ESKOM HOLDING LTD

EIA: PROPOSED EXPANSION OF ASH DAM FACILITY, KRIEL POWER STATION, MPUMALANGA

GEOHYDROLOGICAL EVALUATION

FOR THE

ENVIRONMENTAL IMPACT ASSESSMENT

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NOMENCLATURE

Acronyms

AATC	Anglo Coal Thermal Coal
DEM	Digital Elevation Model
DWAF	Department of Water Affairs & Forestry
EC	Electrical Conductivity
EMP	Environmental Management Program
FeCr	Ferrochrome
GPS	Global Positioning System
GUI	Graphical User Interface
IAEA	International Atomic Energy Agency
IBE	Ion Balance Error
K	Hydraulic conductivity
NGDB	National Groundwater Data Base
PGM	Platinum Group Metals
REV	Representative Elemental Volume
SABS	South African Bureau of Standards
SACE	South African Coal Estates
SANS	South African National Standards
STRM	Shuttle Radar Tomography Mission
T	Transmissivity
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
WRC	Water Research Commission

Measurements

%	Percent
m	Metres
m/d	Meters/day
m^2/d	Square meters/day
M-Alk	Methyl Orange/Total alkalinity
mamsl	Meters above mean sea level
mbgl	Meters below ground level
mm	Millimetres
mS/m	Milli Siemens/meter

P-Alk	Phenolphthalein Alkalinity
ºC	Degrees Celsius

Chemical Symbols

As	Arsenic
B	Boron
Ca	Calcium
Cd	Cadmium
Cl	Chloride
Cr	Chromium
Cr^{6+}	Hexavalent Chromium
Cu	Copper
F	Fluoride
Fe	Iron
K	Potassium
Mg	Magnesium
Mn	Manganese
Na	Sodium
NH_4	Ammonia
NO_3	Nitrate
NO_3-N	Nitrate as Nitrogen
PO_4	Phosphate
SO_4	Sulphate
Si	Silica
U	Uranium
Zn	Zinc

GLOSSARY OF TERMS

Hydraulic conductivity: The volume of a fluid passing through a porous medium in a unit time under a specific unit hydraulic gradient and moving through a unit area perpendicular to the flow direction. It can also be defined as the measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d). Hydraulic conductivity gives an indication of how quickly or slowly groundwater will move.

Transmissivity: The product of the hydraulic conductivity (K) of the aquifer and its saturated thickness (D). It can also be defined as the rate at which water is transferred through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the hydraulic conductivity and the thickness of the saturated portion of an aquifer (m^2/d).

Blow yield: The rate at which water is blown from a borehole by means of an air percussion drilling rig on the completion of the borehole.

Porosity: It is a directly measurable aquifer property; it is a fraction between 0 and 1 indicating the amount of pore space between unconsolidated soil particles or within a fractured rock. The ratio of the void volume to the volume of the material. Porosity does not directly affect the distribution of hydraulic head in an aquifer, but it very strongly effects the migration of dissolved contaminants, since groundwater flow velocities are controlled by it.

Mean annual precipitation: The total annual rainfall as recorded by hydrological stations of either the Weather Bureau or the Department of Water Affairs.

Recharge: It is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation. Recharge replenishes groundwater levels and dilutes contamination.

Evapotranspiration: This is a collective term that groups the loss of groundwater to the air through evaporation from the soil, ponding water and transpiration by plants. In most parts of South Africa this exceeds the total annual precipitation.

SECTION 1

EXECUTIVE SUMMARY

1 EXECUTIVE SUMMARY

Kriel Power Station in Mpumalanga is a coal fired power station owned by Eskom and makes use of a wet ashing process to dispose of its ash. The power station produces coarse and fine ash through burning coal for the generation of electricity. Coarse ash is transferred with a small volume fine ash (fly ash, to limit pipeline wear) from the Power Station to sumps from where it is pumped as a slurry mixture to the ash dams. The fine ash is transported separately to the existing ash dams via a conveyor belt. The three existing ash dams will reach a limiting Rate of Rise (RoR) by end July 2021. Eskom is thus proposing to construct two additional ash dams, Ash Dam (AD) 4.1 and AD 4.2, a Transfer Dam and associated infrastructure. The Transfer Dam is not sized or designed to store any water and was therefore not included in the groundwater study.

The construction of Kriel Power Station (owned by Eskom Holdings SOC Limited, Eskom) was completed in 1979 and was considered to be the largest coal-fired power station in the southern hemisphere at the time. The 38 year old power station, with an installed capacity of 3 000 MW (Eskom, 2010), is located approximately 7 km west of the small town of Kriel (also known as Ga-nala) in the Mpumalanga Province. Through the process of electricity generation, coarse and fine ash is produced by burning coal. At full capacity, each of the six boilers can produce up to 740 000 tonnes/year of coarse ash/ boiler bottom ash (approximately 20% of total ash produced) ash and 2 960 000 tonnes/year of fly ash/ precipitator fly ash (approximately 80% of total ash produced).

Kriel Power Station makes use of a wet ashing process to dispose of its ash. Coarse ash is transferred with a small volume of fine ash (fly ash, to limit pipeline wear) from the Power Station to sumps, from where it is pumped as a slurry mixture to the Wet Ash Disposal Facilities (WADF) (ash dams). The fine ash is transported separately to the existing ash dam complex, via two conveyors that are located south-east of Kriel Power Station. As mentioned above, Kriel uses wet ashing system, which involves conditioning fly ash and coarse ash with water for pneumatic transportation to the ash dams through conveyor belts and ash lines, respectively.

Upon reaching the ash dams, conditioning water, from ash, sluices into the designed lowest point of ash dam wherein it gets drained through penstocks. All the water collected from Kriel ash dams through the penstocks is stored in Ash Water Return (AWR) dams. From the AWR dams the ash water gravitates to a manifold and is then pumped back to a High Level AWR dam. From the High Level AWR dam the water gravitates to the pollution control dams known as the Borrow Pits and Swartpan. The Borrow Pits contain mainly excess ash water from High Level AWR dam while Swartpan contains mainly excess overflow ash water from the Borrow Pits. Both Swartpan and the Borrow Pits dams are part of ash water cycle and are used as emergency containment dams. This water is then pumped from Swartpan for re-use by the Power Station for ashing purposes (Kriel Power Station, 2016).

The three existing ash dams will reach their capacity by end July 2021. Eskom is, thus, proposing to expand its existing ash disposal facility by constructing and commission an additional ash disposal facility footprint before the existing ash dams reach their capacity in 2021.

The complete proposed expansion with new ash dams (AD4.1, AD4.2 and AD4.3) would fulfil the ash disposal requirements for the Power Station's extended operational life, whereby decommissioning of the six generating units is planned to commence in 2039. AD4.3 is, however, located on a previously mined and backfilled area, which needs to be tested first for stability. The expansion project is, therefore, divided into two phases, namely Phase 1, which covers construction of AD4.1 and AD4.2 (the subject of this application) and Phase 2 which covers AD4.3.

A Monitored Test Embankment is underway for AD4.3 and therefore this EIA only deals with Phase 1. Once the stability of AD4.3 has been confirmed, depending on the results, an additional EIA may be undertaken for AD4.3. To smoothen the decommissioning process, a five year contingency has been allowed for, thus it is assumed that the Power Station will be operated for an additional five years, thereby allowing for the power station decommissioning from 2041 to 2045.

The development of ash dam 4 will be sequenced to distribute large immediate capital expenditure cost. Dam 4.2 will be developed first in 2021 and will utilize a ring main system to distribute ash within the ash dam basin. Water generated on the dam will be decanted into solution trenches, running along the toe of the new dams, utilizing penstocks and subsoil drains. Ash water from Dam 4.2 will be gravitated to a transfer dam from where it will be pumped to the AWR dam.

Deposition was split between the existing and new dams in order to reduce the height of the preliminary starter walls, as well as the final height of the new dams. It was assumed that deposition on the existing dams will continue for 4 years after the commissioning of the first phase of AD4 (i.e. until the final phase of AD4 is commissioned). Once AD4.1, AD4.2 and AD4.3 are operational, the existing dams will be decommissioned, and rehabilitated. A period of two (2) years was allowed for between the construction phases of AD4 in order to defer large immediate capital costs. Thus, after AD4.2 is commissioned in July 2021, AD4.1 will be commissioned in July 2023, and subsequently AD4.3 in July 2025.

From the AWR dam, ash water will be pumped back to the power station and ash dam pump-house to be reused in the placement of ash from the power station.

This EIA process covers only AD4.1 and AD4.2 as well as the associated infrastructure that will be developed, including a Transfer Dam. The infrastructure includes pipes and a Transfer Dam that will be located on the mine backfilled area (just south of the proposed siting for AD4.3). A Class C liner has been provided for the ash dams (AD4.1 and AD4.2) and the Transfer Dam, which also has an addition of a concrete liner for maintenance purposes. Geotechnical studies will be conducted in the detail design phase and is expected to provide sufficient information to allow for the appropriate design of the transfer dam and infrastructure.

The Transfer Dam is not sized or designed to store any water and was therefore not included in the groundwater study. The Transfer Dam is designed to collect return water from Dam 4.2 and pump to the AWRD. This will be a continuous process and operations must comply as such;

The design premise of the Transfer Dam's placement & construction is that the weight of the soil in that position (pre-construction) is heavier than the weight of water;

The Transfer Dam position abuts the old Starter Wall of the Pit 2 backfills. Therefore, the Starter Wall would have been compacted and consolidated. The Basin of Transfer Dam is founded on the ash behind the Starter Wall, which would have consolidated after 20 years;

It is also assumed that the soil/ash at that position has caused localised consolidation over time, so no loose soils are expecting directly under the Transfer Dam; and

Therefore, the Transfer Dam will not add weight to the environment & therefore not induce deep settlements.

Going forward in the design, the Transfer Dam will take the detailed geotechnical information into account to design layer works below the Transfer Dam's base. This should ensure that there are no settlements, as any settlement would misalign the pipeworks.

Within the Transfer Dam design the liner is accessible and can be repaired if compromised.

The scope of services involved the quantification of the anticipated impacts on the geohydrological environment caused by the construction/extension, operation and decommissioning of the ash dam mentioned in the previous paragraph.

The natural topography of the area has been disturbed by mining operations over the past few decades. Opencast mining and rehabilitation activities are the main contributors. Generally the project area is drained by the Rietspruit and Steenkoolspruit which flows in a North Easterly direction towards the Olifants River which flows in a northerly direction. The topography of the area in which the ash dam extension is considered is somewhat variable due to the nature of the mining activity and the subsequent rehabilitation that has taken place. The entire area to the east and south of the complex has been disturbed, either by the mining and rehabilitation activities, or by the construction of the existing dams. The western final cut void has been filled with ash from the power station and rehabilitated. The eastern final cut void is still open and is partially filled with water.

The climate is typically "Highveld", with warm summers (12 to 29 degrees Celsius (ºC) range) and cold winters (-3 to 20 ºC range). Frost is usually experienced between May and August. According to the *FAOClim 2.0*[1] database the project area receives on average 693 mm of rain per annum. The mean annual evapotranspiration for the area is 1 418 mm per annum.

The area under investigation comprises the Ecca Group, Dwyka and Vryheid Formations. The sediments of the Vryheid Formation overlie an uneven Dwyka floor, which is controlled by the topography of the pre-Karoo platform upon which the Karoo sediments were deposited. The Ecca sediments consist predominantly of sandstone, siltstone, shale and coal.

The Ecca sediments are weathered to depths between 5 – 12 meters below surface and often form a perched aquifer. This aquifer is generally low-yielding (100 – 2000 ℓ//h) because of its insignificant thickness. The pores within the Ecca sediments are too well cemented to allow any significant permeation of water. Groundwater movement is therefore along secondary structures, such as fractures, cracks and joints in the sediments. The chances of intersecting water-bearing fractures by drilling decrease rapidly with depth. At depths deeper than 30 m, water-bearing fractures with significant yield are widely spaced.

From the available chemical data, the following can be concluded with regards to the aquifer:

- Generally, the groundwater is of good quality with only one borehole exceeding the Class 2 drinking water standards due to elevated sulphate concentrations. The majority of the remaining boreholes fall within Class 1.
- High pH values predominate in some boreholes. This can be attributed to the high pH in Ash Water which is usually above 12.
- High calcium content is also evident in some boreholes. Repeated leaching of calcium from the ash is possible, because of the significant amounts of calcium oxide present within the ash.

[1] FAOClim 2.0 is a global agroclimatic database containing data from almost 32,000 stations for up to 14 observed and computed agroclimatic parameters. The database includes both long-term averages and time series for rainfall and temperatures. The database is linked to real-time daily meteorological data flow.

- High sodium concentrations were measured in one borehole. Sodium is added to the ash water during the disposal of demineralisation effluent.
- High sulphate concentrations were recorded in two boreholes. The main source of sulphate in fly ash water is the demineralisation effluent. Concentrations are typically in the range of 200 - 1000 SO_4.

Even though seepage from the ash dams into the underlying strata occurs, very few of the ash water's components are carried into the underlying aquifer. This is due to the unstable chemistry of the ash water. Hodgson *et al.* (1998) did a comparison between ash water and groundwater chemistries within boreholes in close proximity to ash dams and drew the following conclusions:

- The unstable components are filtered out to a very significant degree from the ash water, before it reaches the aquifer.
- This filtering action is probably a combination of the unstable chemistry of the ash water, as well as adsorption onto clay material or complexation of specific ions underneath the ash dams.

The aim of the numerical modelling was to assess the likely hydrogeological impacts that the proposed extension of the Site 10 ash dam might have on the receiving environment.

It was found through modelling that the lined ash dam is a good design. At worst case, there will be an additional ~ 1 000 m^3/day inflow into the Pit 3 opencast that could add to the current decanting rate. This could increase only somewhat to ~ 1 500 m^3/day for a seriously leaking liner.

However, in this study it was found that the proposed AD4.1 and AD4.2 (with a liner) has almost no impact on the groundwater environment, and limited leakage of the liner seems to be acceptable. It is thus concluded that the proposed design is positive seen from a groundwater impact assessment.

SECTION 2

INTRODUCTION

2 INTRODUCTION

The construction of Kriel Power Station (owned by Eskom Holdings SOC Limited, Eskom) was completed in 1979 and was considered to be the largest coal-fired power station in the southern hemisphere at the time. The 38 year old power station, with an installed capacity of 3 000 MW (Eskom, 2010), is located approximately 7 km west of the small town of Kriel (also known as Ga-nala) in the Mpumalanga Province. Through the process of electricity generation, coarse and fine ash is produced by burning coal. At full capacity, each of the six boilers can produce up to 740 000 tonnes/year of coarse ash/ boiler bottom ash (approximately 20% of total ash produced) ash and 2 960 000 tonnes/year of fly ash/ precipitator fly ash (approximately 80% of total ash produced).

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The scope of services involved the quantification of the anticipated impacts on the geohydrological environment caused by the construction/extension, operation and decommissioning of AD4.1 and AD4.2 mentioned in the previous paragraph.

The report was structured in such a way that it can be incorporated into the final Environmental Management Program (EMPr) document. The geohydrological investigation aims to contain and relate the following objectives:

- Description of the baseline geohydrological conditions prior to the extension/construction of AD4.1 and AD4.2.
- Prediction of the environmental impact of the proposed development on the geohydrological regime of the area. This includes the description of possible negative impacts during construction, operation and decommissioning.
- Design and implementation of a groundwater management framework and monitoring program which could assist in the development of rehabilitation measures based on physical, hydraulic and hydro-geochemical information as gathered and predicted in the preceding phase.

This report is not intended to be an exhaustive description of the proposed project, but rather as a specialist geohydrological study to evaluate the overall geohydrological character of the site and the likely impacts of the proposed activity on the groundwater regime.

The report was compiled in such a way that it adhered to the “Content of Specialist Report” as per Appendix six of the NEMA EIA Regulations of 2014 (

Table 1).

Table 1. "Content of Specialist Report" as per Appendix six of the NEMA EIA Regulations of 2014

(1) A specialist report prepared in terms of these Regulations must contain	Section
(a) details of- (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Section 3 and Appendix B
(b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	Appendix C
(c) an indication of the scope of, and the purpose for which, the report was prepared;	Section 2
(d) the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 4
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process;	Section 4
(f) the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;	Section 8
(g) an identification of any areas to be avoided, including buffers;	Section 9
(h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 8 and 9
(i) a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 12
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment;	Section 14
(k) any mitigation measures for inclusion in the EMPr;	Section 11
(l) any conditions for inclusion in the environmental authorisation;	NA
(m) any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 10
(n) a reasoned opinion- (i) as to whether the proposed activity or portions thereof should be authorised; and (ii) if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 14
(o) a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 13
(p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Data received which was incorporated into Section 7 & 8
(q) any other information requested by the competent authority.	NA

SECTION 3

DETAILS OF ASSESSOR

3 DETAILS OF ASSESSOR

Aurecon is a leading, vibrant, global group created by the recent fusion of three world-class companies, Africon, Connell Wagner and Ninham Shand. Our new group has a combined 210-year history; a staff complement of 6 700; and an office network extending across 28 countries worldwide. Aurecon operates in all major sectors, including:

- Transportation
- Property
- Mining and industrial
- Water
- Energy
- Community development

The project team for this specific project consisted of Water Resource Specialists Louis Stroebel, Dr Mannie Levin, Dr Giep du Toit and Marius Terblanche. The résumés for each member are attached in Appendix A.

Louis Stroebel was the project leader for the investigation. He is a qualified geohydrologist and has more than 15 years' experience in several geohydrological investigations. Extensive field experience was gained during the initial period of employment with Geo-Hydro Technologies. This experience, combined with report writing, project management etc. associated with rural water supply activities and Environmental Management Reports have led to the development of a good understanding of the fundamentals of geohydrology. This was further expanded and integrated with contaminated land investigations (mainly hydrocarbon related) during employment with Geo-Pollution Technologies. More than 50 site investigations were performed which included risk assessments and remediation of soil and groundwater using internationally accepted techniques. International experience was gained in the clean-up of land and marine based organic contaminants during an 8 month secondment in Europe. He obtained his accreditation with the South African Council for Natural Scientific Professions in 2002, when he was registered as a Professional Environmental Scientist (No. 400027/02).

Dr Levin specialises in hydro geochemistry and isotope studies and was responsible for the hydro geochemical inputs for the investigation. He has more than 40 years experience in groundwater related investigations. These include groundwater resources and quality, site selection for waste disposal, pollution investigations related to waste, industry and mining as well as environmental impact assessments. Dr Levin has been involved in diverse projects in South Africa, Botswana, Swaziland, Angola, Mozambique, Taiwan, Ghana, Ethiopia, Gambia, Syria and Algeria. He is a registered expert on isotope hydrology with the International Atomic Energy Agency (IAEA) in Vienna and involved in the Southern African Regional Co-operation Programme as well as a member of the AFRA Team of Experts on Dam Leakages and Dam Safety. Several expert missions on dam leakages and groundwater resources have been undertaken for the IAEA. Dr Levin has also served in various advisory groups and ground water quality management policies and standards. He serves on various Project Steering Committees of the Water Research Commission evaluating research on resources, pollution and waste disposal. He obtained his accreditation with the South African Council for Natural Scientific Professions in 1983, when he was registered as a Professional Earth Science Practitioner (No. 400661/83).

Dr du Toit is a specialist groundwater modeller and practised as a Geohydrologist, Engineering Geologist, Nuclear Physicist and Aerodynamic Engineer during his career. He did the numerical modelling for the investigation. For the last 10 years he specialises in the creation of various numerical groundwater models using both finite difference – and finite element techniques to predict the impact of groundwater withdrawal and/or pollution on the receiving environment. He obtained his accreditation with the South African Council for Natural Scientific Professions in 1986, when he was registered as a Professional Natural Scientist (No. 400043/86).

Marius Terblanche was the field technician for this project and is a qualified geohydrologist who obtained his National Diploma in Geology in 2008 and his B.Tech degree in 2010 at the Tshwane University of Technology. He recently (2016) obtained his B.Sc (Hons) degree in geohydrology from the University of the Free State.

Marius started his career at Lonmin Platinum as a core logger for various exploration projects. For the last two years he was involved in several projects and acted as field/geotechnician where he performed and coordinated fieldwork related to geophysical surveys, hydrocensus, drilling and pumptest supervision, permeability testing and data capturing.

A declaration of independence by Aurecon as defined in the regulation GN R 982 of the National Environmental Management Act, Act No. 107 of 1998 is presented in Appendix C.

SECTION 4

METHODOLOGY

4 METHODOLOGY

The scope of services involved the description of the current geohydrological conditions and the quantification of the anticipated impacts on the geohydrological environment caused by the construction/extension, operation and decommissioning of AD4.1 and AD4.2 and supporting infrastructure, including the Transfer Dam and the Ash Return Water Dam (AWRD). The location of this site is referred to as “Site 10” and is located adjacent to the existing Kriel ash disposal facility.

Keeping the required deliverables in mind, Aurecon’s approach to the project was as follows:

4.1 Desk study

The desk study entailed the collating of all existing relevant data from the client, mining plans from Anglo Coal (Kriel Colliery) and published data in the public domain. This data was used to familiarise ourselves with the site conditions and project objectives.

Various reports for geohydrological investigations undertaken at Matla & Kriel Power Stations exist. The majority of these studies were performed by Prof. Frank Hodgson from the Institute of Groundwater Studies (IGS) in Bloemfontein and Geo Hydro Technologies (GHT), also a Bloemfontein based consultancy. When considering Site 10, it is imperative to incorporate Kriel Colliery’s operations during the development of the conceptual model.

An initial conceptual geohydrological model will be developed based on the desk study. This model will form the basis for the development of a site investigation schedule. Based on the current information, the schedule consisted of:

4.2 Site Visit & Consultation with Mine Personnel

A site visit was conducted by the project team to familiarise themselves with project and adjacent area.

A number of interviews were also conducted with mining personnel at Kriel Colliery to get a better understanding of the physiography and current and historical mining of the study area.

