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**REPORT ON**

# Source-Pathway-Receptor study for the Kendal Power Station's existing Ash Disposal Facility

**Report No :** 17126

**Submitted to :**

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# LIST OF ACRONYMS

| Abbreviation | Full Description |
|---|---|
| Al | Aluminium |
| Sb | Antimony |
| As | Arsenic |
| ADF | Ash Disposal Facility |
| ASLP | Australian Standard Leaching Procedure |
| Ba | Barium |
| B | Boron |
| CaO | Calcium Oxide |
| Cl | Chlorine |
| Cr | Chromium |
| Cr VI | Chromium VI |
| Co | Cobalt |
| COCs | Contaminants of Concern |
| Cu | Copper |
| DEA | Department of Environmental Affairs |
| DWAF | Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation |
| EIS | Ecological Importance and Sensitivity |
| EC | electrical conductivity |
| EAP | Environmental Assessment Practitioner |
| EA | Environmental Authorisation |
| EIA | Environmental Impact Assessment |
| Eskom | Eskom Holdings SOC Ltd |
| F | Fluoride |
| GCL | Geosynthetic Clay Liner |
| GHS | Globally Harmonised System |
| GN | Government Notice |
| HQ | hazard quotient |
| IUA | Integrated Units of Analysis |
| IWQMP | Integrated Water Quality Management Plan |
| KPS | Kendal Power Station |
| LC | Leachable Concentration |
| LCT | Leachable Concentration Threshold |
| Pb | Lead |
| LF | Load Factor |
| MU | Management Units |
| Mn | Manganese |
| MAP | Mean Annual Precipitation |
| MW | megawatt |
| Hg | Mercury |
| mbgl | metres below ground level |

| Abbreviation | Full Description |
|---|---|
| Mt | Million tons |
| Mo | Molybdenum |
| NEMA | National Environmental Management Act, 1998 (Act No. 107 of 1998) |
| NEMWA | National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) |
| NWMS | National Waste Management Strategy |
| Ni | Nickel |
| NO3 | Nitrate |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PES | Present Ecological State |
| RMD | Relative Abundance of Monovalent and Divalent Cations |
| RSA | Republic of South Africa |
| RQO | Resource Quality Objectives |
| RWQOs | Resource Water Quality Objectives |
| Se | Selenium |
| SSL | Soil Screening Levels |
| SSVs | Soil Screening Values |
| SPR | Source-Pathway-Receptor |
| SANS | South African National Standard |
| SAWQG | South African Water Quality Guidelines |
| SO4 | Sulphate |
| TWQR | Target Water Quality Range |
| TC | Total concentration |
| TCT | Total Concentration Threshold |
| TDS | total dissolved solids |
| V | Vanadium |
| WML | Waste Management Licence |
| WMA4 | Water Management Area |
| WQPL | Water Quality Planning Limits |
| WUL | Water Use Licence |
| WULA | Water Use Licence Application |
| Zn | Zinc |

# 1 INTRODUCTION

Zitholele Consulting was appointed by Eskom Holdings SOC Limited to conduct a Source-Pathway-Receptor (SPR) study for the extension of the Kendal Power Station's existing Ash Disposal Facility (ADF). The said study was commissioned to support a motivation to the Department of Water and Sanitation (DWS) relating to possible substitution of the currently authorised Class C barrier system for the future extension of the ADF with a less rigorous barrier system that could nonetheless offer equal or better protection from pollution to the environment.

## 1.1 Project Background

The last unit of the Kendal Power Station (KPS) became operational in 1993, eleven (11) years after construction of the Power Station commenced. Boasting as the world's largest coal-fired Power Station and holding several Eskom performance records, KPS can be regarded as one of Eskom's flagship projects. KPS's cooling towers are the largest structures of their kind in the world with a base diameter of 165 metres.

KPS has an indirect dry-cooling system that uses a closed system to circulate water within its cooling towers. The advantage of this closed system is that there is little loss of water due to evaporation and the system utilises less water in its cooling processes than conventional wet cooled Power Stations. Ash generated through the coal-burning process is transported per conveyor belt system to the KPS ADF where it is disposed through a duel stacker system. The development of the ADF occur in a phased approach where only a portion of the ADF footprint is prepared at a time large enough to allow operation of the duel stacker systems concurrently.

The existing ADF utilised by KPS for the disposal of ash from the electricity generation process is running out of capacity. This is, primarily, due to the KPS life span being extended from 40 to 60 years up to 2053, plus a 5-year contingency up to 2058, thereby requiring the construction of a continued and/or new ADF footprint to address disposal of ash for the next +/- 40 years. Therefore, in order to provide sufficient space to cater for ash generated during the extended lifespan of the power station, Kendal Power Station requires a new additional facility with an approximate footprint of 310 hectares and with a height of 60m, to accommodate an ash volume of 103 Million $m^3$. The full extended ashing area required therefore comprises of the extended current footprint and a new ADF site. The extended current footprint in this context refer to the existing ADF footprint as well as an authorised extension of the ADF footprint area towards the northwest of the existing ADF. This extended ADF footprint is referred to as the "Continuous ADF".

KPS is expected to be decommissioned at the end of 2053. The Conceptual Engineering Designs show that ash may be accommodated at the proposed Continuous ADF up to approximately 2030. Thereafter an alternative / supplementary site will be required for the disposal of ash for the remaining period up to the end of 2053, excluding consideration of the 5-year contingency period that will require disposal up to 2058 (Zitholele Consulting, 2014a).

Eskom commissioned an integrated Environmental Assessment process to extend the existing ADF to enable the station to cater for ash that will be generated from the electricity generation process (coal burning) from the year 2031 to 2058 – approximately 27 years (Zitholele Consulting, 2016a). According to Condition 17.2 of the Integrated Environmental Authorisation that was issued on 28 July 2015, "*Any development on the site must adhere to a Class C containment barrier design as described in Regulation 636, National Norms and Standards for Disposal of Waste to Landfill dated 23 August 2013*."

Taking the aforementioned into account the extent of the proposed KPS Continuous ADF footprint will have a bearing on the remaining required capacity of the additional ADF. The environmental authorisation process for the additional ADF was undertaken as a separate process (Zitholele Consulting, 2016a), and is currently pending the outcome of a wetland offset investigation, prior to submission to the Department of Environmental Affairs (DEA) for decision-making. Allowing for the maximum footprint of the proposed KPS Continuous ADF, and therefore disposal capacity, may result in a reduced footprint of the additional required ADF.

## 1.2 Objectives of the SPR study

The objective is to undertake a Source-Pathway-Receptor study and environmental risk assessment in order to support the motivation for the consideration of an appropriate liner design that would provide the same or better level of protection to water resources as the currently required Class C liner.

Existing and potential liabilities from the Kendal Continuous ADF will be identified to motivate for appropriate feasible alternative design to the full Class C barrier system. Surface water and Groundwater contamination and the resulting risk to offsite receptors is the specific liability that will be addressed by the SPR study. The SPR study will address the potential impact generated from the ADF footprint, considering the compliant design with a liner per Class C barrier system layout and an appropriate design for environmental protection.

## 1.3 SPR Approach

Fundamentally, Source-Pathway-Receptor (SPR) assessment and modelling aims to quantify cause and effect relationships between sources of contamination and (potential) receptors of contamination by considering relevant pathways and exposure mechanisms. The diagram below graphically depicts the mechanism involved

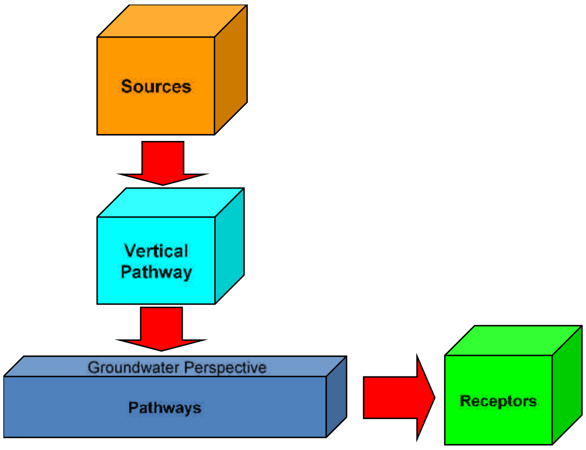


**Figure 1-1: Source Pathway Receptor (SPR) Mechanism**

## 1.4 Terms of Reference

The key tasks for this scope of work are as follows:

1. Source-Pathway-Receptor Characterisation – which will include:
   - Source characterisation. The objective of this task is to develop source-terms which indicate the mass of selected contaminants leaving a source over time.
   - Pathway characterisation. An understanding of the site hydrogeology through interpretation of existing hydrocensus results, updating of existing conceptual hydrogeological model, and development of numerical flow and contaminant transport model.
   - Receptor characterisation. The receiving environment comprises the aquatic ecosystems. The aquatic ecosystems will be characterised from existing baseline and detailed ecology surveys and reports and whole effluent toxicity testing.
   - Integration. Having characterised the sources, groundwater pathway and ecological/ social receptors, the information will be combined into an overall understanding of the surface water and groundwater impacts from the Kendal ADF.
2. Compile a numerical groundwater model for Kendal PS ADF from existing information.
3. Undertake high level conceptual designs for a maximum of 3 mitigation options that will provide the same or better environmental protection as the legislated barrier system design.

