177	560
THY-RP7	19	2.5	2.4	23	2.8	3	0.88	0.12	0.11	13	3.3	16	-0.92	1.6	7.1	1.5	1.3	4.4	1.5	0.81	2.4	1.1	0.99	3.5	-39	310	1100	380	170	550
May 2009 Monitoring																														
THY-SP7	Cancelled																													
THY-RP7	Cancelled																													
May 2011 Monitoring																														
THY-MR4	30.7	5.9	3.1	86	10	3.1	1.41	0.27	0.14	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.2	1.8	0.87	-1,2	1.2	1.2	-25	160	550	-5.4	290	960
RHY-MR12	10.5	3.3	2.8	30.9	5.7	2.8	0.481	0.152	0.130	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.87	1.01	0.97	0.064	0.77	1.30	66	180	590	120	290	960
THY-MR15	31.9	7.1	4.3	265	21	4.3	1.47	0.33	0.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.80	1.05	0.79	-0.32	0.71	1.10	-24	150	520	77	290	950
THY-WBMR1	8.62	2.09	1.4	6.70	1.90	1.4	0.397	0.086	0.063	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.68	1.38	0.91	-1.5	1.4	1.6	-110	160	540	84	290	950
THY-WBMR3	13.4	4.0	3.3	23.7	5.4	3.3	0.615	0.186	0.150	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.66	1.06	0.83	-1.3	1.0	1.5	11	180	610	220	290	960
THY-	9.91	2.40	1.60	5.95	1.94	1.6	0.456	0.111	0.073	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.43	1.44	0.87	-1.2	1.5	1.5	230	170	570	180	290	960

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
WBMR5																														
THY-WP2	20.6	5.3	3.7	26.5	6.1	3.7	0.946	0.244	0.170	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.20	1.21	0.95	-0.55	1.1	1.5	10	170	560	20	290	960
THY-WP3	11.4	3.3	2.6	18.5	4.3	2.6	0.525	0.152	0.120	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.50	1.05	0.86	-0.96	0.80	1.4	-85	160	530	46	290	950
THY-WSP7	9.56	2.20	1.4	14.2	2.7	1.4	0.442	0.101	0.063	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.15	1.05	0.95	-0.05	0.78	1.3	-31	160	550	100	290	960
Municipal Spring	11.3	3.1	2.4	18.7	4.1	2.4	0.523	0.145	0.110	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.56	0.91	0.87	-0.31	0.60	1.2	-16	170	560	130	290	960
November 2011 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-650	560	1900	1140	290	930
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-610	560	1900	976	289	930
THY-WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-450	440	1500	1040	290	920
THY-WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-690	640	2200	1050	290	930
THY-WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-500	390	1300	780	280	910
THY-WP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-480	430	1500	820	280	920
THY-WP3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-310	540	1800	910	500	1600
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-490	670	2200	380	500	1600
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-290	660	2200	520	500	1600
Rebels Rus Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-920	1300	4300	510	520	1700
THY-WP6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-360	600	2000	-73	500	1600
May 2012 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62	74	250	210	170	580
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-16	85	290	130	180	580
THY-WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	540	97	290	320	180	580
THY-WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	37	76	260	240	180	580

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
THY-WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.9	83	290	160	180	580
THY-WP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.8	80	280	110	180	580
THY-WP3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-28	88	310	110	180	590
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	16	87	300	-51	180	590
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-34	88	310	50	180	590
Rebels Rus Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	26	84	290	44	180	580
November 2012 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	190	70	210	-75	290	970
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	74	75	260	-160	290	980
THY-WBMR 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	281	86	260	2.4	290	980
THY-WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	14	62	220	-290	290	970
THY-WP 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	32	75	260	-290	290	980
THY-WP 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	90	59	190	-320	290	960
THY-WSP 7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	28	70	240	-23	290	970
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	34	67	230	-150	290	970
Rebels Rus Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-17	86	310	-130	300	990
May 2013 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-49	86	310	140	140	460
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-54	93	330	260	140	460
THY-WBMR 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-150	110	400	-110	140	470
THY-WBMR 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-66	100	370	2	140	460
THY-WBMR 5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18	87	300	-54	140	460

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
THY-WP 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-6.1	92	320	-49	140	460
THY-WP 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-75	71	260	-250	130	460
THY-WSP 7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	45	110	380	14	140	460
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-130	80	290	-160	140	460
Rebels Rus Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-19	90	320	120	140	460
August 2017 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.03	0.59	0.93	1.25	0.81	1.20	-16	22	95	200	67	210
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.39	1.20	1.10	-0.83	0.62	1.50	43	32	110	170	64	200
THY-WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.67	0.75	0.91	0.55	0.54	1.00	-25	16	74	77	66	220
THY-WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.27	0.64	0.86	1.53	0.76	0.96	19	33	120	130	69	230
THY-WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.22	0.91	1.00	0.96	0.71	1.10	54	27	84	110	68	220
THY-WBMR6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.29	0.87	0.89	1.16	0.72	0.99	15	29	110	170	65	210
THY-WP3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.82	2.48	6.30	4.79	1.99	4.30	-34	26	110	68	68	230
THY-WSP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.87	1.42	0.94	-0.30	0.98	1.30	6	25	95	190	70	220
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.41	1.33	1.10	0.23	1.00	1.50	-6	33	130	-22	71	250
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.47	0.87	0.84	1.38	0.76	0.93	4	23	88	160	75	240
October 2017 Monitoring																														
THY-MR4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.26	0.63	0.85	-0.36	0.87	3.40	27	24	82	110	64	210
THY-MR12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.30	2.10	6.60	-2.80	2.30	12.0	187	41	98	265	67	200
THY-WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.28	0.80	0.77	-0.28	0.69	2.50	-20	16	71	-29	63	220
THY-WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.67	1.02	0.77	-0.35	0.52	2.30	6	29	110	-20	65	220

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
THY-WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.81	0.94	0.85	1.30	0.91	2.50	25	24	85	-99	62	220
THY-WBMR6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.74	0.91	1.90	0.25	0.59	2.10	-50	21	100	110	63	210
THY-WP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.79	1.86	4.30	-3.90	2.00	8.60	102	33	94	397	71	210
THY-WP3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.75	1.04	1.10	1.40	1.10	3.20	-30	28	110	57	68	230
THY-WSP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.60	2.10	7.10	5.20	2.50	5.50	16	25	90	264	72	220
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	1.10	4.80	0.57	2.30	11.0	-23	32	130	-59	70	250
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.40	1.10	3.50	-1.90	1.10	6.50	-9	22	90	409	82	240
April 2018 Monitoring																														
THY-MR 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.50	1.30	4.50	**-1.10**	**0.92**	**4.50**	**4**	**3**	**10**	**4**	**6**	**21**
THY-MR 12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.70	1.40	4.00	**0.55**	**1.20**	**4.50**	**9**	**3**	**10**	**8**	**6**	**21**
WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.40	2.80	8.20	**-1.40**	**2.20**	**9.90**	**-5**	**4**	**15**	**77**	**9**	**22**
WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.51	1.29	2.80	**-0.57**	**1.50**	**6.10**	**3**	**3**	**10**	**11**	**7**	**25**
WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.20	1.80	5.00	**2.50**	**1.80**	**5.00**	**9**	**3**	**9**	**2**	**7**	**22**
WBMR6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.10	1.30	5.50	**-0.39**	**1.10**	**5.10**	**4**	**3**	**12**	**-4**	**7**	**23**
THY-WP 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.50	2.40	7.30	**-0.02**	**1.50**	**3.10**	**3**	**3**	**9**	**-1**	**6**	**21**
THY-WP 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.40	1.00	2.70	**0.14**	**0.85**	**3.40**	**17**	**4**	**9**	**7**	**7**	**22**
THY-WSP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.69	2.03	4.40	**-0.67**	**1.50**	**5.00**	**4**	**3**	**9**	**25**	**7**	**20**
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.30	1.60	5.60	**0.79**	**1.30**	**5.30**	**10**	**4**	**13**	**22**	**7**	**21**
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.70	1.30	3.50	**1.80**	**1.60**	**5.40**	**7**	**3**	**9**	**2**	**7**	**22**
October 2018 Monitoring																														
THY-MR 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.96	1.05	1.00	-2.30	2.50	9.90	17	24	86	92	64	210
THY-MR 12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.80	0.95	2.80	-3.70	2.00	8.80	36	31	100	180	64	200

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
WBMR1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.99	1.34	1.60	1.60	1.10	1.80	0.0040	23	88	449	71	200
WBMR3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.20	0.82	1.60	2.30	1.22	1.80	-11	30	120	54	67	220
WBMR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.48	1.16	1.00	0.91	0.77	1.20	-26	24	100	110	64	210
WBMR6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20.80	3.60	1.70	8.67	2.81	1.90	44	33	110	79	63	210
THY-WP 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.87	1.72	1.70	0.85	1.00	1.80	31	26	89	150	63	200
THY-WP 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.92	1.71	1.30	1.00	1.00	1.50	-9.0	29	110	69	68	230
THY-WSP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.27	1.03	0.89	1.08	0.74	0.99	42	28	93	226	71	220
THY-WSP7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.10	1.40	4.40	-0.40	1.20	4.70	-18	33	130	66	73	250
Municipal Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.70	0.50	0.95	1.00	0.65	1.10	57	32	100	140	66	210

MDA = minimum detectable activity concentration (@ 95% confidence level)

1θ = reported uncertainty from counting statistics; NA = Not Analysed[15];

[15] Analysis of some radionuclides was discontinued due to their extremely low concentrations in the groundwater samples collected at the site. Monitoring programmes from August 2017 included only those constituents listed in NNR Regulatory Guide RG-0011 Rev 0.

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Stable Isotopes and Tritium

Five water samples taken during the SSR drilling programme were submitted for deuterium/hydrogen (D/H), Oxygen-18/Oxygen-16 and H-3 analysis and the results are presented in ***Table 5.11.15***.

The SSR drilling samples in ***Figure 5.11.16*** plot on a line approximately parallel to and just above the GMWL. This trend indicates normal precipitation and recharge processes at the site and surrounding area.

The data shown in ***Table 5.11.15*** indicate H-3 values of between 0.7 to 2.8 TU for both groundwater and spring samples. The detectable levels of H-3 in the groundwater indicate a component of relatively recent recharge, as is to be expected in this shallow, unconfined aquifer. Sample THY-RP16 shows a relatively low H-3 value of 0.7 TU and may therefore represent predominantly pre-1952 groundwater in this Algoa Aquifer sample.

Table 5.11.15
Stable Isotope and Tritium Analyses: Algoa Aquifer

Borehole ID	δ D (‰)	δ O-18 (‰)	Tritium (TU)	
April 2008 Drilling Sampling				
THY-MR2	-16.6	-4.13	1.4	±0.2
THY-MR5	-19.4	-4.58	1.8	±0.3
THY-MR6	-20.3	-4.71	1.7	±0.3
THY-RP7	-18.0	-4.46	1.3	±0.2
THY-RP16	-17.3	-4.39	0.7	±0.2
June 2008 Monitoring				
THY-SP7	-19.5	-4.66	1.2	±0.3
THY-RP7	-17.6	-4.41	1.5	±0.3
November 2008 Monitoring				
THY-SP7	NA	NA	1.2	±0.3
THY-RP7	NA	NA	2.8	±0.3
May 2009 Monitoring				
THY-SP7	NA	NA	1.3	±0.3
THY-RP7	NA	NA	1.1	±0.3

NA = Not analysed[16]

[16] Concentration of environmental isotopes deuterium/hydrogen (D/H), Oxygen-18/Oxygen-16 normally remain stable in groundwater as was indicated by two initial repeat analyses (April and June 2008). Analysis of these isotopes was subsequently discontinued. Monitoring programmes conducted from August 2017 included only those constituents listed for monitoring in the NNR Regulatory Guide RG-0011 Rev 0.

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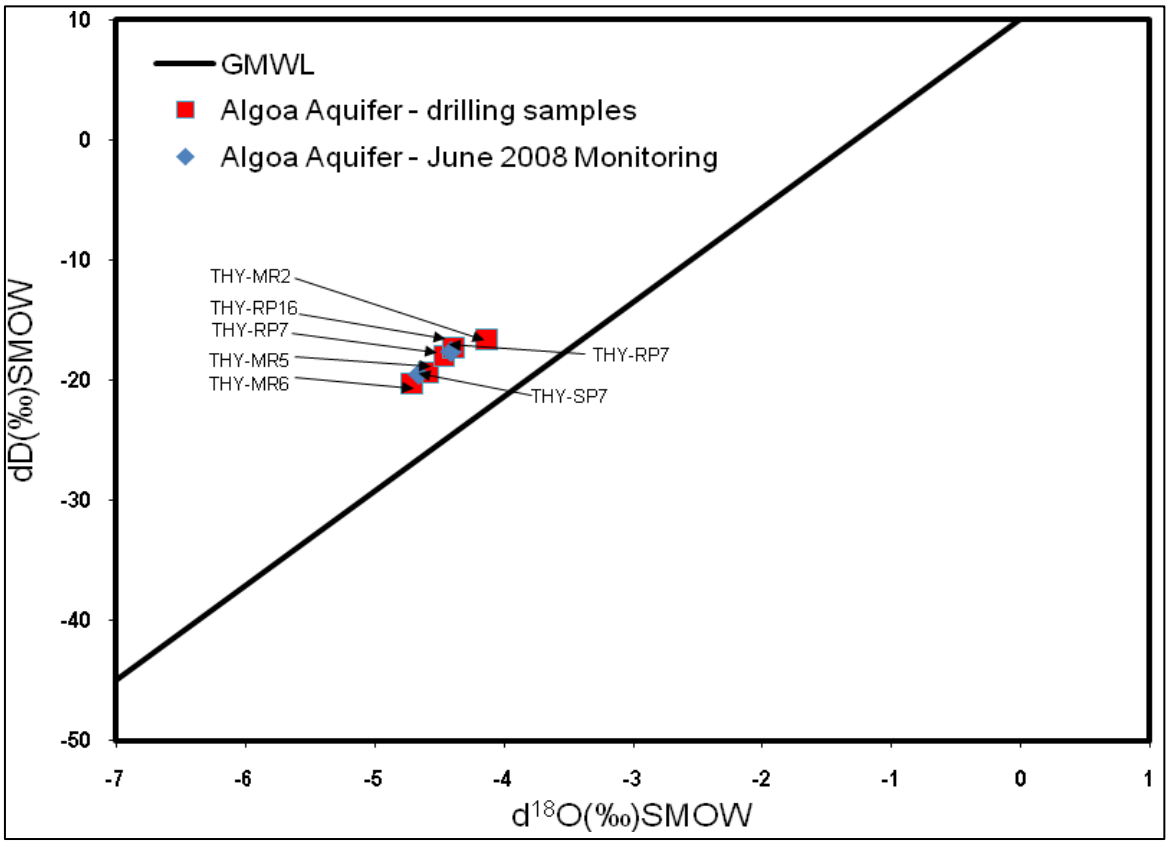


Figure 5.11.16
δO-18 versus δD: Hydrocensus Samples: Algoa Aquifer

Adsorption Testing

The adsorption of contaminants on the solid phases of the soil and aquifer materials is a critical aspect in evaluating the fate and transport of contaminants in the natural environment. The partition coefficient (K_d) provides an estimate of the potential for the adsorption of dissolved contaminants onto the solid phases. The K_d is defined as the ratio of the contaminant concentration associated with the solid to the contaminant concentration in the surrounding aqueous solution when the system is at equilibrium.

Two samples representing the primary aquifer of the site were submitted for adsorption testing. Sample THY-RP5: 4 to 19 m bgl represents a cream coloured, fine to medium grained calcareous silty sand with minor quartz pebbles and harder aeolianite layers, while sample THY-MR12: 2 to 19 m bgl represents a cream to tan coloured fine to medium grained

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calcareous sand. The samples were submitted to Necsa for the determination of the partition coefficients of selected radionuclides (Cs-137, Co-60, Sr-90, U). The method followed is that described by Dr. T Yamaguchi of the Japanese Atomic Energy Research Institute **(Yamaguchi & Nakayama, 2003)**. The K_d values determined for the site samples are summarised in ***Table 5.11.16*** and the Necsa analytical report is given in ***Appendix 5.11.I***.

Table 5.11.16
Partition Coefficients for Selected Radionuclides at Various pH Values

Isotope/Element	K_d (mℓ/g)		
Sample	**pH 3**	**pH 7**	**pH 12**
Cs-137			
THY-RP12-2-19 m bgl.	3.95	4.79	3.60
THY-RP5:4-19 m bgl	3.24	3.42	2.69
Co-60			
THY-RP12-2-19 m bgl.	9.93	5 000	89.90
THY-RP5 4-19 m bgl	6.93	4 310	84.80
Sr-90			
THY-RP12-2-19 m bgl.	1.38	3.12	14.70
THY-RP5 4-19 m bgl	0.74	5.66	4.13
U			
THY-RP12-2-19 m bgl.	2.45	868	220
THY-RP5 4-19 m bgl	1.58	757	635

Low K_d values were measured for the Cs-137 tracer species for both samples with relatively small differences in K_d values at the different pH values. The K_d values for Co-60 show large differences at different pH values. The measured values at a pH of 3 were low while those measured at pH 7 and 12 were high. Low K_d values were measured for the Sr-90 tracer species on both samples with small differences in K_d values at the different pH values. Relatively high K_d values for the different uranium tracer species were measured above pH 7 for both samples. At a pH of 3 the measured K_d values were low.

Given the natural groundwater pH of the site ranging from 7 to 9, the retardation of Cs-137 and Sr-90 in the calcareous sandy aquifer is expected to be low. The rate of migration of both Co-60 and dissolved U species are likely to be moderately retarded relative to that of conservative species

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(H- 3). These are broad conclusions which are constrained by the limited analyses done at this stage and the difference in conditions between the laboratory and *in situ* conditions.

Wetlands

Wetland and borehole monitoring data collected to date **(Eskom, 2011)** indicate the following (***Figure 5.11.17***):

- The Langefonteinvlei wetland is fed by groundwater flowing from the mobile Oyster Bay dune field in the north and the water divide in the northeast, which emerges at the foot of the high dune in the north and northeast of the wetland.
- Depending on the height of the water table, groundwater emerges either at the head of the Langefonteinvlei, into one of two narrow eastern wetland extensions or, during drier periods, slightly further west, where the two eastern extensions join the main wetland body.
- A thick layer of fine organic sediment with high water storage capacity provides a high degree of hydrological buffering of the eastern extremities of the wetland, at times when they are not directly fed by groundwater flows.
- From its point of emergence into the wetland, the groundwater flows as braided surface trickles over the humus-rich layer of the wetland, down-slope towards the south and southwest.
- Beneath the southern portion of the Langefonteinvlei, and the western sections of both the southern and the northern portions of the Langefonteinvlei, the groundwater table lies beneath the wetland and is not directly linked to it. In other words, the water in this portion of the wetland is perched above the groundwater table of the Algoa Aquifer.
- The exact zone where the wetlands shift between direct and indirect links to groundwater is likely to vary between wet and dry periods.
- It is postulated that the western extents of both portions of the Langefonteinvlei are determined by a balance between groundwater inflows and outflows such as evapotranspiration and infiltration. In other words, water flows on the surface and in the layer of organic sediment until it is used up by evapotranspiration.

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- The humus layer has a high water holding capacity and water stored in this layer preserves the wetlands through drought periods.
- Water from the higher-lying northern portion of the wetland flows through the low dune ridge that separates the northern from the southern, smaller portion of the wetland.
- The coastal springs located southwest and west of the Langefonteinvlei, especially the stronger flowing spring THY-WSP4 at White Point, are not fed by water from the Langefonteinvlei. They emerge near the coast, where the bedrock lies close to the surface, and are fed by groundwater draining directly from the Algoa Aquifer and TMG Aquifer to the ocean.

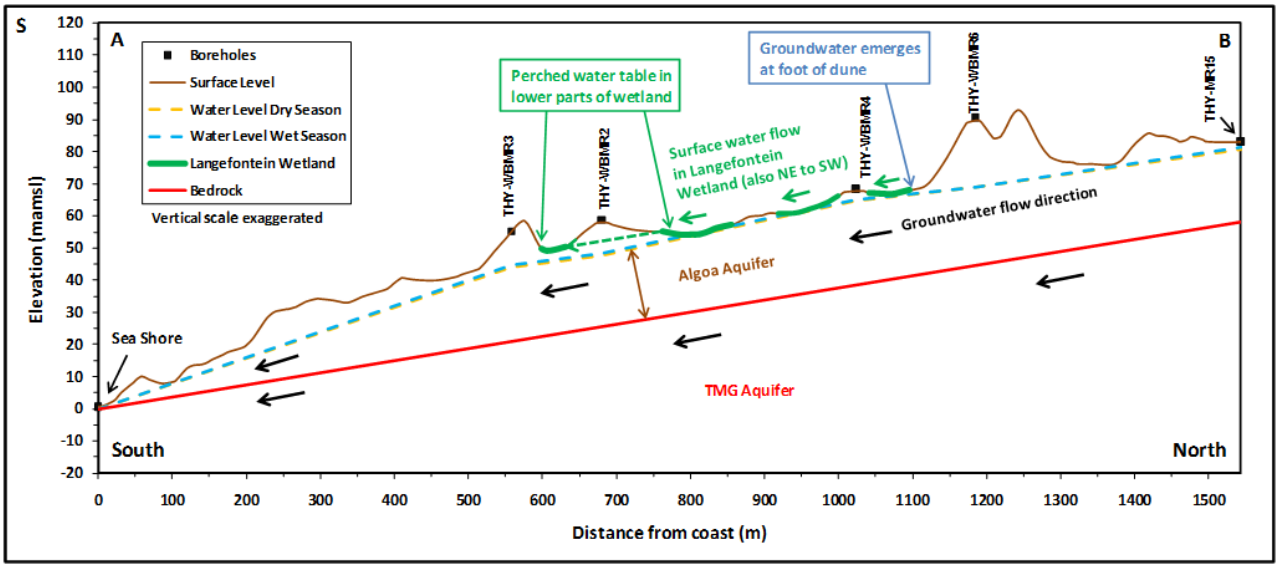


Figure 5.11.17
North-South Cross-Section Through Langefonteinvlei, Showing Inferred Surface/ Groundwater Linkages Resulting in wetland Formation and Function

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5.11.7.2 Aquifer 2: Fractured-Rock TMG Aquifer

The secondary aquifer at the site is comprised mainly of quartzitic sandstones of the TMG. Two main domains can be identified, viz.:

- an area underlying and surrounding the coastal area comprised of quartzitic sandstone of the Skurweberg and Goudini formations (Nardouw Subgroup) interbedded with arenaceous shale and siltstone - The upper surface of this area is relatively flat and slopes gently towards the coast forming a wave-cut platform.