4.3 Hydrocensus

Numerous boreholes exist in the vicinity of Site 10 and are located on the land of Kriel Power Station, Matla Power Station and Kriel Colliery. Routine monitoring (quality & water levels) of the groundwater within these boreholes takes place on a regular basis. The results hereof were made available to Aurecon and were incorporated into the study.

4.4 Geophysical survey

A geophysical survey was envisaged in the area immediately south of Site 10 where the containment wall straddles undisturbed Karoo bedrock adjacent to the rehabilitated opencast to identify possible dykes, faults and/or fracture zones which may act as groundwater flow barriers or pathways. However, as more information became available, it became evident that the local geology are thoroughly mapped and documented and that the majority of Site 10 is situated on a rehabilitated opencast. All such preferred groundwater flow zones have thus been mined out/destroyed. Thus, a geophysical survey made little sense in the current planning scenario.

4.5 Development of a numerical flow & transport model

Using the data collected during the preceding phases, a numerical flow and transport model was constructed to assess potential impacts on the geohydrological environment caused by the proposed project. The numerical model used for this study was the well-proven MODFLOW software. MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent several overall updates since. The latest update (Modflow NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells that has been a problem in Modflow previously.

4.6 Quantification of potential impacts

The methodology to determine the significance of the potential impacts of the proposed activities on the biophysical, social and economic environment was developed in 1995 and has been continually refined to date through the application of it to over 400 EIA processes by Aurecon. The methodology is broadly consistent to that described in the DEA's Guideline Document on the EIA Regulations (1998).

4.7 Reporting

Upon completion of the flow and transport model, a document was compiled which can be included in the Environmental Impact Assessment and Environmental Management Program report. It includes amongst other, the following:

- Extensive executive summary summarising the most important findings of the study;
- The results of the desk study;
- Hydro geochemical description;
- The outcome of the numerical flow and transport model;
- Impact of the proposed development on the geohydrological environment during the construction, operation and decommissioning phase;
- Groundwater management framework which could be used to develop a groundwater management plan to mitigate the identified impacts;
- Groundwater monitoring plan;
- Maps and figures.

SECTION 5

APPLICABLE LEGISLATIVE REQUIREMENTS

5 APPLICABLE LEGISLATIVE REQUIREMENTS

5.1 Legal

Certain legal requirements are applicable to the project concerned from an environmental perspective. Legislation applicable to the development from a geohydrological point of view would include the following:

- National Environmental Management Act (Act 107 of 1998)
- National Water Act (Act 36 of 1998)
- National Environmental Management: Waste Act, 2008 (Act 59 of 2008) (NEM:WA).
- Government Notice (GN) 704 of 4 June 1999: Regulation on use of water for mining and related activities aimed at the protection of water resources.
- Government Notice (GN) R636 of August 2013: National norms and standards for disposal of waste to landfill, in terms of NEM:WA.

5.2 South African National Standards (SANS) & Guidelines

Standards & guidelines applicable to the geohydrological investigation used during this investigation were the water quality guidelines. More than one set of water quality guidelines published by different institutions (WRC, DWAF, SABS, etc.) are available and accepted in South Africa. These guidelines recommend very similar maximum concentrations for dissolved chemical constituents in water and differ only in detail. No specific set is however imposed by the Department of Water Affairs. Aurecon used the SABS guidelines for this study:

- Standards South Africa (2006). **SOUTH AFRICAN NATIONAL STANDARD – Drinking Water.** SANS 241:2006

A series of Best Practice Guidelines (BPGs) for mines in line with International Principles and Approaches towards sustainability were developed by the DWS. This study aimed to comply with these guideline:

- Best Practice Guidelines for Water Resource Protection in the SA Mining Industry, Series A: Best Practice Guideline A2: Water Management for Mine Residue Deposits, July 2008
- Best Practice Guidelines for Water Resource Protection in the SA Mining Industry, Series G: Best Practice Guideline G3: Water Monitoring Systems, July 2007
- Best Practice Guidelines for Water Resource Protection in the SA Mining Industry, Series H: Best Practice Guideline H2: Pollution Prevention and Minimization of Impacts, July 2008

SECTION 6

REGIONAL SITE INFORMATION

6 REGIONAL SITE INFORMATION

6.1 Site Location

The site considered for the development is located 1km to the south of the Kriel Power Station. It is located on farms Driefontein portion 15, 30 and 3, and Onverwacht portions 9, 11 and 23 as well as farm Kriel Power Station Portion 65.

6.2 Topography & Drainage

The natural topography of the area has been disturbed by mining operations over the past few decades. Opencast mining and rehabilitation activities are the main contributors. Generally the project area is drained by the Rietspruit and Steenkoolspruit which flows in a North Easterly direction towards the Olifants River which flows in a northerly direction.

6.3 Climate

The climate is typically "Highveld", with warm summers (12 to 29 degrees Celsius (ºC) range) and cold winters (-3 to 20 ºC range). Frost is usually experienced between May and August. According to the *FAOClim 2.0*[2] database the project area receives on average 693 mm of rain per annum. The mean annual evapotranspiration for the area is 1 418 mm per annum (Figure 1).

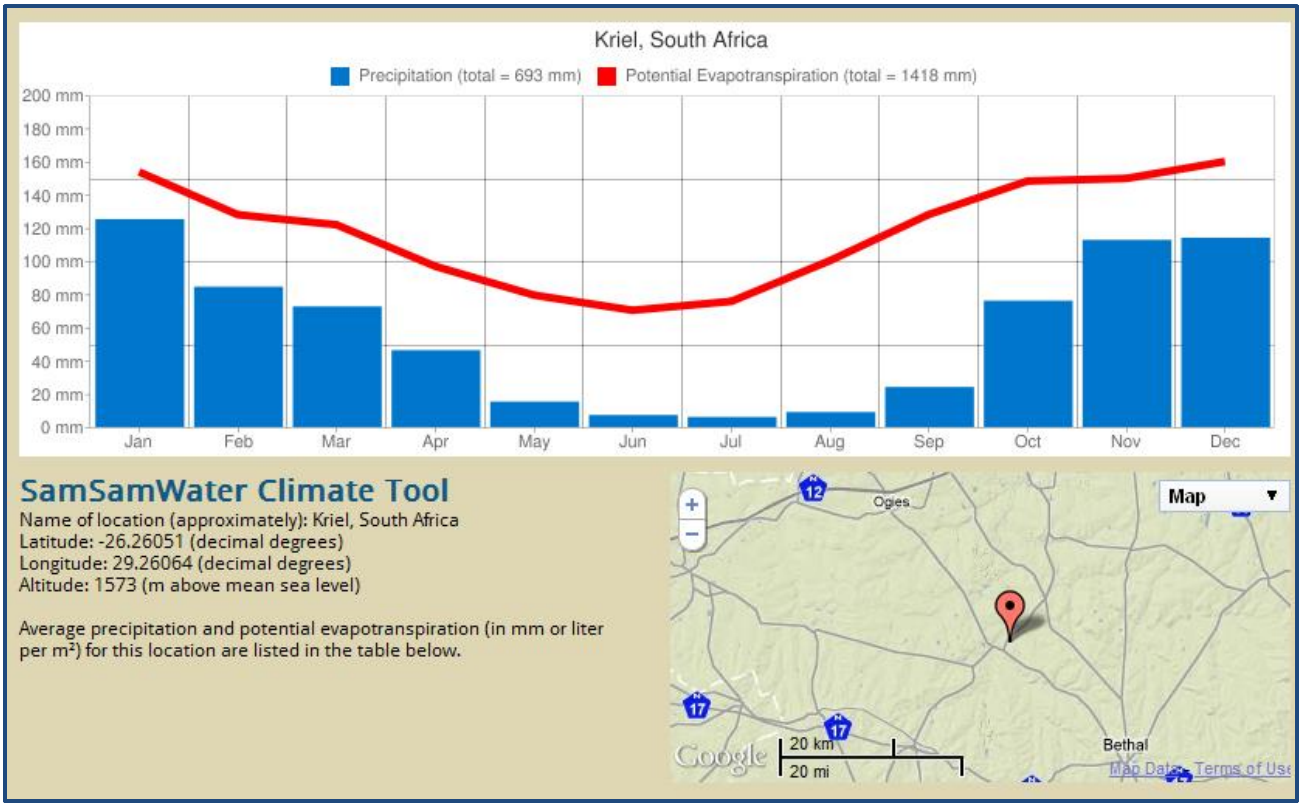

Figure 1. Precipitation and Evapotranspiration of the project area

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[2] FAOClim 2.0 is a global agroclimatic database containing data from almost 32,000 stations for up to 14 observed and computed agroclimatic parameters. The database includes both long-term averages and time series for rainfall and temperatures. The database is linked to real-time daily meteorological data flow.

6.4 Regional Geology & Geohydrology

The regional geology and geohydrology were taken from F.D.I Hodson *et al*.,1998.

6.4.1 Geology

According to the published 1:250 000 geological map (2628 East Rand), the area under investigation comprises the Ecca Group, Dwyka and Vryheid Formations. The sediments of the Vryheid Formation overlie an uneven Dwyka floor, which is controlled by the topography of the pre-Karoo platform upon which the Karoo sediments were deposited. The Vryheid Formation, which is present throughout the Highveld Coal Field, attains some 140 meters at the thickest point and contains a number of coal seams, of which four (No. 1, 2, 4 & 5 Seams) are considered to have economic potential. The deposition of the Vryheid Formation sediments is largely controlled by the irregular pre-Karoo platform on which they were deposited. The pre-Karoo rocks, consisting mainly of felsites of the Bushveld Igneous Complex, have been glacially sculptured to give rise to uneven basement topography. The thin veneer sediments of the Dwyka Formation, which overlies the pre-Karoo, are generally not thick enough to ameliorate the irregularities in the placated surface, which therefore affected the deposition of the younger Vryheid Formation sediments.

The Ecca sediments consist predominantly of sandstone, siltstone, shale and coal. Combinations of these rock types are found in the form of interbedded siltstone, mudstone and coarse grained sandstone. Typically, coarse-grained sandstones are a characteristic of the sediments in the Highveld Area. The overburden thickness and preservation of the coal seams is dependent on the surface geomorphology and the subsurface pre-Karoo basement floor.

Dolerite intrusions in the form of dykes and sills are present within the Ecca Group. The sills usually precede the dykes, with the latter being emplaced during a later period of tensional forces within the earth's crust. Tectonically, the Karoo sediments are practically undisturbed. Faults are rare. However, fractures are common in competent rocks such as sandstone and coal.

6.4.2 Geohydrology

Three distinct superimposed groundwater systems are present within the occurring geology. They can be classified as the upper weathered Ecca aquifer, the fractured aquifers within the unweathered Ecca sediments and the aquifer below the Ecca sediments. A fourth artificial aquifer can be added to the list which comprise of the backfill present in the old opencasts.

6.4.2.1 Ecca Weathered Aquifer

The Ecca sediments are weathered to depths between 5 – 12 meters below surface and often form a perched aquifer. This aquifer is recharged by rainfall and estimated to be between 1-3 % of the annual rainfall. Rainfall that infiltrates into the weathered rock soon reaches an impermeable layer of shale underneath the weathered zone. The movement of groundwater on top of this shale is lateral and in the direction of the surface slope. The water discharges at surface in the forms of fountains and springs where the flow paths are obstructed by a barrier, such as a dolerite dyke, paleo-topographic highs in the bedrock, or where the surface topography cuts below the groundwater table at streams. It is suggested that less than 60% of the water recharged to the weathered zone eventually emanates in streams while the remaining water is evapotranspirated or drained by some other means.

This aquifer is generally low-yielding (100 – 2000 ℓ//h) because of its insignificant thickness. Wells or trenches dug into this aquifer are often sufficient to secure a constant water supply of excellent quality. The excellent water quality can be attributed to the many years of dynamic groundwater flow through the weathered sediments. Leachable salts have been dissolved and it is only the slow decomposition of clay particles which presently releases salts into the water.

6.4.2.2 Fractured Ecca Aquifer

The pores within the Ecca sediments are too well cemented to allow any significant permeation of water. Groundwater movement is therefore along secondary structures, such as fractures, cracks and joints in the sediments. These structures are better developed in competent rocks such as sandstone, hence the better water yielding properties of the latter rock type. It should, however, be emphasised that not all secondary structures are water bearing. Many of these structures are constricted because of compressional forces that act within the earth’s crust. The chances of intersecting a water-bearing fracture by drilling decreases rapidly with depth. At depths deeper than 30 m, water-bearing fractures with significant yield were observed to be spaced at 100 m or greater. Scientific siting of production boreholes is necessary to intersect these fractures.

Statistics from a selection of boreholes within the Olifants River Catchment pump tested by the Institute for Groundwater Studies from the University of Free State are presented in Table 2. The study area falls within the Olifants River Catchment and within the same geological unit.

Table 2. Statistics for the yields of boreholes pump tested within the Olifants River Catchment.

Statistics	Yield (ℓ/h)
Mean Yield	1250
Minimum Yield	12.5
Maximum Yield	5700
Nr. of holes tested	105

Of all the unweathered sediments in the Ecca, the coal seams often have the highest hydraulic conductivity. Packer testing of the No. 2 Seam and underlying Dwyka tillite resulted to have average hydraulic conductivities of 0.1 and 0.001 m/d respectively. It can thus be assumed that seepage of water through the No. 2 Seam is possible. Due to its low hydraulic conductivity, the Dwyka tillite forms a hydraulic barrier between the overlying mining activities and the basal floor.

In terms of water quality, the fractured Ecca aquifer always contains higher salt loads than the upper weathered aquifer. Although the sulphate, magnesium and calcium concentrations in the Ecca fractured aquifer are higher than that in the weathered zone, they are well within expected limits. The higher concentrations can be attributed to the longer exposure time of the water to the rock. The occasional elevated chloride and sodium levels can be attributed to boreholes in the vicinity of areas where salts naturally accumulate on surface, such as pans and some of the fountains.

6.4.2.3 Pre-Karoo Aquifer

Drilling in only a few instances has intersected the basement of the Karoo Supergroup which can be regarded as an insignificant aquifer due to:

- The great depth,
- Low yielding fractures,

- Inferior water quality with elevated concentrations of fluoride associated with the granitic rocks,
- Low recharge characteristics of this aquifer because of the overlying impermeable Dwyka tillite.

SECTION 7

BASELINE INFORMATION

7 BASELINE INFORMATION

Most mines and mining related activities affect groundwater flow and chemistry. The surrounding area and geohydrological environment of the project area are already disturbed by industrial and mining activities, both opencast and underground. The extent to which these activities impacted on the groundwater regime falls outside the scope of study. The impact of the proposed ash dam on the groundwater regime can only be quantified if the "pre-development" environment is known and documented.

The purpose of this section is therefore to describe the "pre-development" geohydrological environment to such an extent that it can be used as baseline information in the quantification of the impact of the development on the groundwater regime. The current physical and chemical properties of the groundwater regime were investigated by means of the methodology outlined in Section 4.

7.1 Site 10

The site would be an extension of the existing ash disposal facility at the Kriel Power Station. The site boundaries as follows:

- East – Eastern portion of the backfilled Kriel Colliery open cast mined pit, Pit 1.
- South – Provincial Road R547 (Evander-Kriel).
- West – Existing active Matla Power Station Ash Dam.
- North – Existing Kriel Power Station Ash Dams 1, 2 and 3.

Numerous geohydrological investigations have been undertaken at the Kriel Colliery and Kriel and Matla Power Stations over the past 20 years. A number of reports were obtained, but it is Aurecon's opinion that the list of reports studied is by no means complete and should not be regarded as exhaustive.

Groundwater monitoring data provided by Kriel Colliery and Kriel and Matla Powers Stations through Geo Hydro Technologies (GHT) were also used to describe the site geohydrology.

7.1.1 Topography & Drainage

The Kriel Power Station has been constructed in gently undulating country on the crest of a southwest-northeast trending ridge. Springs in the vicinity of Kriel Power Station feed the seasonal Onverwacht, Pampoen, and Vaal Pan Spruits (which drain to the east, north, and west respectively). Ultimately, all surface water from this area drains into the Olifants River via the Riet (water draining north and west of the ridge), and Steenkool (water draining east) Spruits.

The topography of the area in which the dam extension is considered is somewhat variable due to the nature of the mining activity and the subsequent rehabilitation that has taken place. The entire area to the east and south of the complex has been disturbed, either by the mining and rehabilitation activities, or by the construction of the existing dams. Where the pit has been rehabilitated, the topography is gently undulating, however, there are areas where the dragline tips still form steep cones of spoil. The western final cut void has been filled with ash from the power station and rehabilitated. The eastern final cut void is still open and is partially filled with water. The ground generally slopes towards the south-west.

7.1.2 Geology & Geohydrology

(Taken from Geo Hydro Technologies, 2001)

As already described in section 6.4.1, the site forms part of the Highveld Coalfield. Two sedimentary units are of interest in the Kriel Coalfield; the Dwyka Formation, and the Vryheid Formation. The younger Vryheid formation is comprised of a succession of sandstones and minor interbeds of siltstone and mudstone up to a thickness of 180m at the site. Typically, five seams, numbered 1 (youngest) to 5 (oldest) are represented across the Highveld Coalfield, although Seam 1 is often absent. Seam 4, a flat lying to gently undulating unit with a thickness of about 4.8 m and regional dip of less than 1^{o} to the southwest, is the only seam currently mined by the Kriel Colliery, and typically occurs at a depth of about 30m in open cut areas. While the entire thickness of the seam is extracted during surface mining, underground operations only exploit the lower two thirds of the unit. The layout of mine operations and subsequent extraction of the coal is influenced by the presence of dolerite sills that tend to displace the coal seams, thereby compartmentalizing the reserves.

Numerous doleritic dykes and sills have been mapped in the area. One sill, located below Seam 2, is up to 14m thick and surrounded by an extensive zone of burnt coal, with observed displacements resulting from sill intrusion generally equivalent to the thickness of the structure. Burnt coal zones from 1 to 30m wide and are also observed along the predominantly southwest to northeast trending doleritic dykes in the area, but unlike adjacent sills, the extent of these zones is apparently independent of the dyke thickness.

One of the earliest investigations was undertaken by Hodgson as part of the design of a groundwater monitoring system for the Kriel Colliery. He installed four boreholes within the project area, all within spoils in Pit 1, pump testing two of these to obtain some indication of the hydraulic characteristics of these materials. Results indicated that the spoils were highly permeable, with values of hydraulic conductivity of at least 50 to 360 m/day suggested. Groundwater samples taken during pump testing had almost neutral pH values and elevated major ion contents, with SO_4 and Total Dissolved Solids (TDS) contents greater than 950 and 2000 mg/l, respectively.

A subsequent investigation by Dingemans and Hodgson into the pit water quality revealed that groundwater quality decreased as it flowed through spoils within Pit 3N from south to north, although there is a high potential for minerals within the spoils to neutralize sulphuric acid generated by sulphide oxidation. They believed, however, that groundwater quality throughout the pit would decline to values measured in the northern margin following a rise in the groundwater table, assumedly because there would no longer be a hydraulic gradient present in the pit.

Comments on the hydraulic behaviour of Pit 1 stated that natural groundwater ingress into both pits (Pit 1 & 3) was of concern to mine management, and suggested that around 40 ML/year infiltrated into the void, although a significant contribution (200 ML/year) from the Kriel Power Station ash dam was also suggested. While supporting calculations and evidence for the infiltration of dam-derived water was not provided, a water balance for the site was nevertheless developed. In addition, they noted that the permeability and storativity of the spoils within the pit is likely to be highly variable vertically, as well as horizontally, but suggested a storage coefficient of 10% for the total volume in this instance. Further, recharge values of 0 to 30% of annual rainfall were also suggested for rehabilitated areas of the spoil.

They did not discuss the influence of cracks in the wall of the Kriel ash dam on site hydrology, however. The cracks, first noted in 1985, resulted in the construction of an extension onto the ash dam, and the disposal of ash into Cut 1 of Pit 1 following the completion of mining there.

Recommendations contained in the report of Dingemans and Hodgson generally related to the management of the site, such minimizing recharge to the pit from rainfall and the adjacent Kriel Power Station ash dam.

Hodgson also addressed pit water quality in a subsequent report. He concluded that, while water quality varied significantly from point to point, four groundwater environments could be identified within Pit 3N on the basis of the chemistry of water samples; stagnant in-pit water; dynamic in-pit water; water accumulation in ramps and void; and; groundwater in areas adjacent to mining. Of these, water quality was worse within the stagnant and accumulated water systems. Hodgson also concluded that groundwater in the area adjacent to the pits was generally very good.

A report compiled by Steffen, Robertson, and Kirsten (SRK) during 1989 reported on the installation of a groundwater monitoring system in the vicinity of the Kriel Power Station ash dam and Cut 1. They oversaw the installation of 18 boreholes in the area, many of which contained multiple piezometers, and selected several surface water sampling sites. Borehole yields determined presumably during drilling were typically <0.5 l/s, although between 2.5 to 3 l/s were airlifted from one borehole (MB15). The existence of a borehole with such a number could however not be confirmed on the provided databases. Falling head tests were also conducted to determine the hydraulic conductivity of the piezometer intervals, with results varying between 10^{-5} to 10^{-9} m/s and independent of the in situ lithology present. Coal measures were generally encountered during drilling and dolerite was encountered at one site. The interception of dolerite at KB4 during drilling is of geohydrological significance due to the increased potential for recharge and preferential flow to occur within this material or along the contact zone of intruded country rock. Dolerite dykes in the occurring geology area often act as aquifers along their fractured margins. They inferred that an east-west striking dolerite dyke occurred to the south of the ash dam may occur in the area, which was both effectively damming horizontal flow away from the dam and acting as a recharge zone for seeping ash water. They further stated that the groundwater table was likely to follow the topography within their investigation area, although artesian conditions were observed within the shallow piezometers of three monitoring sites in the vicinity of the Kriel Power Station ash dam. They suggested that the artesian conditions are a result of dam seepage recharging a shallow unconfined aquifer at two boreholes (KB3 and KB4), while recharge conditions at the third site (KB9) are a combination of dam-related and natural effects. Deeper sedimentary aquifers encountered during drilling were, however, confined and assumedly recharged via natural processes.