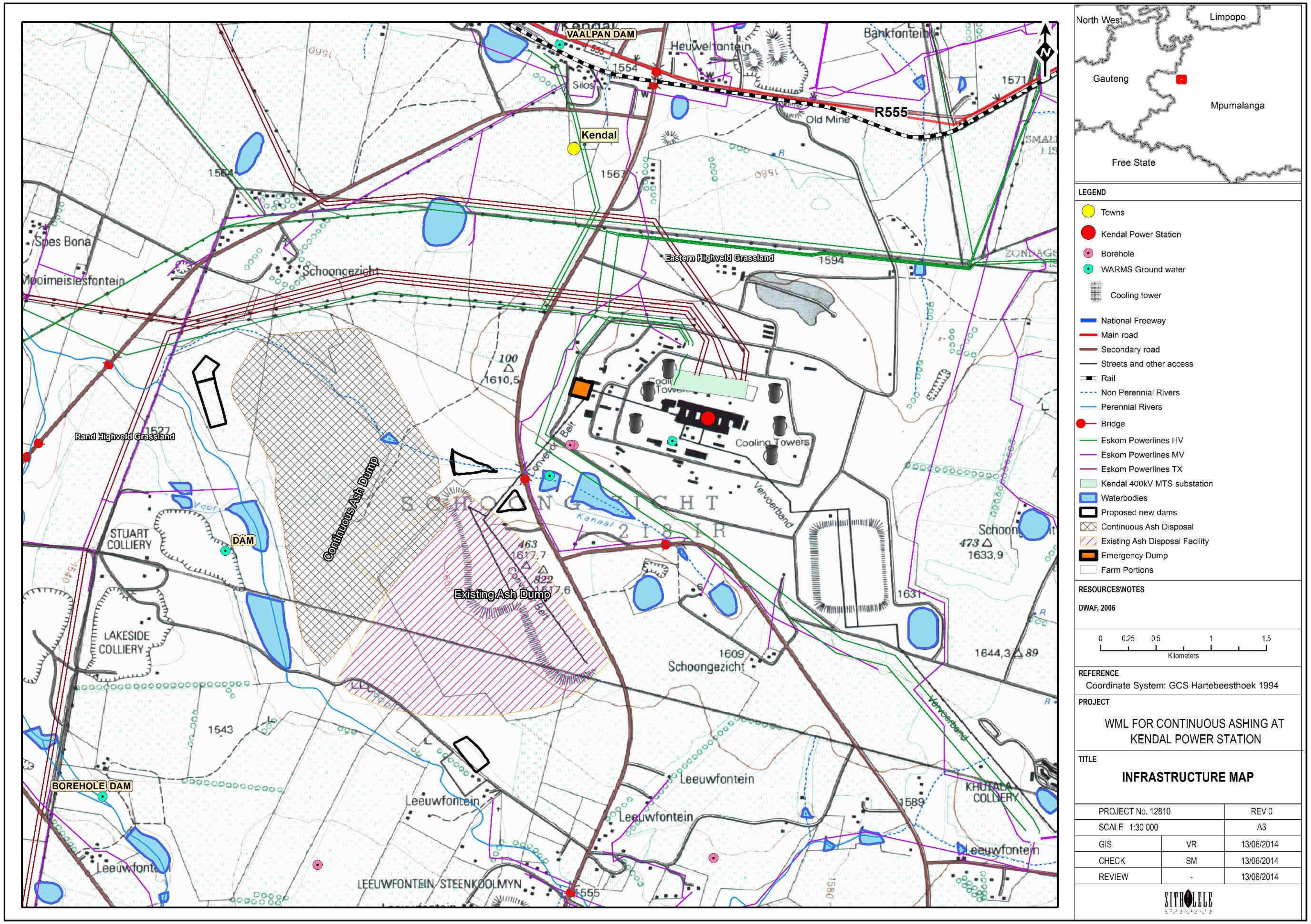


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**Figure 1-2: Locality map for Kendal Power Station**

### 1.5 Assumptions and Limitations

The following assumptions and limitations are applicable to this study:

- The high-level designs undertaken to support this SPR assessment comprise only of such detail required to facilitate discussions with DWS and DEA on the liner relaxation. These designs have therefore not been developed to engineering conceptual design specifications. These designs are only intended to support the SPR in confirming the appropriate liner design for protection of the environment. Engineering concept designs will therefore form part of a subsequent scope of work.
- Only existing reports, data and information relating to all aspects associated with the SPR study was utilised to undertake the numerical groundwater modelling and development of the SPR assessment report.
- Conclusions are drawn about the potential risks caused by the source of contamination. A set of assumptions based on the available information, are considered to reduce the real problem (pollution) and the real aquifer domain to a simplified version that is acceptable in view of the source-pathway-receptor geohydrological modelling and of the associated management problem. The conceptual model excludes any underground mining works and/or and surrounding surface activities (Open pit at the East of the project site). Using the reviewed information, the conceptual model is described with focus on the sources, pathways and receptors.
- A numerical model solves both complex and simple problems and serves as basis for the simulation of various scenarios. However, it should be reiterated that, as a simplified representation (approximation) of the real system, its level of accuracy is sensitive to the quality of the data that is available. Based on the available field data, the following assumptions have been made for the developed conceptual model:
    - The top of the aquifer is represented by the generated groundwater heads.
    - Averages of the distribution of the estimated parameters have been used as input of the model, and a homogenous and continuous aquifer system has been assumed. The complexities of fractured rock aquifers imply that the model can only be used as a guide to determine the order of magnitude of contaminant transport.
    - Where specific aquifer parameters have not been determined for some reason, text book values have been used, where applicable, considering typical hydrogeological environment, with reasonable estimates of similar hydrogeological environments.
    - The system is initially in equilibrium and therefore in steady state, even though natural conditions have been disturbed.
    - The boundary conditions assigned to the model are considered correct.
    - The impacts of other activities (mining, agriculture, etc...) have not been considered as such potential impacts could not be quantified or raw data obtained to consider potential pollution impacts resulting from potential upstream sources.
    - Potential preferential flow paths along the boreholes that exist at the footprint of the facility have not been considered. The locations, depths and characteristics of such preferential flow paths could not be confirmed from the information available during the study and as such could not be factored into the conceptual model.

- The complexities associated with flow and transport in aquifer systems (fractured, fractal, etc.) have not been considered as detailed analysis of the specific underlying aquifer systems was not available during the study. The aquifer conceptualizations provided in existing groundwater models were considered with site specific conditions such as lithology, groundwater level, aquifer parameters, topography and drainage to update the conceptual hydrogeological model. As groundwater flow and aquifer occurrence (development) are linked to the geology and structural features of an area, it was assumed that the surface geology forms the generalized basis on which the conceptual hydrogeological model is based spatially.

# 2 ASH AS A WASTE AND A RESOURCE

## 2.1 Ash production and beneficiation from Eskom coal fired power stations

Eskom Holdings SOC Ltd (Eskom) is the South African utility that generates, transmits and distributes electricity. Eskom generates electricity through the burning of coal. Burning of coal for electricity generation yields pulverised coal fired boiler ash and fly ash as a by-product. Historically, the large volumes of fly and boiler ash produced at power stations through the coal burning process were transported and disposed of at an Ash Disposal Facility (ADF) associated with each power station. Many of these facilities were not lined with a barrier system between the ash body and underlying ground. KPS is one of these power stations which do not have a barrier system installed below its current ADF. In the absence of a market demand for the large-scale utilisation and offtake of ash by commercial entities, as well as challenges with implementation of the waste hierarchy requirements, the disposal of ash over large areas, often spanning hundreds of hectares, is still common practice today.

Eskom operates a fleet of coal-fired power stations within three provinces in South Africa, with the Medupi and Kusile Power Stations partly operational at this time. The power stations are located within Mpumalanga, Free State and Limpopo provinces. It is estimated that the Eskom current coal fired power stations fleet (not considering Kusile Power Station) consume about 122 million tons of coal per year, producing approximately 42 million tons of pulverised coal fired boiler ash (Infotox, 2015). Lethabo, Kendal and Matimba produce the most ash as measured in Million tons (Mt) as is evident from **Figure 2-1**.

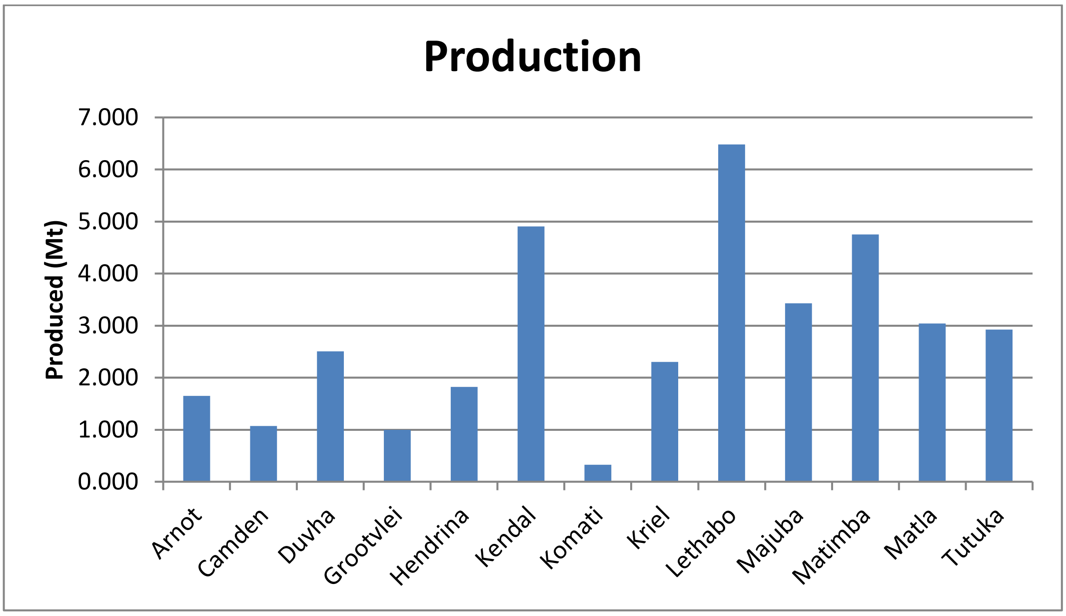


**Figure 2-1: Total ash production data for Eskom coal-fired power stations (Infotox, 2015)**

Multiple environmental benefits can be derived from beneficiation of ash in an environmentally responsible way. Not only will the footprint be limited, the utilisation of ash in new applications will reduce $CO_2$ emissions, acid mine drainage can be treated, and mine rehabilitation supported. Furthermore, the need for use of natural resources for the proposed applications will be reduced, negating the need for mining of these resources, and the associated environmental impact.