- an area to the northwest of the coast that is comprised of fractured quartzitic sandstone of the Peninsula Formation.

For the purpose of this SSR and to facilitate further reference, these are referred to as the Nardouw and Peninsula aquifers, respectively.

These two aquifers are separated by the Cedarberg Formation, mostly composed of shale, which is generally assumed to form a retarding barrier to groundwater flow (Meyer, 2001). However, faults and fracture zones may provide pathways though this formation. The mapped outcrop of the Cedarberg Formation north of Oyster Bay can be extrapolated to cross the site just to the north of the illustrative footprint. The electromagnetic traverse carried out in this area as part of the surface geophysical survey (see ***Appendix 5.11.C***) indicates an anomaly corresponding to a relatively high conductive body, interpreted as being the Cedarberg Formation. Some of the SSR boreholes in this area intersected a grey to black siltstone layer, which may represent this formation. However, while there is no apparent effect on groundwater level contours in this area, on the local scale there should be some retardation of groundwater flow in the TMG Aquifer in the illustrative footprint. The very slow recovery of groundwater level in THY-RP10 could be related to this layer.

Hydraulic Properties

The hydraulic properties of the TMG Aquifer were determined from analysis of pumping and packer tests. Details of locations and set-ups are given in ***Appendix 5.11.E***. Hydraulic properties can be summarised as follows:

- Transmissivity ranges from 0.2 to 30 m^2/day for the Nardouw Aquifer and 1 to 30 m^2/day for the Peninsula Aquifer.

- Flow velocity in the Nardouw Aquifer was calculated to be 0.4 m/d.

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- Packer testing gave a range of K values of 0.002 to 2.30 m/day for the Nardouw Aquifer, apart from a particularly high value of 45 m/day from THY-RP8 between 26 and 31 m depth. The lower values represent the 'matrix' aquifer and the higher values the fractured aquifer.

- Packer testing gave a range of K values of 0.01 m/day (matrix) to 0.45 m/day (fractured) for the Peninsula Aquifer.

A summary of the hydraulic parameters is presented in ***Table 5.11.17***.

The drill logs of many geohydrological and geotechnical SSR boreholes show a high percentage of siltstone and shaley horizons in the Goudini Formation. These more impermeable layers will tend to retard groundwater flow. The influence of these horizons is seen in the lower transmissivity in the Nardouw Aquifer when compared to the Peninsula Aquifer, which is mainly composed of quartzitic sandstones.

Borehole Yields

The Nardouw Aquifer was intersected just below the Algoa Group at depths varying from 2 m bgl along the coast to about 55 m bgl towards the inland dunes. This aquifer is highly fractured with water bearing fractures encountered at depths varying from about 20 to about 110 m bgl. The fractures are moderate to high yielding with airlift yields ranging from 2 to 5 ℓ/s. Sustainable yields of 1.0 to 4.0 ℓ/s have been derived from test pumping data analysis for boreholes tapping the Nardouw Aquifer.

The Peninsula Aquifer was only intersected in two boreholes, THY-RP1 and THY-RP2. At THY-RP2 the aquifer is highly fractured from 18 to 55 m bgl. A sustainable yield of 4.0 ℓ/s has been derived from test pumping data analysis for this borehole (see ***Table 5.11.17***).

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Table 5.11.17
Summary of TMG Aquifer Parameters

Borehole Number	Transmissivity T (m^2/d)	Storativity S	Saturated Thickness (m)	Hydraulic Conductivity K (m/day)	Assumed Porosity (%)	Max. Test Yield (ℓ/s)	Recommended Sustainable Yield (ℓ/s)	Comments:
THY-RP1	1	2.5×10^{-3}	87	0.01	1	0.65	0.20	Matrix (Peninsula Formation)
THY-RP2	30	2.4×10^{-3}	65	0.45	5	8.00	4.00	Fractured (Peninsula Formation)
THY-RP5	30	4.0×10^{-3}	69	0.43	5	5.40	4.00	Fractured (Nardouw Sub-group)
THY-RP6	29	2.4×10^{-3}	15	1.88	5	5.01	3.00	Fractured (Nardouw Sub-group)
THY-RP8	16	6.3×10^{-3}	96	0.002- 45	5	8.02	2.50	Fractured (Nardouw Sub-group) Packer test results from discrete 5 m test zones
THY-RP9	3	3.3×10^{-3}	76	0.04-0.7	1	2.00	0.30	Matrix (Nardouw Sub-group) Packer test results from discrete 5 m test zones
THY-RP10	2	2.9×10^{-3}	50	0.04	1	1.20	0.10	Matrix (Nardouw Sub-group)
THY-RP11	10	1.4×10^{-3}	11	0.97	1	3.03	0.80	Matrix (Nardouw Sub-group)
THY-RP12	7	5.3×10^{-3}	20	0.36	1	3.50	0.40	Matrix (Nardouw Sub-group)
THY-RP13	0.2	1.5×10^{-3}	17	0.01	1	0.22	0.04	Matrix (Nardouw Sub-group)
THY-RP14	10	1.4×10^{-3}	17	0.62	1	2.32	0.70	Matrix (Nardouw Sub-group)
THY-RP15	0.4	4.3×10^{-3}	16	0.03	1	0.70	0.05	Matrix (Nardouw Sub-group)
Average	**12**	**3.2×10^{-3}**		**0.42**		**3.34**	**1.34**	
Median	**9**	**2.9×10^{-3}**		**0.26**		**2.68**	**0.55**	
Average Fractured	**26**	**4.3×10^{-3}**		**0.002- 45**	**5**	**6.61**	**3.38**	
Median Fractured	**30**	**4.0×10^{-3}**		**0.002- 45**	**5**	**6.70**	**3.50**	

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Borehole Number	Transmissivity T (m^2/d)	Storativity S	Saturated Thickness (m)	Hydraulic Conductivity K (m/day)	Assumed Porosity (%)	Max. Test Yield (ℓ/s)	Recommended Sustainable Yield (ℓ/s)	Comments:
Average Matrix	**4**	**2.8×10^{-3}**		**0.26**	**1**	**1.70**	**0.32**	
Median Matrix	**3**	**2.7×10^{-3}**		**0.04**	**1**	**1.60**	**0.25**	

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Groundwater Levels

A detailed groundwater level contour plan of the illustrative footprint areas and surrounds for the TMG Aquifer is shown in ***Drawing 5.11.9***. The groundwater contours indicate that the main groundwater flow direction is in a south to southeasterly direction, i.e. towards the coast, as per the Algoa Aquifer. The contours become more closely spaced towards the coast, probably due to:

- lower T due to siltstone intercalations;
- proximity to the freshwater-saltwater interface.

Water level data for site boreholes are summarised in ***Table 5.11.18***. The data indicate the following:

- Minimum water level depths range from 0.08 m bgl at THY-RP1-M2 to 13.53 m bgl at THY-RP5-M2.
- Maximum water level depths range from 2.96 m bgl at THY-RP13 to 15.23 m bgl at THY-RP5-M2.
- Average water level depths range from 2.68 m bgl at THY-RP13 to 14.23 m bgl at THY-RP5-M2.
- Water level variation between minimum and maximum depths range from 0.90 m at THY-RP13 to 10.17 m at THY-RP2. Similarly, water level variation at boreholes equipped with data loggers range from 2.85 m at THY-RP9 to 10.17 m at THY-RP2.

Hydrographs of currently available groundwater levels measured on data loggers in boreholes THY-RP2, THY-RP5-M1, THY-RP9, THY-RP10-M1[17], THY-RP11 and THY-RP14 between mid-June 2008 and February 2024 are shown in ***Figure 5.11.18*** to ***Figure 5.11.23***, respectively. The six boreholes show the following water level trends:

- THY-RP2: a decline of *c*.2.5 m from May 2008 to May 2011, followed by a rise of *c*.8 m by December 2012 after the “extremely wet” 2012 rainfall year. By February 2019, when the monitoring was stopped, the water level had declined by *c*.10 m due the to “extremely dry” rainfall years of

[17] Monitoring discontinued on 24 July 2018 after the borehole has collapsed. Monitoring in this area moved to nearby THY-RP14.

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2017 and 2018 (***Subsection 5.11.6.3***). The highest groundwater level measured was 0.22 m bgl in December 2012 and the lowest was 10.39 m bgl in February 2019. The graph also shows smaller seasonal water level variations.

- THY-RP5-M1: a decline of *c.*0.8 m from May 2008 to May 2011, followed by a rise of *c.*1.3 m by July 2013. Thereafter, the "extremely dry" rainfall years of 2017 and 2018 (***Subsection 5.11.6.3***) caused the water level to gradually decline by *c.*2.2 m by February 2023. From February 2023, the "very wet" 2023 rainfall year (***Subsection 5.11.6.3***) caused the water level to rise *c.*0.2 m by the latest available measurement in February 2024. The highest groundwater level measured was 11.43 m bgl in July 2013 and the lowest was 13.61 m bgl in February 2023. In comparison to THY-RP2, the graph for THY-RP5-M1 shows hardly any seasonal water level variation.

- THY-RP9: small fluctuations of between 4.10 to 4.45 m bgl which appear to be related to the nearby well utilised by the holiday cottages on site. The graph shows a decline of *c.*0.8 m by July 2010 followed by a rapid rise of *c.*1.0 m by July 2011 after the "very wet" 2011 rainfall year (***Subsection 5.11.6.3***). After a small decline, the water level rose by another *c.*0.7 m until December 2013 after the extremely wet 2012 rainfall year (***Subsection 5.11.6.3***). Thereafter, the "extremely dry" rainfall years of 2017 and 2018 (***Subsection 5.11.6.3***) caused the water level to decline by *c.*2.85 m by February 2019. By February 2024, due to a "very wet" 2023 rainfall year (***Subsection 5.11.6.3***), the water level had risen by *c.*1.4 m.

- THY-RP10-M1: a slight rise of about 0.12 m, with a drop after December 2008 and small increase in June 2009 after heavy rainfall that month. The anomalous 0.30 m water level rise in December 2008 is attributed to the completion of nearby (180 m) core drilling which made use of local groundwater. From April 2011 to July 2011 a rise of *c.*1.5 m is evident due to the "very wet" 2011 rainfall year (***Subsection 5.11.6.3***). This was followed by a *c.*1.1 m decline until June 2012, whereafter the extremely wet 2012 rainfall year (***Subsection 5.11.6.3***) resulted in a small rise of *c.*0.4 m by November 2012. Thereafter, the extremely dry rainfall years of 2017 and 2018 (***Subsection 5.11.6.3***) caused a decline of *c.*0.9 m by July 2018 when monitoring was discontinued after the borehole had collapsed.

- THY-RP11: a consistent decrease from June 2008 until June 2011 of *c.*1.1 m, with minimal changes in water level due to rainfall - After the

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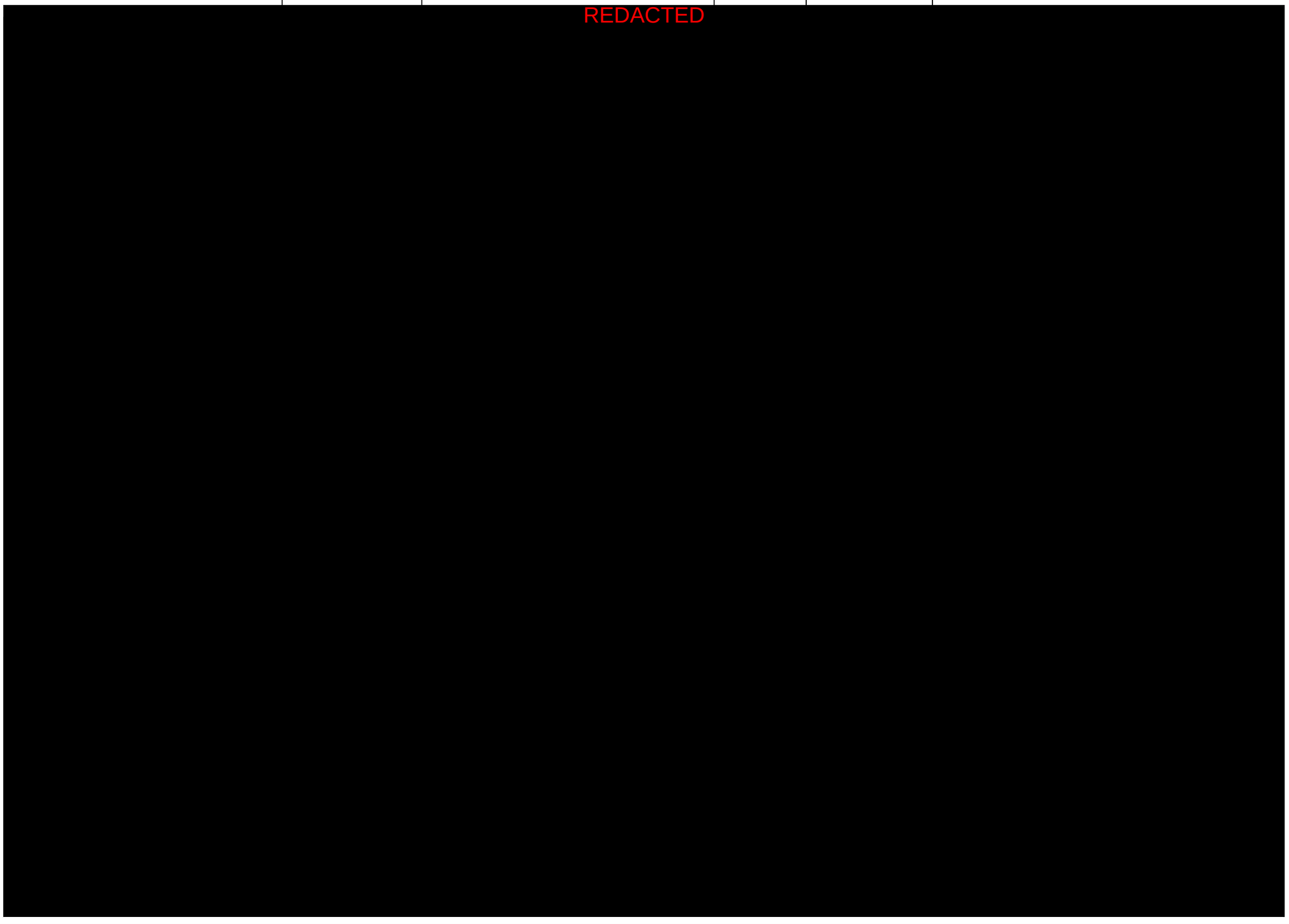
"extremely wet" rainfall year of 2012, a sharp rise of *c*.2.8 m occurred by September 2013. From September 2013 to February 2024 a gradual decline of *c*.3.7 m occurred due to the "extremely dry" rainfall years of 2017 and 2018 (***Subsection 5.11.6.3***). The difference in response at this borehole is attributed to the deeper groundwater level at this site and the closer proximity of the three boreholes (THY-RP5-M1, -RP9 and -RP10-M1) to the coast. The effect of the latter would be to moderate groundwater level fluctuations due to proximity to sea level, which is basically a constant head.

- THY-RP14: due to limited water level measurements from May 2008 to June 2011, the maximum decline during this period is unknown - A rise of *c*.1.1 m by December 2012 after the "extremely wet" rainfall year of 2012. Thereafter, due to the "extremely dry" rainfall years of 2017 and 2018 (***Subsection 5.11.6.3***), a decline of *c*.2.2 m is evident by July 2023. After a "very wet" 2023 rainfall year, a sharp rise of *c*.0.4 m is evident by the latest measurement in February 2024.

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Table 5.11.18
Summary of Groundwater Levels for SSR TMG Aquifer Boreholes

Borehole No.	Depth (m)	Surface Elevation (m amsl)	Minimum Water Level Depth (m bgl)	Maximum Water Level Depth (m bgl)	Average Water Level Depth (m bgl)	Variation in Water Level Depth (m)	Monitoring Status
THY_RP1	133	148.42	0.16	5.94	4.43	5.79	Measured May-08, bi-annually from Jun-11 to May-13, Aug17 to Oct-18, and in Feb-24.
THY_RP1_M1	61	149.70	3.42	6.90	5.62	3.48	Measured May-08 and bi-annually from Jun-11 to May-13.
THY_RP1_M2	73	147.05	0.08	5.09	2.87	5.01	Measured May-08 and bi-annually from Jun-11 to May-13.
THY_RP2	79	88.06	0.22	10.39	5.27	10.17	Measured hourly by logger from 2-Aug-15 to 24-Jan-19 and by dipmeter on 20-Feb-24
THY_RP2_M1	32	88.50	1.27	7.47	3.97	6.20	Measured May-08 and bi-annually from Jun-11 to May-13.
THY_RP2_M2	31	88.46	0.92	7.28	3.73	6.36	Measured May-08 and bi-annually from Jun-11 to May-13.
THY_RP5	150	42.20	10.51	12.72	11.34	2.21	Measured May-08 and bi-annually from Jun-11 to May-13.
THY_RP5_M1	30	42.16	11.43	13.61	12.75	2.18	Measured weekly from 7-Mar-08 to 1-May-08, hourly by logger from 5-May-11 to 29-Jan-24 and by dipmeter on 20-Feb-24.
THY_RP5_M2	42	46.03	13.53	15.23	14.23	1.70	Measured weekly from 7-Mar-08 to 1-May-08 and bi-annually from 2-Jun-11 to 22-May-13.
THY_RP6	49	17.98	4.29	9.52	6.63	5.24	Measured weekly from 7-Mar-08 to 1-May-08 and bi-annually from 2-Jun-11 to 22-May-13.
THY_RP8	121	11.18	6.80	8.25	7.66	1.45	Measured weekly from 18-Feb-08 to 1-May-08 and bi-annually from 2-Jun-11 to 22-May-13,

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Borehole No.	Depth (m)	Surface Elevation (m amsl)	Minimum Water Level Depth (m bgl)	Maximum Water Level Depth (m bgl)	Average Water Level Depth (m bgl)	Variation in Water Level Depth (m)	Monitoring Status
THY_RP9	99	10.42	2.93	5.78	4.15	2.85	Measured weekly from 18-Feb-08 to 1-May-08, and hourly by logger from 12-Sep-08 to 25-Jan-19 and by dipmeter on 20-Feb-24
THY_RP10	98	14.87	5.11	6.19	5.66	1.08	Measured weekly from 25-Feb-08 to 1-Apr-08, monthly from 1-May-08 to 2-Jun-08, and bi-annually from 3-Nov08 to 21-May-13
THY_RP10_M1	50	13.11	3.45	8.90	4.58	5.45	Measured weekly from 18-Feb-08 to 1-May-08 and hourly by logger from 12-Sep-08 to 24-Jul-18 whereafter borehole had collapsed preventing further monitoring.
THY_RP11	49	17.52	6.80	10.67	9.03	3.87	Measured weekly from 18-Feb-08 to 1-May-08, hourly by logger from 12-Sep-08 to 24-Jan-19 and by dipmeter on 20-Feb-24
THY_RP12	49	13.84	4.28	9.61	8.89	5.33	Measured weekly from 18-Feb-08 to 1-May-08, bi-annually from Jun-11 to May-13 and from Aug-17 to Oct-18, hourly by logger from 30-Oct-18 to 24-Jan-19 and by dipmeter on 20-Feb-24
THY_RP13	39	7.63	2.06	2.96	2.68	0.90	Measured weekly from 18-Feb-08 to 1-Apr-08, monthly on 1-May-08, and bi-annually from 2-Jun-11 to 21-May-13
THY_RP14	49	10.62	4.35	6.31	6.14	1.96	Measured weekly from 18-Feb-08 to 1-May-08, bi-annually from 2-Jun-11 to 22-May-13, hourly by logger from 30-Oct-18 to 29-Jan-24 and by dipmeter on 20-Feb-24
THY_RP15	49	20.01	4.37	10.01	6.50	5.64	Measured May-08 and bi-annually from Jun-11 to May-13.