Comments on baseline site water quality were included within the report of SRK. They noted that tested ash waters sampled from the dam itself, and the return dams were typically high in Electrical Conductivity (EC), Alkalinity, Ca, and SO_4. However, major ion contents were lower in perimeter drain samples, a feature attributed to the precipitation of gypsum and calcite during flow. Other chemical similarities were observed between:

- Ash dam samples and the results of leach testing undertaken previously on Kriel Power Station ash samples;
- The major element chemistry of ash dam and backfilled pit groundwater samples, to such a degree that the distinction between respective pollution sources was difficult.

Hodgson (1990) was subsequently commissioned to install a water quality monitoring system at Matla Power Station. He noted that the groundwater table in the vicinity of the old Matla Power Station ash dam was very shallow, attributing this to the use of a wet ash disposal system, with the water level in the naturally recharged areas was much deeper. Several potential pollution sources were identified during this investigation, one being a domestic waste disposal site located to the east of the power station complex near MB1. The site, then covering about 9ha, received several types of waste including building rubble, garden and domestic waste, and ash. Other sites of concern were the ash dam, coal stockyard, and the abandoned Pit 3N. Hodgson noted that the weathered sediments and soil within the vicinity of the Matla Power Station coal stockyard and old ash dam had significant attenuation properties. He suggested, however, that these properties could be negated within 15 years in the area adjacent to the ash dam, apparently due to an increase in the sodium concentration of the make-up water over time, although justification for this claim was not provided. Other chemical processes suggested by Hodgson included the precipitation of calcite following the reaction of CO_2 in the air with ash water, and the potential for gypsum to precipitate from ash water should the SO_4 concentration rise above 800 mg/l.

SRK (1990) noted that water management within Pit 1 was again an issue at Kriel Power Station following the receipt of a fax from the DWAF stating their intention to initiate legal proceedings should Cut 2 overflow. They recommended that a dewatering system be installed as soon as possible to prevent such an event occurring. Groundwater quality in the vicinity of the pit had already started to decline by this time represented by an increase in the concentration of several major ions in samples taken from both shallow and deep piezometers in KB14, KB15, KB16, and KB17. They attributed this decline to the influence of the original pit water, and not ash water sourced from either the ash dam, or Cut 1, where ash was initially placed in 1989.

During 1994, Scheidegger and Hodgson both calculated water balances for the Kriel ashing area. In addition, Hodgson was also commissioned to determine whether any seepage was occurring between Pit 3N and Pit 1, and Pit 1 and Onverwacht Spruit, and if so the amount of seepage that was occurring. After conducting multiple packer tests on *in situ* material within four boreholes, he concluded that the average hydraulic conductivity of the site profiles between the two pits was 0.68m/d. Presumably through the construction of a simple flow net, he also deduced that, for a hydraulic head difference of eight metres, the maximum daily seepage between the two pits would be 0.33 ML/day. However, the presence of a hydraulically continuous aquifer between the two pits seemed inferred rather than confirmed, while no evidence was offered to show that water was not draining from Pit 3N to Onverwacht Spruit, a drainage feature that separates the two pits. The seepage rate between Pit 1 and Onverwacht Spruit was estimated to be between 30 to 40 m^3/day.

Hodgson also gave consideration to Pit 1 water chemistry. He stated that there was no possibility for the mobilization of heavy metals within the pit due to the high base potential of spoil samples. Previous leachate testing undertaken on borehole cores taken at Pit 4 (a pit to the east of Pit 23) by Wates, Meiring, and Barnard during 1993 were not as conclusive. However, their work suggested that spoils generated from coal extraction in this area were neither clearly acid producing or acid consuming, although some shale and carbonaceous siltstone units within the coal measures were found to have a high acid potential.

Using geochemical modelling of water within Pit 1, Hodgson (1994) suggested that gypsum precipitation could not occur if spoil and ash water was to mix, regardless of the mixing ratios, and that no detrimental effects could be expected as a result of that mixing, which contradicts comments made during earlier work at Matla Power Station. This may be due, however, to chemical differences in ash water characteristics used for respective modelling exercises.

A pollution risk assessment of the Kriel Power Station site was undertaken jointly by Ecosys and Jasper Muller and Associates (JMA) during 1994. They note that 2.5 Mm^3 was placed in Cut 1 between 1989 and 1993 to an elevation of about 1570 mamsl and covering an area of around 8.4 ha, by which time approximately 60% of Pit 1 had been rehabilitated. There work suggested that approximately 67 ML/month would overflow from the pit on average if no storage was available, with overflow from Onverwacht Spruit occurring 75% of the time if excess water was not pumped back into the ash disposal system. The elevation of the decant point considered during overflow calculations was not apparent. Ecosys also stated that the SO_4 management objective for overflow from Pit 1 was 155 mg/L, a value set by DWAF.

JMA (1994) suggested that inter-pit flow from Pit3N to Pit 1 and seepage from the adjacent Kriel Power Station ash dam also had to be considered during water balance calculations, but again no evidence was offered to show that recharge from either source was actually occurring.

They suggested, however, recharge between 5 to 45% of natural rainfall could be expected. The Environmental Management Programme Report (EMPR) prepared for Pit 1 by Technology Research and Investigations (TRI) in 1995 notes that no sills, and only a few dolerite dykes of no geohydrological importance, transgress Pit 1. The report also notes that excess water was never a major concern during mining at the site, which suggests that water derived from the drainage of in situ aquifers and any seepage derived from the adjacent ash dam was minimal. Of significance, however, are the report conclusions on the elevation of the decant point. TRI suggested that two elevations are of significance, the seepage level and the decant level. The seepage level (1539 mamsl) was defined as the level at which pit water could drain through weathered horizons and pollute adjacent aquifers, while the decant level, the elevation at which the pit overflows, was determined to be 1546 mamsl. The report goes further, stating that pit water levels should be maintained below these levels to prevent off site pollution.

During 1996, Hodgson modelled groundwater pollution on the combined power station properties. Information used within the model was obtained from databases at the respective power stations, with modelling based on a conceptual understanding of the site. Some main predictions obtained from the model were:

- Pollution migration is slow due to the low hydraulic conductivity of site profiles and the topography of the site;
- The areas at greatest risk of pollution occur in the vicinity of Pit 1 and Pit 3N;
- Unused waste sites and spoil dumps should be rehabilitated;
- Pits contained an excess of water, and where possible, steps should be taken to minimize; and
- the unnecessary influx of water into the respective pits.

In May 1997, ash water was observed entering Bakenlaagte Spruit from the new ash dam constructed in Pit 3N. Subsequent investigations revealed that the dam had been partially constructed on highly permeable spoils as opposed to *in situ* material proposed during the design of the structure. To prevent further degradation of stream water quality, the decision was made to construct a substantial cut-off trench on the southern, eastern, and northern sides of the dam. For design purposes, it was assumed that the seepage across the unit width of the dam was 2.5 x 10^{-6} m^3/s, based on a final ash dam height of 40m, permeability values of 5 x 10^{-8} and 1 x 10^{-5}m/s for ash and spoils material, respectively. In simplest terms, the designed structure is comprised of a slotted 160mm diameter uPVC pipe that has been enclosed within a coarse gravel filter pack, the pack being bound together by a geotextile. An impermeable membrane was also installed on the stream- side of the trench, while the trench itself falls towards a pump-out sump and dam at the lowest hydraulic point within the system.

The threat of pollution to nearby streams and increasing water costs appears to have motivated staff at Kriel and Matla Power Stations to consider the construction of a desalination plant at the site. Available reports suggest that approximately 20 000 ML of polluted water occurs on each site, the vast majority of which has been attributed to past mining operations. A Build-Own-Operate-Maintain (BOOM) system has been proposed for the site by Eskom staff, with the plant capable of processing 12 ML/day at salt rejection and water rates of 95% and 85%, respectively. Water from the Matla Power Station ash dam and Cut 2 in Pit 1 (where ash disposal is proposed) would then be pumped to the current wing dam beneath Cut 1 in Pit 1.

7.1.2.1 Presence of boreholes & springs and groundwater use

As can be seen in the previous section, a large number of boreholes exist within the area earmarked for the extension of the existing Kriel ash disposal facility (Site 10). The latest addition to the existing monitoring network was the drilling of eleven new monitoring boreholes by GHT during July 2010 (GHT 2010).

During 2009 GHT conducted an extensive hydrocensus to identify the water users and usage within the possible impact zone of the Kriel & Matla Power Station. A total number of 100 boreholes/springs were identified (GHT 2009). The majority of the boreholes were drilled for monitoring purposes. Four boreholes are being used for domestic purposes only. A total of 10 boreholes are being used for both agricultural (livestock) and domestic purposes.

The combined database of Kriel Colliery and Kriel & Matla Power Stations contained a total number of 124 boreholes at the time of compiling this report.

7.1.2.2 Groundwater levels

Water levels in boreholes at the Kriel and Matla Power Station are measured on a regular basis as part of a routine groundwater monitoring program. In addition to this data, Kriel Colliery also provided Aurecon with water level data from boreholes monitored by themselves. Measured water levels in the study area varied between 0.12 and 81.79 meters below ground level.

Under undisturbed conditions, a linear relationship can be expected to exist between groundwater levels and surface topography. This is however not the case in the project area as historical and current opencast and underground mining, mine dewatering and rehabilitation activities has altered the static water level and natural groundwater flow directions significantly.

Water levels in each of the measured boreholes must be interpreted in context of the area they are located. The deep water levels (in excess of ~70 mbgl) most probably depict the water level in the underground workings it was drilled into.

The measured water level in the majority of boreholes is less than 5 mbgl which confirms the presence of a perched water table within the Weathered Ecca Aquifer. Water levels between 10 and 20 mbgl most probably represents the water level in the Fractured Ecca Aquifer.

A detailed analysis of the groundwater level and flow directions is presented in section 8.

7.1.2.3 Groundwater chemistry

As previously mentioned, routine groundwater monitoring has taken place at Kriel Colliery, as well as the Kriel and Matla Power Stations for the past ~ 20 years. Data from a selected number of boreholes within the project area was used to describe the groundwater quality at Site 10 as contained in the 2011 specialist report (Aurecon report nr. 106718-2011-V1.0). This section was included in the updated report for reference purposes.

An overview of the groundwater quality will be given in the following paragraphs at the hand of the conventional Piper, STIFF and Box and Whisker diagrams.

A Piper and STIFF diagram is a graphical representation of the chemistry of a water sample or samples which assists to group different water samples into specific water types. The Piper diagram has the advantage of not only showing graphically the nature of a given water sample, but also dictates the relationship to other samples. For example, by classifying samples on the Piper diagram, we can identify geologic units with chemically similar water, and define the evolution in water chemistry along the flow path.

Box & Whisker diagrams again are a convenient way of graphically depicting descriptive statistics of a specific concentration for each borehole through their four-number summaries: the smallest observation (sample minimum), lower and upper quartile range (2 x Std. deviation), largest observation (sample maximum) and latest reported value. The SABS drinking water standards (SANS 241:2005), is also shown on the plots. Water is classified according to their suitability for human consumption.

- Class I: Recommended operational limit.
- Class 2: The maximum allowable concentration for short term use only.

The area under investigation was geographically divided into two areas:

- The current Kriel ash disposal facility (“Ashing Area”).
- The area on to which the extension of AD4.1 and AD4.2 will take place (“Pit1 1 Area”).

The area under investigation was geographically divided into two areas:

- The current Kriel Ash Dam (“Ashing Area”)
- The area on to which the extension of the ash dam will take place (“Pit1 1 Area”)

A Piper Diagram (Figure 2) was constructed using the average values of the entire monitoring period for the boreholes present at the Ashing and Pit 1 areas. From this diagram it can be clearly seen that the boreholes plot over a wide area indicating that boreholes have already been impacted upon by different sources of contamination, in this instance Ash Disposal and Opencast Mining. Furthermore, the following can be seen:

- 67% of the boreholes in the Pit 1 area plot in (Ca, Mg)(Cl_2, SO_4) region.
- 57% of the boreholes in the Ashing area plot in the (Na, K)(HCO_3) region.

A more detailed analysis of the boreholes occurring in each area will be done in the following 2 sections.

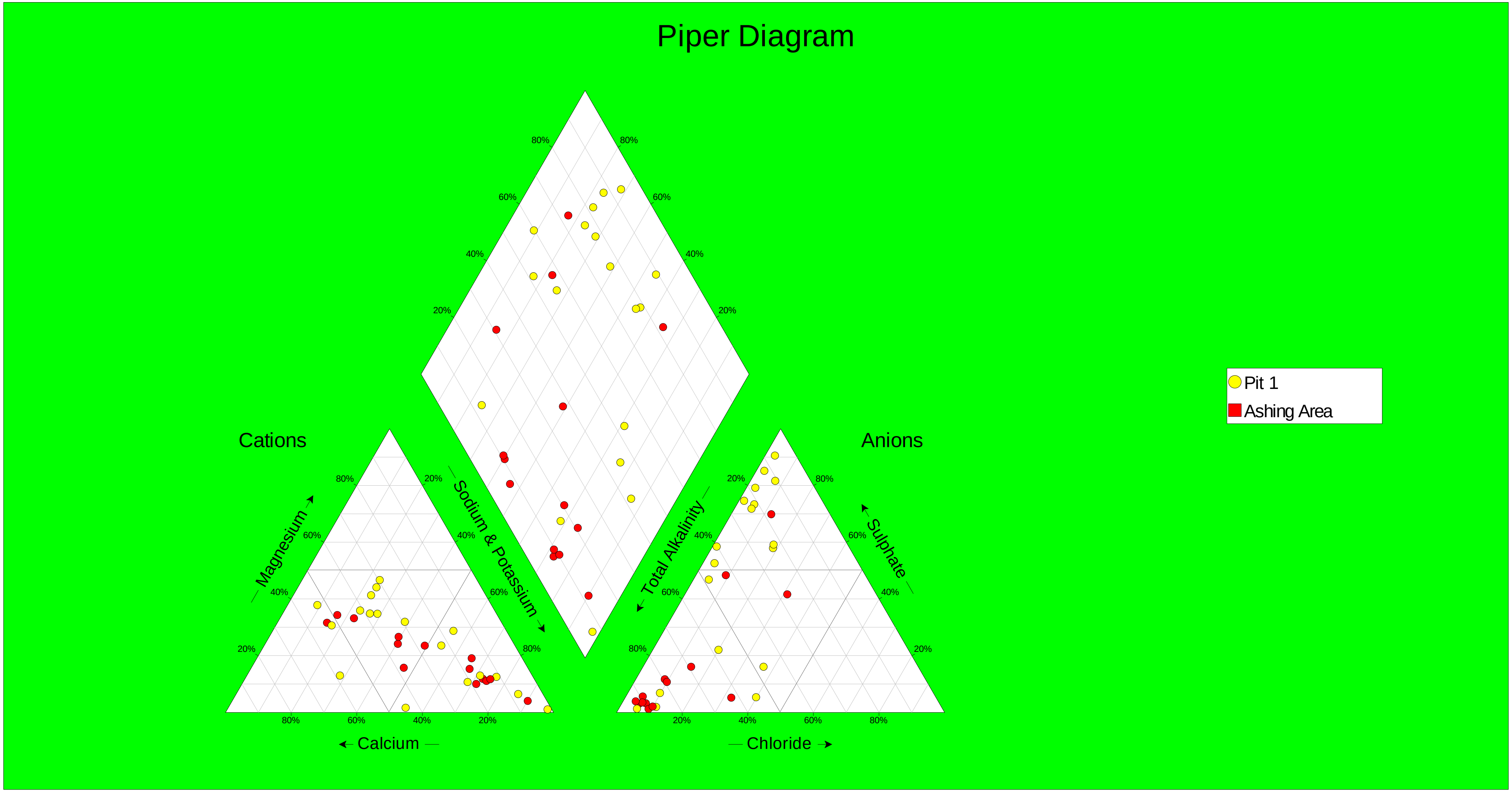

Figure 2: Piper diagram of boreholes at the Ashing & Pit 1 Area using average values over the entire monitoring period.

7.1.2.3.1 Ashing Area

The boreholes used to describe the groundwater chemistry at the Ashing Area are summarised in Table 3.

Table 3: Boreholes present at the Ashing Area

Borehole nr.	Description
KB05D	Between the existing ash disposal facility and AWR Dams
KB05S	Between the existing ash disposal facility and AWR Dams
KB06D	Next to the entrance of the Ash Office
KB06S	Next to the entrance of the Ash Office
KB63	Southeast of the existing ash disposal facility
KB64	Southeast of the existing ash disposal facility
KB08D	Southern side of Ash Dam Extension
KB08S	Southern side of Ash Dam Extension
KB61	Eastern side of Ash Dam Extension
KB62	Eastern side of Ash Dam Extension
KB10D	Next to dam KP16 in game reserve
KB10S	Next to dam KP16 in game reserve
KB65	South west of the existing ash disposal facility
KB35	South of the existing ash disposal facility

Piper (Figure 3) and Stiff Diagrams (Figure 4) were constructed for the relevant boreholes using average concentrations over the monitoring period.

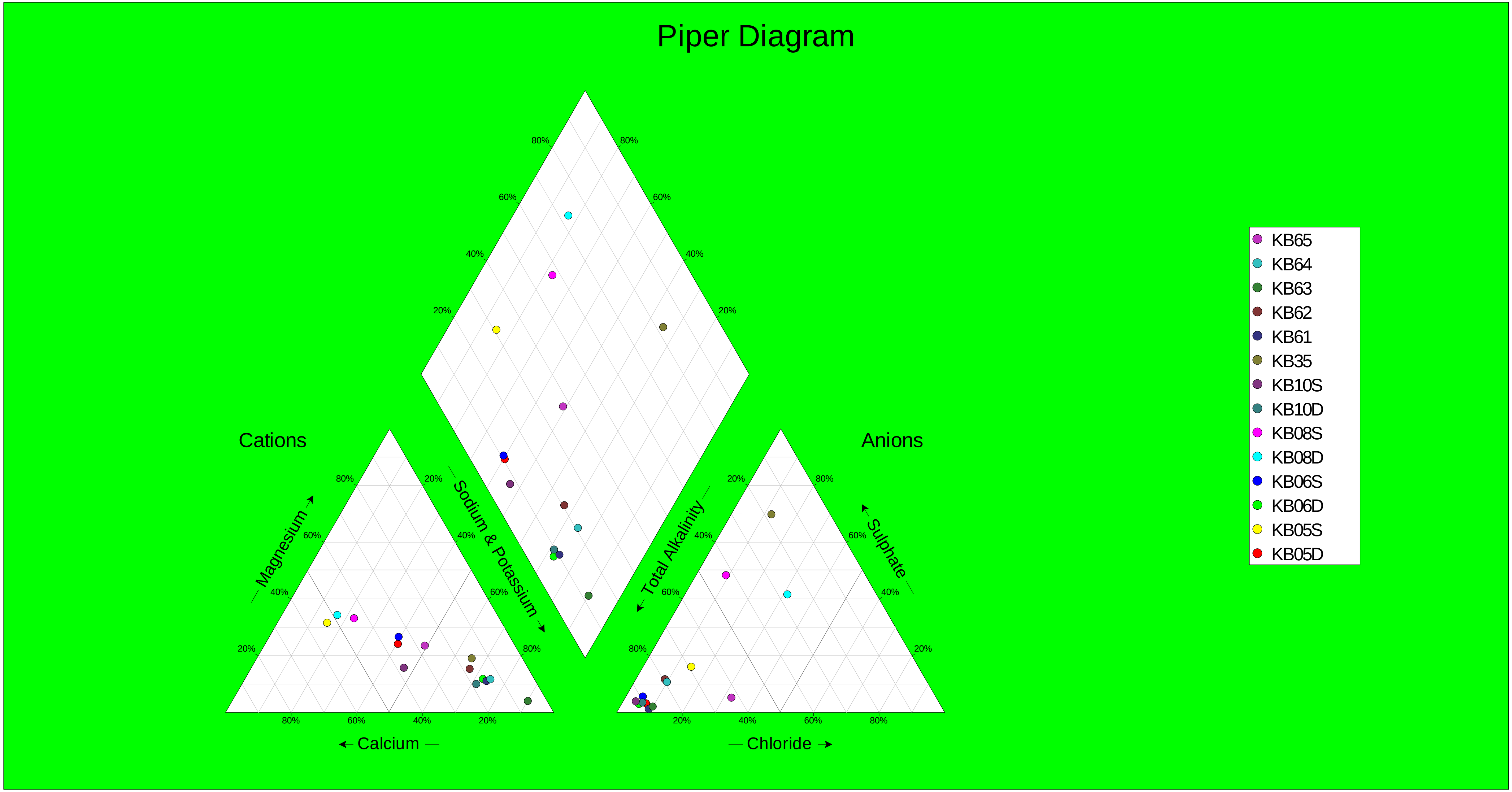

Figure 3: Piper diagram of boreholes at the Ashing Area using average values over the monitoring period.