South Africa, however, has one of the lowest  ash utilisation rates in the world (Zitholele Consulting, 2016b). An assessment undertaken in 2015 (Infotox, 2015) found that only 6 power stations at the time of the assessment sold the ash produced to contracted commercial partners. Of the total amount of ash that was sold, Lethabo power station sold almost 50% (Infotox, 2015). The utilisation of coal ash is however still dominated by its application in the cement and concrete industries in South Africa (Infotox, 2015).

## 2.2 Characteristics of pulverised coal fired boiler ash

Pulverised coal fired boiler ash comprises of very fine, spherical and irregular shaped particles of different sizes. The spherical particles of ash could be hollow (cenospheres) or filled with smaller amorphous particles and crystals (plerospheres). Angular non-spherical phases are typically more refractory mineral phases such as quartz. The size of pulverised coal fired boiler ash particles typically range between 0.074 to 100 µm. Pulverised coal fired boiler ash in some cases has a smooth, hydrophilic surface and is extremely porous. Some particles are edgy and rough on a micro scale while others may be partly covered with a powder condensed from a vapour phase after solidification (Iyer & Scott, 2001) and sources referenced therein.

Ash particles are glassy and transparent due to the melting of the silicate materials during combustion (Young, 1993, as referenced in (Iyer & Scott, 2001)). The heating and cooling processes during coal combustion have a significant effect on the physical characteristics of ash. During combustion, at a very high temperature, the minerals in coal become fluid after which the minerals cool rapidly at the post-combustion zone. The rapid cooling in the post-combustion zone therefore results in the formation of spherical and amorphous particles of ash (Iyer & Scott, 2001), and referenced cited therein.

**Table 2-1: Mineral contents of pulverised coal-fired boiler ash from different Eskom power stations**

| Contituents of ash | Eskom Power Stations | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Arnot | Kriel | Camden 1E | Camden 18 | Duvha | Hendrina | Majuba | Matimba | Matla | Tutuka | Kendal | Lethabo | Komati | Grootvlei |
| $SiO_2$ | 56.05 | 48.84 | 52.62 | 52.52 | 53.01 | 54.38 | 51.29 | 58.46 | 50.19 | 56.67 | 51.54 | 54.65 | 51.31 | 50.64 |
| $Al_2O_3$ | 26.13 | 26.60 | 26.06 | 27.29 | 28.10 | 26.24 | 29.48 | 25.52 | 29.03 | 25.61 | 31.14 | 29.05 | 29.43 | 29.33 |
| $Fe_2O_3$ | 4.58 | 3.23 | 5.42 | 5.36 | 6.04 | 6.79 | 4.27 | 5.85 | 3.39 | 4.40 | 3.44 | 3.69 | 4.44 | 6.67 |
| $TiO_2$ | 1.51 | 1.55 | 1.64 | 1.64 | 1.51 | 1.52 | 1.67 | 1.24 | 1.53 | 1.33 | 1.68 | 1.52 | 1.73 | 1.89 |
| $P_2O_5$ | 0.38 | 0.98 | 0.58 | 0.69 | 0.81 | 0.65 | 0.60 | 0.45 | 0.78 | 0.23 | 0.77 | 0.38 | 0.57 | 0.49 |
| CaO | 5.13 | 10.54 | 6.06 | 5.27 | 4.70 | 4.90 | 5.89 | 3.25 | 7.32 | 5.08 | 5.41 | 4.29 | 6.15 | 5.25 |
| MgO | 1.74 | 2.20 | 1.42 | 1.42 | 1.38 | 1.50 | 1.45 | 1.07 | 2.14 | 1.69 | 1.72 | 1.23 | 1.88 | 1.06 |
| $Na_2O$ | 0.10 | 0.15 | 0.12 | 0.07 | 0.10 | 0.13 | 0.07 | 0.08 | 0.17 | 0.21 | 0.12 | 0.10 | 0.12 | 0.12 |
| $K_2O$ | 0.50 | 0.72 | 0.72 | 0.64 | 0.56 | 0.58 | 0.61 | 0.77 | 0.64 | 0.71 | 0.65 | 0.54 | 0.54 | 0.79 |
| $SO_3$ | 3.15 | 4.04 | 3.15 | 3.48 | 2.83 | 2.79 | 3.51 | 2.60 | 3.70 | 3.20 | 2.64 | 2.72 | 3.14 | 3.04 |
| MnO | 0.02 | 0.06 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.06 | 0.02 | 0.02 | 0.05 | 0.01 | 0.02 | 0.12 |

When chemical composition of pulverised coal fired boiler from different power stations was considered (**Table 2-1**), it was found that the predominant elements in the Eskom pulverised coal fired boiler ash include calcium, silicon, aluminium, iron and oxygen. Relatively lower amounts of elements include potassium, titanium and sulphur.

### 2.3 The pozzolanic effect of pulverised coal-fired boiler ash

As concluded by (Infotox, 2015) in the preceding section, it is not surprising that the utilisation of coal ash is still dominated by its application in the cement and concrete industries in South Africa given the pozzolanic properties of ash produced in South Africa.

The use of ash as a substitute material in the construction industry, including its use in cement and concrete products, lies in its Calcium Oxide (CaO) content. Depending on its CaO content, pulverised coal fired boiler ash can be referred to as either cementitious or pozzolanic (Yao, et al., 2015). According to Alejandra Tironi (2013, as referenced in (Yao, et al., 2015)), pozzolans are defined as "*a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties*". In other words, the pozzolans contained in ash in South Africa can react with water and free lime (calcium oxide) to produce a cement-like compound.

South African ash has mainly pozzolanic properties that increases its attractiveness relating to its use as substitute material for concrete (Yao, et al., 2015). Some of the benefits that was listed by several studies for the use of pulverised coal-fired boiler ash in cement production (cement block making) include the following:

- **Increased strength against natural weathering action:** Pulverised coal fired boiler ash concrete provides increased strength and stable protective cover to the steel against natural weathering action. Owing to the presence of cementitious compounds of calcium and a reactive glass, high-calcium ash is quite suitable in Portland cement products (Ahmaruzzaman, 2010);
- **Reduced permeability:** The use of pulverised coal fired boiler ash in concrete produces less permeability owing to the spherical particles, and therefore improved packing, i.e. a denser paste and pozzolanic reaction (Ahmaruzzaman, 2010).
- **Reduced Heat of Hydration:** In particular, when Class F ash is used lower heat of hydration is associated with a high percentage replacement of cement with pulverised coal fired boiler ash compared to straight Portland cement concrete. Heat of hydration refers to the heat that is generated when Portland cement is mixed with water (Ahmaruzzaman, 2010);
- **Increased resistance to corrosion:** ash increases resistance to corrosion, and ingress of corrosive liquids by reacting with calcium hydroxide in cement into a stable cementitious compound of calcium silicate hydrate (Ahmaruzzaman, 2010);
- **Reduced Carbon Dioxide Emissions:** Simulations indicate that including pulverised coal fired boiler ash in cement produces Carbon Dioxide ($CO_2$) emissions (Vargas & Halog, 2015). The reduced $CO_2$ emissions is owing to the omission of clinker avoided in

production when replacing with pulverised coal fired boiler ash (Vargas & Halog, 2015); and
- **Durability:** Studies have shown that ash-based geopolymer concrete has similar strength and durability properties to those of traditional cement concrete (Yao, et al., 2015).

Class F ash typically contains from 2%-6% percent calcium oxide and requires additional lime to obtain self-hardening properties, however, hardening of the ash body has been reported at some power stations.

## 2.4 Consideration of radioactivity of coal-fired boiler ash

From a radioactivity perspective, it was found that the ash is below the limit set for material to be considered as radioactive. Uranium and thorium have been found in ash, though the levels are considered insignificant in comparison to typical concentrations in soils or rocks. The presence of these radioactive elements is internationally noted as a concern, however (Singh, et al., 2010).

## 2.5 Classification of Kendal Power Station ash

The classification of Kendal Power Station's ash was undertaken in 2014 (Jones and Wagener, 2014). The Contaminants of Concern (COCs) were compared to the total concentration thresholds (TCT) and leachable concentration thresholds (LCT) detailed in the GN R. 635 of 2013 (National Norms and Standards for the assessment of waste for Landfill Disposal), and included, amongst others, Aluminium (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Boron (B), Cadmium (Cd), Chlorine (Cl), Chromium (Cr) (total), Chromium VI (Cr VI), Cobalt (Co), Copper (Cu), Fluoride (F), Lead (Pb), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Vanadium (V), Zinc (Zn), Polycyclic Aromatic Hydrocarbons (PAH), Sulphate ($SO_4$) and Nitrate ($NO_3$).

Kendal Power Station ash data was also compared to soil screening levels through consideration of stipulated Soil Screening Values (SSVs) detailed in the National Norms and Standards for the Remediation of Contaminated Land and Soil Quality (GN R.331 of 2014) in 2016 as part of a high-level human health risk assessment undertaken by Golder Associates (Golder Associates, 2016a). In this assessment analytical data was extracted from the waste classification report of 2014 (Jones and Wagener, 2014), while additional analytical data was received from Eskom in March 2016.