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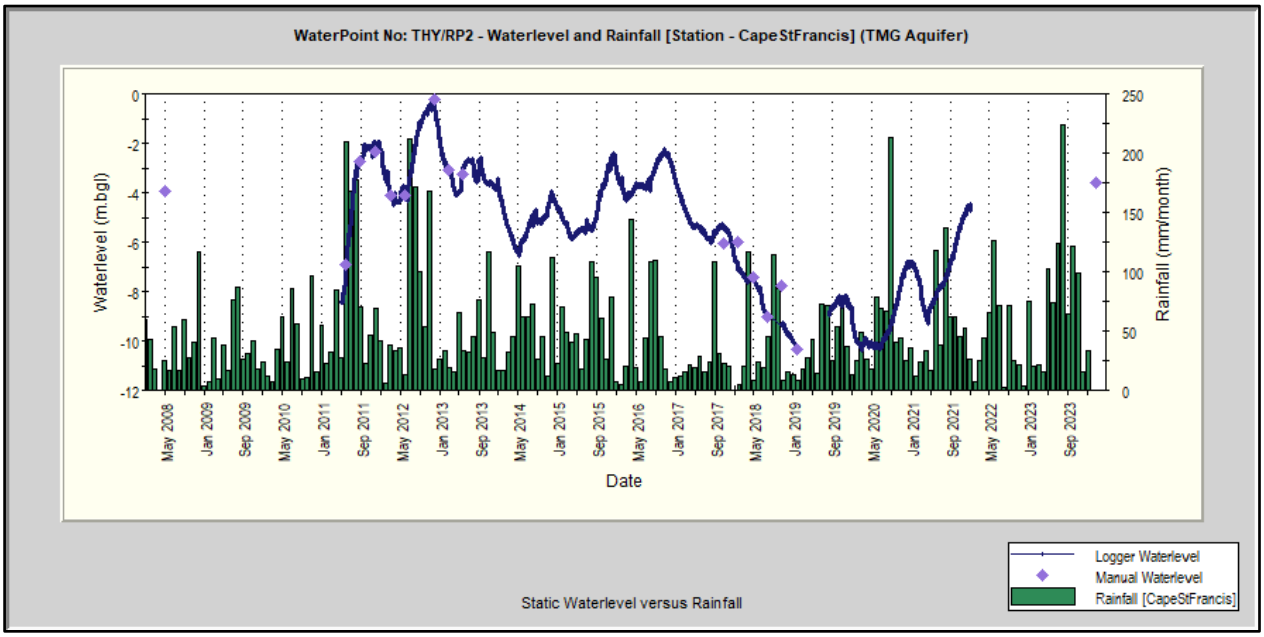


Figure 5.11.18
Hydrograph: THY-RP2 (TMG Aquifer)

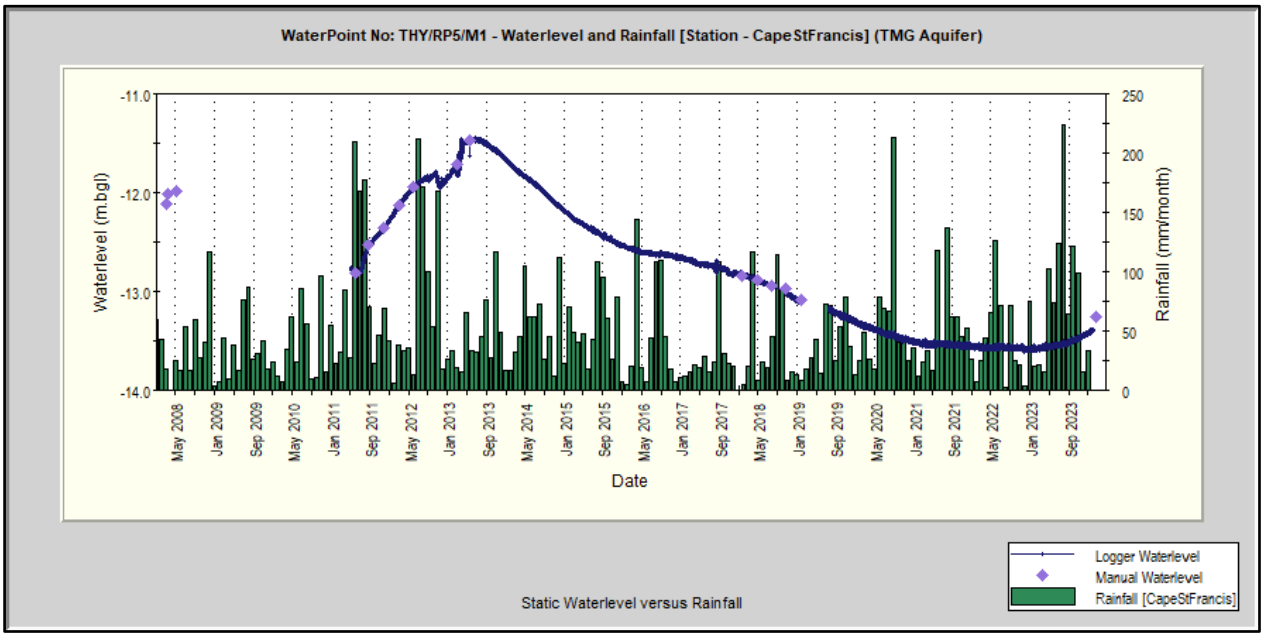


Figure 5.11.19
Hydrograph: THY-RP5-M1 (TMG Aquifer)

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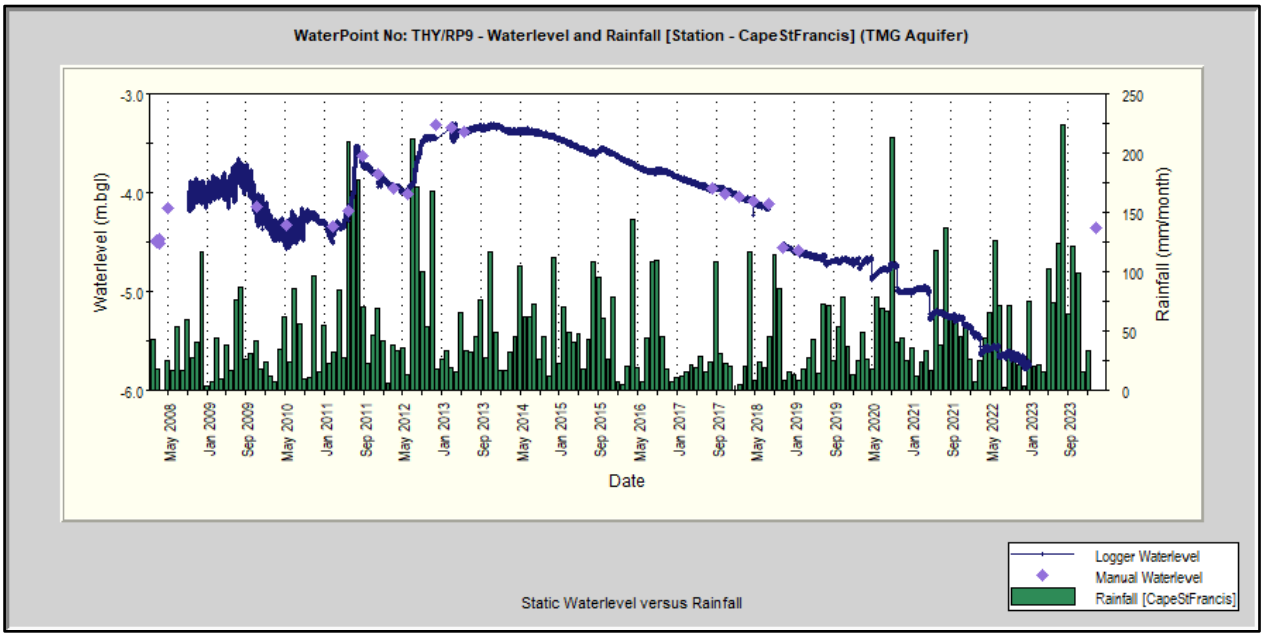


Figure 5.11.20
Hydrograph: THY-RP9 (TMG Aquifer)

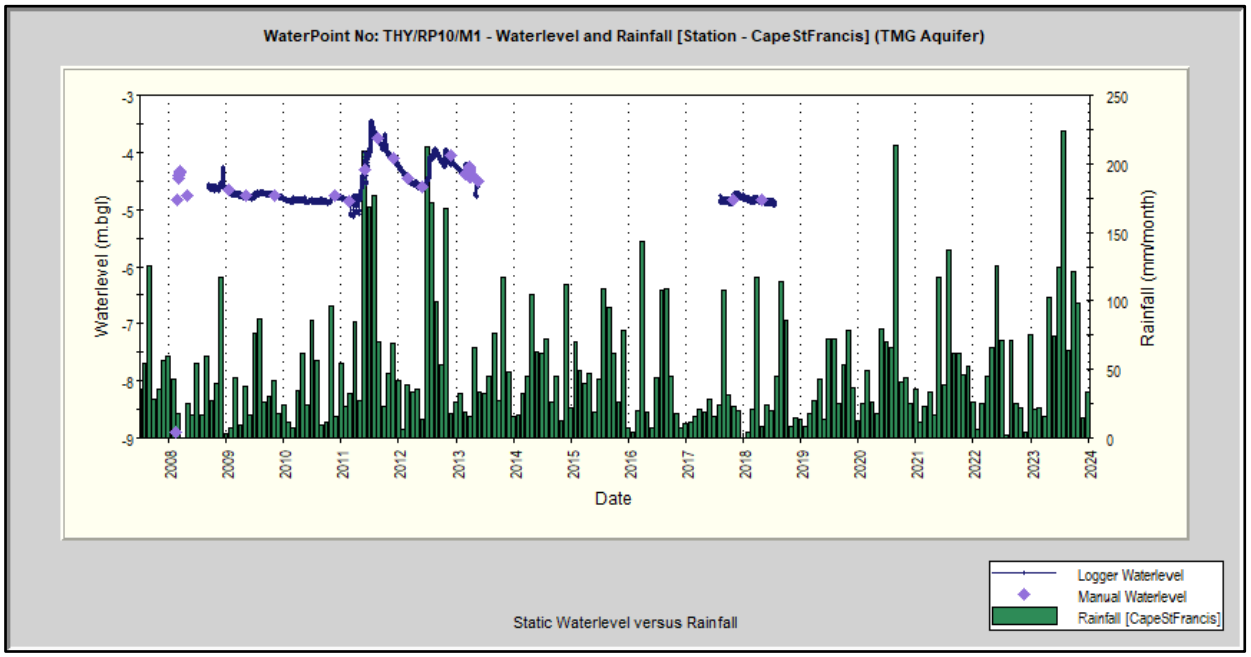


Figure 5.11.21
Hydrograph: THY-RP10-M1 (TMG Aquifer)

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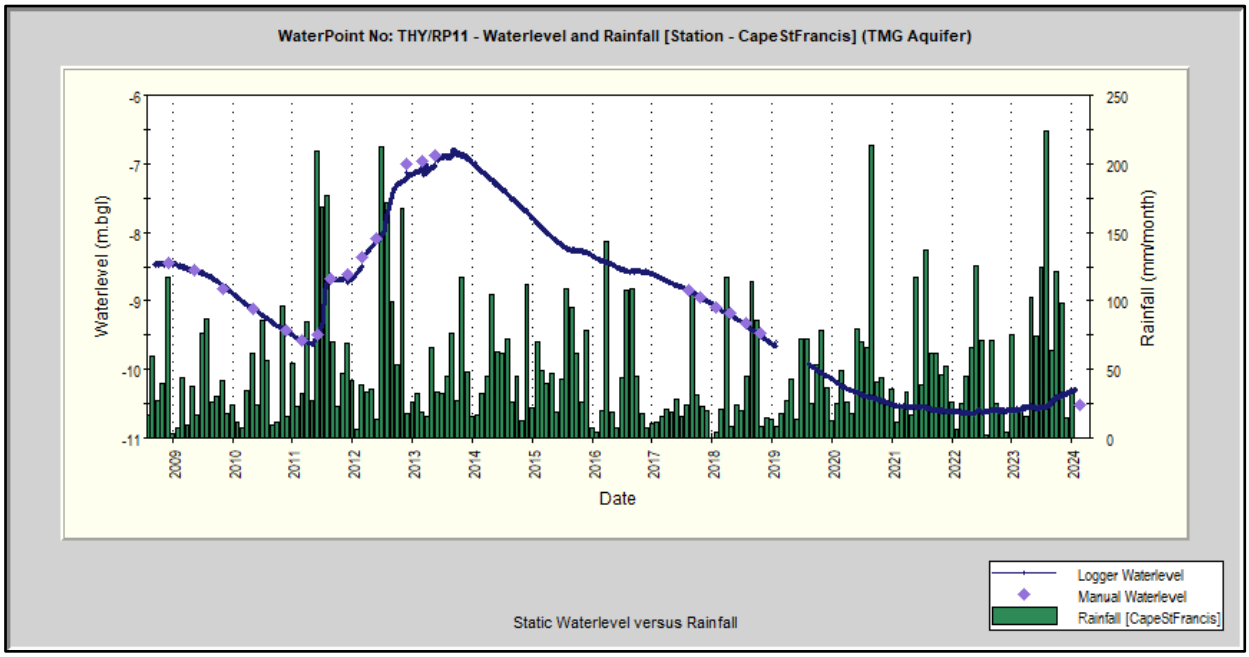


Figure 5.11.22
Hydrograph: THY-RP11 (TMG Aquifer)

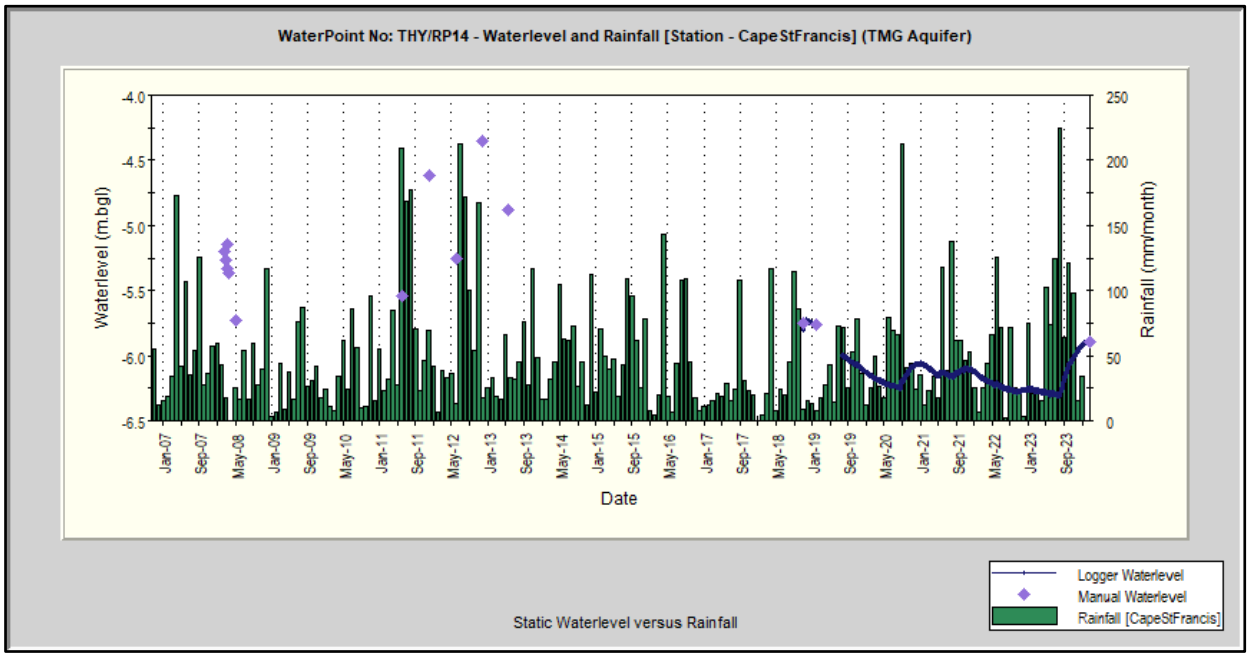


Figure 5.11.23
Hydrograph: THY-RP14 (TMG Aquifer)

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With the exception of borehole THY-RP2, which is inland of the dune belt and the overlying Algoa Aquifer, there appears to be little, if any, definite response to higher rainfall months/events. This is to be expected given the distance of these boreholes from the postulated recharge area further inland where the TMG is exposed at surface. At the site itself, the Algoa Aquifer provides a buffering layer between the TMG Aquifer and any direct influence of rainfall. High rainfall events would therefore not appear to be a threat to site safety in terms of groundwater levels in the TMG Aquifer.

A geotechnical borehole, TB10, is free-flowing. This borehole was drilled near the high-water mark and is therefore in the groundwater discharge zone.

A piezometer was installed in THY-RP6 so that groundwater levels in the TMG (piezometer) and Algoa aquifers (open borehole) can be monitored at the same site. A measurement on 11 May 2009 showed the following:

- TMG Aquifer: 7.64 m bgl;
- Algoa Aquifer: 7.55 m bgl.

This indicates that, at this drill site at least, groundwater levels in the two aquifers are in approximate equilibrium. Evidence of hydraulic connectivity between the TMG and Algoa aquifers is seen in the time-drawdown plots of the constant discharge tests in some of the THY-RP (TMG) boreholes (see ***Appendix 5.11.E***). Where a significant thickness of saturated Algoa Aquifer is present above the TMG Aquifer, the drawdown shows a levelling-off with time during pumping (e.g. THY-RP6 and THY-RP11, ***Appendix 5.11.E***). This indicates leakage of groundwater from the Algoa Aquifer into the TMG Aquifer as the hydrostatic pressure in the latter is lowered relative to the former.

Groundwater Quality

Down-hole EC and pH profiling of the SSR boreholes revealed that EC ranges from 60 mS/m to 180 mS/m and pH from 7.4 to 8.9. In 52 per cent of the boreholes the EC increases with depth by approximately 23 mS/m, the pH decreases by approximately 0.8 pH units and the temperature decreases by approximately 0.5ºC. In about 42 per cent of the boreholes the EC decreases with depth by about 14 mS/m. (see examples in ***Figure 5.11.24*** and ***Figure 5.11.25***). The rest of the logs are included in ***Appendix 5.11.E***.

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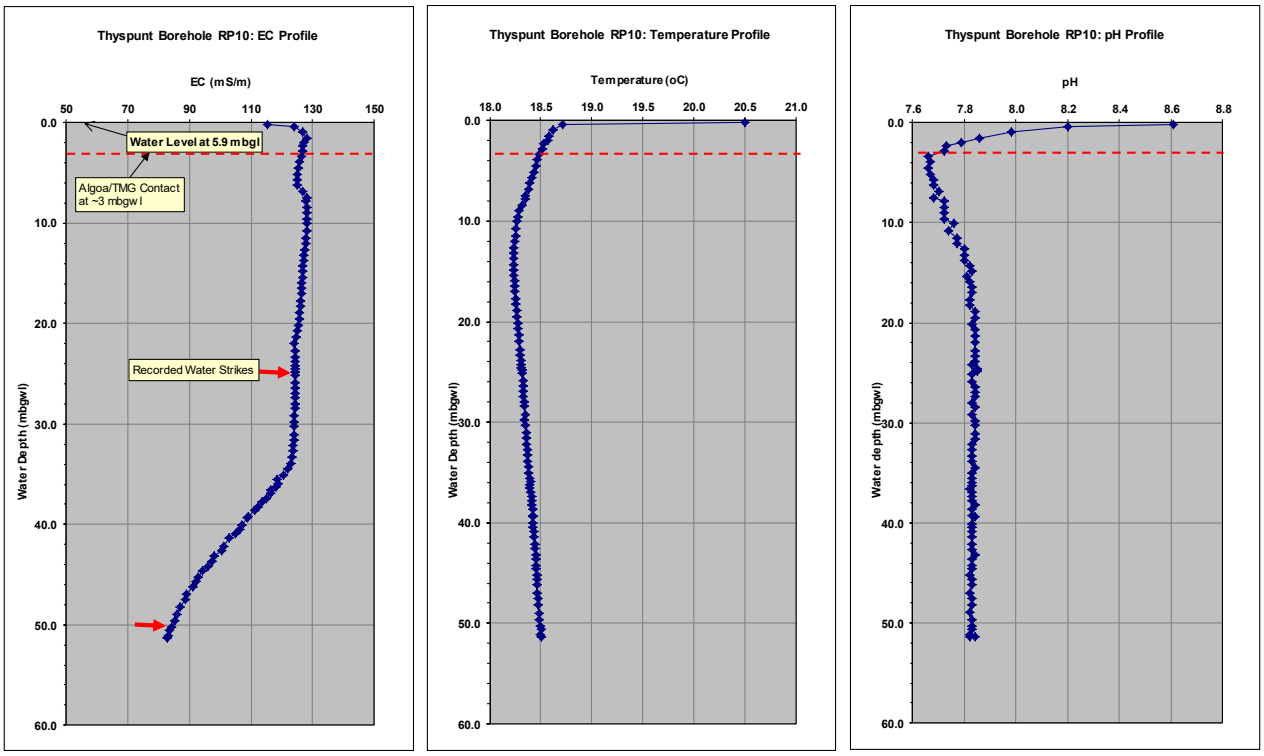


Figure 5.11.24
Down-hole EC, Temperature and pH Log: THY-RP10 (TMG Aquifer)

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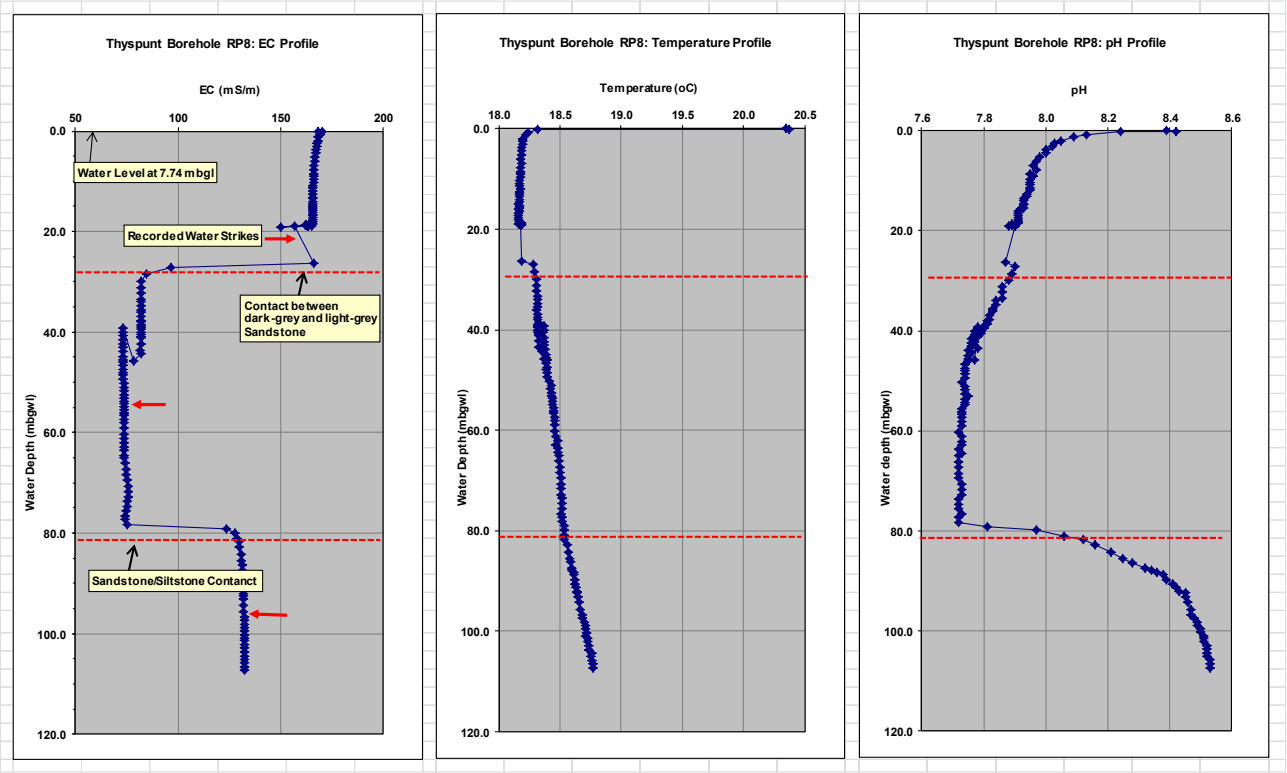


Figure 5.11.25
Down-hole EC, Temperature and pH Log: THY-RP8 (TMG Aquifer)

A summary of chemical analyses of groundwater from the TMG Aquifer for various sampling runs is given in ***Table 5.11.19***.