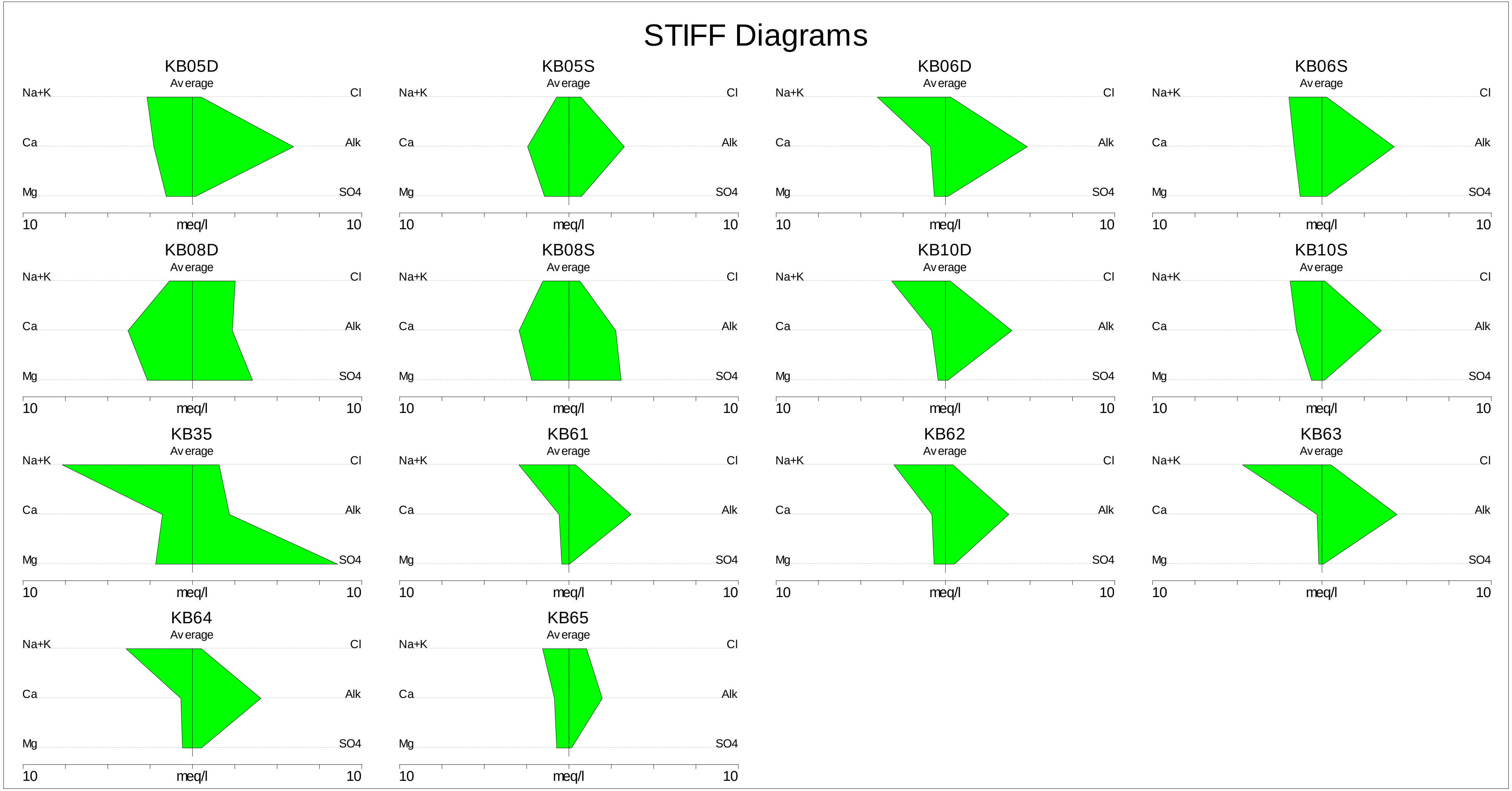

Figure 4: STIFF diagrams of boreholes at the Ashing Area using average values over the monitoring period.

From the Piper & STIFF diagrams it can be confirmed that the boreholes have a chemical character as depicted in Table 4.

Table 4: Chemical character of boreholes at the Ashing Area

$NaHCO_3$	$Ca(HCO_3)_2$	$Ca(SO_4)_2$	Na_2SO_4
KB05D KB06D KB06S KB10D KB10S KB61 KB62 KB63 KB64 KB65	KB05S	KB08D KB08S	KB35

Box and Whisker Plots for pH, Ca, Na and SO_4 were constructed for the boreholes as can be seen in the following figures (Figures 5 – 8). These chemicals were selected as they occur in elevated concentrations in ash water.

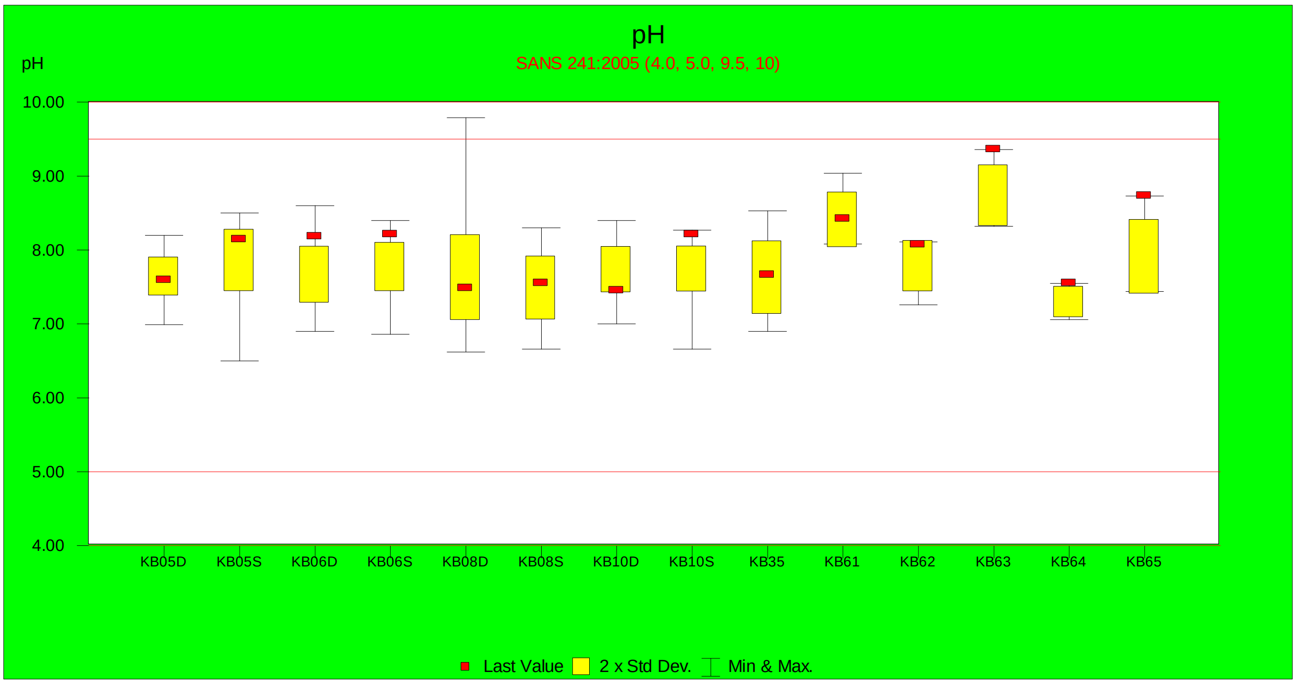

Figure 5. pH Box and Whisker Plot for the boreholes at the Ashing Area.

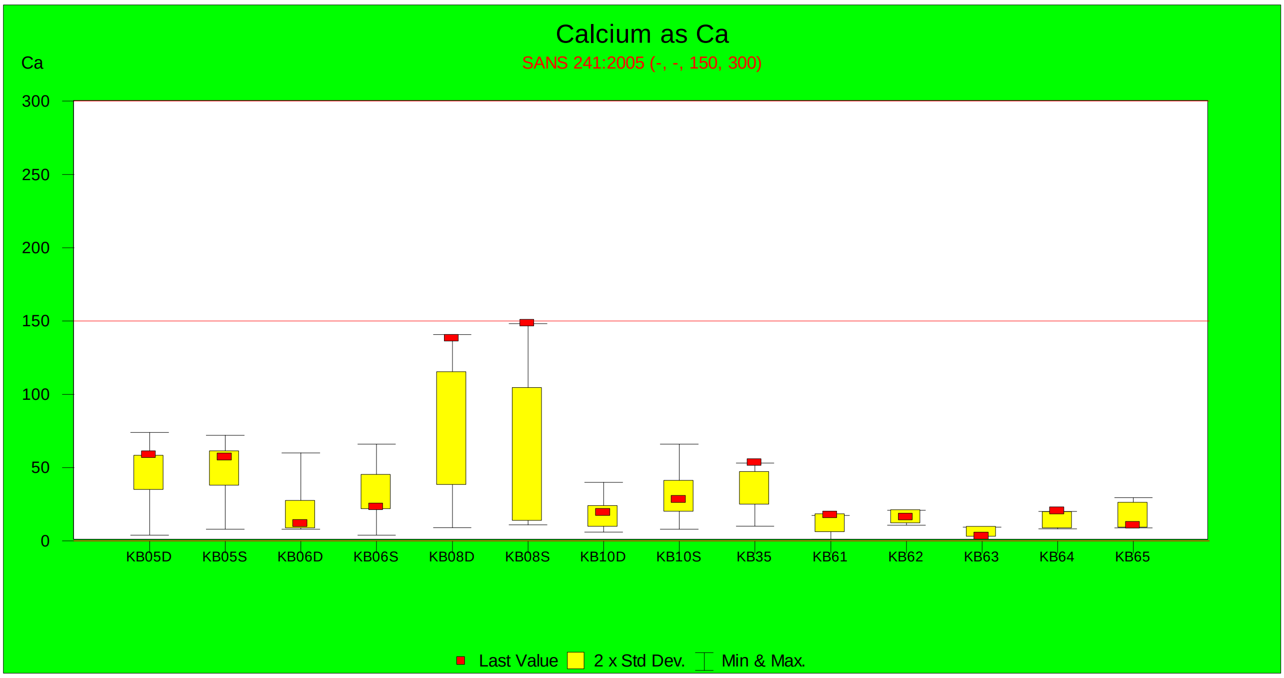

Figure 6. Ca Box and Whisker Plot for the boreholes at the Ashing Area.

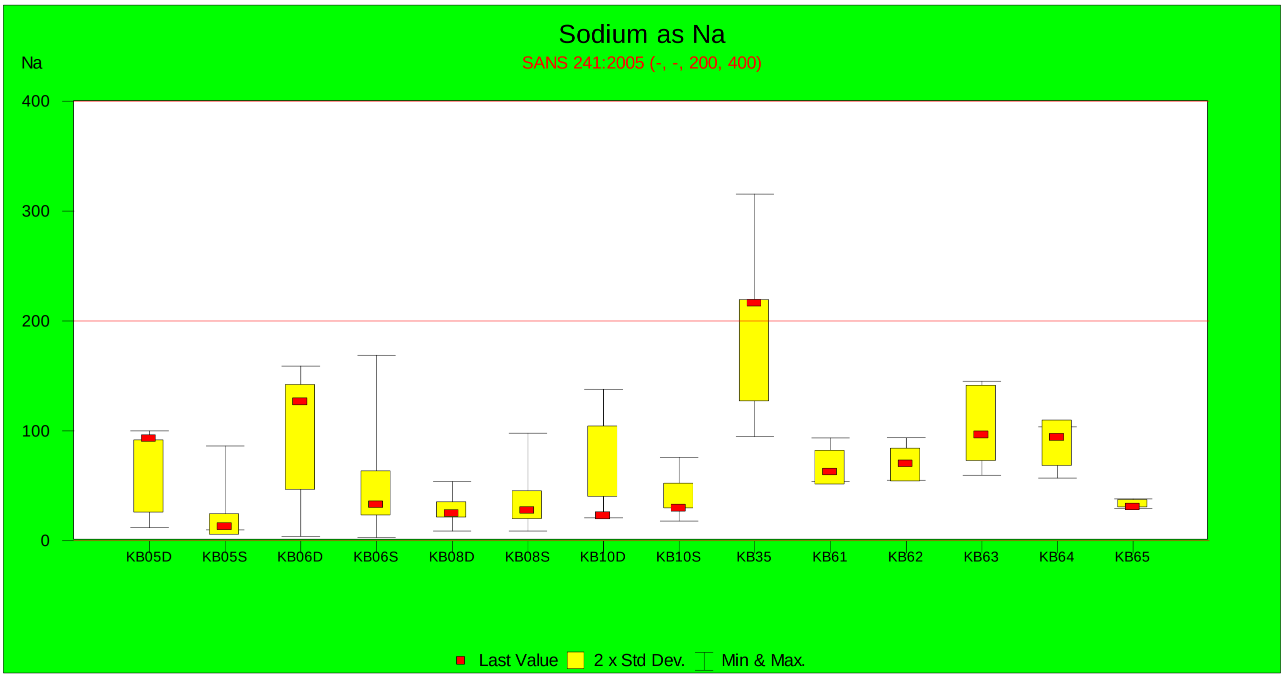

Figure 7. Na Box and Whisker Plot for the boreholes at the Ashing Area.

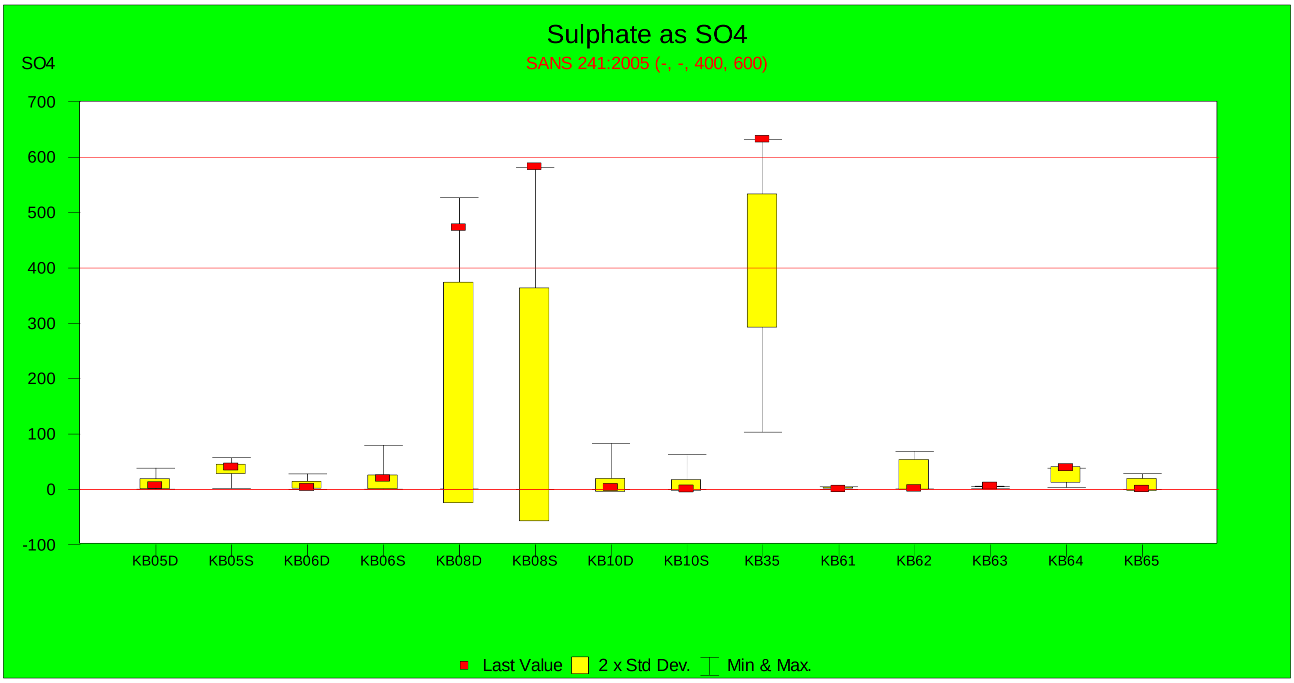

Figure 8. SO_4 Box and Whisker Plot for the boreholes at the Ashing Area.

From the different constructed chemical diagrams, the following can be concluded with regards to the aquifers underlying the Ashing Area:

- Generally, the groundwater is of good quality with only one borehole (KB35) exceeding (on most occasions) the Class 2 drinking water standards due to elevated sulphate concentrations. The majority of the remaining boreholes fall within Class 1.
- High pH values in boreholes KB61, 63 & 65. This can be attributed to the high pH in Ash Water which is usually above 12 (Hodgson *et al*.,1998)
- High calcium content in boreholes KBH8D & S. Repeated leaching of calcium from the ash is possible, because of the significant amounts of calcium oxide present within the ash (Hodson *et al*.,1998).
- High sodium concentrations in borehole KB35. Sodium is generally not a constituent that is present in significant quantities within ash water. Sodium is, however, added to the ash water during the disposal of demineralisation effluent. In the actual field situation, variable amounts of sodium may therefore be encountered within the ash water, depending on the exact circumstances under which the sample was taken. A tendency however exists for sodium to migrate from the ash dams into the adjacent areas. The sodium is mostly derived from sodium hydroxide that is being used to regenerate resin in the demineralisation plant. At all power stations, the demineralisation effluent is disposed of in the ash dams. Sodium is almost endlessly soluble in water, with the result that a build-up of sodium in semi-closed systems, such as the ash dams, is inevitable. As the ash water seeps away from the ash dams, capillary action draws water to the surface and white crystals of sodium sulphate crystallise on surface. Upon rainfall events, the sodium sulphate is again dissolved and mobilised with overland run-off. ***In all, sodium pollution from ash dams is probably the only real concern for groundwater and surface water (Hodgson et al 1998).***

- High sulphate concentrations in boreholes KB8D & S and KB35. The main source of sulphate in fly ash water is from the demineralisation effluent. Concentrations are typically in the range of 200 - 1000 SO_4.

Even though seepage from the ash dams into the underlying strata occurs, very few of the ash water's components are carried into the underlying aquifer. This is due to the unstable chemistry of the ash water. Hodgson *et al.* (1998) did a comparison between ash water and groundwater chemistries within boreholes in close proximity to ash dams and drew the following conclusions:

- The unstable components are filtered out to a very significant degree from the ash water, before it reaches the aquifer.
- This filtering action is probably a combination of the unstable chemistry of the ash water, as well as adsorption or complexation of specific ions onto clay material underneath the ash dams.

7.1.2.3.2 Pit 1 Area

The boreholes used to describe the groundwater chemistry at the Pit 1 Area are summarised in Table 5. The proposed extension of the current Kriel ash disposal facility will not extend across the Pit 1 Area.

Table 5: Boreholes present at the Pit 1 Area

Borehole nr.	**Description**
KB12S	East of Pit 1 edge of spoils next to the gravel road
KB67	East of Pit 1 edge of spoils next to the gravel road
KB68	East of Pit 1 edge of spoils next to the gravel road
KB16	South of Pit 1 near haulage road
KB18D	East of Pit 1 between spoils and Onverwacht Spruit
KB18S	East of Pit 1 between spoils and Onverwacht Spruit
KB19	Between Cut1 and Cut2 inside spoils
KB20	Between Cut1 and Cut2 inside spoils
KB28	West of Pit 1 between Pit 1 and RWD
KB29	East of Pit 1 between spoils and Onverwacht Spruit
KB30	South of Pit 1 near haulage road
KB69	East of Cut2 on edge of spoils
KB70	East of Cut2 on edge of spoils
KB38	East of Cut2 inside spoils
KB39	South of Cut 2 next to the spoils
KB40	East of Cut2 inside spoils
KB41	Into Cut 1 filled with ash
KB42	West of Cut 1 inside spoils

Piper (Figure 9) and Stiff Diagrams (Figure 10) were constructed for the relevant boreholes using average concentrations over the monitoring period.

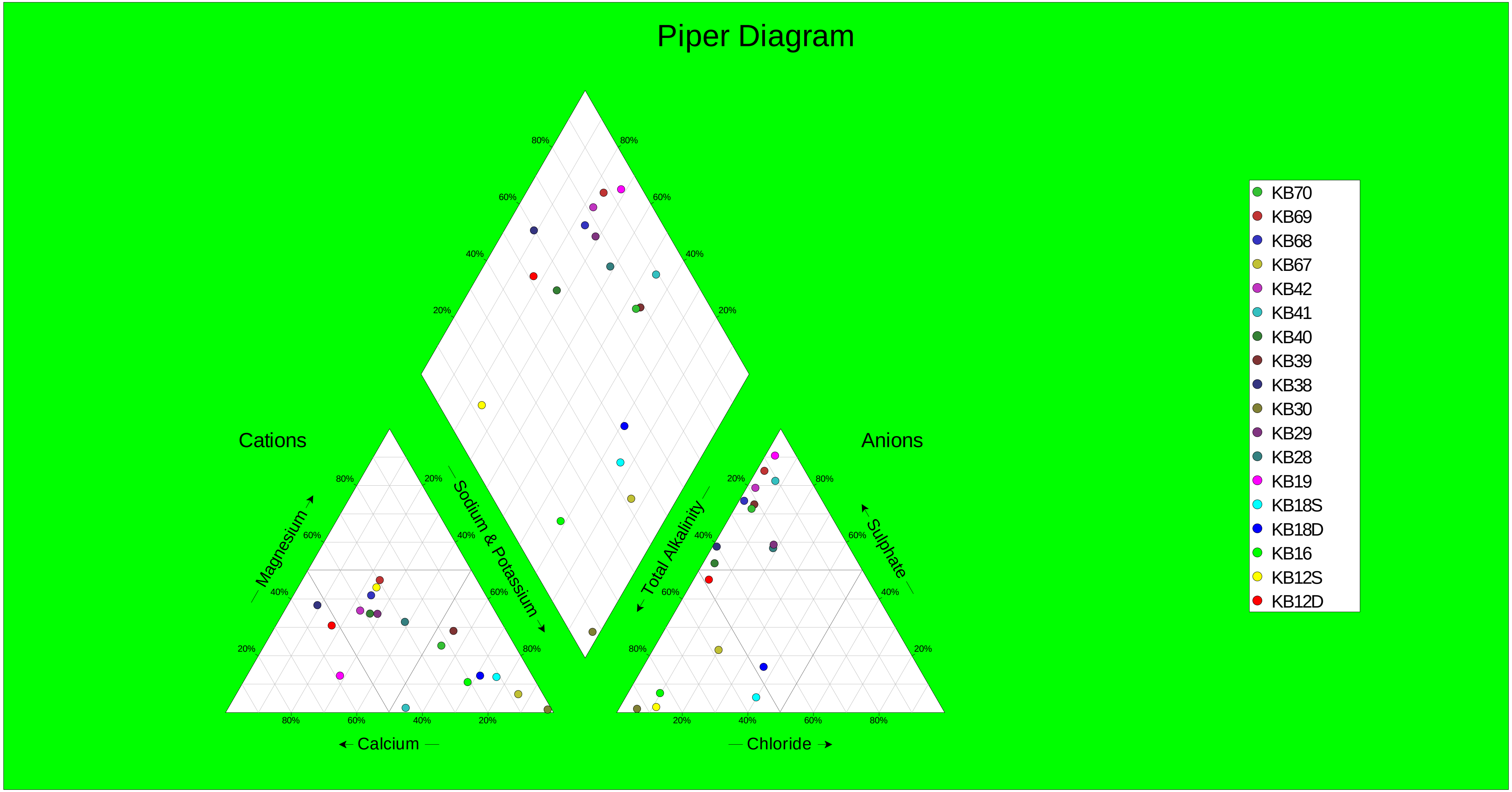

Figure 9: Piper diagram of boreholes at the Pit 1Area using average values over the monitoring period.