A summary of the waste classification results for Kendal Power Station is presented in **Table 2-2** (total concentrations) and **Table 2-3** (leachable concentrations) in relation to GN R.635 TCT and GN R.331 soil screening levels. The SSV1 levels in GN R.331 is protective of the groundwater resource, while the SSV2 levels are protective of risk to human health in the absence of a water resource. Where no SSV levels are available in the GN R.331, Soil Screening Levels (SSL) of the US EPA Region 9 were adopted.

The waste assessments undertaken by (Jones and Wagener, 2014) and (Golder Associates, 2016a) concluded the following regarding Kendal Power Station ash:

- The total As concentrations in the fly ash source data from 2016 exceeded TCT0 and SSV1 levels, but were lower than SSV2 for Standard Residential and SSV2 for Informal Residential use;
- Total Cu and Pb concentrations exceeded TCT0 and SSV1 levels at the Kendal Power Station, but were less than SSV2 for Informal as well as Standard Residential use;
- The total Ba concentrations exceeded the TCT0 level while it was lower than the SSV1 level (US EPA Region 9 soil screening levels) and the US EPA SSL for Residential Soil;
- The leachable concentrations for Kendal Power Station fly ash samples were below LCT0 and Soluble SSVs, besides B which were higher than the 0.5 mg/l LCT0 limit.

The waste assessment classified the Kendal Power Station ash as a Type 3 wastes requiring disposal on a landfill with a Class C barrier system. The Type 3 waste classification was the result of the LC value of boron exceeding its LC0 value of 0.50 mg/ℓ, and the TC value of barium and fluoride exceeding their respective TC0 values.

**Table 2-2: Total concentrations (mg/kg) of potential CoCs in Ash samples compared to TCT and SSV levels**

| CoCs | GN R.635 TCTs | | | GN R.331 Soil Screening Levels | | | | Kendal Power Station | |
|---|---|---|---|---|---|---|---|---|---|
| | TCT0 | TCT1 | TCT2 | SSV1 Protect Water Resource | SSV2 Informal residential | SSV2 Standard residential | SSV2 Industrial | (Jones and Wagener, 2014) | Data received from Eskom 2016 (Golder Associates, 2016a) |
| **Al** | ng | | | 600000* | ng | 77000* | 1100000* | ND | |
| **As** | **5.8** | 500 | 2000 | **5.8** | 23 | 48 | 150 | <2 | 14.0 |
| **B** | 150 | 15000 | 60000 | 260* | ng | 16000* | 230000* | 82 | |
| **Ba** | **62.5** | 6250 | 25000 | 3200* | ng | 15000* | 220000* | 570 | 960 |
| **Cd** | 7.5 | 260 | 1040 | 7.5 | 15 | 32 | 260 | 2.8 | |
| **Co** | 50 | 5000 | 20000 | 300 | 300 | 630 | 5000 | <5 | 7.3 |
| **Cr(VI)** | 6.5 | 500 | 2000 | 6.5 | 6.5 | 13 | 40 | ND | |
| **Cr(total)** | 46000 | 800000 | N/A | 46000 | 46000 | 96000 | 790000 | 33 | 281 |
| **Cu** | **16** | 19500 | 78000 | **16** | 1100 | 2300 | 19000 | <5 | 25.5 |
| **Hg** | 0.93 | 160 | 640 | 0.93 | 0.93 | 1 | 6.5 | <0.2 | 0.1 |
| **Mn** | 1000 | 25000 | 100000 | 740 | 740 | 1500 | 12000 | 190 | 280 |
| **Mo** | 40 | 1000 | 4000 | 40* | ng | 390* | 5800* | <5 | |
| **Ni** | 91 | 10600 | 42400 | 91 | 620 | 1200 | 10000 | <5 | 79.4 |
| **Pb** | **20** | 1900 | 7600 | **20** | 110 | 230 | 1900 | <2 | 53.1 |
| **Sb** | 10 | 75 | 300 | 7* | ng | 31* | 470* | <2 | |
| **Se** | 10 | 50 | 200 | 10.4* | ng | 390* | 5800* | <2 | 3.4 |
| **V** | 150 | 2680 | 10720 | 150 | 150 | 320 | 2600 | <5 | 78.6 |
| **Zn** | 240 | 160000 | 640000 | 240 | 9200 | 19000 | 150000 | 35 | 28.4 |
| **Total PAH** | ng | 50 | 200 | ng | ng | ng | ng | <0.8 | |
| ng – no guideline ND – not determined * SSV derived from US EPA Region | | | | | | | | | |

**Table 2-3: Leachable concentrations (mg/l) of potential CoCs in Ash samples compared to LCT and soluble SSVs**

| CoCs | LCT0 | LCT1 | LCT2 | LCT3 | Soluble SSV | Kendal Power Station (Jones and Wagener, 2014) |
|---|---|---|---|---|---|---|
| **As** | 0.01 | 0.5 | 1 | 4 | 0.2* | <0.01 |
| **B** | 0.5 | 25 | 50 | 200 | 80** | 0.733 |
| **Ba** | 0.7 | 35 | 70 | 280 | 76** | 0.044 |
| **Cd** | 0.003 | 0.15 | 0.3 | 1.2 | 0.1* | <0.005 |
| **Co** | 0.5 | 25 | 50 | 200 | 0.12** | <0.025 |
| **Cr (total)** | 0.1 | 5 | 10 | 40 | 440** | <0.025 |
| **Cr(VI)** | 0.05 | 2.5 | 5 | 20 | 1* | 0.028 |
| **Cu** | 2 | 100 | 200 | 800 | 20* | <0.025 |
| **Hg** | 0.006 | 0.3 | 0.6 | 2.4 | 0.1* | <0.001 |
| **Mn** | 0.5 | 25 | 50 | 200 | 20* | <0.025 |
| **Mo** | 0.07 | 3.5 | 7 | 28 | 2** | <0.025 |
| **Ni** | 0.07 | 3.5 | 7 | 28 | 7.8** | <0.025 |
| **Pb** | 0.01 | 0.5 | 1 | 4 | 1* | <0.01 |
| **Sb** | 0.02 | 1 | 2 | 8 | 0.156** | <0.01 |
| **Se** | 0.01 | 0.5 | 1 | 4 | 1* | <0.01 |
| **V** | 0.2 | 10 | 20 | 80 | 2* | 0.049 |
| **Zn** | 5 | 250 | 500 | 2000 | 60* | <0.25 |
| **Cl** | 300 | 15000 | 30000 | 120000 | 12000 | <5 |
| **$SO_4$** | 250 | 12500 | 25000 | 100000 | 4000 | 36 |
| **$NO_3$** | 11 | 550 | 1100 | 4400 | 120 | <0.2 |
| **F** | 1.5 | 75 | 150 | 600 | 30 | 0.4 |

* Soluble SSV derived from SA Water Quality Guidelines ** Soluble SSV derived from US EPA Region 9 Tap water standards

## 2.6 High Level Health Risk Assessment of Eskom Ash

A high-level human health risk assessment of Eskom's pulverised coal fired fly ash was undertaken in 2016 to support a motivation to the Minister of Environmental Affairs to exempt specific waste management activities from the requirements of a Waste Management Licence (WML) in terms of section 19 of the National Environmental Management: Waste Act, 59 of 2008 for the use of fly ash in selected downstream applications (Golder Associates, 2016a). These applications included the proposed use of ash in brick and block making, road construction, mine backfilling, soil amelioration and agricultural use.

The high-level risk assessment was conducted with the RISC5 model, which is a software package for performing fate and transport modelling, human health and ecological risk assessments for contaminated sites. Fate and transport models are available in RISC5 to estimate receptor point concentrations in groundwater, indoor and outdoor air (volatile constituents and particulate matter). The risk assessment was based on human exposure to the Ash (source) in its current form (no treatment and no dilution) presenting a worst-case scenario. The pathways which were considered include soil (ingestion by children and dermal contact), ingestion of vegetables, inhalation of particulate matter and groundwater (ingestion and dermal contact). The analytical data for ash from Camden, Kendal and Matimba Power Stations were evaluated, as well as analytical data received from Eskom on total concentrations of constituents in Fly Ash from their different facilities (Golder Associates, 2016a).

One of the pathways that was assessed during this high-level human health risk assessment included the groundwater pathway. During this risk assessment it was anticipated that groundwater resources may be impacted due to infiltration and mobilization of contaminants from the source (ash). The vulnerability of the groundwater depends on the mobility of the contaminants and the ability of the soil to retain the contaminants. The depth to groundwater was set at 2 metres below ground level (mbgl), while the soil type was taken as sandy soil for the risk assessment.

**Table 2-4: Exposure parameters for resident adult, child and workers relating to groundwater pathway exposure (Golder Associates, 2016a)**

| Exposure Parameters | Adult Resident | Child Resident | Worker |
|---|---|---|---|
| Body weight (kg) | 70 | 15 | 70 |
| Exposure duration (year) | 24 | 6 | 25 |
| Exposure frequency for groundwater (events/year) | 350 | 350 | 250 |
| Ingestion rate for groundwater (l/day) | 2 | 1.5 | 1 |
| Time of exposure while washing (h/day) | 0.58 | 1 | 0.58 |
| Inhalation rate in the shower ($m^3$/h) | 0.625 | 0.625 | 0.625 |
| Total skin surface area (for groundwater) ($cm^2$) | 23000 | 8760 | 23000 |

Receptors that were considered in the risk assessment include the potential impact on humans, i.e. workers handling the fly ash, and adults and children residing in nearby residential areas where the fly ash is used. The potential impact on children will be the highest since this is the most sensitive human receptor. All these human receptors were considered in the risk assessment and the generic exposure parameters used by RISC5 relating to exposure via groundwater pathway are shown in **Table 2-4**.