The table shows a very variable chemistry within the TMG Aquifer. Electrical conductivity ranges from 69 to 286 mS/m and pH from slightly acidic (6.5) to alkaline (8.3). Piper plots of water samples taken from selected SSR boreholes in the TMG Aquifer are shown in ***Figure 5.11.26.*** The results show a dominant NaCl character and to a lesser extent also a $Ca(HCO_3)_2$ character. Samples tending towards the latter character are likely indicating recent recharge from the overlying Algoa Aquifer, or mixing of the water from both aquifers, possibly along the casing string which may not seal-off the Algoa Aquifer completely.

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Table 5.11.19
Chemical Analyses: TMG Aquifer

Borehole Number	Determinand*														
	Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	PO_4	Fe	Mn	pH**	EC***
April 2008 Drilling Sampling															
THY-RP5	81	13	80	3.7	234	114	14	<0.25	0.3	0.130	0.167	<0.050	0.100	7.8	82
THY-RP8	129	23	266	4.8	258	473	42	0.15	0.2	0.015	0.143	<0.050	<0.050	8.0	215
THY-RP10	97	15	110	4.4	239	180	69	0.08	0.2	0.081	0.162	<0.050	<0.050	7.9	105
THY-RP13	101	7	53	1.7	218	89	33	0.27	0.2	0.013	0.114	<0.050	<0.050	7.8	76
June 2008 Monitoring															
THY-RP8	107	26	216	4.0	184	431	123	1.30	0.1	<0.100	<0.120	<0.001	<0.001	6.9	181
THY-RP10	98	21	169	3.4	252	280	45	5.20	0.1	<0.100	<0.120	<0.001	<0.001	7.8	140
THY-RP12	85	10	47	1.3	212	91	35	<0.10	0.1	<0.100	<0.120	<0.001	<0.001	7.8	73
THY-RP13	137	46	324	10.8	236	759	101	12.90	0.1	<0.100	<0.120	<0.001	<0.001	7.7	278
THY-RP13 (duplicate)	140	46	325	10.8	232	759	101	14.50	0.2	<0.100	<0.120	<0.001	<0.001	7.6	277
THY-RP14	78	16	71	2.2	208	125	30	3.70	0.1	<0.100	<0.120	<0.001	<0.001	7.7	83
November 2008 Monitoring															
THY-RP8	94	23	192	5.8	277	321	52	0.70	0.2	<0.100	2.400	<0.001	<0.001	8.0	143
THY-RP10	90	17	122	4.4	259	198	49	0.90	0.2	<0.100	3.000	<0.001	<0.001	8.2	116
THY-RP12	78	9	52	3.5	207	94	29	1.20	0.2	<0.100	4.300	0.060	<0.001	7.4	74
THY-RP13	139	42	365	13.1	235	688	118	2.80	0.2	<0.100	2.900	0.003	<0.001	8.2	279
THY-RP13(duplicate)	142	43	367	13	240	687	113	3.10	0.2	<0.100	2.000	0.004	<0.001	8.1	282
THY-RP14	80	14	71	4.4	225	125	30	2.40	0.2	<0.100	2.500	0.030	<0.001	8.2	85
May 2009 Monitoring															
THY-RP8	118	16	166	5.6	237	272	44	0.50	0.2	<0.100	<0.120	0.130	0.009	8.0	145
THY-RP10	118	17	122	3.6	254	225	40	0.50	0.2	<0.100	0.290	0.070	<0.001	8.3	113
THY-RP12	81	9	104	3.3	254	102	27	0.30	0.2	<0.100	<0.120	0.190	0.009	6.7	69
THY-RP13	224	41	485	12.5	239	853	85	5.60	0.2	<0.100	<0.120	0.100	<0.001	7.0	286
THY-RP13(duplicate)	234	41	489	12.2	240	853	81	5.00	0.2	<0.100	<0.120	0.110	<0.001	6.5	287
THY-RP14	107	11	80	3.6	220	131	29	1.40	0.2	<0.100	<0.120	0.100	0.050	7.8	93
May 2011 Monitoring															
THY-RP1	6	9	82	1.0	10	124	14	<0.1	<0.1	<0.100	NA	<0.1	0.019	6.1	48
THY-RP2	18	23	143	1.5	35	213	104	0.2	<0.1	<0.100	NA	<0.1	0.029	6.2	99
THY-RP5	68	11	69	4.7	199	97	14	0.1	0.1	<0.100	NA	<-0.1	0.100	7.8	75
THY-RP9	68	13	70	8.8	181	85	30	<0.1	0.1	0.100	NA	<0.1	0.019	8.0	77
THY-RP12	70	7	55	2.0	133	100	8	0.3	0.1	<0.100	NA	<0.01	<0.019	7.6	66
November 2011 Monitoring															
THY-RP1	4	7	49	1.2	8	87	14	0.2	0.2	<0.100	NA	0.004	0.008	6.3	85
THY-RP2	16	18	133	1.1	48	203	50	<0.1	0.2	<0.100	NA	<0.001	0.569	6.1	73
THY-RP5	63	11	67	2.7	215	101	19	-<0.1	0.3	<0.100	NA	<0.001	0.129	6.7	79
THY-RP9	66	13	70	4.8	190	117	46	<0.1	0.3	<0.100	NA	<0.001	0.035	5.6	65
THY-RP12	64	7	48	1.3	137	115	12	<0.1	0.4	<0.100	NA	0.008	0.050	6.1	89
May 2012 Monitoring															
THY-RP1	3	7	50	1.1	7	87	12	1.4	0.1	<0.100	NA	0.039	0.006	5.5	36
THY-RP2	22	18	131	0.9	92	196	36	0.1	0.1	<0.100	NA	0.039	0.140	7.3	94
THY-RP5	71	11	71	3.0	231	97	14	0.3	0.1	<0.100	NA	0.019	0.109	7.7	76
THY-RP9	17	7	73	5.1	52	120	3	0.1	0.2	0.100	NA	0.019	<0.001	7.6	55

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Borehole Number	Determinand*														
	Ca	Mg	Na	K	Alkalinity (as $CaCO_3$)	Cl	SO_4	NO_3 (as N)	F	NH_4 (as N)	PO_4	Fe	Mn	pH**	EC***
THY-RP12	99	8	51	1.4	221	91	29	0.1	0.1	<0.100	NA	0.019	0.180	7.7	77
November 2012 Monitoring															
THY-RP1	4	6	40	0.6	18	77	13	0.1	0.2	<0.100	NA	0.019	0.019	5.3	31
THY-RP2	16	16	121	0.9	58	207	1	<0.1	<0.1	<0.100	NA	0.019	0.129	7.8	87
THY-RP5	70	12	65	3.0	207	103	1	<0.1	0.1	<0.100	NA	0.004	0.1	7.4	77
THY-RP9	76.0	13	67	4.4	196	127	46	0.1	0.2	<0.100	NA	0.270	0.029	7.6	84
THY-RP12	86	8	44	1.1	185	109	24	0.2	0.1	<0.100	NA	0.019	0.002	7.8	72
May 2013 Monitoring															
THY-RP1	4	7	48	1.2	10	96	14	0.2	0.1	0.620	NA	0.019	0.004	6.6	33
THY-RP2	15	13	125	1.1	70	239	<0.2	<0.1	0.1	0.540	NA	0.019	0.004	8.0	80
THY-RP5	73	12	70	3.4	237	115	17	<0.1	0.1	0.390	NA	0.039	0.029	8.3	72
THY-RP9	17	5	65	4.4	20	139	1	<0.1	0.1	<0.100	NA	0.030	0.001	7.6	49
THY-RP12	82	8	46	1.3	162	113	8	<0.1	0.1	<0.100	NA	0.030	0.209	8.3	67
August 2017 Monitoring															
THY-RP1	9	17	117	4.1	34	228	11	<0.04	0.3	NA	<0.05	3.714	0.014	7.4	83
THY-RP9	75	14	71	4.7	192	113	32	<0.04	0.50	NA	0.27	0.116	0.017	8.3	79
THY-RP12	92	10	54	1.3	220	92	34	0.1	0.4	NA	<0.05	0.112	0.017	8.1	77
October 2017 Monitoring															
THY-RP1	5	8	57	1.5	4	102	13	0.5	<0.3	NA	<0.05	0.027	0.010	5.9	42
THY-RP9	76	13	67	4.3	196	101	29	<0.04	0.4	NA	<0.05	0.092	0.017	7.5	80
THY-RP12	112	9	51	0.8	244	89	33	0.1	0.3	NA	0.18	<0.01	<0.002	8.1	81
April 2018 Monitoring															
THY-RP1	5	10	71	3.0	48	128	4	1.0	<0.3	NA	<0.05	14.67	0.020	6.8	180
THY-RP9	77	13	69	4.7	200	110	33	1.0	0.3	NA	<0.05	0.078	0.016	7.4	82
THY-RP12	110	10	52	1.3	244	88	35	1.1	<0.3	NA	<0.05	0.020	<0.002	7.8	83
October 2018 Monitoring															
THY-RP1	4	7	54	1.2	5	99	11	0.5	<0.3	NA	<0.05	0.027	0.010	5.8	38
THY-RP9	78	14	70	4.8	210	114	30	<0.04	0.4	NA	<0.05	0.167	0.020	7.7	81
THY-RP12	113	10	51	0.8	248	84	35	0.3	0.4	NA	<0.05	0.020	<0.002	7.6	81

* all determinands in mg/ℓ apart from: **pH value at 22°C; and ***EC measured in mS/m at 25°C NA = Not Analysed

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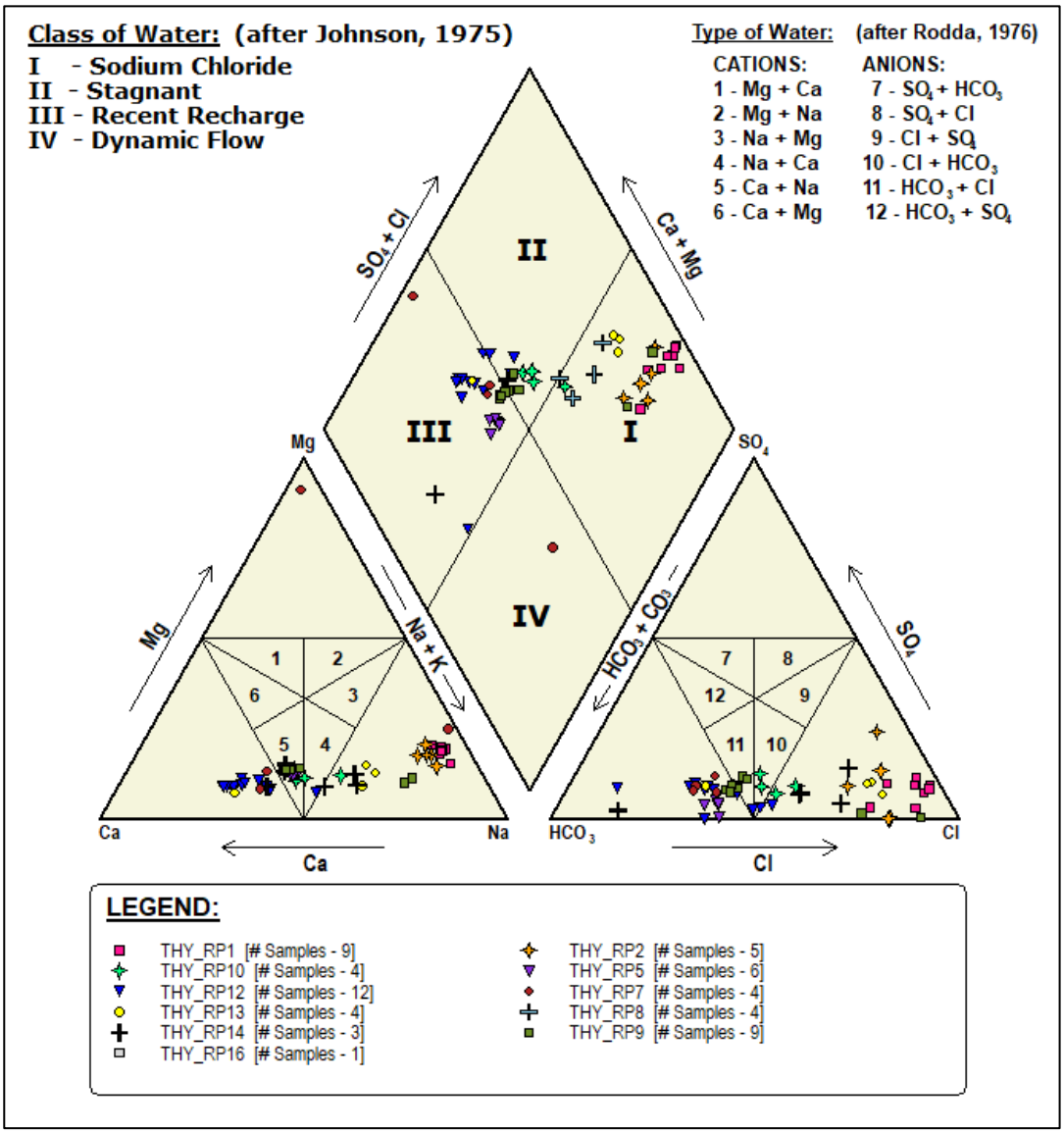


Figure 5.11.26
Piper Diagram of Samples from the TMG Aquifer SSR Boreholes

Radionuclide analyses of water samples from SSR boreholes were conducted in order to determine baseline levels. The results of these analyses are presented in ***Table 5.11.20***.

Langelier indexes vary from 0.40 to 0.96 indicating that groundwater from the TMG is likely to cause scaling rather than being corrosive. Sulfate concentrations are generally below 100 mg/ℓ but a few higher values occur in the groundwater from THY-RP13.

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Table 5.11.20
Radionuclide Analyses: TMG Aquifer

Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
April 2008 Drilling Sampling																														
THY-RP5	68.2	13.3	18	372	31	26	3.14	0.61	0.82	617	99	35	28.7	12.1	28	56.3	11.2	15	NA	NA	NA	NA	NA	NA	47	250	890	250	270	900
THY-RP8	383	35	8.9	376	36	8.9	17.7	1.6	0.41	29	9.1	120	32.6	9.6	16	8.53	4.27	5.8	NA	NA	NA	NA	NA	NA	-270	410	1 400	1 290	290	920
THY-RP10	67.8	13.1	6.8	145	19	6.8	3.12	0.60	0.31	3.4	5.0	15	20.9	5.3	11	7.87	3.06	6.9	NA	NA	NA	NA	NA	NA	-200	220	730	860	270	890
THY-RP13	49.3	12.3	20	41.6	11.7	20	2.27	0.56	0.94	117	21	14	5.8	2.9	8.2	0.95	0.95	2.6	NA	NA	NA	NA	NA	NA	-250	200	680	160	270	890
June 2008 Monitoring																														
THY-RP8	19.9	4.9	2.6	20.9	4.5	2.6	0.915	0.227	0.47	40.5	8.9	38	9.48	3.75	7.8	4.14	2.07	2.8	4.66	1.57	3.1	3.5	2.0	5.0	60	180	610	150	180	600
THY-RP10	19.1	4.5	2.2	55.5	7.6	8.9	0.880	0.206	0.32	28.4	5.9	20	6.32	2.22	4.1	2.7	1.6	5.0	6.81	1.48	2.2	5.50	2.07	4.0	-110	200	670	120	140	460
THY-RP12	6.62	2.29	4.9	11.0	2.7	1.8	0.305	0.16	0.22	53	12	84	21.2	7.1	11	25.5	7.0	14	4.17	1.40	3.5	14.6	2.6	2.4	20	140	460	190	180	580
THY-RP13	44.3	6.5	2.6	80.8	8.9	2.6	2.04	0.30	0.12	35	11	73	15	8.7	25	33.5	8.7	6.1	27.8	3.2	2.4	8.64	3.02	3.8	-39	200	680	430	190	600
THY-RP14	59.8	6.3	4.8	66.2	6.8	6.0	2.76	0.29	0.22	27	12	83	3.6	7.7	29	25.7	8.7	18	39.2	4.2	2.9	0.20	3.6	8.1	36	140	470	390	180	580
THY-RP13 (duplicate)	33.3	6.8	9.5	40.7	7.6	9.5	1.53	0.31	0.44	63.7	12.9	36	19.7	5.9	14	20.2	5.0	7.8	25.7	3.0	2.2	1.7	2.3	3.0	-63	210	700	460	190	600
November 2008 Monitoring																														
THY-RP8	49.2	12.6	21	180	23	7.8	2.27	0.58	0.98	82.2	15.2	32	6.5	4.2	14	0.026	1.9	8.6	6.46	1.5	3.0	4.0	2.1	5.7	-220	390	1 300	640	175	560
THY-RP10	13.3	2.3	2.9	24.7	3.1	1.1	0.611	0.108	0.13	4.6	5.4	39	13.8	4.4	8.5	6.8	3.6	11	11.2	1.8	2.1	1.0	1.6	4.0	-170	350	1 200	520	170	560
THY-RP12	8.39	2.17	1.5	23.7	3.7	1.5	0.386	0.100	0.07	8.3	8.5	11	-2.5	1.4	4.1	39.6	3.6	0.89	4.01	1.27	3.0	0.45	1.4	4.9	-63	320	1 100	626	172	550
THY-RP13	136	8	3.3	127	8	4.9	6.26	0.36	0.15	8.6	8.8	11	3.93	1.50	2.5	5.73	1.39	0.91	21.0	2.5	2.2	-8.7	1.8	4.0	-200	530	1 800	1 240	190	580
THY-RP14	38.3	4.0	1.1	43.1	4.3	1.1	1.76	0.18	0.051	20.8	4.6	17	7.72	2.43	3.7	8.42	2.26	4.6	32.8	3.1	2.1	2.3	3.3	6.3	-160	330	1 100	902	175	550
THY-RP13 (duplicate)	29.4	4.8	2.2	37.6	5.8	7.4	1.36	0.22	0.099	167	28	30	7.0	3.7	8.1	13.9	3.5	2.4	33.2	3.0	2.9	8.06	3.34	4.8	91	540	1 800	804	183	580
May 2011 Monitoring																														
THY-RP1	12.5	3.6	2.8	9.82	3.29	2.8	0.574	0.166	0.13	NA	NA	NA	NA	NA	NA	NA	NA	NA	51.3	4.0	0.86	-2.8	2.8	1.2	310	160	510	560	290	950
THY-RP2	11.3	3.8	3.4	18.3	4.9	3.4	0.521	0.174	0.16	NA	NA	NA	NA	NA	NA	NA	NA	NA	68.4	4.8	0.91	1.94	3.67	1.2	200	180	590	490	290	960

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
THY-RP5	61.2	9.4	3.9	348	23	3.9	2.82	0.43	0.18	NA	NA	NA	NA	NA	NA	NA	NA	NA	190	8	0.84	-5.6	5.5	1.1	440	170	540	280	290	960
THY-RP9	71.9	6.9	1.8	128	9	1.8	3.31	0.32	0.082	NA	NA	NA	NA	NA	NA	NA	NA	NA	82.9	5.3	0.91	-1.8	3.8	1.2	120	170	560	320	290	960
THY-RP12	15.3	3.3	1.9	64	6.7	1.9	0.705	0.150	0.087	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.6	1.7	0.77	0.16	1.3	1.0	-54	160	530	92	290	950
November 2011 Monitoring																														
RHY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-250	280	940	974	282	910
THY-RP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-420	480	1600	1170	290	920
THY-RP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	490	1600	1200	290	920
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-344	520	1700	1390	290	920
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-550	470	1600	910	290	920
May 2012 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62	74	250	210	170	580
THY-RP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-16	85	290	130	180	580
THY-RP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	540	97	290	320	180	580
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	37	76	260	240	180	580
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.9	83	290	160	180	580
November 2012 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	546	71	140	780	290	960
THY-RP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	432	74	180	400	290	960
THY-RP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	953	102	190	290	290	960
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	306	71	200	230	290	970
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62	41	130	-74	290	950
May 2013 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	36	49	170	160	140	450
THY-RP2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17	82	280	48	140	460
THY-RP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	485	94	260	320	140	460

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Sample	U-238			U-234			U-235			Th-230			Th-227			Th-228			Ra-226			Ra-223			Total α Activity			Total β Activity		
ID	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA	mBq/ℓ	1θ	MDA
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.9	61	210	80	140	460
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-87	76	270	32	140	460
August 2017 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	37.50	3.50	0.91	-3.00	2.40	1.20	-11	28	110	523	77	210
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	84.10	5.20	0.86	-2.30	3.70	1.10	202	39	87	428	72	210
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.50	1.40	5.10	0.62	1.20	4.50	21	25	88	98	64	210
October 2017 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17.60	2.40	2.90	-5.00	3.10	8.90	-15	23	90	110	64	210
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	110.00	7.00	4.60	-19.00	9.10	5.00	204	40	89	262	68	210
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.60	2.30	6.80	-2.60	2.70	10.00	1	23	90	-36	60	210
April 2018 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	9.64	1.86	0.97	-2.80	1.90	6.70	7	2	7	35	7	20
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	96.80	5.50	2.90	1.30	2.60	3.70	19	4	9	39	7	20
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.10	1.80	5.40	-0.18	2.50	9.90	9	3	8	10	7	22
October 2018 Monitoring																														
THY-RP1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.80	2.10	4.80	-3.50	1.60	6.20	7	22	81	140	65	210
THY-RP9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	97.70	5.50	0.83	0.61	4.00	3.30	133	35	89	413	72	210
THY-RP12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.40	1.40	3.10	-3.30	1.90	8.20	-25	20	89	28	61	210

MDA = minimum detectable activity concentration (@ 95 % confidence level) NA - Not Analysed[18] 1θ = reported uncertainty from counting statistics

[18] Analysis of some radionuclides was discontinued due to their extremely low concentrations in the groundwater samples collected at the site. Monitoring programmes from August 2017 included only those constituents listed for monitoring in NNR Regulatory Guide RG-0011 Rev 0.