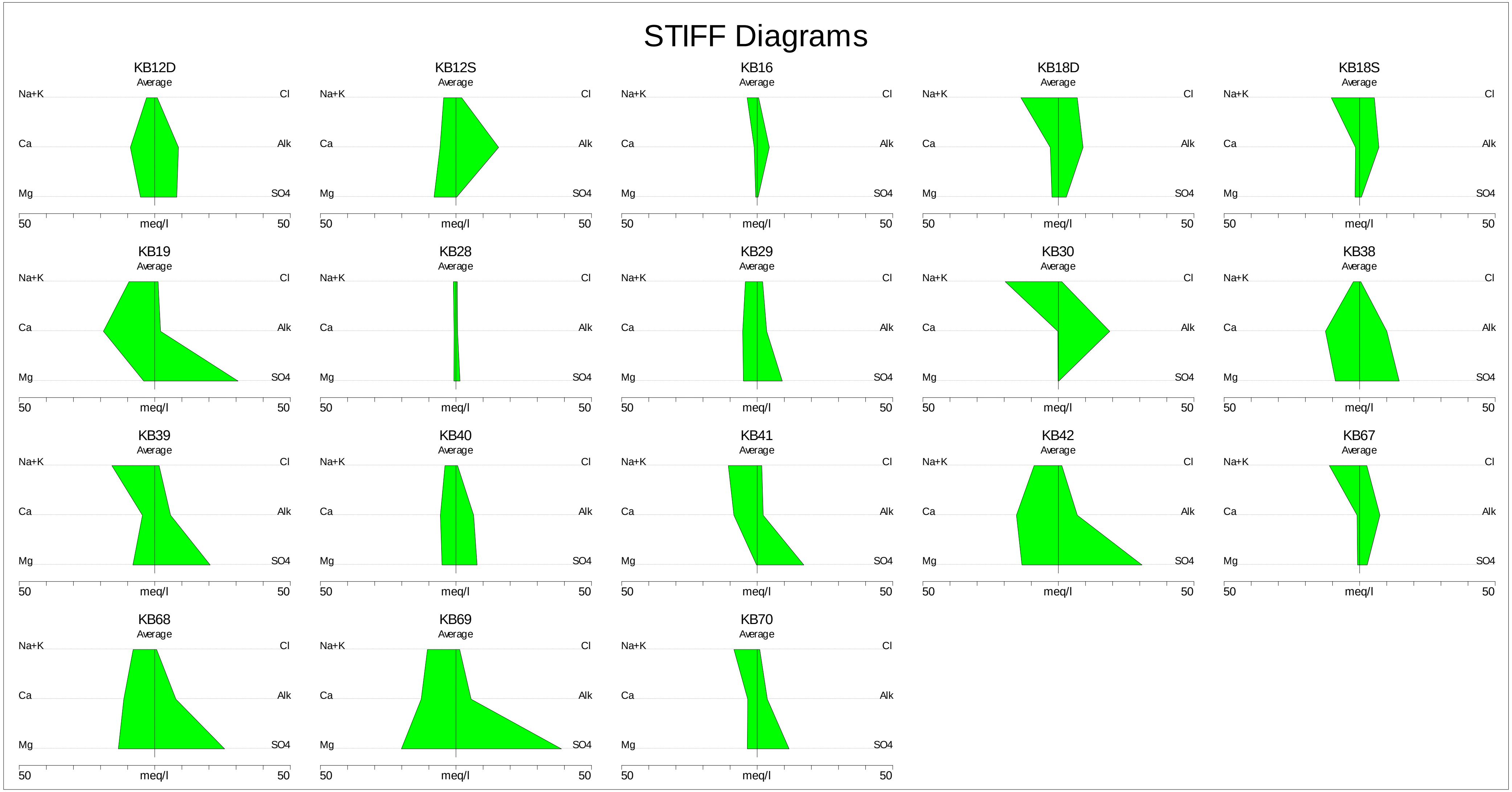

Figure 10: STIFF diagrams of boreholes at the Pit 1 Area using average values over the monitoring period.

From the Piper and STIFF diagrams it can be confirmed that the boreholes have a chemical character as depicted in Table 6.

Table 6: Chemical character of boreholes at the Pit 1 Area

$NaHCO_3$	$Ca(HCO_3)_2$	$Mg(HCO_3)_2$	$CaSO_4$	$MgSO_4$	Na_2SO_4
KB16 KB18D KB18S KB30 KB67	KB12D	KB12S	KB19 KB29 KB38 KB40 KB42	KB68 KB69	KB28 KB39 KB41 KB70

Box and Whisker Plots for pH, SO_4 and Mn were constructed for the boreholes as can be seen in the following figures. These chemicals were selected as elevated concentrations thereof in groundwater are usually associated with coal mining activities. The SABS drinking water standards (SANS 241:2005), is also shown on the Plots. Water is classified according to their suitability for human consumption.

- Class I: Recommended operational limit.
- Class 2: The maximum allowable concentration for short term use only.

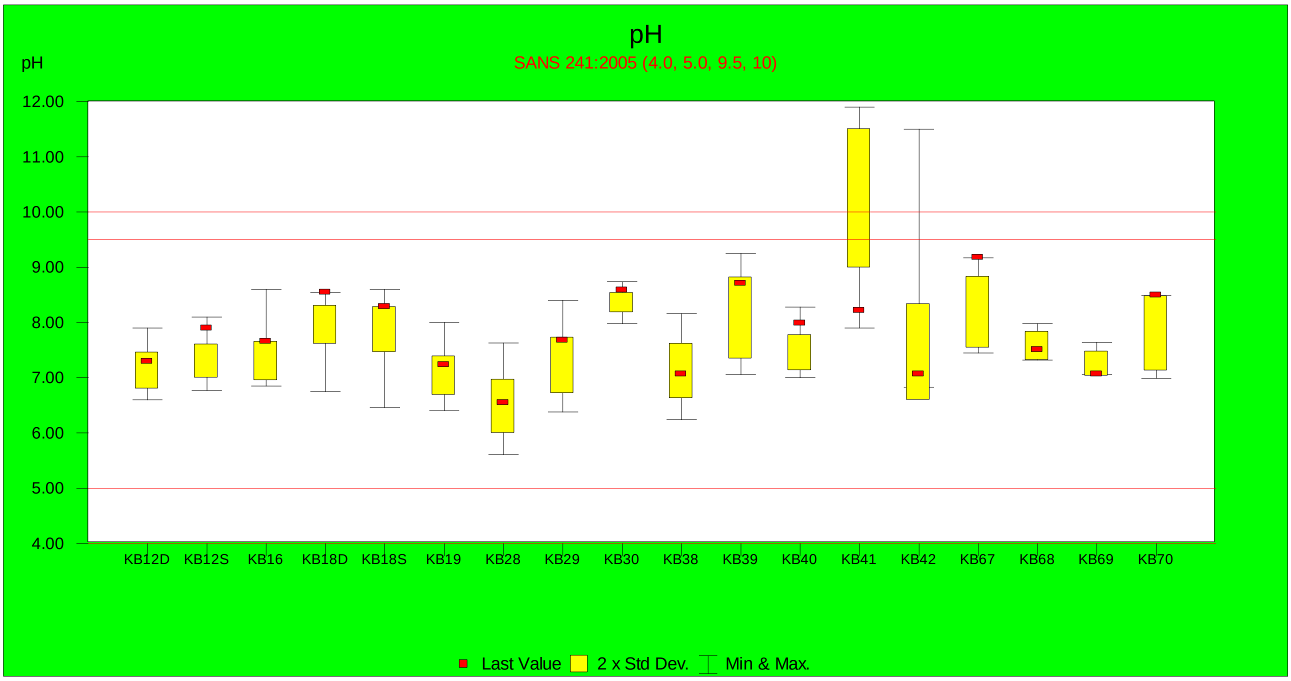

Figure 11: pH Box and Whisker Plot for the boreholes at the Pit 1 Area.

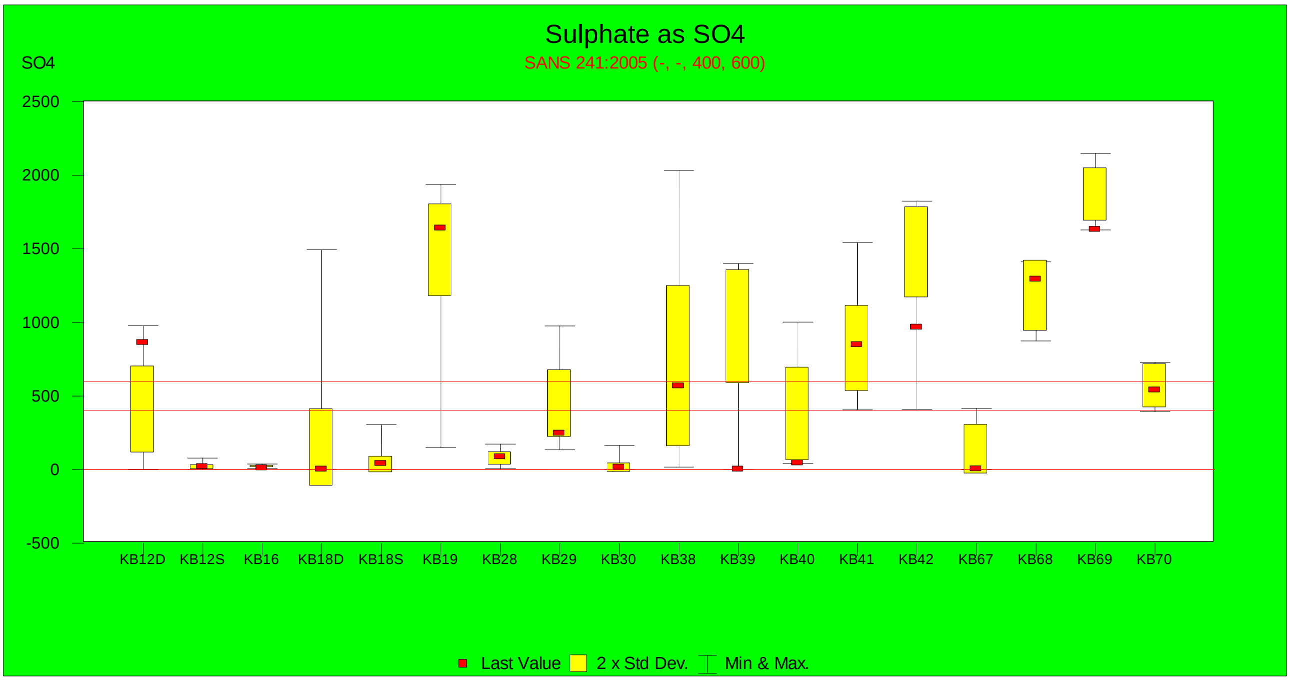

Figure 12: SO_4 Box and Whisker Plot for the boreholes at the Pit 1 Area.

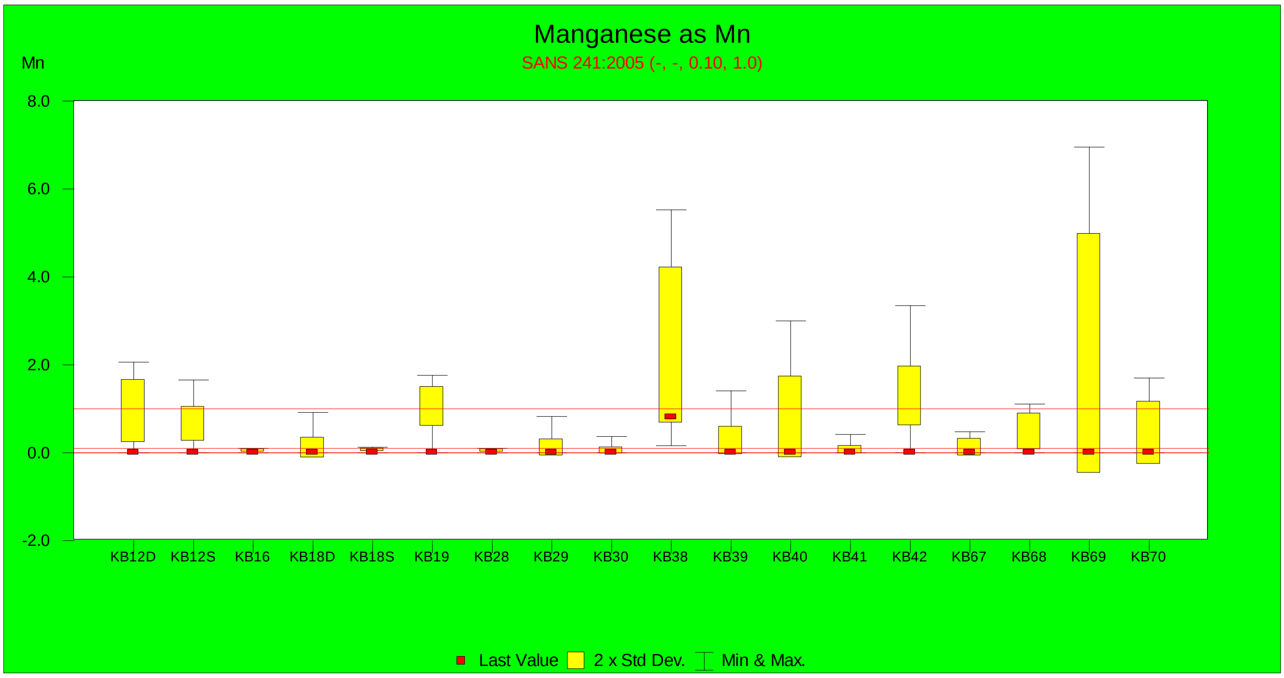

Figure 13: Mn Box and Whisker Plot for the boreholes at the Pit 1 Area.

From the different constructed chemical diagrams, the following can be concluded with regards to the groundwater in the Pit 1 Area:

- The wide range of values indicates that the groundwater in certain areas have been impacted upon by mining/in-pit ashing areas. In-pit ash disposal has taken place into some of the ramps and voids of Pit 1 (Hodgson *et al*.,1998).
- The majority of boreholes drilled in this area exceed the Class 2 drinking water standards, with only a small number of boreholes falling within Class 1.

- Boreholes drilled into the spoils do not necessarily have a low pH due to pyrite oxidation (KB19, 38, 40 & 42). The spoil in the pit has an inherent resistance to acidification and the ash has an even higher base potential than the spoil, thus further reducing the risk of in-pit water acidification (Hodgson *et al*.,1998). Borehole KB41 has a high pH (drilled into Cut 1 filled with ash).
- Borehole KB19, 38, 39, 41, 42, 68 & 69 generally exceed the Class 2 sulphate concentrations with concentrations in excess of 1000mg/l reported on a regular basis.
- Boreholes KB38 & 69 generally exceed the Class 2 drinking water standards for Mn.

Hodgson *et al.* (1998) performed in-depth investigations and geochemical modelling of in-pit ash disposal at Kriel Power Station and concluded that it is safe to dispose of power station fly ash into Pit 1, on condition that the necessary precautions are taken that ash water does not decant from the pit into public streams. The most important objective of this investigation would therefore be to predict the behaviour of the water table in the occurring aquifers after the extension of the current Kriel Ash Dam.

SECTION 8

NUMERICAL MODEL

8 NUMERICAL MODEL

It is the aim of this chapter to assess the likely hydrogeological impacts that the proposed extension of AD4.1 and AD4.2, might have on the receiving environment. Potential groundwater environmental impacts from all these facilities will be addressed in the modelling exercise.

It must be emphasised that this modelling study will concentrate on the impact of AD4.1 and AD4.2 on Site 10, and not the other current and historical mining in the area which is beyond the scope of work. Therefore, simplistic but reasonable assumptions will be made regarding the effect of mining on the groundwater regime for the sole purpose of serving as reference scenarios with which the additional impacts can be compared.

Thus, the chosen scenarios that will be considered in this modelling study are:

1. **Current situation:** This scenario aim to depict the current status to serve as a reference scenario to which the long term impact of the new ash dams will be compared.
2. **Operational ash dams:** This scenario depicts the ash dams while ash is deposited. In this scenario there will be considerable water deposited on the dams that needs to be modelled. AD4.1 and AD4.2 are proposed to be lined. Thus, limited pollution should emerge from these dams if the system operates to design parameters.
3. **Leaking Liner:** However, there is always the possibility that something might go wrong (excessive leaking of the lining, for example) and that the pollutants from the ash dam could reach the aquifer below. This modelled scenario will include such a worst case scenario. It must however be stated that a “Leaking Liner” scenario is not comparable to a “No Liner” scenario. A “Leaking Liner” restricts some of the flow where a “No Liner” scenario would not restrict any flow.

The finite difference numerical model was created using the US Department of Defence Groundwater Modelling System (GMS10) as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent several overall updates since. The latest update (Modflow NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells that has been a problem in Modflow previously.

MT3DMS is a 3-D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

8.1 Flow Model Set-up

In this section the setup of the flow model will be discussed in terms of the, elevation data used, boundaries of the numerical models and assumed initial conditions, against the background of the conceptual model previously discussed.

It needs to be clarified at this stage that it was deemed best to simplify the models as far as practical to include only the proposed ash dams and their immediate environments in the model. The reason for this is simply that the area around Area10 is extensively mined. To include all mining operations over this large area is a challenging undertaking that would actually serve little purpose for the study at hand. Fortunately it was possible to reduce the model boundaries without compromising on the integrity of the model, as will be described below.

8.1.1 Elevation Data

Elevation data is crucial for developing a credible numerical model, as the groundwater table in its natural state tend to follow topography, and evapotranspiration takes place from this surface. Regional elevation data was derived from the STRM (Shuttle Radar Tomography Mission) DEM (Digital Elevation Model) data. The SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000, during which elevation data was obtained on a near-global scale to generate the most complete high-resolution digital topographic database of Earth[3]. Data is available on a grid of 30 metres in the USA and 90 metres in all other areas.

Several studies have been conducted to establish the accuracy of the data, and found that the data is accurate within an absolute error of less than five metres and the random point-to-point error between 2 and 4 metres for Southern Africa[4]. Over a small area as in this study, the relative error compared to a neighbouring point is expected to be less than one metre. This is very good for the purpose of a numerical groundwater model, especially if compared to other uncertainties; and with the wealth of data this result in a much improved model.

[3] http://www2.jpl.nasa.gov/srtm/

[4] Rodriguez, E., et al, 2005. An assessment of the SRTM topographic products. Technical Report JPL D-31639, Jet Propulsion Laboratory, Pasadena, California.