Simulations were run for 100 years at 1-year time steps for an assumed on-site borehole, for groundwater located 2 mbgl. The simulated groundwater data indicates that:

- The concentrations of all CoCs in groundwater of an on-site borehole will be within acceptable levels (less than South African Water Quality Guidelines for Domestic use) even after 100 years simulation;
- The highest expected concentration will be Al at 0.12 mg/l;
- The cumulative Al load to groundwater will be highest of all CoCs at 4.8 kg after 100 years for a 1 ha area.

Due to the alkaline pH of the Fly Ash (>8), most of the CoCs are insoluble and will have a minimal impact on groundwater quality. However, the solubility of Al increases at low pH (<5.5) as well as alkaline pH (>8), which explains why the potential impact on groundwater is more pronounced for Al than for the other CoCs (Golder Associates, 2016a).

Carcinogenic risk was considered in the high-level human health risk assessment. A carcinogenic risk of 1:100000 (1.0E-05) is internationally deemed acceptable for human receptors. Arsenic is a potential carcinogen present in the Fly Ash. These results for on-site human receptors showed that the ingestion of and contact with groundwater impacted by fly ash will not have an unacceptable carcinogenic risk on human receptors, based in the simulations assumptions mentioned above (Golder Associates, 2016a).

Furthermore, the hazard quotient (HQ) for exposure to groundwater impacted by fly ash was considered in the high-level human health risk assessment. HQ is the ratio of the potential exposure to the substance (CoCs in the fly ash) and the level at which no adverse effects are expected. If the HQ is calculated to be less than 1, then no adverse effects are expected as a result of exposure. If the HQ is greater than 1, then adverse effects are possible. However, the HQ cannot be translated to a probability that adverse effects will occur: a HQ exceeding 1 does not necessarily mean that adverse effects will occur. Results from the HQ assessment indicated that the potential non-carcinogenic risk to human receptors from exposure to fly ash impacted groundwater does not pose an unacceptable health risk to children, adults or workers on-site (Golder Associates, 2016a).

# 3 DESCRIPTION OF KENDAL POWER STATION ADF DEVELOPMENT

## 3.1 Introduction

Construction on KPS commenced in 1982, while the last generation unit became operational in 1993, eleven (11) years after construction of the power station commenced. Kendal Power Station has an indirect dry-cooling system that uses cooling towers and water. This is a closed system as there is little loss of water due to evaporation and the system utilises less water in its cooling processes than conventional wet cooled power stations. KPS has six 6 x 686 megawatt (MW) generation units. The Power Station is located approximately 40km south of Witbank in the Mpumalanga Province and employs more than 830 staff.

## 3.2 Kendal Power Station's existing Ash Disposal Facility

### 3.2.1 Original ADF overview

The Kendal Power Station Dry Ash Disposal Facility was designed in the mid 1980's for a 40-year station life, plus an 8-year contingency area. However, the existing ADF utilised by KPS for the disposal of ash from the electricity generation process is running out of capacity

There are a number of issues which have contributed to the reduction in the capacity of the original ADF design geometry. For example, the actual dry density of the ash of 850kg/m$^3$ is lower than the assumed density of 1000kg/m$^3$ which makes the ADF 18% under capacity. The actual station average Load Factor (LF) is also higher than the 75% assumed LF due to the 90:7:3 requirement. The actual LF was anticipated to be closer to 85%, which resulted in a further 13% reduction in capacity. In addition, the land required for the second half of the ADF was not purchased at the time of the power station construction and uncontrolled open cast coal mining took place on the land. It is thus no longer feasible for the ADF to cross the western stream onto the coal mined area, resulting in a further loss of about 20% of the ADF volume. These factors resulted in the ADF capacity effectively being reduced to only 57% of its original anticipated capacity (Eskom, 2010).

During planning and construction of KPS, an area earmarked for disposal of the ash was delineated during the planning stages of the power station as per **Figure 3-1** (Black lines). Environmental authorisation was not previously required for the Kendal ash disposal facility, due to the fact that no environmental regulations were in place when construction started. Ash was furthermore not categorised as waste until the enactment of NEM:WA in 2008 (Zitholele Consulting, 2014b).

***Therefore, no requirement to line the area that would be covered by the proposed KPS ADF existed and the area was not lined with a barrier system.***

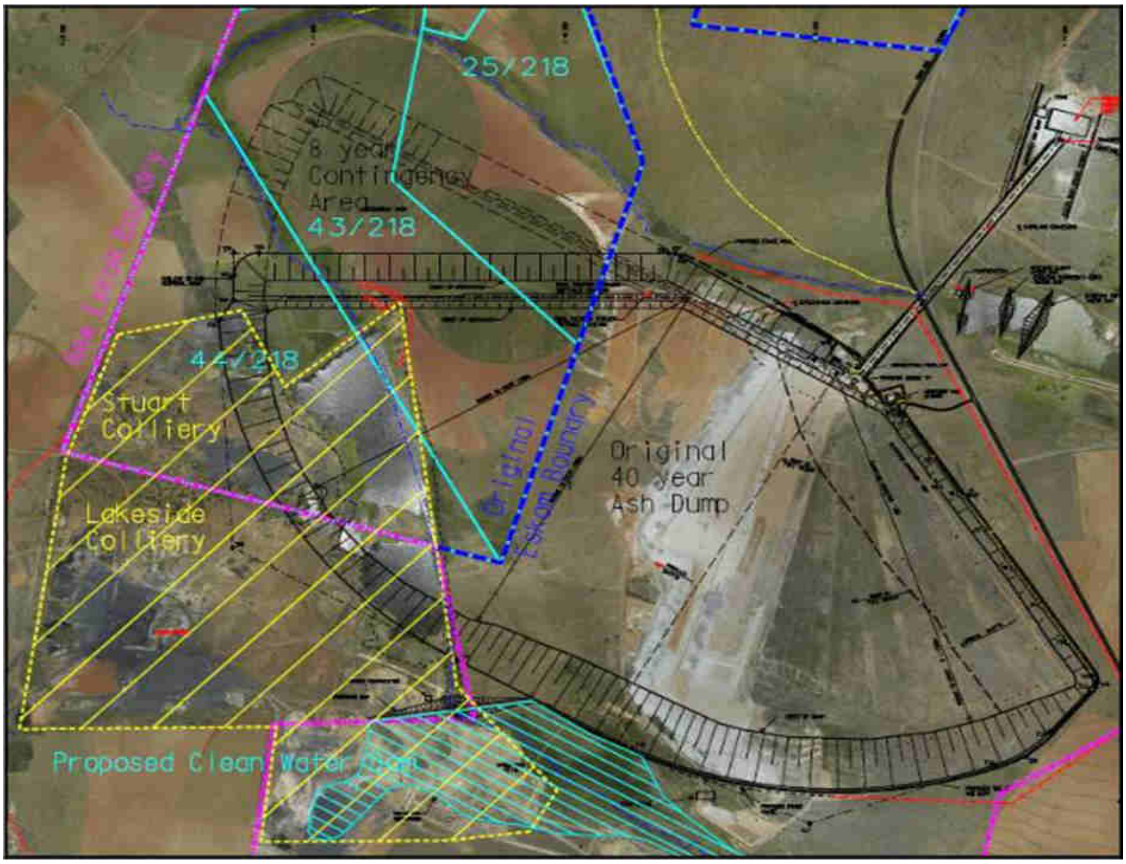


**Figure 3-1: Original area earmarked during planning stages of KPS**

The north-eastern extent of the existing ADF is located approximately 2km to the southwest of KPS, and to the west of the R686. The area on which the ADF is now situated has an overall slope towards the west and is drained by three tributaries of the Wilge River. The site's north-eastern extremes are bounded by one of these. The second runs to the south-east of the ADF area but is crossed by the western most corner of the ADF and will be cut off completely. The third runs approximately 1km west of the dump area and will carry water diverted from the cut off tributary (Eskom, 1999).

### 3.2.2 Original ADF ashing operations and philosophy

Initially, all ashing was done using the spreader as the main system. The unused extendible conveyor was utilised as the temporary stand-by ashing system to be used only when the spreader was unavailable. This was due to the fact that the Kendal Power Station was still in the commissioning phase of its boiler units and therefore ash volumes were still relatively small. Earth platforms were constructed for the overland conveyors and for the first positions of both the shiftable conveyors. Commissioning of the stacker commenced in October 1991 by placing ash on the backstack area behind the ash previously placed by the spreader (Eskom, 1999).

A solution trench has been provided along the eastern toe of the ADF to collect run-off water from the ADF surface and side slopes and transport it around the sides of the ADF. A similar trench has been provided at the toe of the old stand-by area of the ADF to collect run-off water from that area. All run-off water is considered dirty water and so cannot be allowed to enter a water course. To conform with this requirement the water is discharged into containment areas formed by earth berms where evaporation is allowed to occur thus leaving behind the ash silt. These berms are positioned such that they will be covered by ash in the future and therefore do not require cleaning. Water run-off from the advancing ash face is also collected in similar berms and allowed to evaporate (Eskom, 1999). Clean water runoff from the ADF is allowed to flow into natural watercourses or into the clean water dam.

Considering shape and height of the ADF, it was concluded from the findings of the short-term stability review on the Karoo geology that the ADF may be raised to 50m maximum frontstack height and the safe edge distance could be relaxed to a minimum of 15m back from the stacked crest to the closest part of any of the strategic stacking equipment for ash, which does achieve a reasonable average pozzolanic cementing strengthening gain with time. Due to the more extensive strength testing done on the Kendal ash with the latest stability review, it is felt that **a degree of this pozzolanic cementing strength can be relied upon, to safely raise the frontstack height within acceptable risk levels**, in view of the temporary construction nature of the dry ADF, as well as the expected level of monitoring of the construction process (Eskom, 1999).