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Stable isotope (deuterium/hydrogen [D/H], O-18/O-16) and H-3 analyses for TMG Aquifer groundwater are shown in ***Table 5.11.21*** for water samples taken during the SSR drilling and monitoring programmes.

Table 5.11.21
Summary of Isotope and Tritium Analyses: TMG Aquifer

Borehole ID	δ D (‰)	δO-18 (‰)	Tritium (T.U.)	
April 2008 Drilling Sampling				
THY-RP5	-17.6	-4.44	0.2	±0.2
THY-RP8	-20.0	-4.76	2.0	±0.3
THY-RP10	-19.8	-4.80	0.9	±0.2
THY-RP13	-16.9	-4.19	1.4	±0.2
June 2008 Monitoring				
THY-RP8	-19.0	-4.63	1.8	±0.3
THY-RP10	-21.9	-4.98	1.8	±0.3
THY-RP12	-16.7	-4.19	1.9	±0.3
THY-RP13	-20.5	-4.80	1.8	±0.3
THY-RP14	-18.9	-4.56	0.8	±0.2
THY-RP13 (duplicate)	-20.6	-4.81	1.7	±0.3
November 2008 Monitoring				
THY-RP8	NA	NA	1.2	±0.3
THY-RP10	NA	NA	1.4	±0.3
THY-RP12	NA	NA	2.0	±0.3
THY-RP13	NA	NA	1.9	±0.3
THY-RP14	NA	NA	1.5	±0.3
THY-RP13 (duplicate)	NA	NA	1.8	±0.3
May 2009 Monitoring				
THY-RP8	NA	NA	1.0	±0.2
THY-RP10	NA	NA	1.0	±0.2
THY-RP12	NA	NA	1.7	±0.3
THY-RP13	NA	NA	1.7	±0.3
THY-RP14	NA	NA	1.1	±0.2
THY-RP13 (duplicate)	NA	NA	1.8	±0.3
NA – Not Analysed[19]				

[19] Concentration of environmental isotopes deuterium/hydrogen (D/H), Oxygen-18/Oxygen-16 normally remain stable in groundwater as was indicated by two initial repeat analysis (April and June 2008). Analysis of these was subsequently discontinued. Monitoring programmes conducted from August 2017 included only those constituents listed for monitoring in the NNR Regulatory Guide RG-0011 Rev 0.

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The samples in ***Figure 5.11.27*** plot on a line approximately parallel and just above the GMWL. This trend of data indicates normal (i.e. not affected by isotopic processes) precipitation and recharge processes at the site and surrounding area.

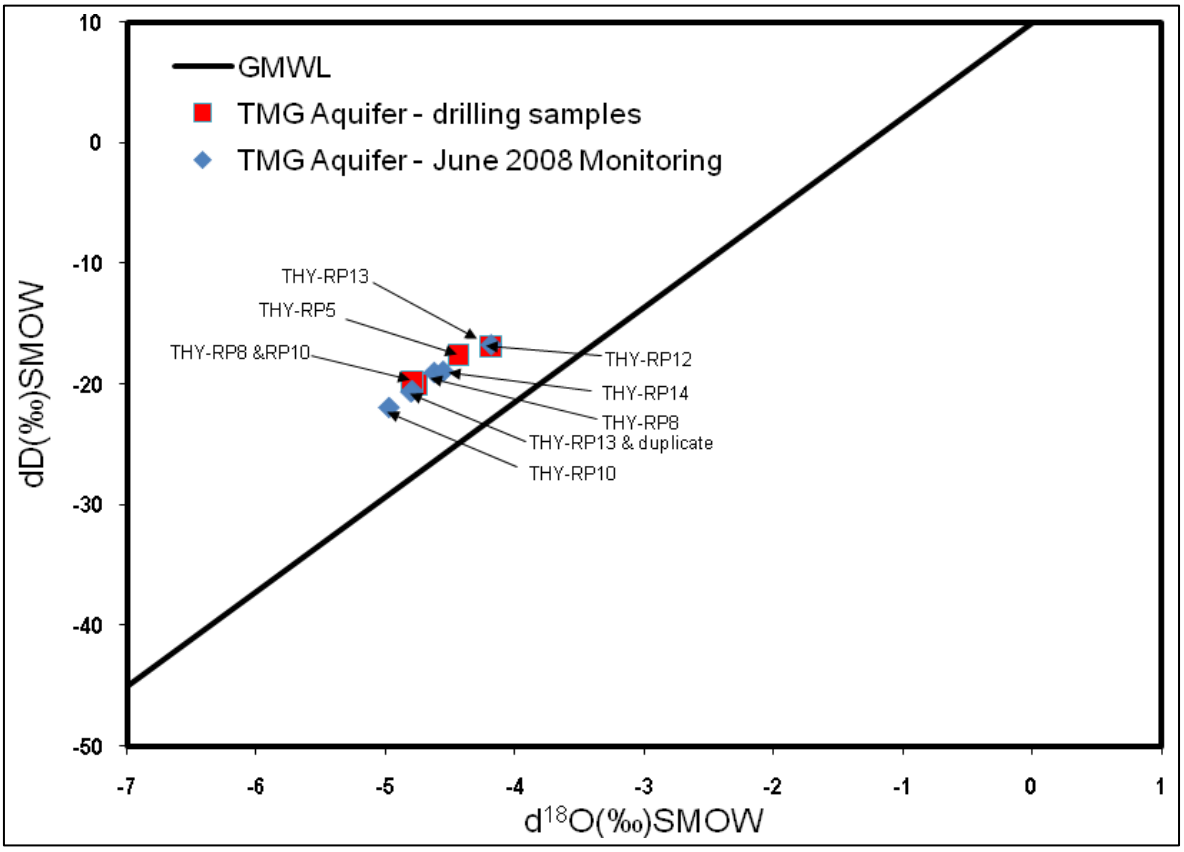


Figure 5.11.27
δO-18 versus δD: Hydrocensus Samples: TMG Aquifer

The H-3 values indicate a component of relatively recent recharge ranging up to 2 TU. This could indicate mixing with Algoa Aquifer groundwater given that the main direct recharge to the TMG Aquifer is postulated to occur on TMG outcrop areas from the northern site extremity and further to the northwest in the higher-lying areas.

5.11.8 Modelling

To assist in the characterisation of the existing groundwater regime and the evaluation of possible future changes and impacts on the site under different scenarios (e.g. abstraction and construction dewatering), a numerical flow

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model has been developed. This was carried out in two stages following standard international practice (Institute for Groundwater Studies, 2003), viz.:

- conceptual model;
- numerical flow model;

Conceptual Model

Having collated all available information related to the site and the surrounding areas and carried out detailed site investigations, the next step is to conceptualise these characteristics. This is in terms of aquifers/aquitards, boundaries, recharge, borehole data, groundwater levels/contours and flow directions and quality, and assign hydraulic parameters to the various formations, i.e. K, T and S. The development of a conceptual model for the site and its surroundings encompasses all of the information presented in the preceding sections.

A conceptual model and cross-section of the site and its immediate surroundings are presented in and ***Figure 5.11.28***, respectively. Hydrogeological cross-sections of the site are also shown in ***Figure 5.11.29***, ***Figure 5.11.30*** and ***Figure 5.11.31***. As can be seen, the Nuclear-1 footprint is located very close to the coastline. In terms of the hydrological/groundwater cycle, this means that the nuclear installation(s) will likely be located in or close to a groundwater discharge zone. Taking this into account and data from the investigations performed on site for this SSR, the following characteristics were assumed in the conceptual model:

- There is no downstream use of groundwater apart from some ecological dependence.
- Groundwater is near/at the end of its flow path.
- Groundwater levels are shallow.
- There will be an upward component of groundwater flow towards the water table.
- The upper surface of the bedrock comprises a wave-cut platform.
- The aquifer system at the site comprises three layers; a top unit of aeolian sands, a thin and discontinuous middle unit of cobbles and a bedrock basal unit dominated by quartzitic sandstone.

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- The aquifers are in hydraulic connection separated by an insignificant weathered zone in the bedrock.

- Local direct recharge only affects the Algoa Aquifer. The TMG Aquifer is mainly recharged inland, many kilometres from the site boundaries. There may be upward leakage of groundwater from the TMG Aquifer into the Algoa Aquifer (and *vice versa*) depending on relative groundwater heads in each aquifer.

- Groundwater flow rates are relatively low in the sand layer aquifer but very high in the highly transmissive cobble layer.

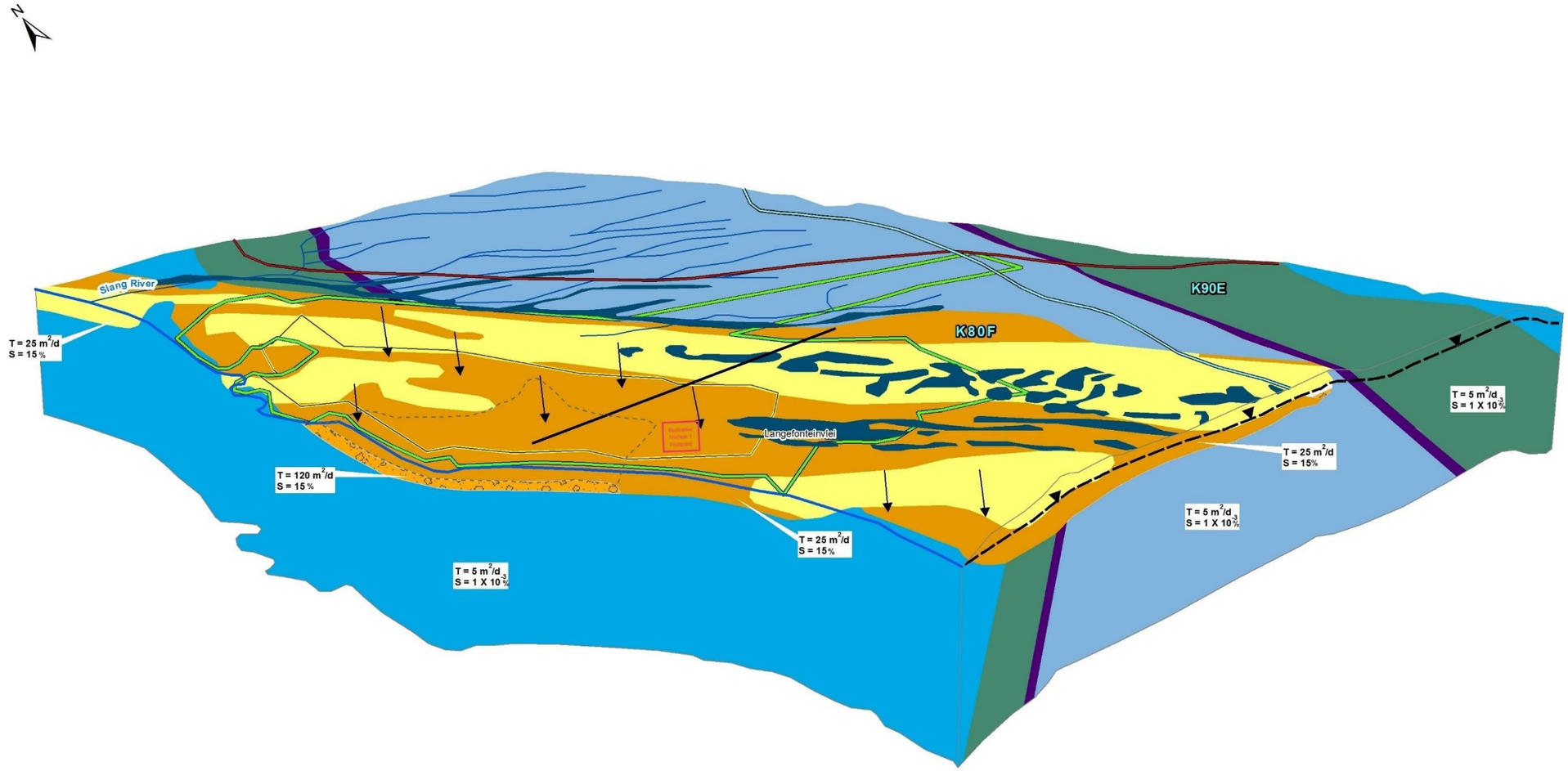
- The interface between 'fresh' groundwater from inland and saline groundwater in the shore-zone is located many tens of metres below the level at which the nuclear installation foundations will be established.

- Natural groundwater quality is relatively good and of a mixed NaCl and $Ca(HCO_3)_2$ character.

In order to set up a groundwater flow model for the area, a water level contour map must first be generated. An interpolation technique, using the available data, was used to simulate water levels over the entire model area. The interpolation technique used is referred to as Bayesian interpolation where water levels are correlated with altitude. All available levels were plotted against the topographic altitude as shown in ***Figure 5.11.32***. The results indicate a correlation of 89.7 per cent between the data sets. Therefore, Bayesian interpolation is valid and used to calculate water levels for the entire model area (Institute for Groundwater Studies, 2003).

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Legend

- Thyspunt Site
- Enveloping Footprint
- Wetlands
- Quaternary Catchment boundary
- Inferred Groundwater Flow Direction
- Inferred Groundwater Level
- Geohydrological Cross Section (Figure F-5.11.18)
- Rivers
- Coastline
- Roads

Simplified Geology

Quaternary Deposits	Algoa Aquifer
Nanaga Formation	
Nanaga Formation; cobble horizon	
Skurweberg Formation	TMG Aquifer
Goudini Formation	
Cedarberg Formation	
Peninsula Formation	
Extent of cobble layer	

Not to scale

COORDINATE SYSTEM	Eskom	SITE SAFETY REPORT FOR THYSPUNT		
Map Projection: Datum: Spheroid: Scale factor: Central meridian: Units:	CONCEPTUAL HYDROGEOLOGICAL MODEL		REV BY	
SRK CONSULTING			AUTH BY	
COMP MAHH 21/10/2024	SOURCE OF INFORMATION:		DWG NO	REVISION
REV VISS 21/10/2024	RELEASED BY ESKOM	NOTE: For proper clarity this drawing must be printed at A3 scale	5.11.10	1
SCALE N.T.S.				

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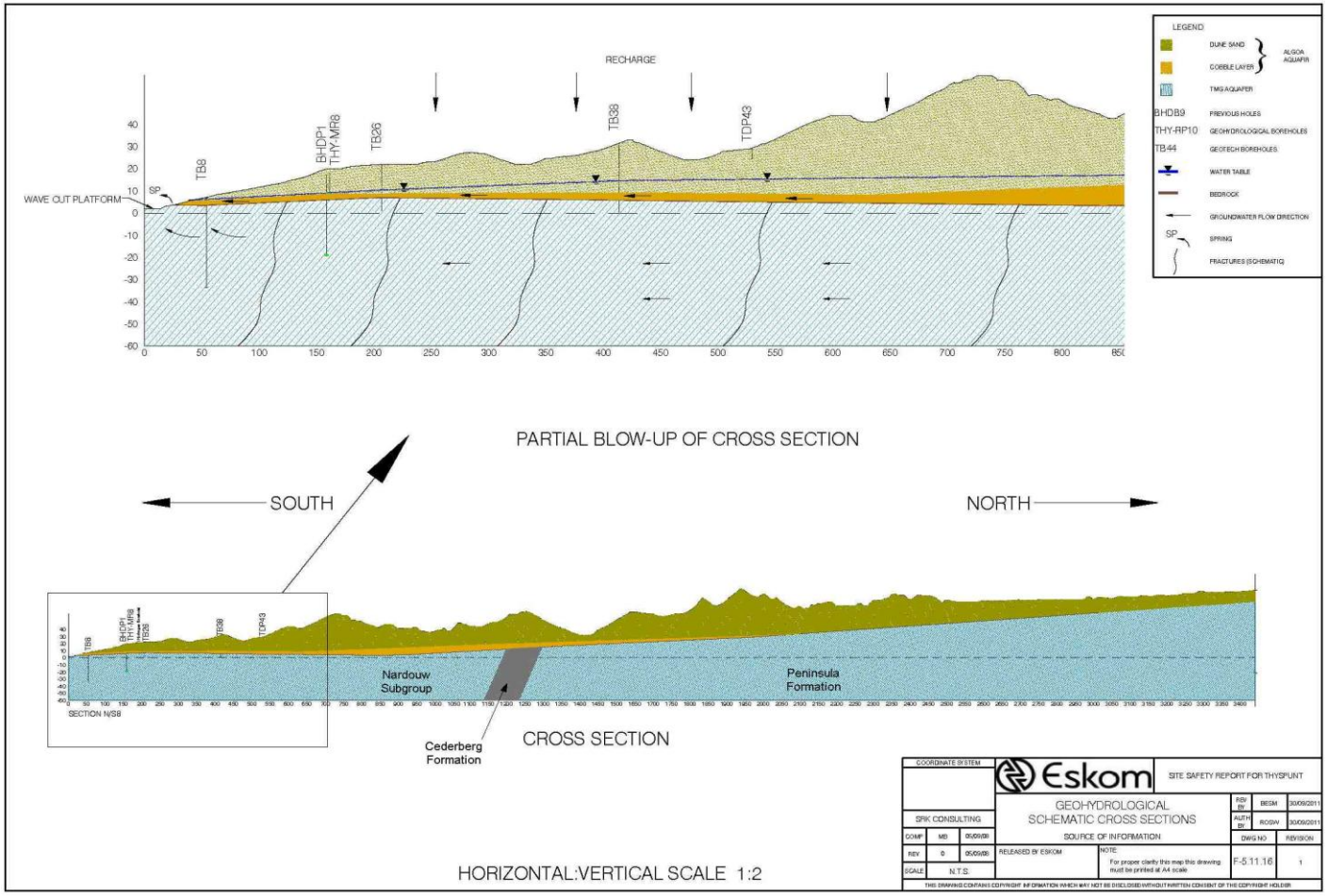


Figure 5.11.28
Geohydrological Schematic Cross-sections

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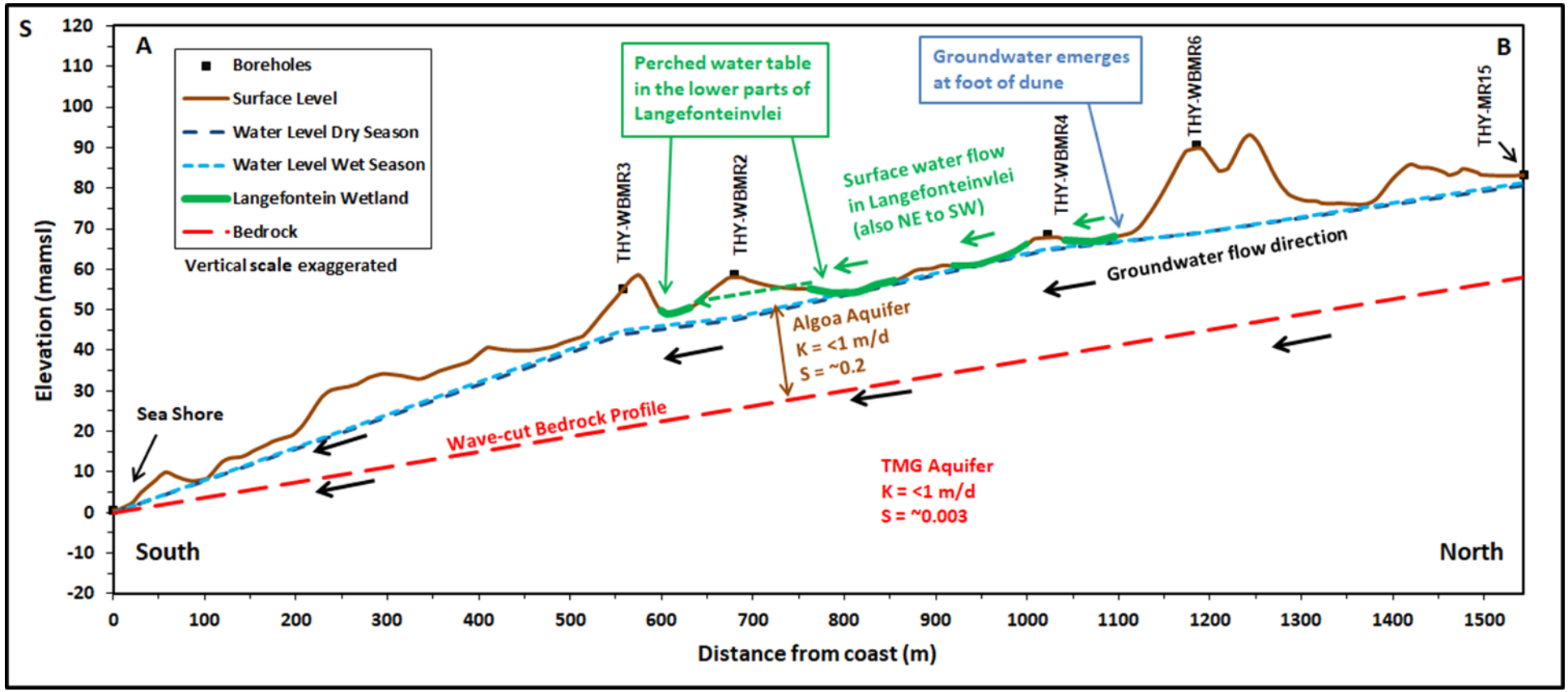