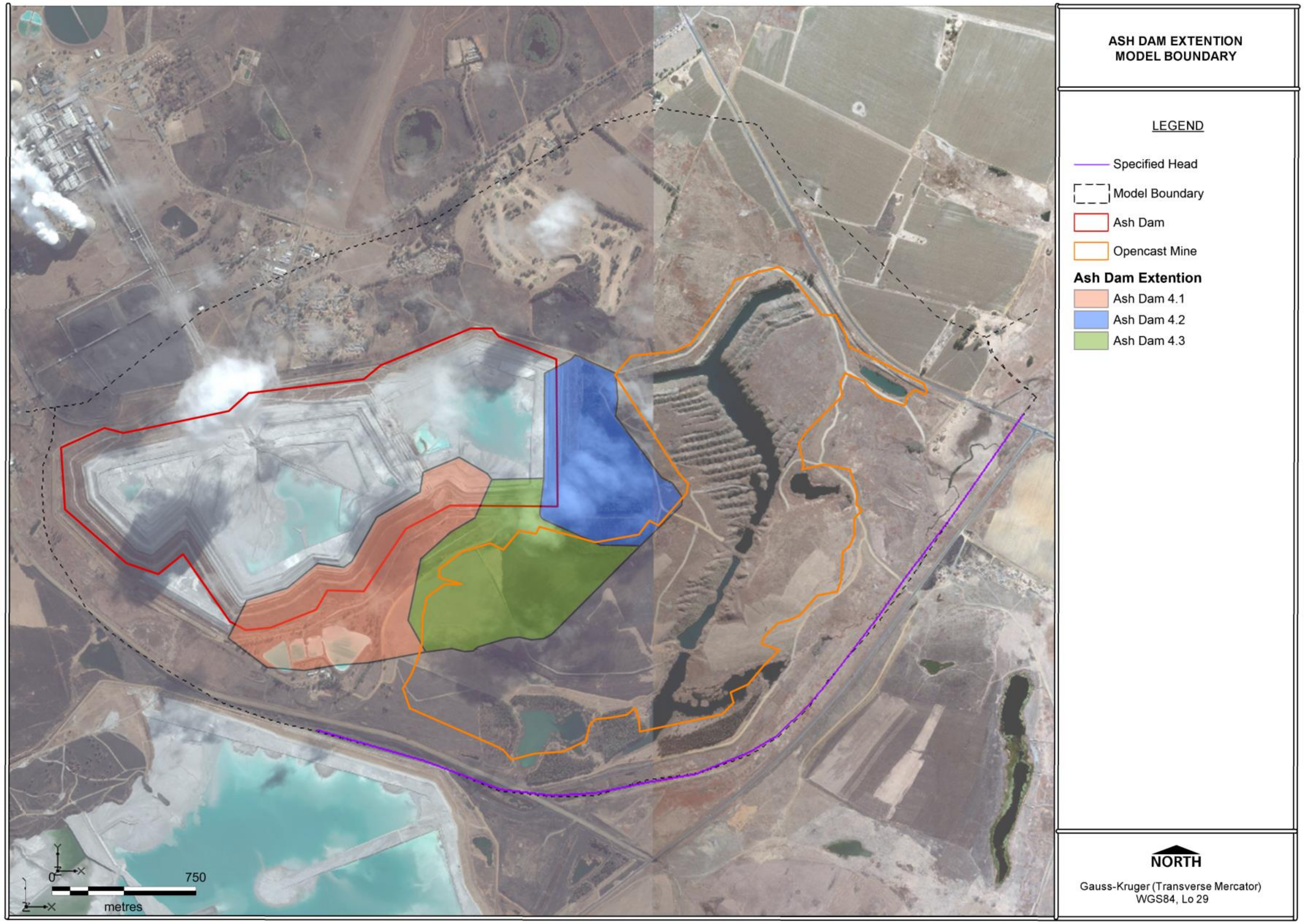

Figure 14: Model boundaries Area 10

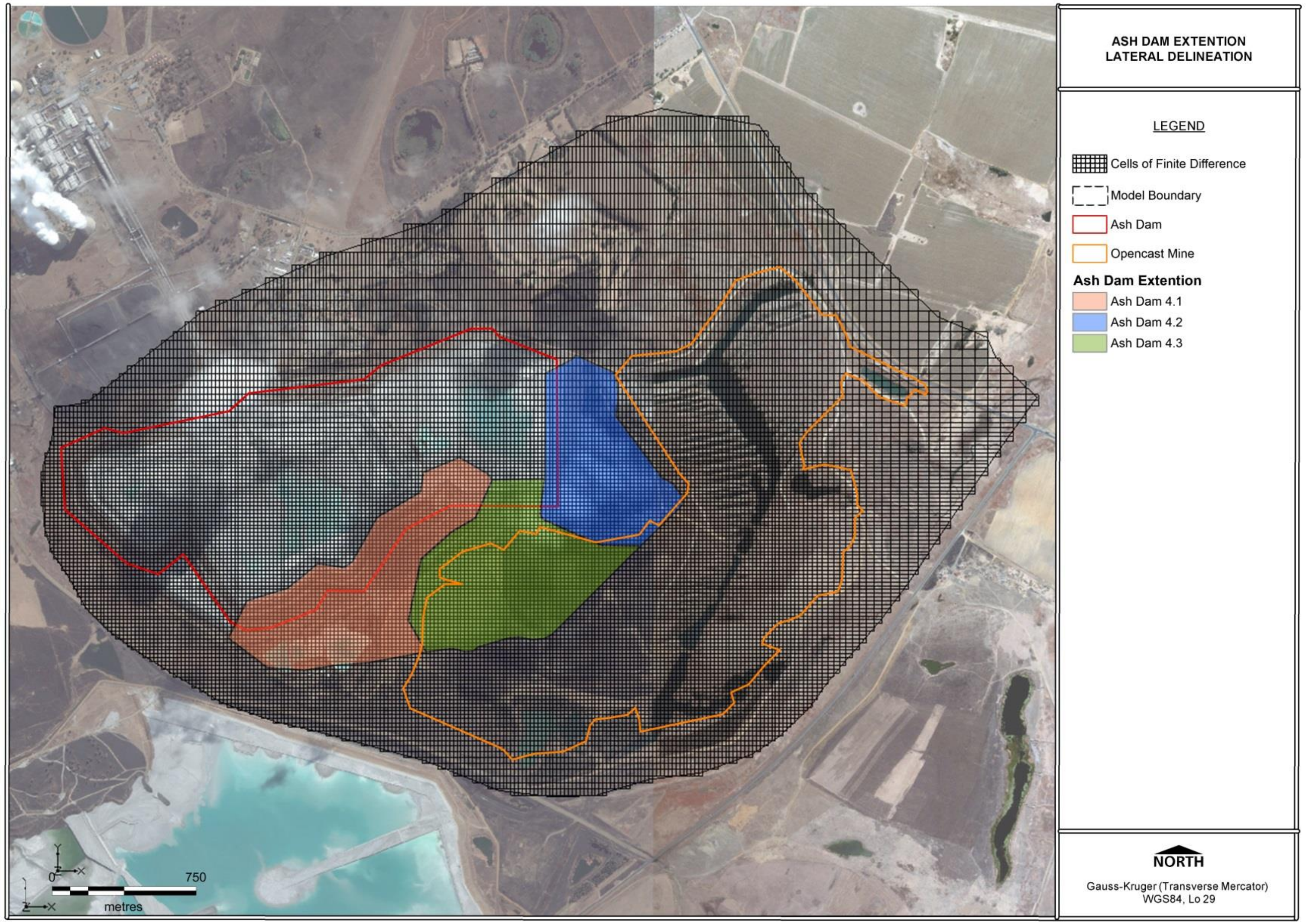

Figure 15: Model grid Area 10

8.1.2 Boundaries

Boundaries for the numerical model have to be chosen where the groundwater level and/or groundwater flow is known. The most obvious locations are zero flow conditions at groundwater divides, while groundwater levels are known at prominent perennial dams, streams and rivers.

A major problem in aquifer delineation is the large scale of opencast and undermining in this area, and interconnectivity between mines, rendering it almost impossible to create model boundaries that will encompass everything. After careful deliberation, it was decided to use the closest possible boundaries around the perimeter of the proposed new ash dams as model boundaries that is not underlain by undermined areas. This would allow focus on the differential impact of the ash dams while ignoring the complexity which is actually unimportant for this investigation. Fortunately, natural boundaries were to be found in close vicinity, and realistic model boundaries could be delineated without compromising the outcome of the model.

Thus, to simulate the groundwater impacts of the ash dam, the aquifers as described below has been modelled.

For Area 10, it was very opportune to find a topographical high just to the north of the existing ash dam. Under undisturbed conditions, a topographical high would also be a groundwater divide. In this instance the water divide is undermined and groundwater levels would be disturbed. However, mining is underground at a depth ranging from about 70m to 100m, while the influence of the ash dam is mostly in the upper parts of the fractured aquifer. It was thus decided to model only the upper 50 metres of the aquifer where most of the flow from the ash dam to the backfilled opencast (30m below surface) and surrounding intact aquifer is expected to occur. It is known that the hydraulic conductivity of fractured rock decrease by an order of magnitude about every 50 metres[5] due to compression forces on the fractures in the bedrock, resulting in fractures closing up with depth. The amount of groundwater flow will thus also decrease by an order of magnitude and the shallower model should thus account for at least 90% of the flow.

In this a situation, the natural topographical water divide to the north is a realistic no-flow boundary. A parallel flow barrier was created in the eastern section of the model. In the west and south, the Dwars-in-die-weg Spruit was used a stream boundary to complete the model boundaries. In addition, seepage face boundary was created in the area of the backfilled opencast (Pit 1) to remove excessive flooding of the model. There are no known hydraulic characterised dykes in the area.

The modelling area was discretizised by a 300 by 200 grid, refined at the main area of interest, Area 10 ash dam, as depicted in **Figure 15** above, resulting in finite difference cells of about 20 by 20 meters at the ash dam and up to 300 meters at the edges of the model. All modelled features are sizably larger than these dimensions, and the grid is thus adequate for the purpose. Nevertheless, the total amount of active cells over all layers added up to about 150 000.

The grid was delineated into four vertical layers. The first two layers represent the deep clay in the area as exposed by borehole drilling. The first layer is 13m in depth and contains the ash dam, where the layer thickness increases to 40-50m, depending on topography. The second layer is also a clay layer, is 5m thick and was used to contain the lining. The two deeper layer is fractured

[5] Barnes, S. L. et al. Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Pennsylvania Department of Environmental Protection

rock layer; the first to accommodate the opencast to a depth of about 40m, and the second to serve as low hydraulic conductive slightly weathered bedrock.

8.1.3 Aquifer Parameters

For this modelling exercise, the hydraulic aquifer parameters at Area 10 were estimated, rather than calibrated as usual. The reason for this is that the water levels in the area on which the ash dam is to be constructed, is highly disturbed by the current ash dam as well as historic opencast and underground mining. Aquifer parameters were thus calculated and/or judged by conventional means, such as previous studies in the area and best current knowledge.

The following fixed assumptions and input parameters were used for the numerical model applicable to the area:

- Horizontal Hydraulic Permeability of the bedrock = 0.01 m/d. This value was deduced from the geometric mean results of various pumping tests[6)7)8)9] conducted in the area.
- Hydraulic Permeability of the mined out and rehabilitated opencast areas = 100 m/d[10)]. This is three orders of magnitude larger than the pre-mining conditions, typical that of a sandy gravel, though not too high as to result in numerical instability of the model.
- Hydraulic Permeability of the ash dump = 0.2 m/d. This value was deduced from the geometric mean results of falling head permeability tests undertaken on undisturbed ash samples[7)] and confirmed by an expert report[8)].
- Hydraulic Permeability of the weathered zone (clay layer) = 0.0001 m/d[8)].
- Vertical Hydraulic Anisotropy (K_H/K_V) of the bedrock = 10. By nature of the pronounced horizontal layering, this value is commonly used in the Karoo sedimentary layers.
- The effective porosity of the bedrock was taken as 0.01. This value was taken as typical of the fractured bedrock[7)8)].
- The effective porosity (specific yield) of the backfilled opencast area was assumed to be 0.25, typical of unconsolidated gravel[7)11)].
- Porosity of the ash dump = 0.5. This value was also calculated from the geometric mean results of tests undertaken on undisturbed ash samples[7)].
- The specific storage over the area was taken as 0.000001 (10^{-6}). This is a typical value for saturated layers, taking only compressibility of the matrix and water into account.
- Recharge on undisturbed ground surfaces = 25.6 mm/a ≈ 0.00007 m/d. This value was calculated using the RECHARGE program[12)] (Table 7 below) as described in the

[6] Vermeulen P. D. et al: Determination of the Impact of Coal Mine Water Irrigation on Groundwater Resources, February 2008. Institute for Groundwater Studies, Bloemfontein RSA.

[7] Van Niekerk L. J., Staats S: Tutuka Power Station Ash Stack Plume Model, August 2010. GHT Consulting Scientists.

[8] Hodgson F. D. I., Krantz, R. M.: Investigation into Groundwater Quality Deterioration in the Olifants River Catchment above The Loskop Dam... WRC Report 291/1/95

[9] Jones and Wagener: Kriel Power Station Ash Dam 4: Interum Geotechnical Report. No JW/15/04/9158

[10] GHT Consulting Scientists: Site Hydrology at Kriel and Matla Power Stations, 2001.

[11] Hodgson F.: Mine Water Balance for Kriel Colliery. Report 2011/01/FDIH

methodology. This value relates to a recharge percentage of ~3.5%, which correlates with general accepted value of 3-5% for the Karoo sediments[13]. Please note that this is not effective recharge, as evapotranspiration was also modelled as discussed below. The result will thus be higher recharge in high topographical areas and lower recharge where the water table is shallow, similar to the conditions in nature.

- Recharge into rehabilitated opencast areas = 0.0004 m/d, which is about 20% of mean annual precipitation[8)]. (All opencasts at this site are unrehabilitated.)
- Recharge into unrehabilitated opencast areas = 0.001 m/d, which is about 60% of mean annual precipitation[14)].
- Recharge into ramps and voids of opencast areas = 0.0015 m/d, which is about 70% of mean annual precipitation[14)]. (This is applicable to the unrehabilitated opencast)
- Recharge into the operating wet ash dam = 0.003 m/d[7)]. Note that evaporation is catered in the model as a separate process.
- Recharge into the closed but un-rehabilitated ash dam = 0.0004 m/d, which is about 20% of mean annual precipitation, similar to that of an opencast[7].
- Recharge into the closed and well rehabilitated ash dam = 0.00006 m/d, which is about 3% of mean annual precipitation, very close to that of undisturbed ground[7)].
- Maximum evapotranspiration = 1812.9 mm/a ≈ 0.005 m/d. This value is based on the E-pan evaporation data for this area[15]. Note that this rate of evapotranspiration is used by the modelling software only if the groundwater should rise to the surface. For the groundwater level between the surface and the extinction depth, the evapotranspiration is calculated proportionally.
- Evapotranspiration extinction depth = 1 m. This depth relates to the expected average root depth of plants in this area, as well as loss through capillary action in unvegetated areas.
- Longitudinal dispersion was taken as 50 metres, which is about 10% of expected plume dimensions, as recommended in various modelling guidelines.
- Transverse and vertical dispersion was taken as 5 metres and 0.5 metre respectively to reflect the stratification of the bedrock.

The values as listed above fitted the measured groundwater levels remarkably well, as illustrated in Figure 16 below (head interval 5m). The mean residual head is -1.38m and the mean absolute residual head is 2.14m.

---

[12] Gerrit van Tonder, Yongxin Xu: RECHARGE program to Estimate Groundwater Recharge, June 2000. Institute for Groundwater Studies, Bloemfontein RSA.

[13] Vermeulen P D, Usher B H: An investigation into recharge in South African underground collieries. The Journal of the Southern African Institute of Mining and Metallurgy, Vol. 106 Nov 2006.

[14] Hodgson, F.D.I, Krantz, R,M.: Groundwater Quality Deterioration in the Olifants River Catchment Above the Loskop Dam With Special Investigations in the Witbank Dam Sub-Catchment. WRC Report 291/1/98.

15 http://www.dwaf.gov.za/hydrology

Table 7: Recharge calculation

Method	**mm/a**	**% of rainfall**
Qualified Guesses :		
Soil	37.3	5.1
Geology	24.3	3.3
Vegter	45.0	6.1
Acru	15.0	2.0
Harvest Potential	17.8	2.4
Base Flow (minimum Re)	14.0	1.9
Average recharge	**25.6**	**3.5**

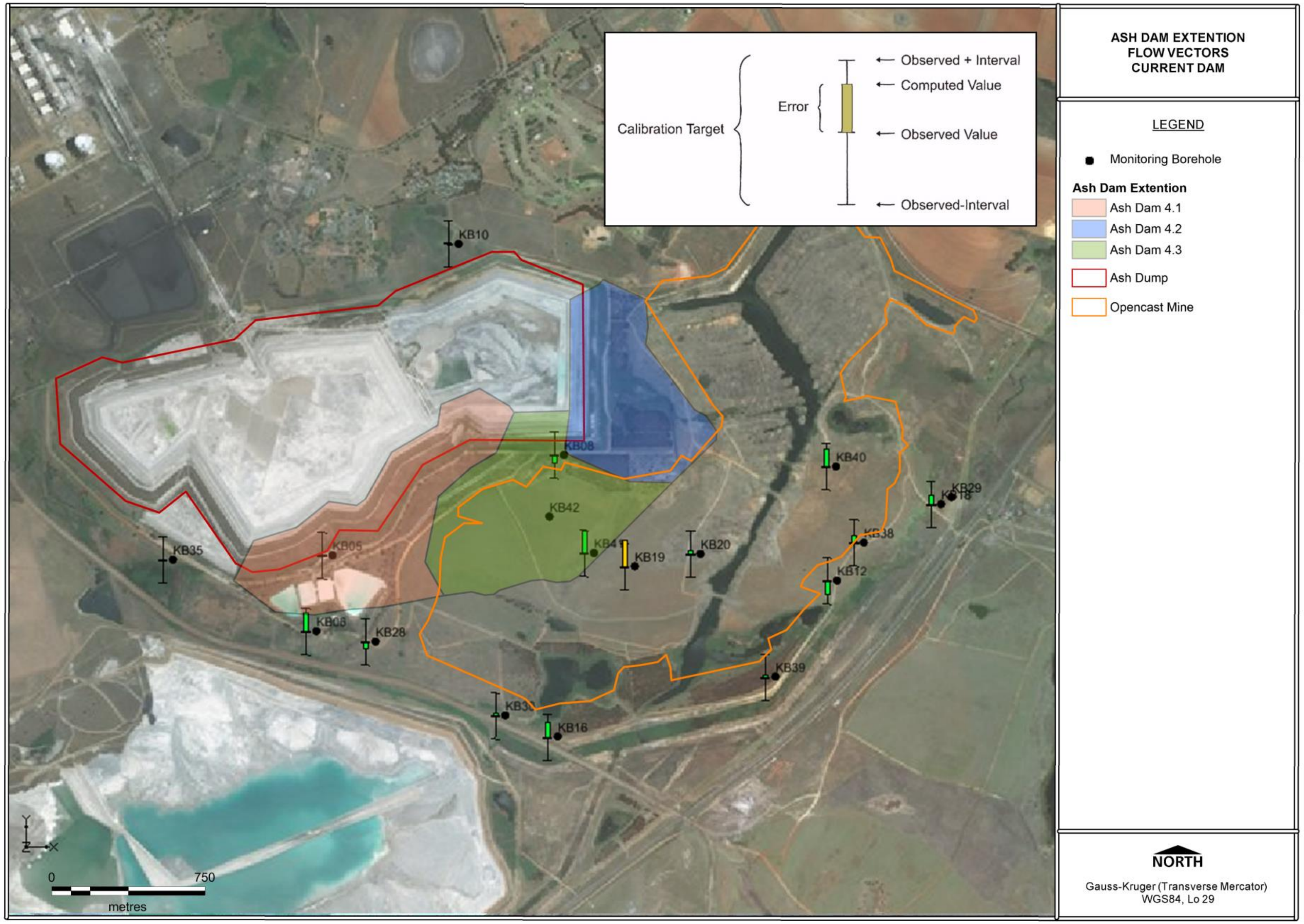

Figure 16: Computed vs Measured Groundwater Levels

SECTION 9

IMPACT ASSESSMENT

9 GEOHYDROLOGICAL IMPACTS

The results of the modelling for Site 10 will now be discussed under the following headings:

1. The reference scenario, being the current operational ash dam. The steady state prevailing groundwater levels and flow volumes will be the reference to determine whether any future ashing scenario is more (or less) desirable than the present hydrogeological situation.
2. A most likely scenario would be that AD4.1 and AD4.2 as well as the current ash disposal facility is fully operational, and that ash is actively deposited over the whole dam area. The new AD4.1 and AD4.2 are to be equipped with an impermeable liner[9].
3. Another scenario is that the lining of AD4.1 and AD4.2 can fail.

Although various other scenarios are plausible, they would all constitute intermediates of the scenarios above. Should any alternative scenario being considered important in future, it would be easy to simulate with the current model.

9.1 Current (reference) scenario

As described above, this scenario represents the current operating ash disposal facility at the Kriel Power Station.

The steady state groundwater levels in this scenario are depicted in Figure 17 below. It is noticeable to what extent the water levels flatten at the locations of the opencasts, due to the high hydraulic conductivity of the opencast backfill material. Very similarly, the water levels in the ash dam are also relatively flat, but this is probably more due to the flat top topography of the ash dams and the high water input.

In Figure 18 the groundwater flow directions are depicted. It is clear that the main flow direction is predicted to be away from the current ash dam and towards the Pit1 Opencast, as can be expected from water sources and sinks and the general topographical features

The numerical model also facilitates the calculation of flow budgets not only for the whole model, but also for any sub-section required. As Pit1 is clearly the receiving component in this complex groundwater flow system, the flow budget for Pit1 will be presented at the end of each scenario and compared to the reference. The current groundwater conditions have been chosen as the reference, as it is a well-known situation that is well managed currently. Obviously, any rise in groundwater level in Pit1 will increase the decant problems, while additional inflow from the new ash dam will need to be handled.

The current modelled flow budget for Pit1 area only as determined by the Zone Budget software, is tabled below; where the components of flow are:

- The seepage face is flow derived from a drain modelled over the Pit1 area to remove surface water from the groundwater model, as runoff in nature.
- Evapotranspiration constitutes evaporation and transpiration from the Pit 1 area only
- Recharge is infiltration of rainwater into the pit area only.
- Sub-surface inflow is groundwater flow from upstream areas into Pit 1.