The dry ashing system has the potential to create severe dust blow problems. Some of the methods that are implemented for dust control on the ADF include smooth drum roller compaction, dosing with water via a mobile sprinkler machine or water bowsers, dust suppression with water via a sprinkler system, the use of polymers, and the application of soil cover. **One of the key benefits of drum roller compaction is that nominal compaction will increase the possibility of a crust being formed due to pozzolanic action** (Eskom, 1999).

The Conceptual Engineering Designs show that ash may be accommodated at the proposed Continuous ADF up to approximately 2030. Thereafter an alternative / supplementary site will be required for the disposal of ash for the remaining period up to the end of 2053, excluding consideration of the 5-year contingency period that will require disposal up to 2058.

### 3.3 Proposed Continuation of original Ash Disposal Facility

Due to the fact that the capacity of the initial ADF would no longer suffice to accommodate the volume of ash that will be generated over the extended operating life, of the Kendal Power Station, as discussed in **Section 3.2.1**, it is proposed that the existing ADF be continued to accommodate ash disposal while the establishment of a new ADF site takes place.

#### 3.3.1 Consideration of ADF continuation design options

Since the available space west of the existing ADF would not be sufficient to cater for disposal of all the ash generated during the extended life of power station, an additional waste disposal elsewhere would be required. Naturally, the size of the new ADF is dependent on the area available and volume of ash that can be disposed on that area through continuation of the ashing operations at the existing ADF. Considering the area in which KPS is situated it would be beneficial from the outset to develop as large as possible area for continuation of the existing ashing operations in order to reduce the area and size requirements for the required additional ADF elsewhere. The immediate area surrounding KPS did pose some significant constraints and as a result two broad options were considered in determining the air space required for the extended facility. The broad options are as follows:

- **Option 1: Minimum Dump** – The continuation of the existing ADF remain positioned between the two streams as previously described, with some constraints reducing the available area as described in **Section 3.2.1**. The minimum volume refers to the proposed minimum footprint of the ash disposal facility with a total footprint of 480ha;
- **Option 2: Maximum Dump** – The continuation of the existing ADF requires the northern stream to be diverted. The maximum volume refers to the proposed maximum footprint of the ash disposal facility with a total footprint of 530ha.

An Environmental Impact Assessment (EIA) process (Zitholele Consulting, 2014a) and Water Use Licence Application (WULA) (Zitholele Consulting, 2014b) were undertaken between 2013 and 2015 to assess the impact of the proposed continuation of the existing ADF on the surrounding environment. Upon conclusion of the EIA and WULA, authorisation of Option 2 (**Figure 3-2**) was recommended for authorisation by the Environmental Assessment Practitioner (EAP).

Environmental Authorisation (EA) for implementation of the recommended Option 2 was granted by the DEA on 28 July 2015, while the Water Use Licence (WUL) was issued by the DWS on 18 December 2015 to licence water uses that would be triggered by the implementation of Option 2.

One of the most significant conditions emanating from the EA and WUL is the need to implement a Class C barrier system to prevent pollution of the underlying groundwater system. Aspects of the proposed design of the ADF relating to the barrier system, prevention of pollution of the groundwater and management of clean and dirty water systems are discussed in subsequent sections.

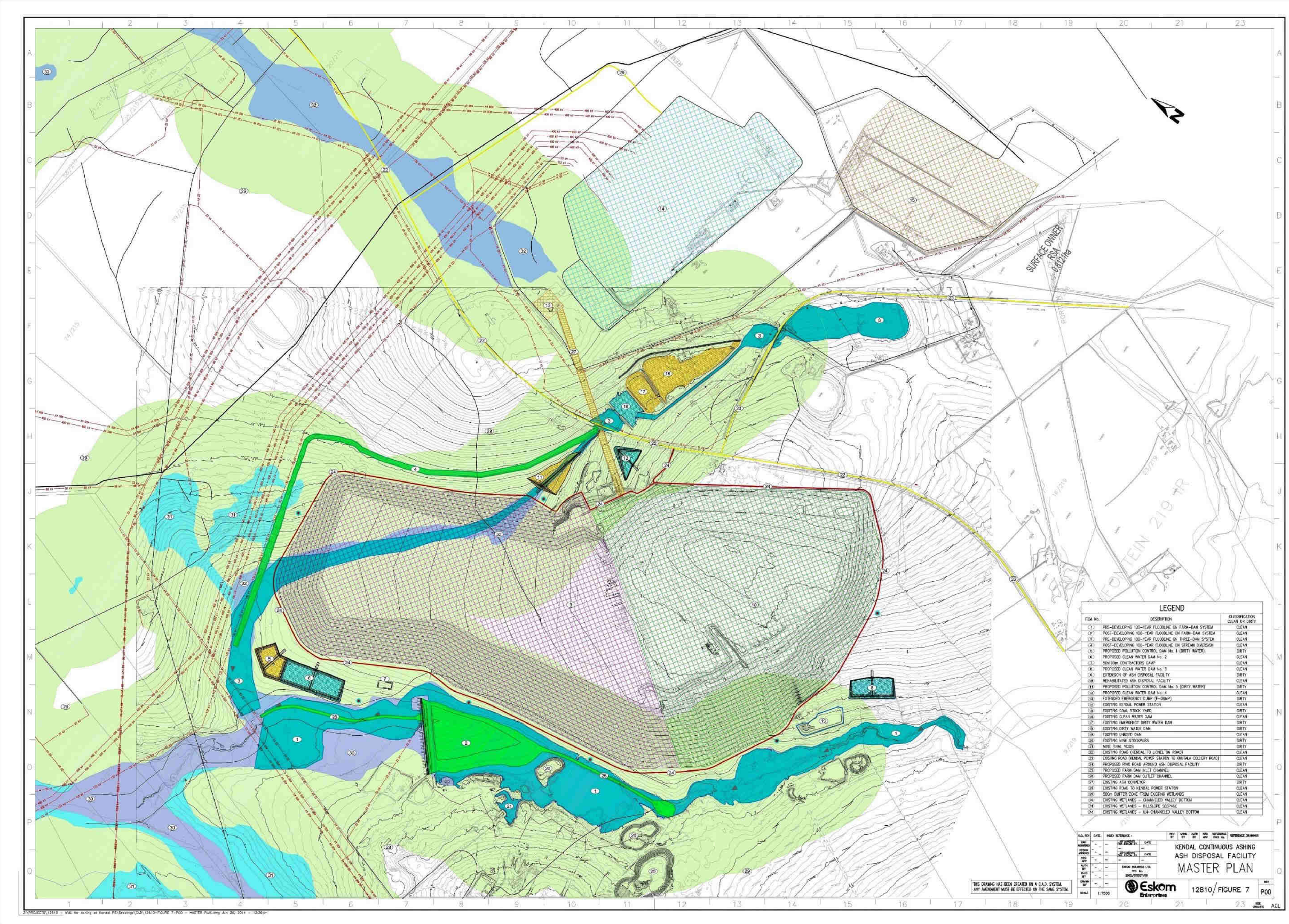


**Figure 3-2: Masterplan for the maximum dump option authorised by the competent authority (Zitholele Consulting, 2014b)**

### 3.3.2 Authorised ADF conceptual design (Maximum Dump)

The maximum volume option (refer to **Table 3-1**) falls outside the original design's footprint and requires the diversion of the stream located to the north-east of the proposed Continuous ADF. The physical parameters of the Maximum Dump are provided in Table 3-1.

**Table 3-1: Physical Parameters of the Maximum Dump**

| | |
|---|---|
| **Total Footprint Area** | 583 hectares |
| **Remaining dump volume** | 98 $Mm^3$ from January 2015 |
| **Remaining life** | 15 years from January 2015 |
| **Maximum Height** | 60 meters |
| **Lined Area** | 224 hectares |

<u>Conveyor and stacker alignment</u>

The ash is deposited onto the "dry" ADF by means of a conveyor stacker system. The transverse conveyors move the ash from the Power Station to Transfer House E. The E-Dump is located just to the north of the transfer house and was initially designed to provide a capacity of two days of ashing for emergencies such as breakdowns and maintenance to the overland conveyors etc.

From Transfer House E the ash is transported via the overland conveyors which cross under a provincial road and over the north eastern stream to Transfer House F at the ADF. The extendable conveyors transfer the ash from Transfer House F to the shiftable conveyors. The extendable conveyors were initially designed to extend in the direction of their current bearing as soon as the shiftable conveyors are perpendicular to the extendable conveyors. This method of deposition is called parallel shifting, but this deposition strategy cannot be implemented due to the new boundary extents of the existing area.

The shiftable conveyors are the stacker shiftable conveyor (Primary system) and the spreader shiftable conveyor (Standby system). These are used to deposit the ash onto the ADF. The current deposition strategy is to place ash only via radial shifting. The layout and various elements of the conveyor system are shown in Figure 3-3.

There are some limitations to these shiftable conveyor systems as the ash is only placed radially. Some of the limitations are:

- The maximum gradient the system can traverse is 1V:20H
- As the conveyor cannot bend in plan, the advancing face as well as the final face position cannot have any kinks or bends as this meant that the conveyor had a bend in place
- The maximum frontstack height the of the spreader system is approximately 45m and 62m for the stacker system

- The spreader system can only place a front stack where the stacker system can place a front stack and back stack.
- Shift intervals need to be kept to a minimum, between 4-6 months per shift.