Figure 5.11.29
North-South Cross-Section AB Through Langefonteinvlei, Showing Inferred Surface/ Groundwater Linkages Resulting in Wetland Formation and Function

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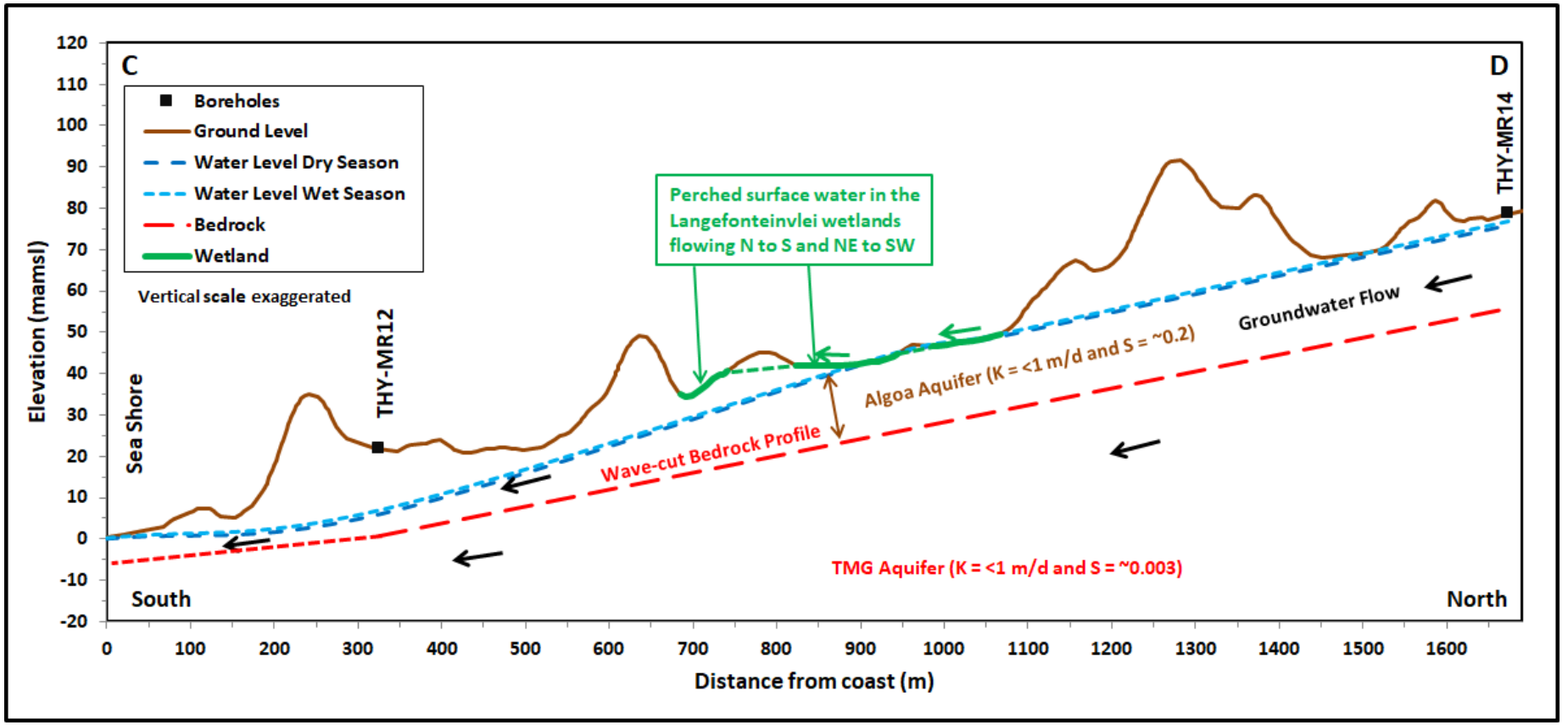


Figure 5.11.30
North-South Cross-Section CD Through Langefonteinvlei, Showing Conceptual Surface/ Groundwater Linkages Resulting in Wetland Formation and Function

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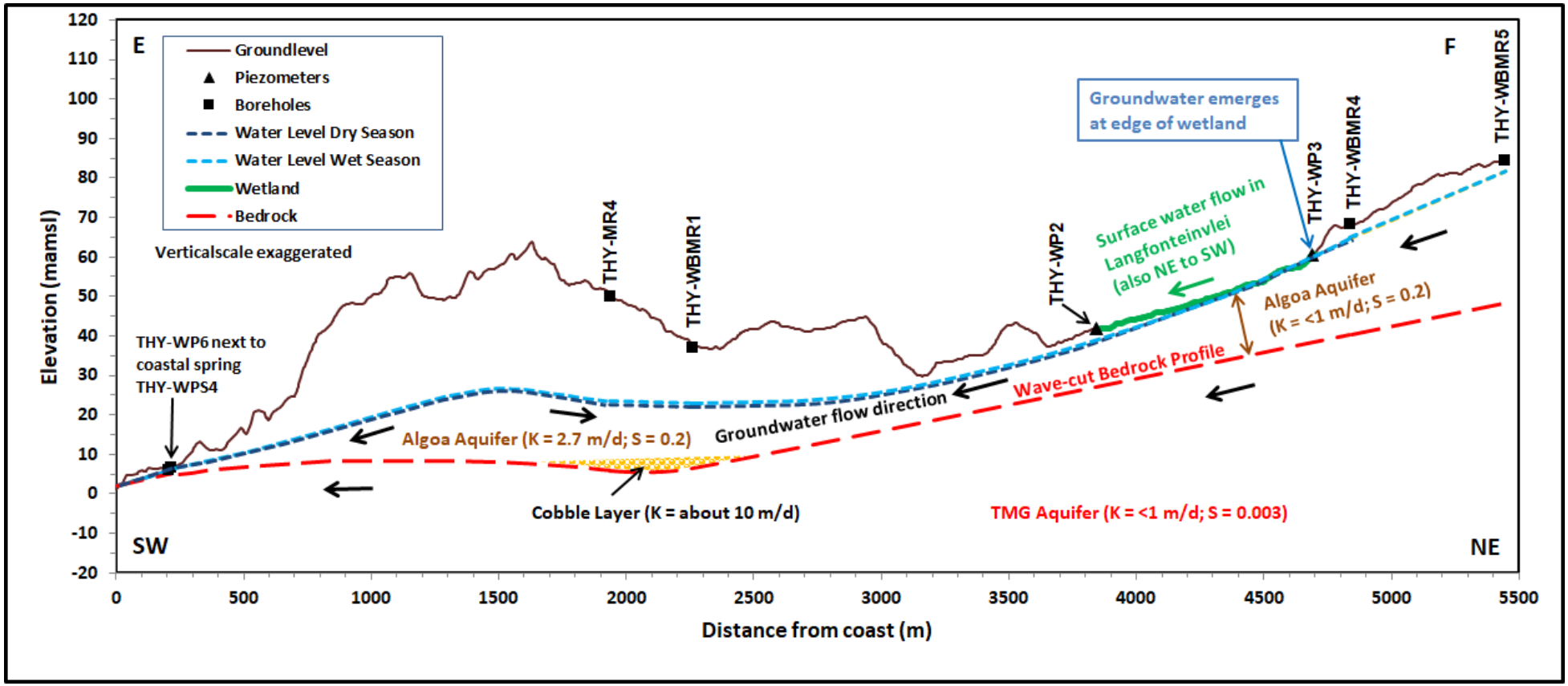


Figure 5.11.31
Southwest-Northeast Cross-Section EF Through Langefonteinvlei, Showing Conceptual Surface/ Groundwater Linkages Resulting in Wetland Formation and Function

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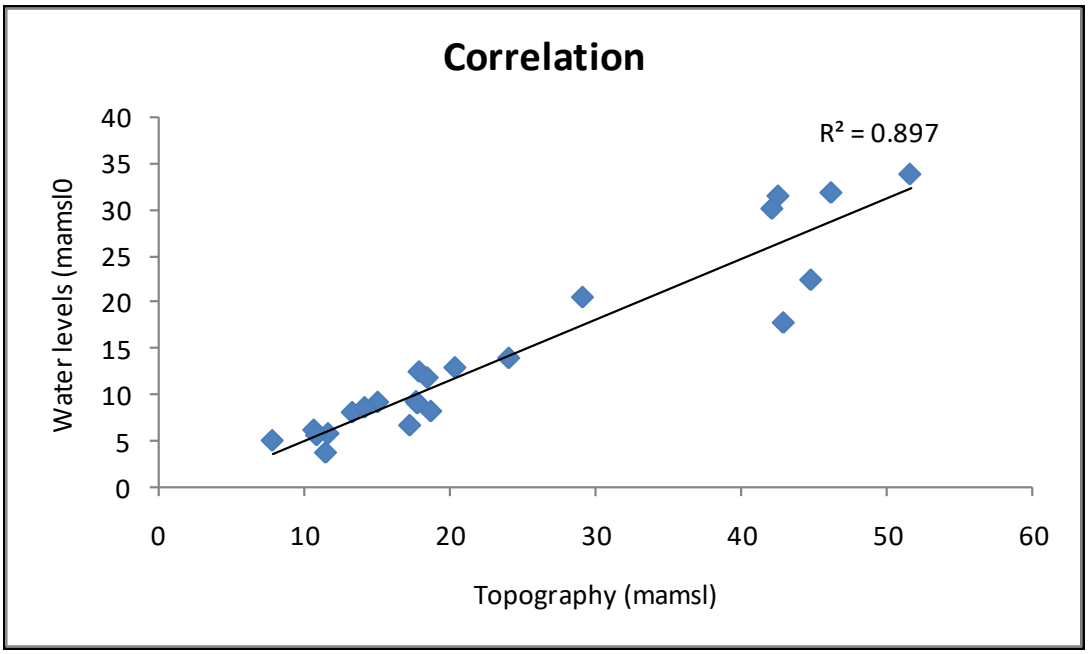


Figure 5.11.32
Correlation Between Groundwater Levels and Topography

As groundwater levels are higher at higher altitude and flow is to lower topography towards the ocean, it can be assumed that groundwater flow takes place under generally unconfined to semi-confined conditions. Model calibration and validation are required to translate the usually relatively limited point source data to a regional scale. They also facilitate the simplification of the natural system in the model. In model calibration, simulated values such as water levels or contaminant concentrations are compared with field measurements. The model input data were altered within reasonable ranges based on geohydrological and modelling experience and the available information, until the simulated and observed values were in correspondence with an acceptable tolerance.

Numerical Model

A numerical model has been developed for the site specifically to address the following scenarios that are relevant to site safety:

- assess the potential dewatering requirements during construction and to determine the zone of depression and area of influence as a result of dewatering of the foundation excavation (scenario 1);

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- evaluate the effect of predicted sea level rise on the site groundwater system (scenario 2);
- evaluate the effect of sea level rise on dewatering (scenario 3);
- assess the amount of groundwater available for possible water supply to the site (scenario 4);
- assess the potential extent of sea water intrusion (scenario 5);
- assess potential for contaminant transport (scenario 6);
- assess the effect of climatic extremes on the above, as appropriate.

Model Selection

In order to investigate the behaviour of aquifer systems in time and space, the mathematical model *MODFLOW-USG* was selected for the evaluation of the site. *MODFLOW-USG* (Panday, et al., 2013) is a modular three-dimensional finite difference groundwater flow model, which was developed by the U.S. Geological Survey. It is an internationally accepted and benchmarked modelling tool, which is used for calculation of the solution of the groundwater flow equation using the finite difference approach. A professional graphical interface *Groundwater Vistas*, developed by Environmental Simulations, Inc (Rumbaugh & Rumbaugh, 2020) was also used to apply the model to the site, and to analyse and to display the modelling results.

The reasons for the selection of *MODFLOW* as the modelling tool for this SSR and more specifically *Groundwater Vistas* as the graphical interface are the following:

- *MODFLOW* simulates steady and non-steady state flow in an irregularly shaped flow system. In this system the aquifer layers can be confined, unconfined, or a combination of the two.
- Flow from external stresses (e.g. flow to boreholes, aerial recharge, evapotranspiration, flow to drains, and flow through river beds) can be simulated.
- Hydraulic conductivities or transmissivities for any layer may differ spatially and be anisotropic.
- The Storage coefficient/Specific storage may be heterogeneous.

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- Internationally, *MODFLOW* is currently the most used numerical model for flow solutions.

- The flow equations incorporated in the model provide a reasonable approximation of the aquifer conditions prevalent on site, particularly in the Algoa Aquifer, which will have the main influence on site development.

- *MODFLOW* was successfully used for the dewatering simulations for the Koeberg Nuclear Power Station (KNPS) (Eskom, 2006) and planned (cancelled in 2010) Pebble Bed Modular Reactor Demonstration Power Plant (Murray & Saayman, 2000).

A limitation of *MODFLOW* is the simulation of flow in specific fracture zones. Such zones exist within the study area, but on the scale of the regional and local scenario modelling, it is considered that *MODFLOW* will provide adequate representation of the system response. This is because the TMG Aquifer is a generally fractured aquifer at the site rather than one where flow is dominated by one or more major fractures or faults, i.e. groundwater flow will be pseudo-radial at the local and regional scale (continuing investigations will further test this assumption). Another key factor is that the main aquifer that will impact on dewatering and groundwater control measures will be the intergranular Algoa Aquifer.

Simulation of the seawater/freshwater interface also cannot practically be done using *MODFLOW* as the density differences cannot be accommodated. However, as this interface has been found not to occur within the zone of interest and influence with respect to the nuclear installation(s), this is not considered a constraining factor. Lowering of the water table due to dewatering is unlikely to significantly impact the position of this interface.

Other modelling packages such as *FEFLOW*, *FLAC* and *AQUA3D* were considered, and each has its own strengths and weaknesses for this particular application. This evaluation is elaborated in the V&V report in ***Appendix 5.11.J***. These and other specialist packages should be further evaluated for the detailed modelling that will be required for actual dewatering system design and long-term groundwater control measures.

Calibration

In order to develop a model of an aquifer system, certain assumptions have to be made. Assumptions include the following:

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- The system is initially in equilibrium and therefore in steady state.
- The available information on the geology and field tests is considered acceptable and representative.

Based on the information presented in the preceding subsections, it is considered that these two assumptions have been adequately met.

Once the numerical model was constructed, model calibration and validation were carried out to translate the relatively limited and point source data to a regional scale, while also accommodate the simplifications of the natural system inherent in the model. In model calibration, simulated values of water levels and contaminant concentrations were compared with field measurements. The model input data were then altered within reasonable ranges based on the modeller's experience and available information, until the simulated and observed values fit within a reasonable tolerance.

Table 5.11.22 shows the modelling and simulation requirements for the SSR groundwater models to be adequately functioning and calibrated for the purposes for which they were developed, along with the derived acceptability criteria that should be met to satisfy these requirements (as defined by quantitative and qualitative measures).

The acceptability criteria were derived using a combination of groundwater modelling accepted best practices, local knowledge of the area's hydrogeological characteristics, and an assessment of the model's intended use, modelling objectives, investigation scale and confidence level required.

Table 5.11.22
Acceptability Criteria

No.	Modelling and Simulation Requirements	Acceptability Criteria
1	Convergent	Head change criteria within 0.001 m. (This is the maximum absolute value of the head change for the iteration for each cell.) Residual criterion is within 1 m^3. (This is the maximum absolute value of the difference between inflows and outflows for each cell.)
2	Well-balanced	Water Flow Mass Balance (inputs versus outputs) has an error less than 0.5%

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No.	Modelling and Simulation Requirements	Acceptability Criteria
3	Model cells don't go 'dry' and hinder vertical flow unnaturally	No dry model cells below the top active layer in the model. Dry cells in the top layer should correlate approximately with areas of likely unsaturation.
4	All pumping wells are able to pump to the historical volumes specified	Mass balance totals for well abstraction volumes should match 100% with the input historical abstraction volumes.
5	Long term groundwater flow directions correlate with the conceptual model	Qualitative check that the groundwater flow directions correlate with the conceptual model flow directions.
6	Long term regional water levels correlate reasonably to observed data	80% of simulated regional water levels (multiple boreholes, often over different time periods and with few data points per site) are within 10 m of historical observations *and/or* a correlation of above 75% is achieved (where correlation is calculated as the square of the Pearson product moment correlation coefficient through data points). This acceptability criterion was selected by taking into account the variability of aquifer conditions and large number of data points (>100 boreholes) included in the calibration.
7	Long term local site measured water levels correlate well to observed data	90% of simulated regional water levels (multiple boreholes, often over different time periods and with few data points per site) are within 3 metres of historical observations *and/or* a correlation of above 95% is achieved. This acceptability criterion was selected by assuming that the local site aquifer conditions are less variable and there are fewer (<20), high quality data points included in the calibration.
8	The losing and gaining of river baseflow correlates with the conceptual model, as well as any river flow data and observations available	Mass balance totals over zones in a river will show the volumes lost and gained from a river to groundwater. The expected lengths of river gain or river loss to groundwater should be in keeping with the conceptual model gains and losses over a minimum of 90 % of the river reaches, with actual volumes lost and gained not more than double or less than half of the volumes measured or calculated analytically at any particular location where historical baseflow data is available.
9	Short term pumping test drawdowns and recoveries are well simulated	Good correlation between graphs of simulated and observed water levels during pumping tests, with explainable reasoning (such as non-simulated well losses) over periods of deviation.

All acceptance criteria were successfully met and a correlation of 99 per cent was achieved for the regional steady state model (version v2g, 2024), which is considered to be excellent. Following steady state calibration, transient

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model scenarios were run to simulate the time period from January 2008 to December 2023, as this is a period for which the most data was available regarding rainfall, observed wellfield abstraction rates and water level monitoring data. The modelled water level trends generally mimic the observed data very closely, with just a few occasions where water levels are slightly high or low compared to the observed. The specialist modelling report is in ***Appendix 5.11.J***.

Sensitivity

The following conceptual comments are noted from the sensitivity testing results:

- Changes in the modelled K_h with a 20 per cent increase or decrease across all defined zones have the following effects:
  - When K_h is increased, the average inflow rates (with a 'calibrated base case model' estimate of 20.8 ℓ/s) rise by approximately 9 per cent (to 22.7 ℓ/s). Conversely, when Kh is decreased, the average inflow rates drop by about 10 per cent (to 18.7 ℓ/s).
  - The impact on the drawdown zone is minimal with a K_h increase, resulting in a slight decrease of around 1 per sent. However, a decrease in K_h leads to a more significant increase of about 16 per cent.
- The model has a very low sensitivity to K_v with a 20 per cent increase or decrease influencing the inflows by less than one per cent, and the drawdown zone by less than four per cent.
- The model shows a medium sensitivity to long-term changes in recharge. By increasing and decreasing the recharge by 20 per cent, the average dewatering inflows increase by *c*.9 per cent (to 22.6 ℓ/s) and decrease by *c*.9 per cent (to 18.9 ℓ/s), respectively. The influence on the radius of influence is less than 3 per cent.
- By increasing the number of time steps per month from one time step to ten time steps, there was negligible effect (<0.5 per cent) on average inflows drawdown zone, and only *c*.1 per cent influence on the seasonal variance on flows. Thus, the model has very low sensitivity to the number of time steps per monthly stress period.
- Changes in K_v have a low influence. This is related to there being lower modelled flow within the overlying and underlying layers, and already

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relatively high vertical flows defined within the other layers. If K_v were altered in all layers then this would have a greater impact. Additionally, there is often little data on vertical conductivities, and variances could be in greater factors than ten (as was tested here).

- Recharge is a relatively sensitive parameter. Increases in recharge result in increases in inflow as well as a larger drawdown radius of influence (due to the higher water levels from increased recharge being pulled down 'further' to the dewatering site level).

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Table 5.11.23
Thyspunt Sensitivity Testing Results (using model Thyspunt_v2g

Test No.	Parameter	Parameter Amendment	Impact to 20 m bgl Dewater Site Inflow	Impact on Maximum Radius of Influence (using 4 m Drawdown Contour)
1	Mesh	Halve (from '50 x 50 m' to '25 m x 25 m')	-5%	-1%
2	Transmissivity	20% increase (L2 T zone from 30 m^2/d to 36 m^2/d)	7%	-1%
3		20% decrease (L2 T zone from 30 m^2/d to 24 m^2/d)	-7%	11%
4	Vertical Hydraulic Conductivity	Factor of 10 increase (L2 K_v zone from 10 m/d to 100 m/d)	<1%	<1%
5		Factor of 10 decrease (L2 K_v zone from 10 m/d to 1 m/d)	-1%	<1%
6	Recharge	20% increase (from 182 mm/a to 218 mm/a)	7%	11%
7		20% decrease (from 182 mm/a to 146 mm/a)	-7%	-11%

Validation and Verification

In terms of RG-0016 **(National Nuclear Regulator, 2006)**, all computer codes used in simulation of processes associated with nuclear installations must undergo a thorough validation and verification (V&V) process. Validation is the confirmation that the calculation method is fit for purpose, while verification shows that the controlling physical equations have been correctly translated into the software code. The V&V report for the geohydrological modelling is in ***Appendix 5.11.J***.

The information presented in the V&V report demonstrates the following:

- An adequate software code selection process was followed.
- The software code chosen, MODFLOW, is the most widely used groundwater flow modelling code internationally.
- Benchmark uses including use for the regional flow modelling by the USGS for the Yucca Mountain nuclear waste repository in the USA

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(Sinton, 1987).

- Modelled results obtained for groundwater levels compare favourably with actual measured values (long term averages and seasonal variation), giving confidence in the results of the predictive scenario modelling carried out.

- Geohydrology is not an exact science and outputs from the modelling give a qualitative indication of likely conditions, not an absolute prediction.