Table 8: Flow budget at Pit1 currently

Flow Budget For Pit1 (volumes in m^3/day, and levels in metres) (+ into Pit1, - Out of Pit1)	IN		OUT
Seepage Face	0	Seepage Face	4749
Evapotranspiration	0	Evapotranspiration	193
Recharge	4609	Recharge	0
Sub-surface Inflow	817	Sub-surface Outflow	484
Total IN	5426	Total OUT	5426
In-Out	-0.03	Percent Error	-0.05%

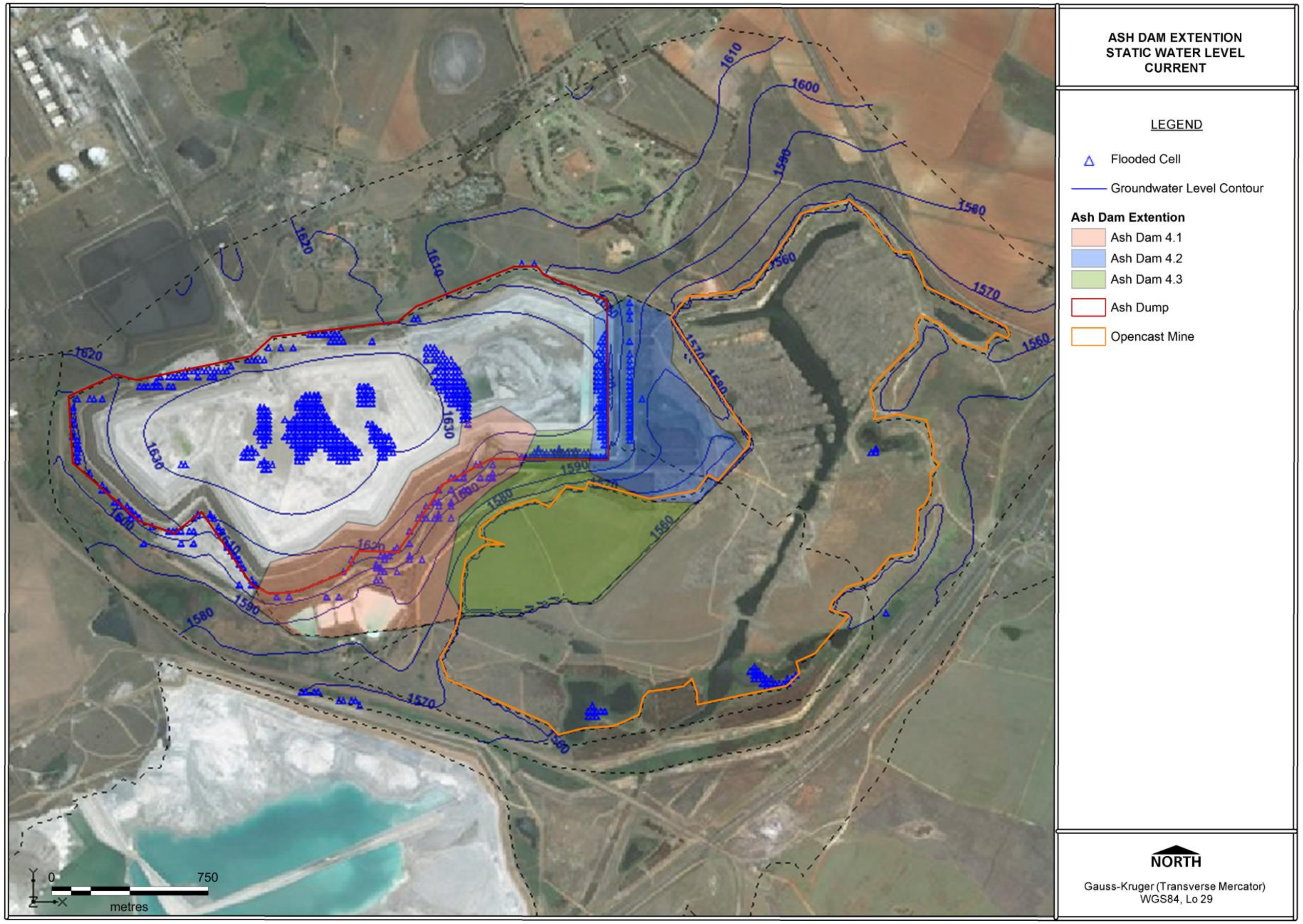

Figure 17: Current groundwater levels

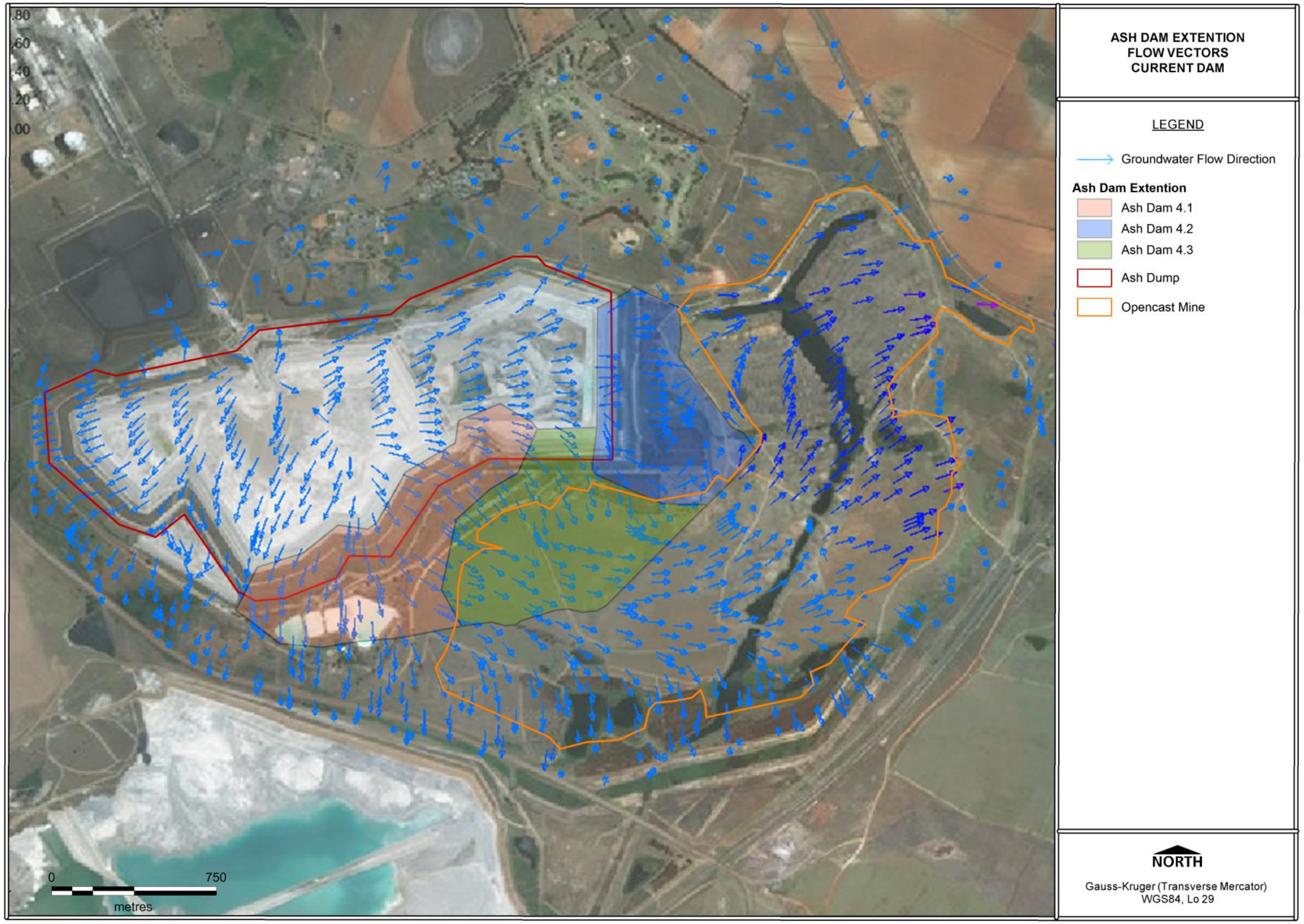

Figure 18: Current flow of groundwater

Figure 19: Main flow budget items

9.2 Current Ash Disposal Facility and New AD4.1 and AD4.2 Operational with Liner

This scenario is the most likely situation[16]. During this phase, ash will be deposited on the new AD4.1 and AD4.2 while the existing ash disposal facility also still operational.

The steady state groundwater levels in this scenario are depicted in Figure 20 below. The most significant change is the rise in groundwater levels over the extension area of the tailings dams, as expected. Over the remainder of the area the groundwater levels are almost identical to the current situation.

In Figure 21 the groundwater flow directions is shown. It follows from the figure that the main flow direction has not changed significantly. Groundwater flow is very similar to the current scenario, except that flow from the new ash dam is forcing groundwater more to the south.

The flow budget for this scenario is listed in Table 9 below. There will be an additional ~ 2 500 m^3/day inflow into the Pit1 opencast (Seepage Face flow in the table) that will have to be removed just to maintain current groundwater levels and current decanting level(s). It should further be taken into account that these numbers represent steady state conditions, while seasonal fluctuations will definitely result in higher volumes in summer and vice versa.

In conclusion, it is evident that the planned liners of the new AD4.1 and AD4.2 are very effective to contain additional impacts, and that only an additional amount of water will be added to the current decant volume.

[16] Jones & Wagener, 2016. Kriel Power Station Ash Dam 4 – Site 10: Concept Design Update. Report No.: JW044/16/E821 – Rev 0.

Table 9: Flow budget for Pit1 with all ash dams operational and liner under AD4.1 and AD4.2

Flow Budget For Pit1 (volumes in m^3/day, and levels in metres) (+ into Pit1, - Out of Pit1)	IN		OUT
Seepage Face	0	Seepage Face	7257
Evapotranspiration	0	Evapotranspiration	351
Recharge	4601	Recharge	0
Sub-surface Inflow	3553	Sub-surface Outflow	546
Total IN	8154	Total OUT	8154
In-Out	-0.05	Percent Error	-0.06%

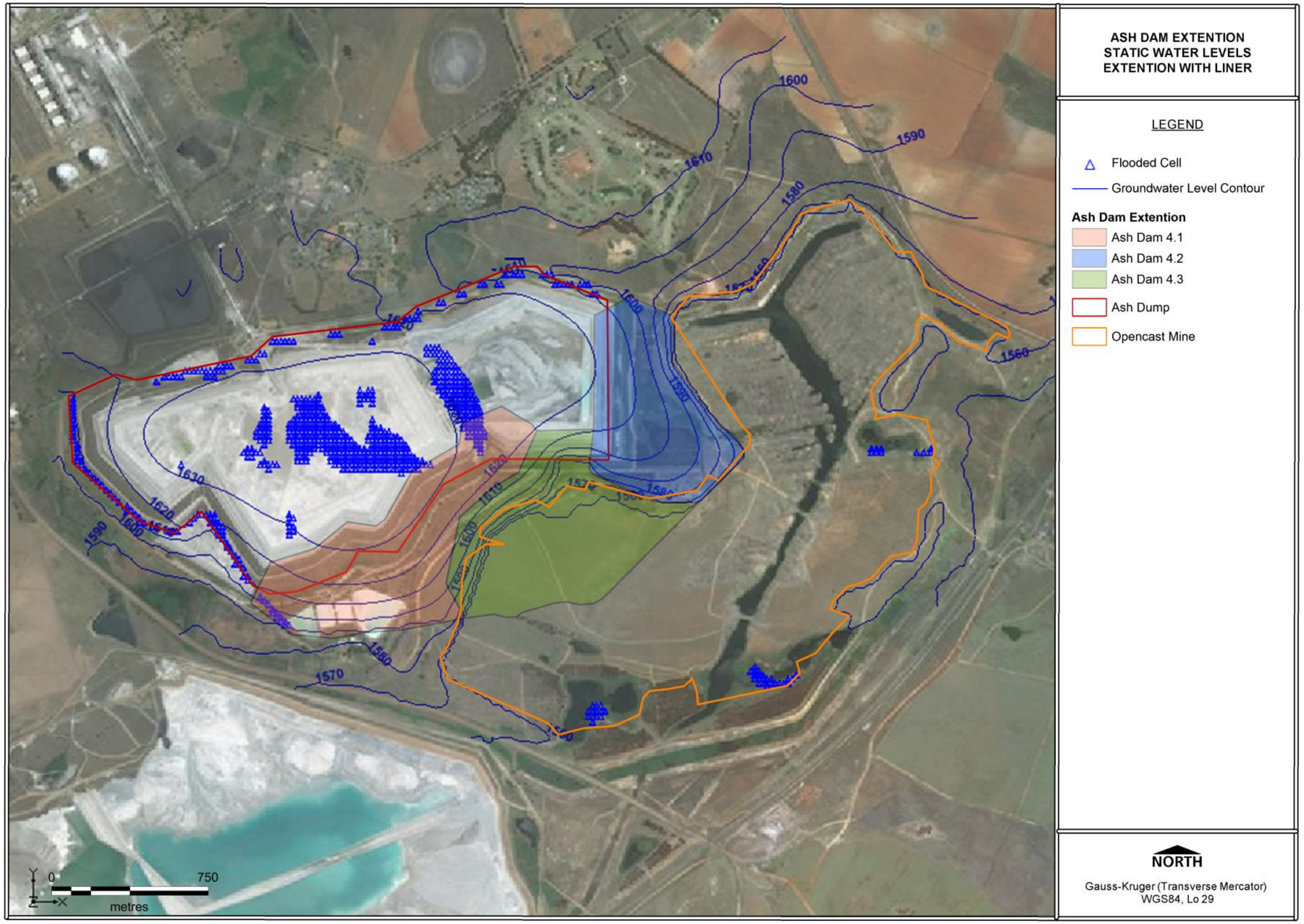

Figure 20: All ash dams operational and liner under new dam – water levels

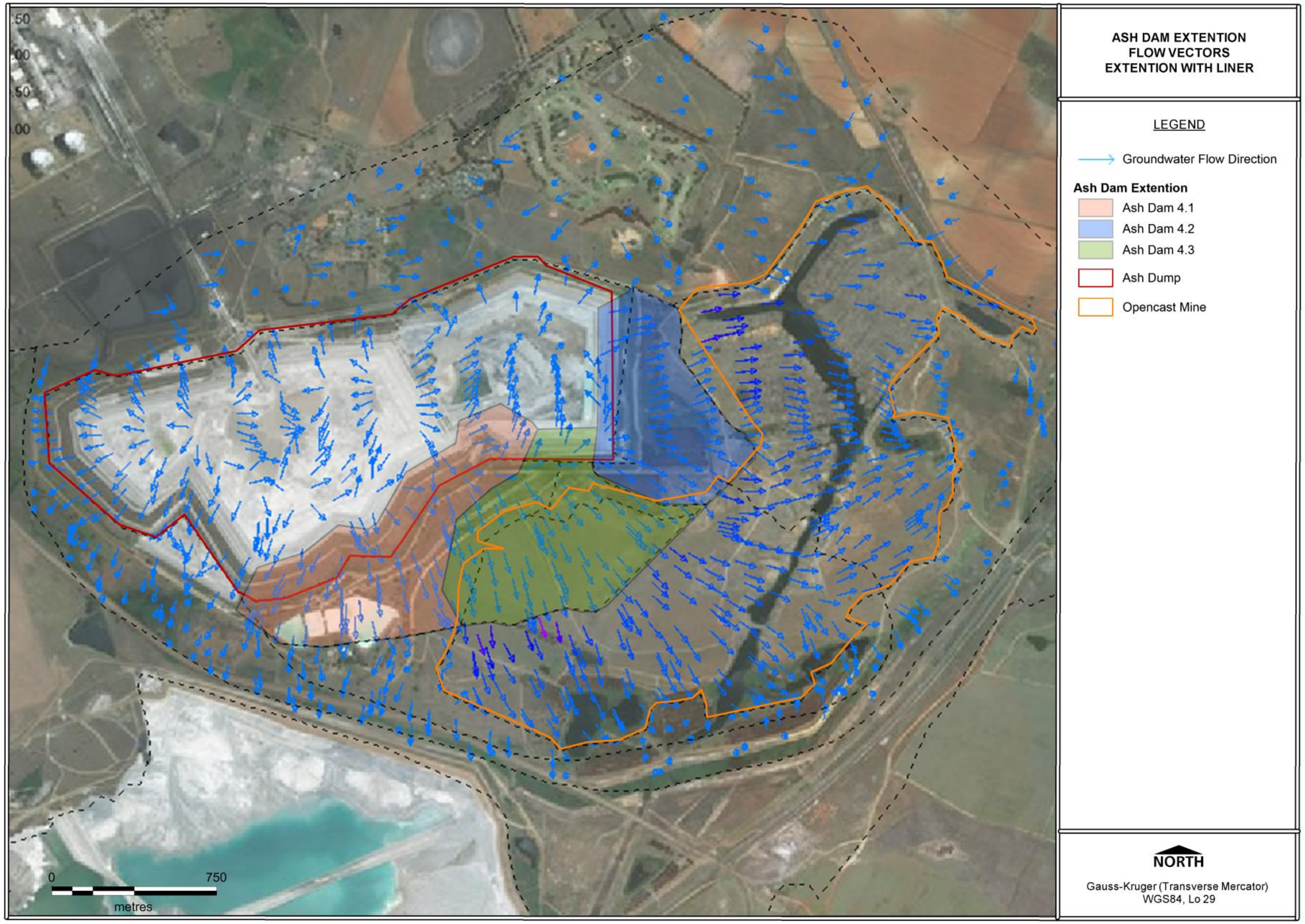

Figure 21: All ash dams operational and liner under new dam - flow of groundwater

9.3 Current Ash Disposal Facility and New AD4.1 and AD4.2 Operational with Leaking Liners

It was seen in the previous paragraph that the impacts on the groundwater of the lined AD4.1 and AD4.2 are insignificant. The logical remaining question is thus what the impact of leaking liners would be.

To model thus scenario, the hydraulic conductivity was increased tenfold, and the model rerun. Surprisingly, the result indicated neither a significant increase in groundwater levels, nor in-flow towards the decant area. Inspection revealed that normal processes such as recharge, as well as flow from the current ash disposal facility, are the main sources of water to the opencast. Therefore, the slight increase of infiltration from the new AD4.1 and AD4.2 do not affect the eventual amount of water to the defunct opencast to any significant degree.

To better illustrate this affect, the hydraulic conductivity of the liners were subsequently increase by another order of magnitude, thus increasing seepage from this dam 100-fold. The results are shown in Figure 22 to Figure 23. It is clear that no significant changes in groundwater flow patterns are observed. It is thus concluded that the impact to the groundwater is relative insensitive to slight leaking of the liners.

For completeness, the flow budget is shown below. It is clear from the numbers that the difference from the previous scenario is in detail only.

Table 10: Flow budget for Pit1 with all ash dams operational and leaking liner

Flow Budget For Pit1 (volumes in m^3/day, and levels in metres) (+ into Pit1, - Out of Pit1)	IN		OUT
Seepage Face	0	Seepage Face	7257
Evapotranspiration	0	Evapotranspiration	351
Recharge	4601	Recharge	0
Sub-surface Inflow	3553	Sub-surface Outflow	546
Total IN	8154	Total OUT	8154
In-Out	-0.03	Percent Error	-0.04%

This is further illustrated in Table 11 below. It is inferred from the table that an intact liner and a slightly leaking liner have virtually the same outflows. The reason for that is that the difference in hydraulic conductivity between the two scenarios (10^{-5} to 10^{-7} m/d) is not significantly different compared to the bedrock hydraulic conductivity of 10^{-2} m/d. However, if there should be no liner, the outflow to especially bedrock, is considerably larger, as can be expected.

Table 11: Flow from New Ash Dams under varying liner scenarios

Flow from new ash dams (m^3/day)	Intact Liner	Slightly leaking Liner	No Liner
Drains	2778	2775	2422
ET	223	222	199
New TSF to bedrock	5	9	462
New TSF to opencasts	159	159	144
New TSF to current ash dam	27	27	26

9.4 Limitations of the Modelling Exercise

The modelling was done within the limitations of the scope of work of this study and the amount of monitoring data available. Although all efforts have been made to base the model on sound assumptions, the results obtained from this exercise should be considered in accordance with the assumptions made. Especially the assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REF, Representative Elemental Volume) this assumption should hold reasonable well.