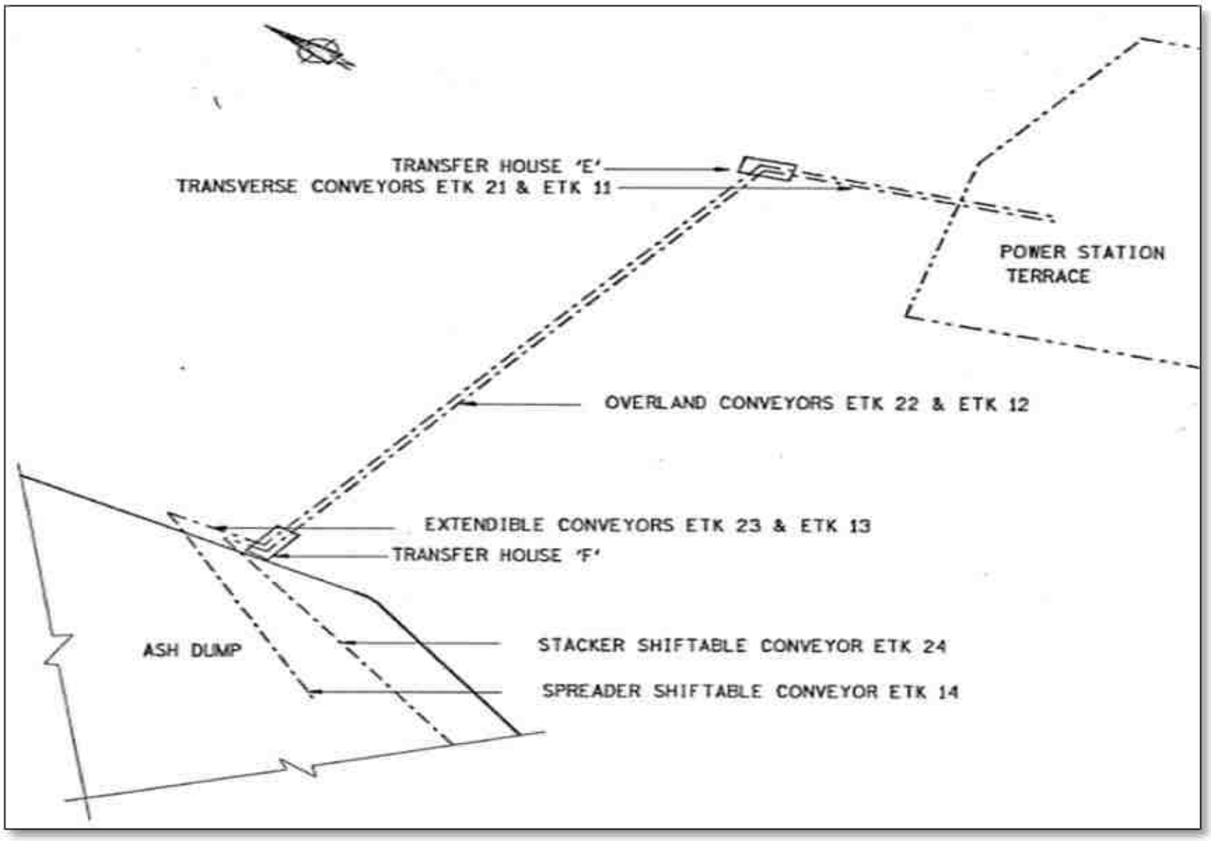


**Figure 3-3: Schematic Layout of conveyor system used to deposit ash**

Transition period for ashing without a barrier system

It was estimated that additional time would be required, after receiving authorisation from the authorities, to provide detailed designs, finalise commercial requirements and undertake construction, during which time the KPS still needs to continually ash and thus a certain amount of ashing will still take place on an unlined area, as per the existing operation, after the authorisation has been received. Consideration and motivation for this transition period was included in the EIA and WULA that was submitted to the authorities prior to authorisation.

The expected impact of the proposed ashing without a barrier system during the transition period on groundwater resources was considered by the groundwater specialist commissioned to undertake the groundwater impact assessment for the Kendal Continuous ADF EIA.

**From the groundwater study it was evident that the current Dry Ashing ADF did not present any impacts to groundwater resources** (Zitholele Consulting, 2014b). According to the Golder (2014) the groundwater vulnerability at the proposed Kendal Continuous and emergency ash sites are shown on the national map as low to medium. Furthermore, the impact assessment for groundwater indicates that the Continuous ADF, unlined, will pose a risk to groundwater that is of low significance and will be limited to the study area.

The groundwater assessment report indicates that: "from the available data and assessment thereof it is concluded that the current ash disposal facility (that has been in operation for more than 25 years) has currently **an insignificant impact on the local groundwater quality if compared to the background levels and DWS Water quality guidelines for Domestic use**" (Golder Associates, 2014a).

The soils assessment report (ESS, 2014) has indicated that the majority of the soils within the existing ADF area are free draining. This means that any polluted leachate from the existing ADF would definitely be mobile through these soil layers and reach groundwater resources. Therefore, the fact that, despite free draining soils, no significant impact from the existing ADF has been evidenced in the groundwater monitoring, is evidence that there is a low risk that polluted leachate is leaving the existing ADF. This is indicative that there is a very low risk that continued operation of the Continuous ADF in the current manner will pose an impact to the receiving environment during the three-year transition period (Zitholele Consulting, 2014b).

Barrier system

In accordance with the provisions of Government Notice (GN) no. 635 the proposed Continuous ADF facility will include an appropriate barrier system. Following the Waste Classification of the ash disposed of at KPS, it was recommended that a Class C barrier system be implemented because the ash was classified as Type 3 waste. A typical Class C barrier system is provided in **Figure 3-4**.

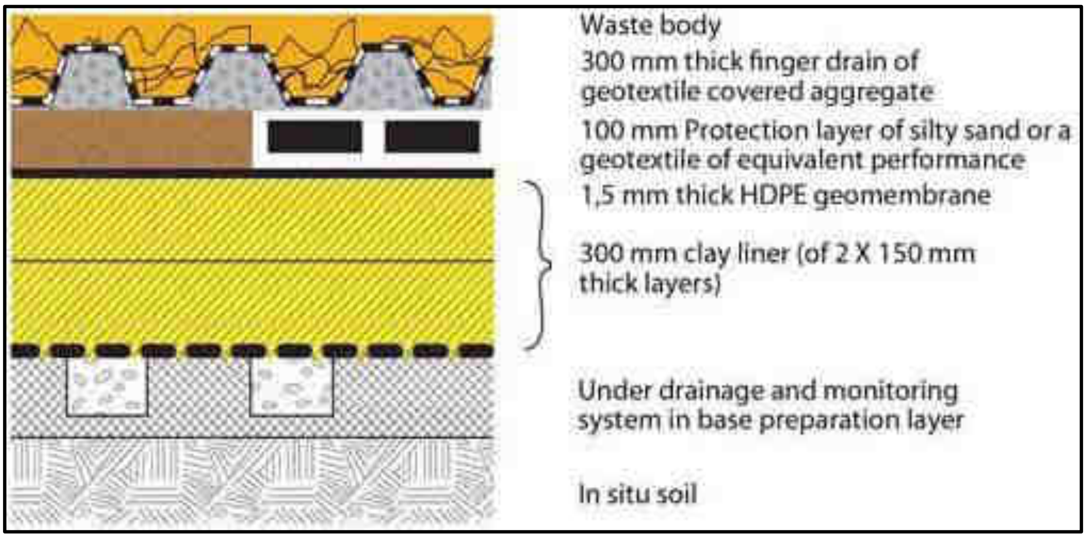


**Figure 3-4: Typical Class C Landfill Barrier System**

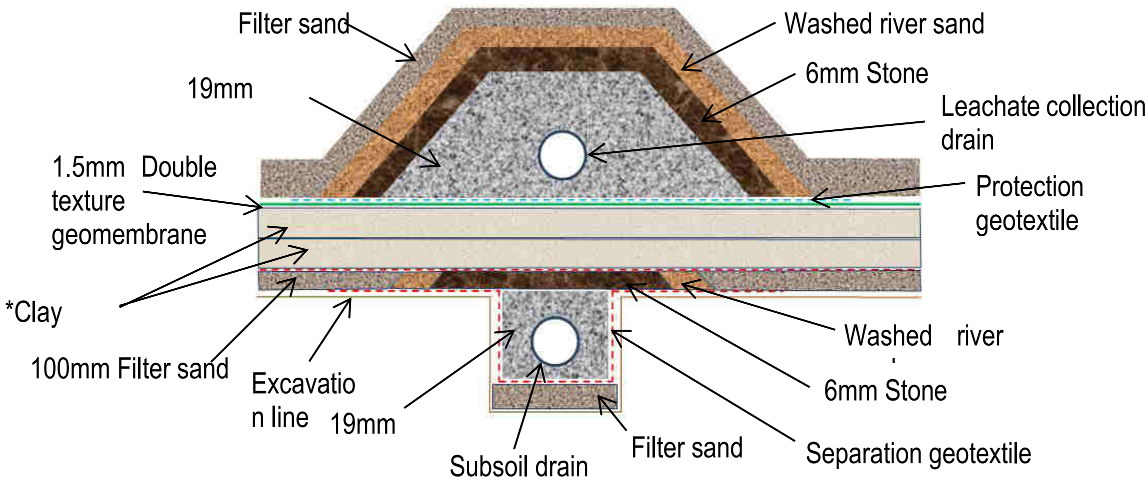


**Figure 3-5: Proposed Class C Barrier System**

**2 x 150mm silty material blended with 6-8% Na bentonite compacted to 98% Std. Proctor (k: 1x10-7 cm/s)*

The Class C barrier system is made up of, amongst other materials, a 300 mm clay layer. Due to the lack of natural clay in close proximity to Kendal Power Station, a Geosynthetic Clay Liner (GCL) was proposed as an alternative to the natural clay layer. This proposal was put forth to the Technical Compliance Unit at Department of Water and Sanitation (DWS) and the Department of Environmental Affairs (DEA) for approval. The DWS raised a concern that bentonite in the GCL will result in an increased permeability of the liner. This may occur due to the potential effect that divalent cations, such as calcium and magnesium, may have on the permeability of bentonite contained in the GCL. The DWS recommended additional tests to determine the Relative Abundance of Monovalent and Divalent Cations (RMD) (Zitholele Consulting, 2014c).