- The flow modelling was undertaken by suitably qualified and experienced practitioners and was adequately peer reviewed.

Thus, the model was found to be 'fit for purpose' to run predictive scenarios.

Scenario Simulations

A more detailed but smaller extent three-layer model was constructed and calibrated for the scenario modelling, incorporating the cobble layer, using the key parameters listed in ***Table 5.11.24***. This model was constructed for site-scale modelling of scenarios related to the nuclear installation(s).

The hydraulic parameters in ***Table 5.11.24*** differ somewhat from those described in ***Subsection 5.11.5***. This is because the latter were derived from testing of relatively small volumes of the aquifers whereas the modelling requires/derives more averaged, large-scale values. The site work carried out is still very important, however, in order to provide guidance on the bounding parameter values and in the future for more detailed larger-scale modelling of specific foundation dewatering. The higher recharge value used corresponds with the higher recharge calculated for the enveloping footprint area as shown in ***Drawing 5.11.5***.

An excellent correlation of 93.5 per cent for simulated versus observed data was achieved for the local model, which is of key importance for the site-specific simulations. These correspond to the key scenarios listed at the start of this section and are described below. The good correlation indicates that the hydraulic parameters used are likely to be a good representation of actual site conditions.

Together with the calibration, a sensitivity analysis was run on the model. The model is most sensitive to T values in the three layers of the numerical model. Vertical K is the second most sensitive parameter. Very little information is available concerning this parameter. However, as the primary

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aquifer is considered to be isotropic it can be reasonably assumed that vertical K is similar to the horizontal K. Further discussion on sensitivity analysis is given in the detailed modelling report in ***Appendix 5.11.J***.

Table 5.11.24
Parameters Used for Numerical Modelling

Layer	Aquifer	Transmissivity (m^2/d)	Storage	Recharge (% of MAP)
Layer 1	Algoa (sands)	25	0.15	25
Layer 2	Algoa (cobble layer)	120	0.15	-
Layer 3	TMG	5	1×10^{-3}	-

Scenario 1: Dewatering of Nuclear Installation Foundations

The nuclear installation(s) is envisaged to be founded on TMG bedrock, necessitating extensive and relatively deep (*c*.20 m) excavation into the largely unconsolidated Algoa Aquifer sediments (depending on final location of the nuclear terrace). These have a shallow water table and pre-dewatering and continuous dewatering/groundwater control will be required during much of the construction process.

In this scenario, the Nuclear-1 footprint is fully dewatered, with excavations assumed to be down to bedrock. The resultant zone of depression is shown in ***Drawing 5.11.11***.

The predicted rates of inflow of groundwater (rounded-off) that will be generated under average and “wet” climatic conditions are 21 and 24 ℓ/s. Based on practical experience in similar geohydrological environments, these amounts will be about 30 per cent less than the pumping requirements to actually dewater the area to be excavated. However, refinement of these calculations is a design issue, and the above predictions serve to indicate that groundwater control at the site is feasible.

The zone of water table depression to >1 m is confined to the enveloping footprint. By including an impermeable cut-off wall (in the first two layers[20] of the model) upstream of the footprint the maximum inflow is reduced to 8.7 ℓ/s. The zone of depression is significantly smaller, as can be seen in

[20] Layer 1 = sands, layer 2 = cobbles and sands

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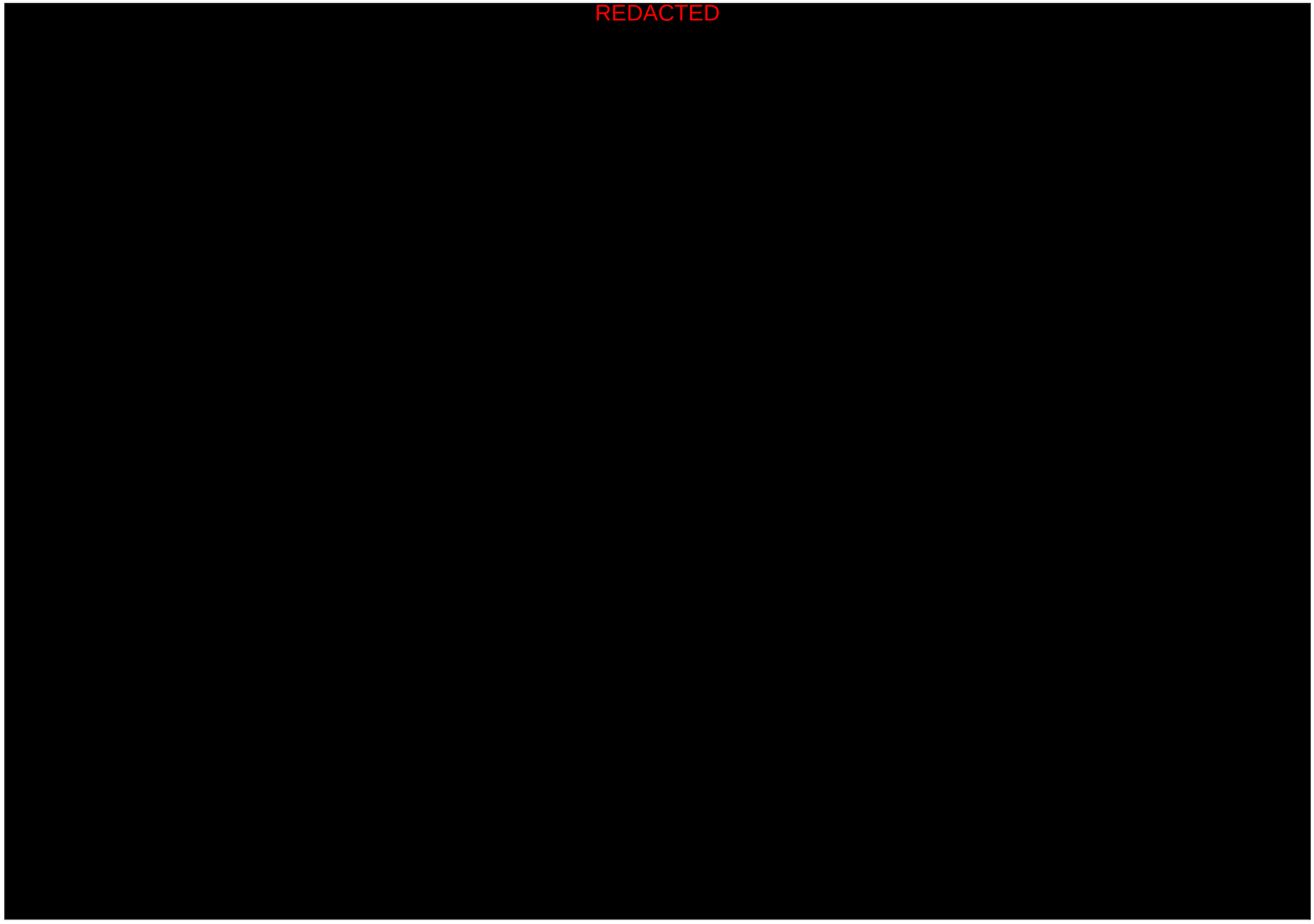
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Drawing 5.11.12. In practice, various groundwater control methods will need to be assessed to determine their suitability for the site conditions.

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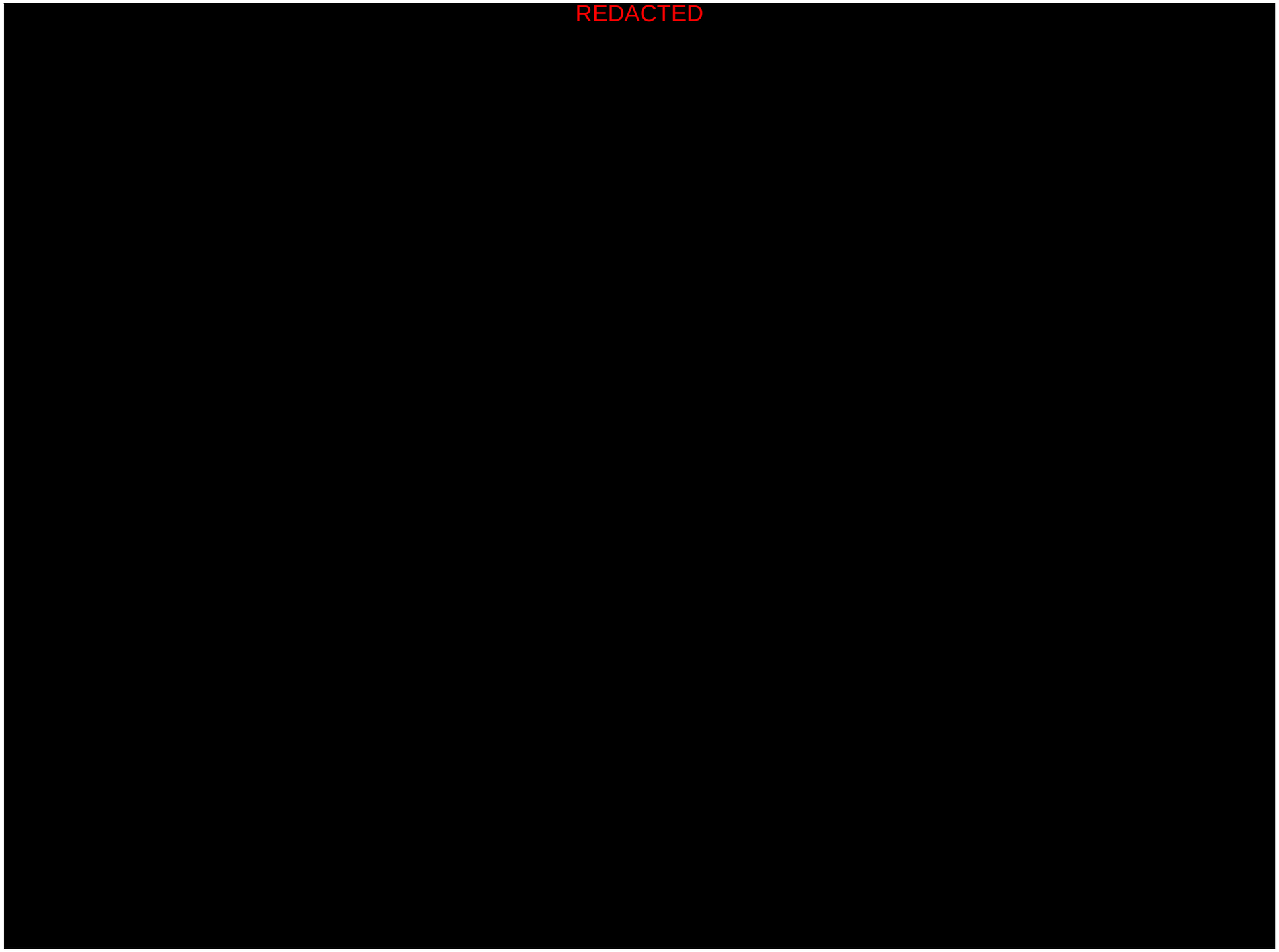
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Scenario 2: Impact of Increase in Sea Level on the Groundwater System and Flooding Risk

The estimated encroachment of the sea due to a sea level rise is based on predictions contained in ***Section 5.9***, Oceanography and Coastal Engineering, as per ***Table 5.11.25***.

Table 5.11.25
Estimates of Sea Level Rise

Confidence Level	Year	Rise (m)
Medium	2034	0.14
Medium	2134	1.76
Low	2034	0.18
Low	2134	3.28

The resultant increase in groundwater levels is shown in ***Drawing 5.11.13***.

There is very little difference in effects on groundwater levels between the two scenarios. The zones where groundwater is closer to the surface within the nuclear footprint are natural topographic depressions, as also reflected by the topographic contours. The absolute groundwater levels are between 10 and 20 m amsl, and are thus not significantly altered by the potential sea level rise occurring downgradient. The 3.28 m sea level rise model scenario shows greater inundation near the coastline, and also pushes the 0.5 m contour of modelled groundwater level rise further inland compared to that of the 1.76 m sea level rise scenario. However, this effect dissipates rapidly across the nuclear footprint due to the natural steeper hydraulic gradient inland. The coastline will shift inland by an insignificant distance which has not been reflected in the model outputs of ***Drawing 5.11.13***.

These are insignificant rises and can be considered with groundwater control measures under scenario 1 and pose no additional significant risk of flooding to the nuclear installation(s). Sea level rise will also drive the seawater/freshwater interface inland but, as previously discussed, this interface is deeper than the zone of likely impact of the nuclear installation(s).

Scenario 3: Impact of Rise in Sea Level on Dewatering

This scenario repeats scenario 1, but with a worst-case sea level rise of 3.28 m and average precipitation conditions. The expected inflows for the illustrative footprint are slightly higher than for scenario 1 at 25 ℓ/s. The zone of depression does not extend far beyond the footprint area and is contained well within the

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site boundaries (see ***Drawing 5.11.13***).

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Scenario 4: Groundwater as a Potential Source of Water

The numerical model was used to calculate a water balance for both the study area and the Eskom site catchment area. Under conservative "dry" conditions, as previously defined, it is estimated that there is approximately 30 ℓ/s of sustainably available groundwater, 13 ℓ/s from the Algoa Aquifer and 17 ℓ/s from the TMG Aquifer.

Eskom intends to use 17.4 to 23.1 ℓ/s of water for a period of approximately one year prior to commissioning of a permanent desalination plant. In terms of the results of the drilling and test pumping carried out at the site, this amount can be obtained from existing site groundwater sources as shown in ***Table 5.11.26***. Groundwater from these sources is potable.

Table 5.11.26
Sources for On-Site Groundwater Abstraction

Source	Yield (ℓ/s)	Depth	Aquifer	Comment
THY-RP2	4	79	TMG	
THY-RP5	4	150	TMG	
THY-RP6	3	49	TMG	
THY-MR11	9	21	Algoa	Install 2 additional monitoring boreholes
Spring 4	5	n/a	Algoa	Overflow from spring area
TOTAL	25			

n/a = not applicable

These sources are scattered over the site (see ***Drawing 5.11.3***) and it may be possible to obtain the required supply from a more concentrated area around THY-MR11, but this would require additional drilling. This would also provide valuable additional information on the probable effects of dewatering of the Nuclear-1 footprint area. However, desalination of seawater is the preferred option for long-term freshwater supply to the site. Freshwater supply is discussed in detail in ***Section 5.12***.

Scenario 5: Seawater Intrusion

In this scenario the potential of seawater intrusion is investigated under the influence of dewatering of foundations. *PMWIN* is not ideal for simulating seawater intrusion and can only provide a qualitative indication of the possibility of such intrusion. *PMPATH* is included in the *PMWIN* package. This add-on package simulates the advective transport of particles within an aquifer system. Particles were introduced at the coastline and tracked with

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time. The results indicate that seawater intrusion could occur in a zone of 400 m along the coastline in the vicinity of the illustrative footprint and may occur mostly in the TMG Aquifer. Mitigation/groundwater control measures, such as use of a cut-off wall and reintroduction of pumped groundwater into the Algoa Aquifer, would lessen the effects of any such intrusion. Any saline intrusion should reverse with time once the temporary dewatering measures are deactivated after casting of foundations.

Scenario 6: Transport of Radionuclides

This scenario assesses the potential transport of contamination (radionuclides) from the Nuclear-1 Island in groundwater, should there be a liquid leak from the site. The assumptions used were as follows:

- a surrogate contaminant was assumed at 100 per cent concentration at the footprint.

- a partition coefficient, Kd, within the range derived from laboratory tests for Sr-90 (1.18 mℓ/g) was assumed. Sr-90 and Cs-137 are fission products that account for the bulk of the radioactivity in spent fuel waste and have the longer half-lives. Sr-90 is considered a conservative (worst-case) option for potential contaminant footprint modelling due to its relatively low retardation factor (which is derived from the porosity, bulk density and Kd, and noting that the lower the Kd, the higher the mobility in groundwater). The selection of the modelled value of Kd = 1.18 mℓ/g represents a relatively low partition coefficient within the range of the test results (***Table 5.11.16***). By also considering likely pH conditions in the groundwater at the site (7 to 9), the selected value reflects a balance between conservatism and realistic (albeit worst-case) site conditions.

- scenario 6a (Sc6a) assumes contamination over the whole footprint for 50 years.

- scenario 6b (Sc6b) assumes a localised leak for one month at the northern corner of the footprint and two years for spreading.

- scenario 6c (Sc6c) assumes a localised leak for one month at the northeastern corner of the footprint and spreading for 50 years.

The potential groundwater contamination plumes for Sc6a, Sc6b and Sc6c are shown in ***Drawing 5.11.14***, ***Drawing 5.11.15*** and ***Drawing 5.11.16*** respectively. In all three scenarios, contaminant migration is minimal and confined to the illustrative Nuclear-1 footprint. This scenario also assumes

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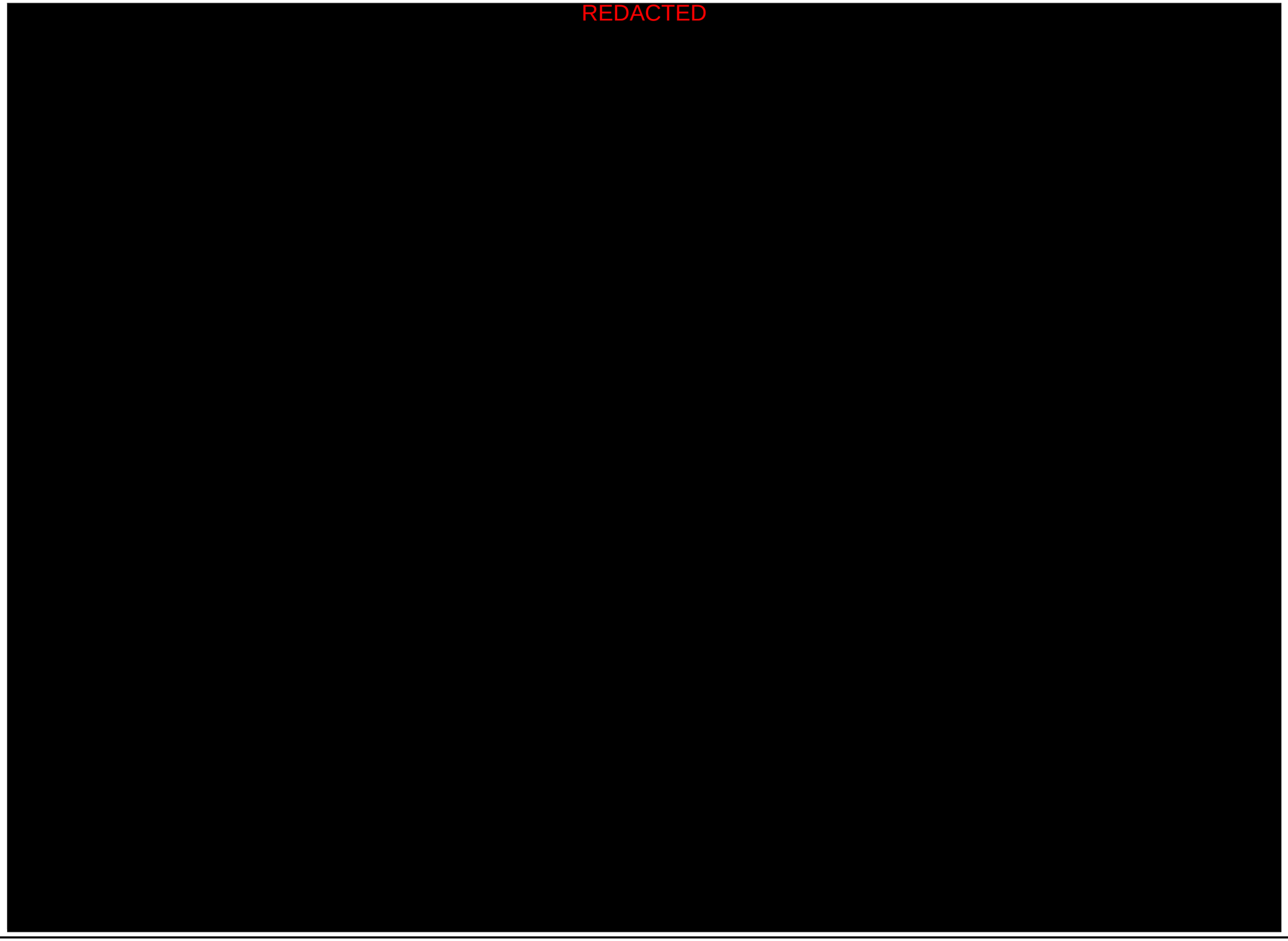
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that there is no remedial action, whereas in reality, the monitoring programme will pick up any such leakage before it has a chance to spread over the footprint.