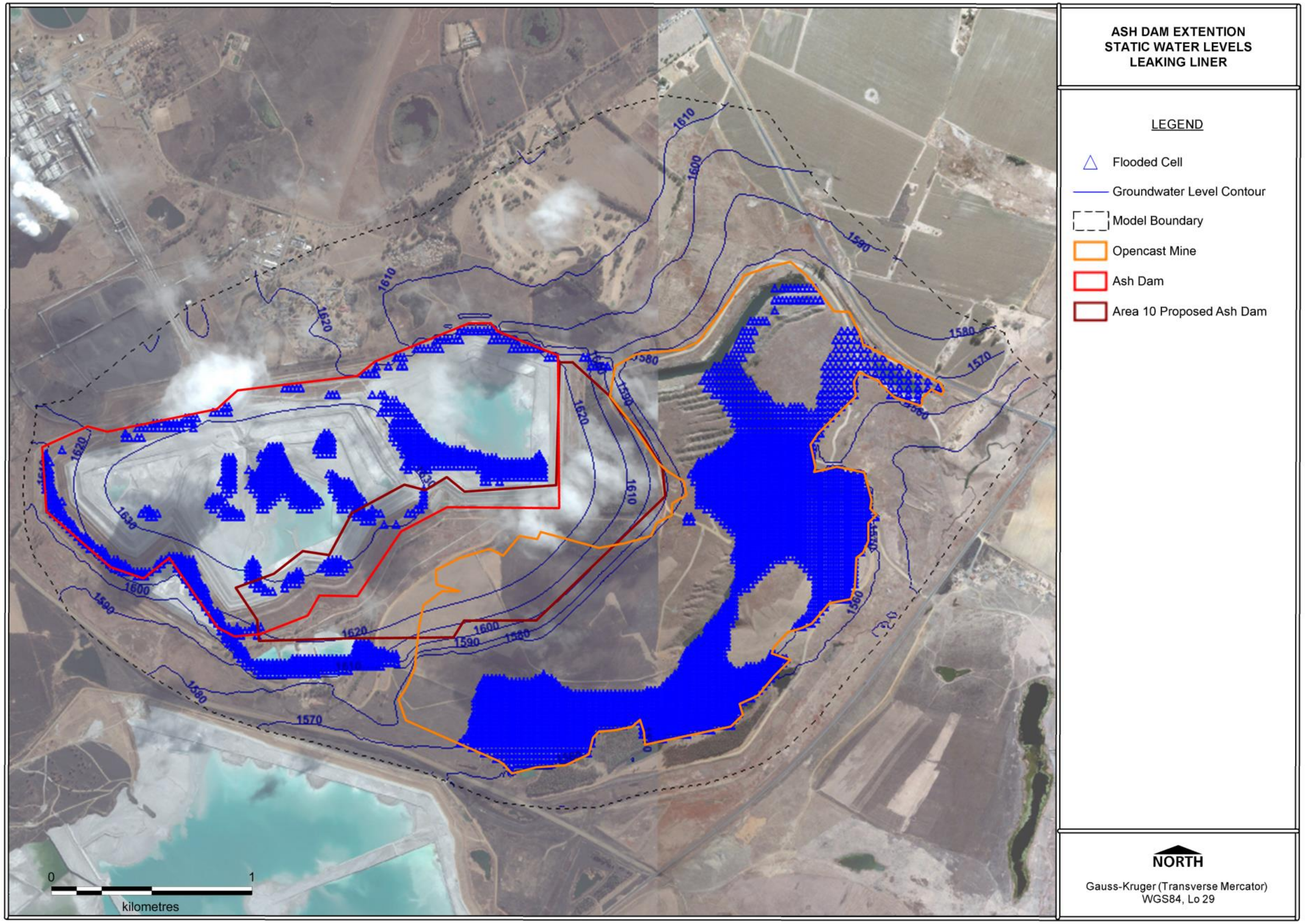

Figure 22: All ash dams operational and leaking liner – water levels

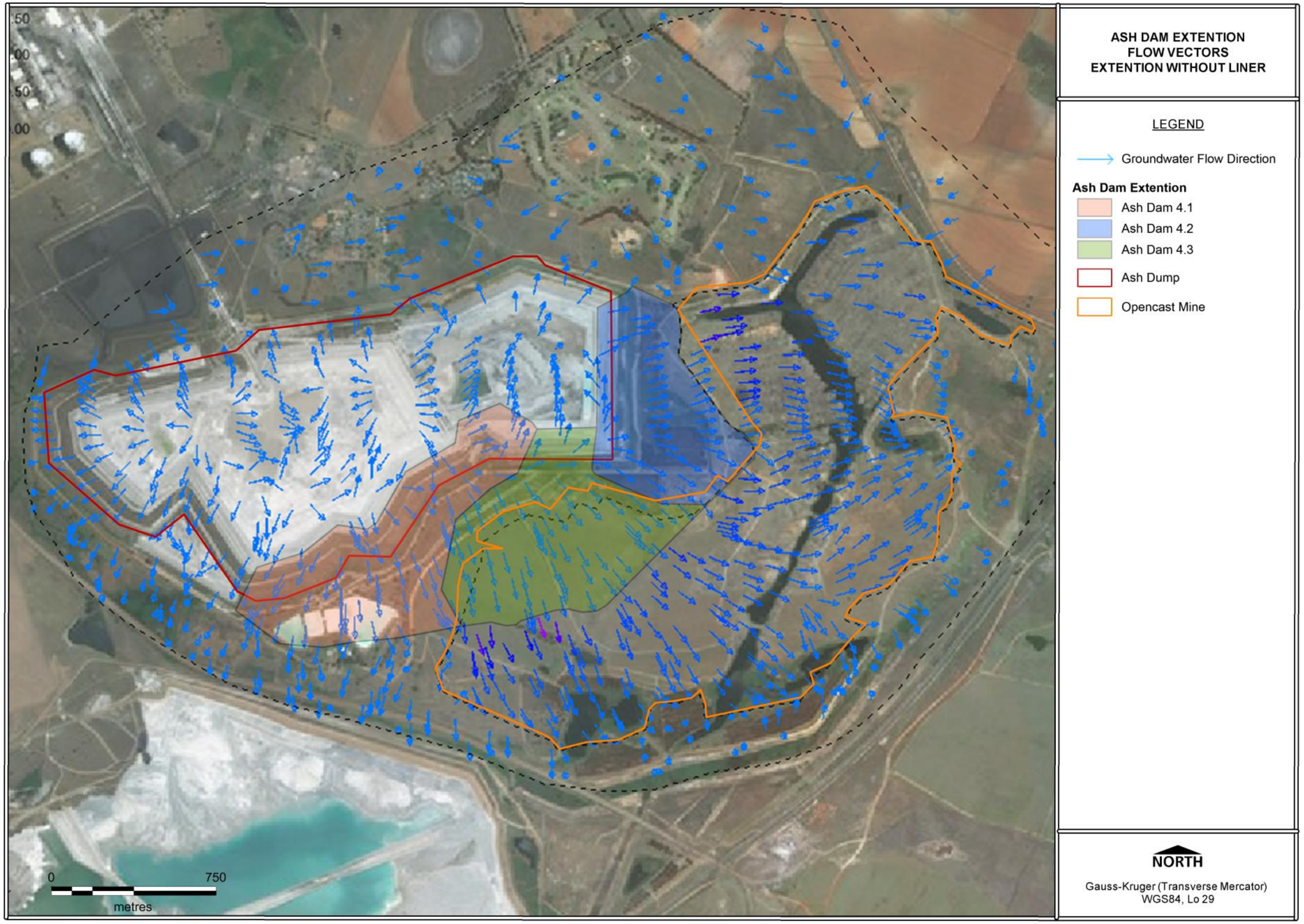

Figure 23: All ash dams operational and leaking liner - flow of groundwater

9.5 Quantification of Significance of Geohydrological Impacts

Impacts were quantified (Appendix A in Section 16) according to the methodology described in section 4.6 and using predictions from the modelling exercise.

As has been shown in the detailed groundwater analyses, the main sources of pollution to the groundwater are expected to be:

1. Hydrocarbon (mainly oil and diesel) pollution during the construction phase
2. Inorganic (e.g. sulphate, chloride) pollution during operation
3. Hydrocarbon (again oil and diesel) pollution during the decommissioning phase
4. Decanting of Pit1 during the construction, operation and decommissioning phases.

Cumulative groundwater impacts are envisaged as mining operations (both opencast and underground) in close proximity to the project area already had a detrimental impact on the groundwater environment both in terms of quality and the regional groundwater table.

The following background and assumptions should be noted:

- This report is a follow-up report on the original ash dam design which extended over the backfilled opencast which indicated medium to high groundwater impacts, and had to be mitigated. This report specifically deals with the mitigated new design.
- The baseline for this assessment is the current operational ash disposal facility which was not lined before. All impacts of AD4.1 and AD4.2 were thus judged over and above the current situation.
- It is only the decant water that could spread to a regional extent due to surface water transport of pollutants. However, this can be mitigated through the decant control mechanisms currently in place.
- The disposal of wet fly ash could marginally increase the pollution emanating from AD4.1 and AD4.2 for a temporary period during construction. However, the deposit from AD4.1 and AD4.2 would most likely be a dry deposit, and can thus be mitigated.

The only long term impact is the pollution plume spreading from the ash dams. The marginal contribution of the lined AD4.1 and AD4.2 are judged to be insignificant in comparison to the existing plume.

9.5.1 Groundwater Pollution by Organic Substances

The significance of the groundwater being polluted by hydrocarbon spillages can be rated as “very low” during construction, operation and the decommissioning phase before, and after mitigation.

9.5.2 Groundwater Pollution by Inorganic Substances

The significance of the groundwater being polluted by inorganic substances can be rated as “medium” during the operation phase without mitigation. If mitigation measures are put in place significance of the impact can be rated as “low”.

During the decommissioning phase the impact can be rated as “low” before, and after mitigation.

9.5.3 Decanting of Pit1 during the construction, operation and decommissioning phases.

The significance of the groundwater decanting can be rated as “low” during construction and the decommissioning phase and “medium” during the operational phase. The impact can be rated as “low” for all 3 phases after mitigation.

SECTION 10

MONITORING PROGRAM

10 MONITORING PROGRAM

A groundwater monitoring network has been developed incorporating boreholes identified during the hydrocensus and all newly drilled boreholes. The boreholes to be incorporated into the monitoring network at Site 10 are listed in Table 12 and coordinates of the boreholes listed in Table 13. A map indicating the location of the monitoring boreholes are presented in Figure 24. It is important to note that a groundwater-monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

Table 12: Monitoring boreholes at Site 10

BH nr.	Description	BH nr.	Description
Ashing Area		**Pit 1 Area**	
KB05D	Between the existing ash disposal facility and AWR Dams	KB12S	East of Pit 1 edge of spoils next to the gravel road
KB05S	Between the existing ash disposal facility and AWR Dams	KB67	East of Pit 1 edge of spoils next to the gravel road
KB06D	Next to the entrance of the Ash Office	KB68	East of Pit 1 edge of spoils next to the gravel road
KB06S	Next to the entrance of the Ash Office	KB16	South of Pit 1 near haulage road
KB63	Southeast of the existing ash disposal facility	KB18D	East of Pit 1 between spoils and Onverwacht Spruit
KB64	Southeast of the existing ash disposal facility	KB18S	East of Pit 1 between spoils and Onverwacht Spruit
KB08D	Southern side of Ash Dam Extension	KB19	Between Cut1 and Cut2 inside spoils
KB08S	Southern side of Ash Dam Extension	KB20	Between Cut1 and Cut2 inside spoils
KB61	Eastern side of Ash Dam Extension	KB28	West of Pit 1 between Pit 1 and RWD
KB62	Eastern side of Ash Dam Extension	KB29	East of Pit 1 between spoils and Onverwacht Spruit
KB10D	Next to dam KP16 in game reserve	KB30	South of Pit 1 near haulage road
KB10S	Next to dam KP16 in game reserve	KB69	East of Cut2 on edge of spoils
KB65	South west of the existing ash disposal facility	KB70	East of Cut2 on edge of spoils
KB35	South of the existing ash disposal facility	KB38	East of Cut2 inside spoils
		KB39	South of Cut 2 next to the spoils
		KB40	East of Cut2 inside spoils
		KB41	Into Cut 1 filled with ash
		KB42	West of Cut 1 inside spoils

Table 13: Coordinates (decimal º, WGS84) of monitoring boreholes at Site 10

BH nr	S	E
KB05	29.19194	26.27582
KB06	29.19116	26.27917
KB08	29.20328	26.27138
KB10	29.19810	26.26208
KB12	29.21666	26.27690
KB16	29.20299	26.28380
KB18	29.22175	26.27352
KB19	29.20675	26.27628
KB20	29.20997	26.27573
KB28	29.19406	26.27962
KB29	29.22226	26.27321
KB30	29.20042	26.28287
KB35	29.18413	26.27602
KB38	29.21797	26.27522
KB39	29.21365	26.28114
KB40	29.21660	26.27187
KB41	29.20475	26.27570
KB42	29.20257	26.27410
KB61	29.18590	26.26384
KB62	29.20543	26.26930
KB63	29.20545	26.29340
KB64	29.19613	26.27287
KB65	29.18045	26.27332
KB67	29.18733	26.25520
KB68	29.21942	26.27591
KB69	29.21640	26.27787
KB70	29.21643	26.27791

Water samples must be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Samples should be analysed for both organic as well as inorganic pollutants, as vehicle activities often lead to hydrocarbon spills in the form of diesel and oil.

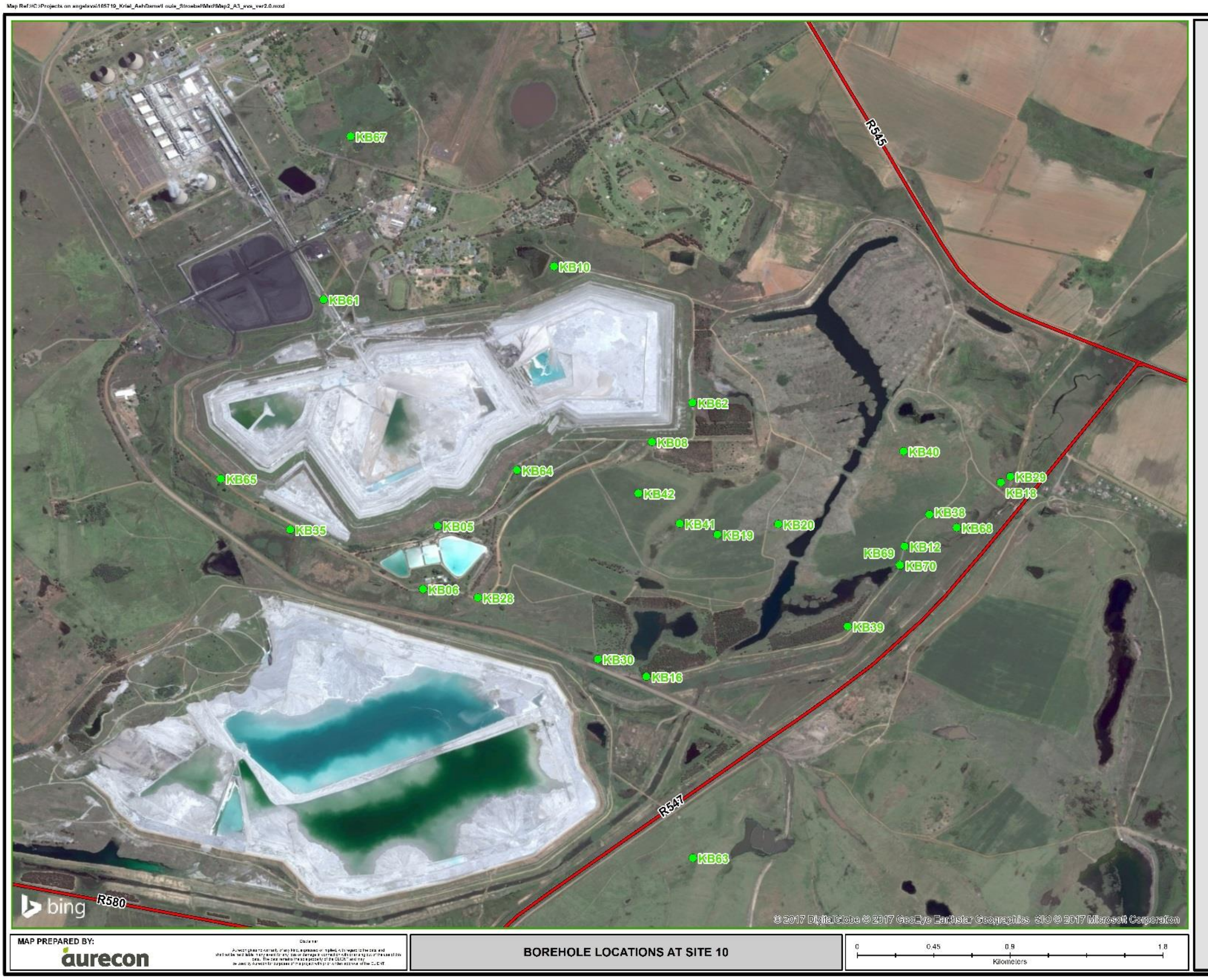

Figure 24: Map indicating location of monitoring boreholes.

Table 14 below presents the parameters and frequency that should form part of the groundwater monitoring program.

These results should be recorded on a data sheet. It is proposed that the data should be entered into an appropriate database and reported annually to the DWS.

Figure 24: Map indicating location of monitoring boreholes.

Table 14. Proposed monitoring requirements

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Monthly	Time dependant data is required for transient calibration of numerical flow models. Changes in static water levels may give early warning of dewatering in the area.
	Rainfall	Daily	Recharge to the saturated zone is an important parameter in assessing groundwater vulnerability. Time dependant data is required for transient calibration of numerical flow models.
	Groundwater abstraction rates if present	Monthly	Response of groundwater levels to abstraction rates can be used to calculate aquifer storativity – important for groundwater management.
Chemical	Major chemical parameters: Ca, Mg, Na, K, NO_3, SO_4, Cl, Fe, Alkalinity, pH, EC TPH (Total Petroleum Hydrocarbons)	Quarterly	Background information is crucial to assess impacts during operation and thereafter. Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. Legal requirement. Groundwater chemistry forms an integral part of the development of conceptual models.
	Minor chemical constituents Full scan of trace metals	Quarterly	Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. Legal requirement.
	Other Stable isotopes	Ad hoc basis	The monitoring program should allow for research and refinement of the conceptual geohydrological model. This may, from time to time, require special analyses like stable isotopes.

SECTION 11

MANAGEMENT FRAMEWORK

11 MANAGEMENT FRAMEWORK

It is stated in several Department Water and Sanitation (previously Department of Water Affairs) publications, such as main policy documents[17], requirements of waste handling[18] and pollution prevention guidelines[19], that waste should be reduced to the minimum and pollution should preferably be prevented at the source. Should this fail, impacts must be minimised by reuse, reclamation and treatment. In the last instance, waste water can be discharged on a risk based approach, but at the cost of polluter pays principle. This framework is drafted to address and adhere to these principles.

Objectives:

- Minimisation of waste.
- Contain pollution as far as is practicably possible on AD4.1 and AD4.2.
- Reduce the level of contamination outside the boundaries of AD4.1 and AD4.2.
- Adopt a user driven approach for the ground water quality.
- Implement a suitable ground water monitoring programme.

[17] Department of Water Affairs and Forestry, Number W.1.0: First Edition 2000. Policy and Strategy for Groundwater. Quality Management in South Africa.

[18] Department of Water Affairs and Forestry, Second Edition, 1998. Waste Management Series. Minimum Requirements for Water Monitoring as Waste Management Facilities.

[19] Department of Water Affairs and Forestry, 2007. Best Practice Guideline H2: Pollution Prevention and Minimisation of Impacts.

Objectives	**Mitigation intended**	**Actions**	**Responsible Person**
Minimising of ash waste to be disposed on ash dam	Alternative disposal options	Investigate the possibility of underground storage by appropriate mixing ash with cement and disposing in closed underground areas in close vicinity of the power station site.	Design team
Containment of pollution on ash dam	Contain pollution as far as is practicably possible on the ash dam.	Ensure that AD4.1 and AD4.2 are equipped with a suitable lining and seepage interception system.	Design team
Reduction of the level of contamination outside the ash dam.	Prevent deterioration of groundwater quality in the opencast.	Install suitable seepage monitoring systems below the lining of AD4.1 and AD4.2 and procedures for correction in the event of leakage.	Design team Hydrogeologists
Verify the impact of the activities on the groundwater environment.	Implement a ground water monitoring programme.	• Monitor the water quality and water levels of the sampling points as mentioned in Section 10. • Assess the groundwater water quality inside, upstream and downstream of AD4.1 and AD4.2 annually, and recommend mitigation measures if needed. • Audit the suitability of monitoring network annually. • Maintain the groundwater water monitoring network.	Environmental Officer. Hydrogeologist
	General	• Address the concerns and complaints of affected parties regarding the ground water issues. • All remedial action should be done in close liaison with the Department of Water and Sanitation. • The liabilities and proposed preventative and remedial actions will also have to be quantified. • Ensure that all surface water and storm water related EMPr's are adhered to.	Environmental Officer

SECTION 12

KNOWLEDGE GAPS

12 KNOWLEDGE GAPS

The understanding of interaction of alkaline water from the ash disposal facility and acidic water in the opencast pit, could be very important in the long term, and is considered worth further investigating.

At the time of the study very little information was available on these sources of water and it was also outside the scope of work of this particular study. Nevertheless, it is considered a knowledge gap of significance and it is thus suggested that the following advanced studies be undertaken as soon as feasible as it could even influence the final placement of ash and/or design of AD4.1 and AD4.2:

- As relatively sparse data have been available on ash hydraulic characteristics, an investigation on the in-situ ash character is strongly recommended, taking the effects of layering into account.
- An investigation should be done on the most likely quality of water in the opencast pit after equilibrium have been reached post closure.

SECTION 13

CONSULTATION AND COMMUNICATION

13 CONSULTATION AND COMMUNICATION

The following personnel from Kriel Colliery were consulted to source mining & geology plans and environmental data (borehole data, chemistry, etc.) used in the study:

- Mr Alan Walters (Survey Manager)
- Mrs Dolly Mthethwa (Environmental Coordinator)
- Mr Johan Coetsee (Geologist)

SECTION 14

CONCLUSION

14 CONCLUSION

However, in this study it was found that the construction of AD4.1 and AD4.2 with liners are very effective to contain additional impacts, and that only an additional amount of water will be added to the current decant volume.

What could also be important is that the pH of ash dam water is characteristically higher than that of an opencast. It is thus very likely that the water draining from the entire ash disposal facility to the opencast below will rather increase the buffer capacity of the opencast backfill and reduce AMD in the long term. Thus, the siting of an ash dam in close proximity of an opencast could be beneficial if planned correctly.

SECTION 15

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15 REFERENCES

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SECTION 16

APPENDICES

APPENDIX A

IMPACT ASSESSMENT MATRIX

APPENDIX B

RÉSUMÉS

APPENDIX C

DECLARATION OF INDEPENDENCE

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/ or 12/9/11/L
NEAS Reference Number:	DEA/EIA
Date Received:	

Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 921, 2013

PROJECT TITLE

INTEGRATED ENVIRONMENTAL IMPACT ASSESSMENT:
PROPOSED EXPANSION OF ASH DISPOSAL FACILITY, KRIEL POWER STATION, MPUMALANGA

Specialist:	Aurecon (Hydrogeology)		
Contact person:	Louis Strachel		
Postal address:	PO Box 74381, Lynnwood Ridge		
Postal code:	0040	Cell:	082 857 9488
Telephone:	012 427 3151	Fax:	086 606 0346
E-mail:	louis.strachel@aurecongroup.com		
Professional affiliation(s) (if any)	SACNAS		

Project Consultant:	Aurecon South Africa (Pty) Ltd		
Contact person:	Franci Gresse		
Postal address:	PO Box 494, Cape Town, South Africa		
Postal code:	8000	Cell:	082 8912384
Telephone:	021 5266022	Fax:	086 7231750
E-mail:	Franci.Gresse@aurecongroup.com		

4.2 The specialist appointed in terms of the Regulations_

I, Louis Stroebel, declare that --

General declaration:

I act as the independent specialist in this application;
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, Regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

Aurecon SA (Pty(Ltd

Name of company (if applicable):

24 July 2017

Date:

delta h
WATER SYSTEMS MODELLING

Contact: +2772 506 1343 / +2782 497 9088 / +2782 043 8075
kai@delta-h.co.za / martin@delta-h.co.za / helen@delta-h.co.za
www.delta-h.co.za
PO Box 66662
Woodhill
0076
Pretoria, South Africa

28 June 2017

DELTA-H REVIEW OF AURECON REPORT:

GEOHYDROLOGICAL EVALUATION FOR THE ENVIRONMENTAL IMPACT ASSESSMENT DOCUMENT NUMBER 113084 V1.0 2016

To whom it may concern:

Delta-H undertook an independent specialist peer review of the Geohydrological Evaluation, including the groundwater model prepared for the Project no. 113084 – Kriel ash dam extension in order to confirm the rigour of the modelling section of the report only and the developed model in informing the assessment of the potential groundwater effects of ash dam extension on predicted decant rates.

During the review, Delta-H engaged the Aurecon hydrogeologist on the following technical aspects of the report:

- Model Setup;
- Model Calibration;
- Water Balances;
- Predictive Scenarios; and
- Model Results.

Following correspondence between Delta-H and the Aurecon hydrogeologist on these aspects of the model and the report, Delta-H is satisfied that the model and report satisfactorily predicts potential changes to groundwater characteristics; primarily decant rates, at the project site due to the proposed extension of the ash dam.

Yours faithfully,

Prof Kai Witthüser (Pr.Sci.Nat.)