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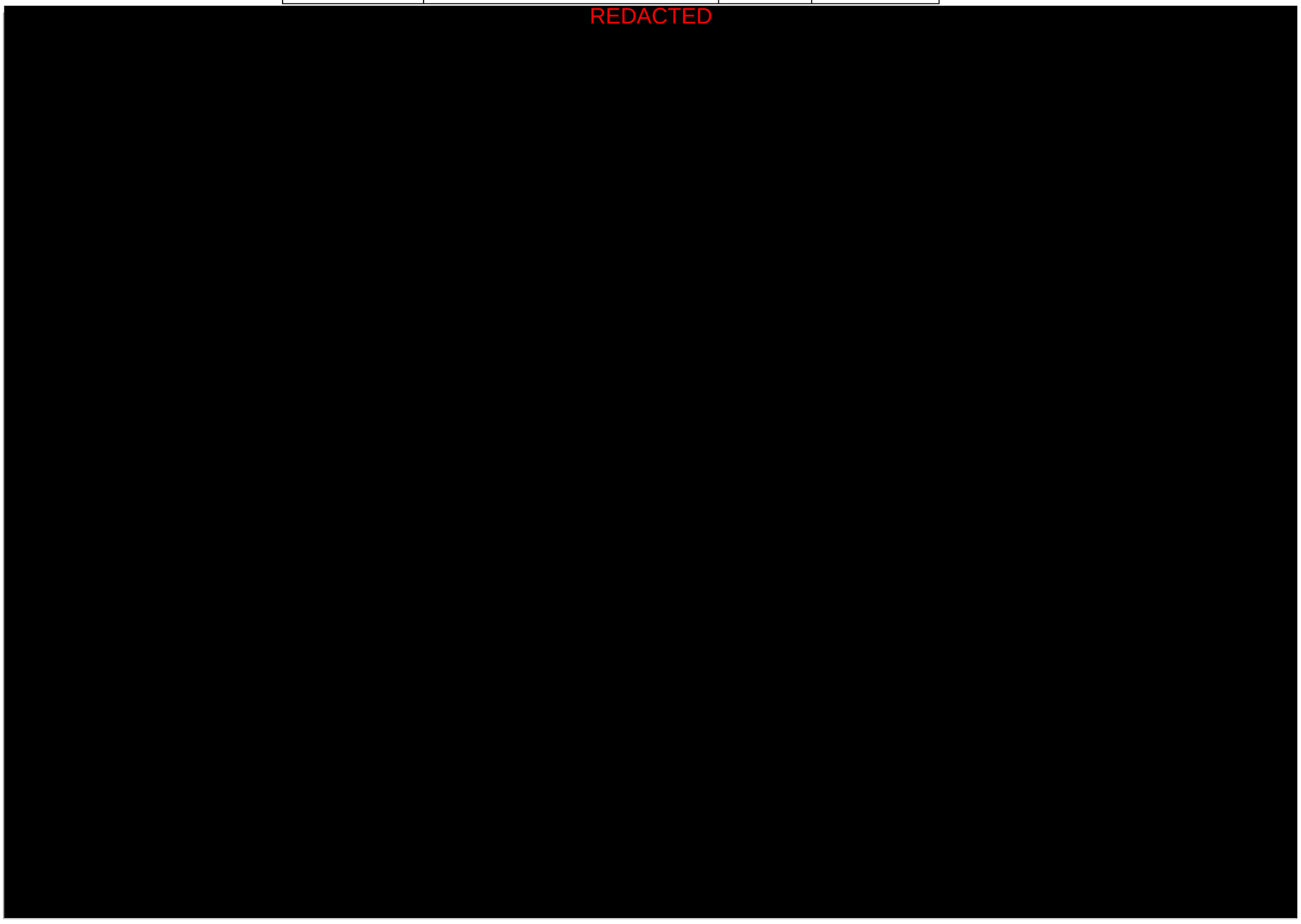
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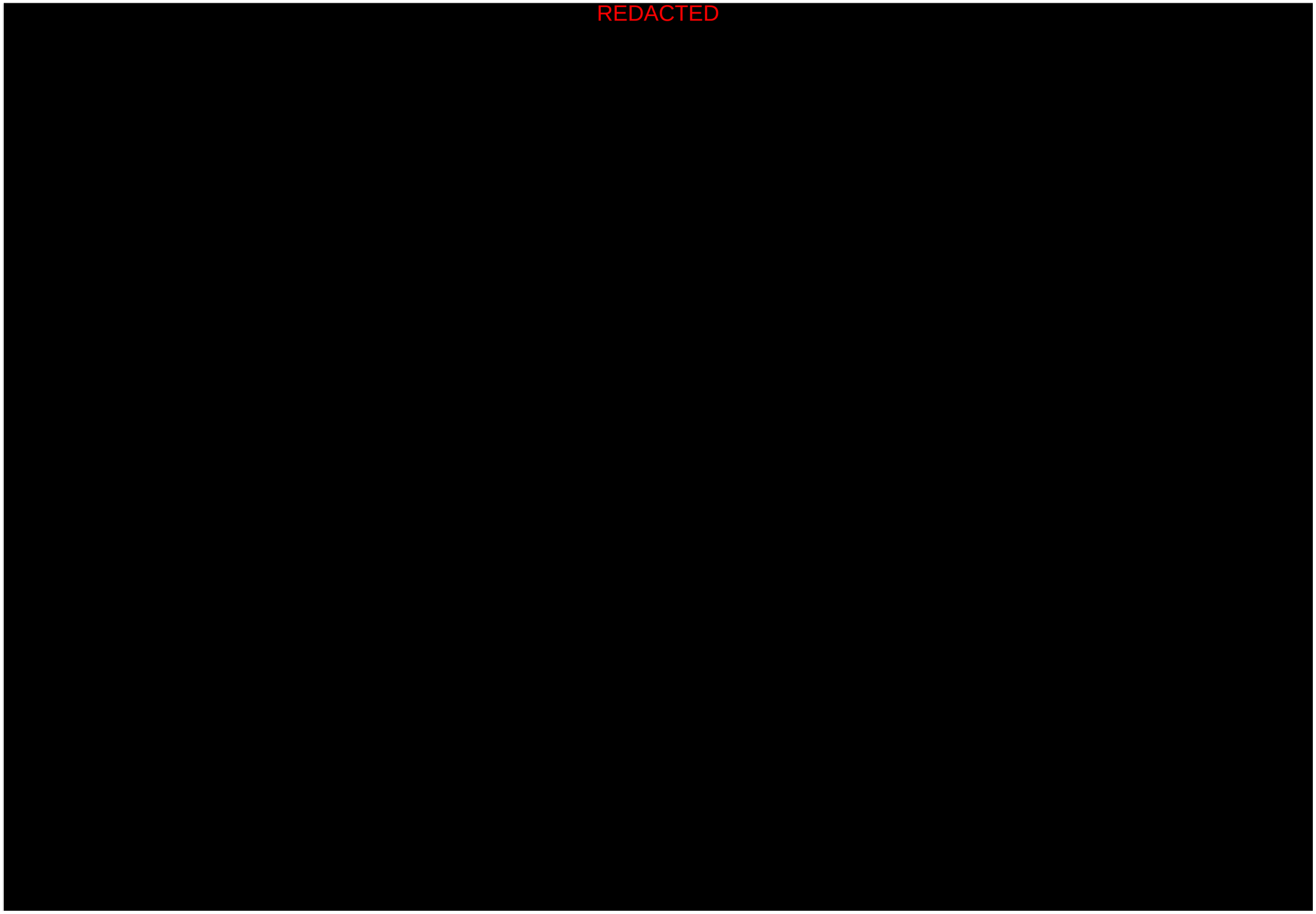
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5.11.9 Monitoring

The investigation of the site and the understanding gained of its geohydrological characteristics was supported by the establishment of a representative monitoring network covering the three main aquifers present, i.e. the dune sands, the postulated high groundwater flow regime in the cobble layer and fractures and matrix rock within the TMG. Meteorological monitoring was carried out by means of a purpose-built meteorological station (see ***Section 5.8***). This network was established in mid-2008 with the purpose of determining baseline groundwater levels and quality and ranges in values thereof (Eskom, 2009), viz:

- **groundwater levels** - establishing seasonal trends and response to extreme weather conditions, i.e. high rainfall events and droughts, and help to refine understanding of the groundwater flow regime;
- **wetlands/seeps** – determination of interaction with groundwater;
- **groundwater quality** - analysis of samples for selected radionuclides, macro-groundwater quality and trace elements, as described in more detail below.

The monitoring network (see ***Drawing 5.11.17***) comprises of:

- Three Algoa Aquifer boreholes (THY-MR5, THY-MR11 and THY-RP11) and two TMG Aquifer boreholes (THY-RP10-M1 and THY-RP9) at or near the illustrative footprints were equipped with automatic water level/temperature recorders.
- A barometric logger installed in THY-RP9 to record the barometric pressure variation in order to correct the water level data.
- Six boreholes and one spring (THY-RP7, 8, 10, 12, 13 and 14 and THY-SP7), located at or near the illustrative footprints, monitored on a six-monthly basis (May and November). The first monitoring run was conducted during May 2008 and this programme was halted after the May 2009 sampling as sufficient data had been collected for SSR requirements.
- Samples are taken for macro- and micro-chemical, stable isotope and selected radionuclide analysis. Analyses include cations (Na, K, Ca, Mg, NH_4) and anions (Cl, SO_4, NO_3, NH_3, PO_4, HCO_3), heavy metals (Fe, Mn,), trace elements (F), radionuclides (U, Th, Ra, alpha & beta activity), isotopes (D/H-1, O-18/O-16, H-3), pH and EC.

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- Six additional boreholes and six piezometers were installed in and surrounding the Langefonteinvlei in February 2010 for further detailed assessment of interaction with the Algoa Aquifer.

On the basis of the monitoring results to date and this SSR developed for the site, additional monitoring points will be established to provide a more extensive network and confirmation of the site parameters prior to construction activities. This network will take into account the exact location of the nuclear terrace and the position of any water supply boreholes established for the construction period prior to commissioning of the desalination plant. The current monitoring network is shown in ***Drawing 5.11.17***. Results up to February 2024 have been described in previous subsections and show no anomalous or concerning trends.

Monitoring reports will be used in the regular update of the SSR. The monitoring reports that are gathered over the life of the nuclear site and used in the development and update of the SSR will be stored in the Nuclear Sites archive and will be available to the regulator on request.

5.11.10 Management of Uncertainties

Uncertainties in terms of geohydrology of the site and impacts on site safety considerations mainly centre on inherent uncertainties with derivation of geohydrological parameters, possible occurrence of so far undetected fault/fracture zones, and sea level rise due to global warming. These uncertainties have been managed and minimised at the site by:

- carrying out multiple tests and analyses;
- comparing results to other similar areas and published data;
- applying experience of the project geohydrologists and peer reviewers;
- numerical model calibration and sensitivity analysis (plus additional data collection and more detailed modelling at the design stage);

In terms of nuclear installation safety, long-term monitoring is being carried out to build up a record of fluctuations in measurable geohydrological, hydrological and meteorological parameters and inputting these into the conceptual and numerical models and adjusting as necessary.

The above measures have all been applied to the evaluation of the geohydrology of the site for this SSR. The analyses and inferences drawn in this section on geohydrology are therefore considered to be realistic and

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present a sufficient level of confidence for the purpose of this SSR. The SSR monitoring record covers a drought period and high rainfall events and the groundwater level responses recorded indicate that the aquifer(s) have a sufficient buffering capacity to absorb such events with insignificant fluctuations in groundwater levels.

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5.11.11 Management System

The geohydrological investigations performed for this SSR entailed the following:

- desk study;
- site investigation;
- data analysis and reporting;
- use of computer software codes for interpretative and predictive modelling;
- monitoring.

The main sources of information used in compilation of this section are referenced in the text and listed under ***Subsection 5.11.13***.

All site work was carried out with reference to a quality data pack, which includes, *inter alia*, an overall Project Quality Plan, Method Statement, Environmental Management Plan, Risk Assessment, Quality Control Plan and Monitoring Plan. Details on justification for borehole site selection, drilling methodologies, aquifer tests and other site investigation approach details are mainly contained in the respective appendices to this section and are not discussed in the main body of the text to facilitate ease of reading.

A quality assurance programme was established to control the effectiveness of the execution of these investigations, the data analysis and the formulation of conclusions on the site acceptability. This conforms to the overall management system for the SSR (***Chapter 10***, Management System), NNR regulations and international guidelines (***Subsection 5.11.3***) and relevant Eskom classification procedures. The geohydrological evaluation of the site has been determined as Safety Class C, i.e. not important to nuclear safety, and in terms of the procedure, compliance with an ISO 9001 or equivalent system was implemented (Eskom, 2009).

The activities carried out as part of the evaluation of the site and the results achieved are presented in detail in appendices to this section. These appendices provide the quality assurance records for key decisions and methodologies used and provide the back-up for the data presented in the section. They present a clear and auditable trail showing how key decisions were made and conclusions reached. The information presented in the appendices includes:

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- ***Appendix 5.11.A*** – Historical borehole data.
- ***Appendix 5.11.B*** – Hydrocensus.
- ***Appendix 5.11.C*** - Geophysical data and graphs and borehole site selection; criteria.
- ***Appendix 5.11.D*** - Exploration borehole logs.
- ***Appendix 5.11.E*** - Yield testing, down-hole video camera surveying, down-hole EC-pH-Temp logging and packer testing and tracer testing data, analysis and sheets.
- ***Appendices 5.11.F, G & H*** – Laboratory analytical results for hydrocensus, drilling and monitoring, i.e., macro-chemistry, radionuclides and isotopes, as well as monitoring data for field water quality measurements and water levels.
- ***Appendix 5.11.I*** – Adsorption testing report.
- ***Appendix 5.11.J*** – Numerical model specialist report and validation and verification assessment.
- ***Appendix 5.11.K*** – Quality data pack including a detailed process map containing references to the various data files, plus:
  - calibration sheets for field equipment such as pH/EC and dip meters (GPS did not require calibration as it contained no internal compass);
  - list of approved suppliers used;
  - sign-off sheet for borehole sites;
  - Project Quality Plan;
  - Method Statement;
  - Quality Control Plan;
  - Risk Assessment;
  - Health, Safety and Environmental Management Plan;
  - Peer review reports.

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The characterisation of geohydrological site parameters and their evaluation do not lend themselves to direct verification by inspections or tests that can be precisely defined and controlled. A peer review process was therefore followed. This was carried out by suitably qualified, independent and experienced professionals, approved by Eskom, details of which are included in the quality data pack in ***Appendix 5.11.K***.

Electronic records have been stored in a secure central repository with regular off-site back-up procedures. The overall quality management system complied with are set out in ***Chapter 10***. All references cited are saved on the central repository.

The activities that have been carried out with their respective links to other SSR sections/chapters and quality control requirements are presented in ***Table 5.11.27***.

Table 5.11.27
Summary of Activities, Links and Quality Requirements

Activity	Links		Quality Requirements
	Inputs	Outputs	
Hydrocensus	DWS NGA Existing reports	***Section 5.5*** (Land and Water Use); ***Section 5.10*** (Hydrology and Hydraulics); ***Section 5.12***. Information on existing groundwater use from boreholes and springs will provide essential input into the Land Use, Hydrology and Water Supply (***Sections 5.5.*** ***5.10*** and ***5.12***), mainly on quantities used and quality.	Calibration of field equipment, e.g. pH, EC and dip meters.
Geophysics	***Section 5.13*** and ***5.15***	***Sections 5.13***; ***5.14*** (Seismic Hazard) and ***5.15***. Interpretation of the geophysical surveys will provide key input to geotechnics, geology and seismics regarding concealed structures and lithologies	Method Statement

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Activity	Links		Quality Requirements
	Inputs	Outputs	
Borehole Siting	***Sections 5.13***; ***5.14***; and ***5.15***. Discussion with the geotechnical, geology and seismic teams and Eskom to optimise on siting and use of boreholes. Use of modelling where appropriate.		Table showing rationale for number, position, aquifer, depth, construction. Peer Review
Drilling/Testing		***Sections 5.13***; ***5.14***; and ***5.15***. ***Chapter 11*** (Conclusions) Lithological logs and other geological and hydrogeological information will be used as key input into the geotechnical, geology and seismics sections.	Use of approved suppliers. Rationale for drilling methods used. Risk assessment. Method Statement. Health, Safety and Environmental Management Plan. Peer Review. Adherence to contract specifications regarding recording of data, sampling, borehole completion, verticality and alignment. Appropriate ISO standards.
Laboratory Analysis		***Sections 5.5***; ***5.10***; ***5.12***. Water quality data will be used as input to the Land Use, Hydrology and Fresh Water Supply sections	Use of approved suppliers. Certificate of accreditation for selected laboratories. (SABS code 0259 or equivalent international standard)
Modelling		***Section 5.12***; ***Chapters 6, 7*** and ***11***	Table showing rationale for selection of model code(s). International benchmarking, use and acceptability. V&V of computer software codes used to comply with NNR requirements.

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Activity	Links		Quality Requirements
	Inputs	Outputs	
			Uncertainties and management/incorporation thereof. Sensitivity analysis. Peer Review
Monitoring		***Section 5.2*** (Monitoring)	Method statement

A regulatory compliance summary is given in ***Table 5.11.28*** to show what Acts/regulations are relevant to geohydrology and where in this SSR they have been dealt with.

Table 5.11.28
Regulatory Compliance Matrix

Act/Regulation	Regulation	Issue	Section where Covered
The Regulations on Licensing of Sites for New Nuclear installations (Department of Energy, 2011)	4 and 5	External events	5.11.6; 5.11.7;5.11.8
Regulatory Guide RG-0011	8.2 11.3	Land and Water Use in the Region Monitoring of Groundwater and Surface Water	5.11.6.7 5.11.9

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5.11.12 Conclusions

A comprehensive investigation of the geohydrology of the site has been carried out in order to obtain the required level of understanding of the site characteristics in support of this SSR and the licence application. Based on the results and knowledge gained to date, the following key conclusions are drawn (with reference to the site unless otherwise stated):

- There are two aquifers present, the upper intergranular Algoa Aquifer and the lower fractured-rock TMG Aquifer. The former is a major aquifer and has a basal, discontinuous cobble layer up to 6 m thick that is highly transmissive.

- Groundwater levels are relatively shallow in the illustrative footprint areas, i.e. 4.8 to 10.2 m bgl, being deeper in some elevated dune areas further inland, i.e. 21.55 to 22.45 m bgl;

- Groundwater flow is generally in a southerly to southeasterly direction towards the Indian Ocean.

- High rainfall events show insignificant and delayed effects on groundwater levels due to overflow into wetlands, the highly absorptive capacity of the Algoa Aquifer sands and efficient drainage properties of the underlying cobble layer.

- The extremely wet year of 2012 resulted in groundwater levels in the monitoring boreholes reaching their highest level since commencement of monitoring in February 2008 up until February 2024. In 2012 groundwater levels at Algoa Aquifer monitoring boreholes ranged from 0.25 m bgl at THY-MR15 to 21.35 m bgl at THY-MR5. At Algoa Aquifer monitoring boreholes closest to the Nuclear-1 footprint groundwater level in 2012 ranged from 2.22 m bgl at THY-MR11 to 21.35 m bgl at THY-MR5.

- Similarly, during 2012 groundwater levels measured in the TMG Aquifer monitoring boreholes ranged from 0.16 m bgl at THY-RP1 to 13.53 m bgl at THY-RP5-M1. At TMG Aquifer monitoring boreholes near the Nuclear-1 footprint 2012 groundwater levels ranged from 4.28 m bgl at THY-RP12 to 6.80 m bgl at THY-RP 11, whilst at THY-RP9 close to the coast the 2012 groundwater level was 2.93 m bgl.

- The 2017-2018 ”extremely dry” years resulted in a groundwater level decline of *c*.6.2 to *c*.7.7 m at Algoa Aquifer monitoring boreholes

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equipped with data recorders that are located inland from the coast and footprint. At Algoa Aquifer monitoring boreholes equipped with data recorders nearer to the coast and the Langefonteinvlei, the groundwater level decline ranges from *c*,1.1 to *c*.5.0 m.

- At inland TMG Aquifer monitoring boreholes equipped with data recorders the “extremely dry” groundwater level decline ranges from *c*.2.2 to *c*.10.2 m, whilst at those near the coast the decline ranges from *c*.1.9 to *c*.3.9 m.

- Groundwater quality is moderate to good with EC in mostly below 150 mS/m and the groundwater is slightly acidic to alkaline and of a mixed NaCl and $Ca(HCO_3)_2$ type. Provision for corrosion resistant materials should be made for all subsurface installations.

- Extensive use is made of groundwater in the region, with the towns of Oyster Bay, Humansdorp and St. Francis Bay all being supplied from this resource.

- Numerical flow simulation of the site water balance indicates that approximately 30 ℓ/s could be abstracted from the site aquifers for sustainable supply during initial construction activities prior to commissioning of a desalination plant. This is under “dry” climatic conditions.

- The thick saturated and unconsolidated sediments of the Algoa Aquifer will require dewatering prior to excavations for nuclear installation foundations.

- Estimates for potential inflows to a nuclear installation excavation of 20 m depth for the illustrative footprint areas vary from 21 ℓ/s to 25 ℓ/s, the latter taking into account the effects of sea level rise. Experience indicates that actual volumes required to be pumped for dewatering could be about 30 per cent higher.

- Numerical model simulation of a 3.28 m rise in sea level indicates a 0.8 m rise in groundwater level to a maximum distance of 350 m inland. This is an insignificant rise and can be managed using appropriate groundwater control measures and poses no additional significant risk to a nuclear installation(s).

- Numerical model simulations with a sea level rise of about 3.28 m show slightly higher inflows to excavations, but all scenarios only give a small

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range of 21 to 25 ℓ/s. The zone of depression caused by such inflows or equivalent groundwater abstraction is contained to the site.

- Contaminant transport modelling of a hypothetical liquid leak from the nuclear installation indicates minimal impact, confined to the Nuclear-1 footprint. This is a worst-case scenario as, in reality, any such leak will be detected by the monitoring programme and remedial action will be taken.

- Groundwater level and quality monitoring since mid-2008 has not shown any concerning or anomalous trends that could affect nuclear safety, apart from the need to allow for corrosive conditions below the water table.

Although the investigation and monitoring period has been relatively short, the conceptual and numerical models are considered robust and adequate to provide a realistic representation of geohydrological conditions at the site. There are therefore no significant uncertainties in this respect. Monitoring will continue and the numerical flow model will be updated if new data indicate significant deviations from established trends. With respect to geohydrology, the site is therefore considered to be suitable for safe establishment of a nuclear installation(s).

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APPENDICES

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The following appendices are provided in electronic format:

Appendix 5.11.A
Historical Borehole Data

Appendix 5.11.B
Hydrocensus Data (2007), (2017) & (2024)

Appendix 5.11.C
Surface Geophysics

Appendix 5.11.D
Exploration Borehole Data & Logs

Appendix 5.11.E
Down-hole EC/pH/Temp and Video Camera Survey, Pump, Packer and Tracer Test Data

Appendix 5.11.F
Macrochemical Laboratory Analyses and Monitoring Database

Appendix 5.11.G
Radionuclide Analyses

Appendix 5.11.H
Isotope Analyses

Appendix 5.11.I
Adsorption Testing Report

Appendix 5.11.J
Numerical Model and Validation & Verification Reports

Appendix 5.11.K
Quality Data Pack

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