In response to queries raised by the DWS additional tests were carried out including Ash Bentonite Tests. The objectives of these additional tests were to:

- Conduct leach tests on the Kendal ash and analyse the leach solution for the major mono and divalent cations in order to calculate the RMD; and
- Conduct swell tests on the bentonite using the leach solution and verify whether or not the leach solution has an impact on the short-term hydration of the bentonite.

The findings of the tests concluded that the long-term permeability of the bentonite in the GCL may be negatively affected due to a low RMD. In light of the findings of the Ash Bentonite Test, as prescribed for a Class C liner, sodium enriched bentonite blended at a rate of between 6 – 8% into in-situ silty material is recommended as opposed to making use of a clay layer as prescribed. Similar blended material has proven successful on other sites for similar applications. The permeability rate achieved in tests was less than 10 - 7cm/s, which meets the target for a barrier material.

The base material can be sourced from site and the bentonite is available on the local market. However, it is the opinion of the regulator that the bentonite in the enriched soil, although a small percentage, will still be subject to significant swell and hence compromise the integrity of the barrier system. It was advised that the in-situ material be used in lieu of clay, due to the grading of it, compacted to 98% Standard Proctor at between optimum and 2% wet to achieve a target permeability of 10-5cm/s. The proposed 1.5mm geo-membrane that is placed on top of the clay will need to be upgraded to 2mm.

The regulator also had a concern regarding the heat of the leachate that comes into contact with the geo-membrane. The regulator proposed that a cuspated drain be placed on top of the geo-membrane, filled with 100mm layer of blended fly ash and in-situ soils. This will act as a leachate collection system as well as a void former between the leachate and geo-membrane. The current method of deposition was queried and advised to change in order to allow the ash ample time to cool down. KPS will need to address this as it is an operation requirement (Zitholele Consulting, 2014c).

The barrier system proposed for implementation with the Continuous ADF. is provided in **Figure 3-5**.

Infrastructure associated with the Continuous ADF

Infrastructure associated with the proposed Continuous ADF include the following:

- Pollution Control Dams (PCDs);
- Clean Water Dams
- Toe Paddocks
- Storage Reservoirs
- Conveyance infrastructure, including pumps, pipelines and channels

Rehabilitation of the ADF

The system of top-soiling and grassing currently employed on the existing ADF will be continued on the Continuous ADF (Zitholele Consulting, 2014b). A representation of the rehabilitation is provided in **Figure 3-6**.

Storm Water Management Philosophy

The storm water management philosophy that is applied to the proposed Continuous ADF will be based on compliance with GN704, Clause 6 (d), i.e. design, construct, maintain and operate any dirty water system at the facility or activity so that it is not likely to spill into any clean water system more than once in 50 years.

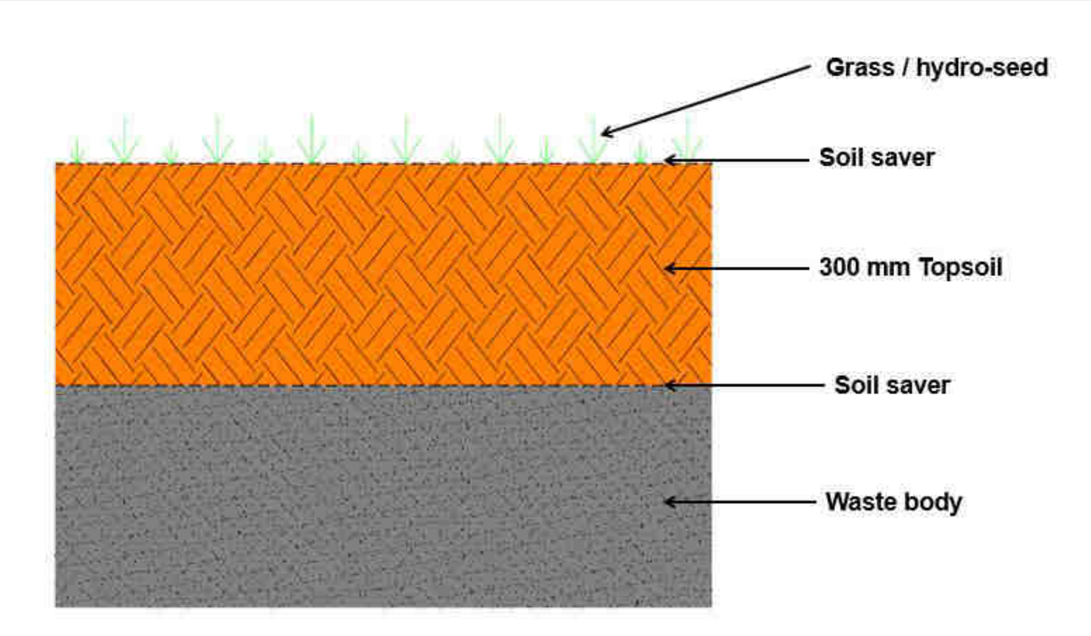


**Figure 3-6: Cross Section of rehabilitated ADF**

Stream diversion

The current extent of the ADF is bordered by one perennial stream to the East and one non-perennial stream to the West. A non-perennial stream drains the north eastern site of the ADF. The stream to the East flows in a north-westerly direction whilst the stream to the West flows northerly. The two streams converge north of the existing ADF. In order to achieve the maximum volume footprint as required for the authorised Continuous ADF footprint, the stream forming the eastern border of the ADF be diverted in a northerly direction. This is indicated by the grey linear infrastructure in **Figure 3-2**.

The diversion channel will be sized to match the discharge capacity of the existing clean water dam spillway, as well as the additional storm water runoff to the east side of the diversion channel. This clean water dam spillway is located upstream of the culvert system across the district road adjoining the R555 and R50 national roads.

# 4 LEGISLATIVE CONTEXT

This section of the report is intended to provide a detailed account of all environmental legislation which may have a bearing on the project. Particular attention will be paid to the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA). The NEMA[1] (1998) is regarded as South Africa's Environmental Management Framework Act.

With the introduction of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) (NEMWA), South Africa committed itself to accountable and responsible management of waste through guidance and alignment with global trends. Careful thought, consultation and discussion preceded the introduction of the revised legislation. Like in the USA, the Department of Environmental Affairs (DEA) drew heavily on the preceding legislation in drawing up the regulations, guidance and policy that comprises NEMWA (Kruger & Thomson, 2011).

Environmental legislation in South Africa is based, amongst others, on the "Precautionary principle" and "Cradle-to-the-grave" and Integrated Environmental Management approach. This has resulted in onerous regulation of all activities that may have a detrimental impact on the environment as a result of the undertaking of the activity.

In contrast to RSA, the international trend shows that ash is either not classified as a waste nor is it considered a hazardous waste. It is therefore pertinent to start with an overview of international regulatory trends governing beneficial uses of ash in order to place waste management and legislation in the RSA into context (Zitholele Consulting, 2016b).

## 4.1 The Constitution of the Republic of South Africa, 1996 (Act No. 108 Of 1996)

Any current legislation regulating the management of ash in South Africa should be viewed against the backdrop of Section 24 of the Constitution of the Republic of South Africa, 108 of 1996, which obligates waste generators to manage waste in a manner that is not harmful to human health and well-being, prevent pollution and ecological degradation and promote ecologically sustainable development.

The Constitution of the Republic of South Africa, 1996 (hereafter referred to as "the Constitution") is the supreme Law in South Africa. The Bill of Rights is included in Chapter 2 of the Constitution. The Environmental Right, set out Section 24 of the Constitution, states that –

Everyone has the right –

a) to an environment that is not harmful to their health or well-being; and
b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
    i. prevent pollution and ecological degradation;
    ii. promote conservation;

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[1] NEMA: National Environmental Management Act, 1998 (Act 107 of 1998).

iii. secure ecologically sustainable development and use of natural resources; and
iv. while promoting justifiable economic and social development.

The National Environmental Management Act, 1998 (Act No. 107 of 1998) is the primary statute which gives effect to Section 24 of the Constitution. The Environmental Right contained in Section 24 of the Constitution also places responsibility on the Applicant and Competent Authority to ensure that this right is not infringed upon.

## 4.2 National Environmental Management Act, 1998 (Act No. 107 of 1998)

Environmental Management can be defined as the management of human interaction with the environment. Fuggle and Rabie (2009) defines Environmental Management as the regulation of the effects of peoples' activities, products and services on the environment. Although South Africa has a comprehensive array of environmental legislation and policies in place, these must be aligned with the provisions of the NEMA (1998), in particular the National Environmental Management Principles stipulated in Chapter 1 of the NEMA (1998). The Environmental Management Principles are centred on providing explicit guidance for co-operative and environmental governance on all matters relating to decision-making which will affect the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state and to provide for matters connected therewith.

The Continuous ADF project, falls within the ambit of the NEMA (1998). The project activities triggered activities listed in the Environmental Impact Assessment Regulations Listing Notice 1 (Government Notice R544[2]) and Environmental Impact Assessment Regulations Listing Notice 2 (Government Notice R545[3]), as amended, therefore Environmental Authorisation was required before they may be implemented. An Integrated Environmental Impact Assessment Process was undertaken in 2013/2014 and the Integrated Environmental Authorisation was issued on the 28 July 2015 for the Continuous ADF project

## 4.3 The National Environmental Management Waste Act, 2008 (Act No. 59 of 2008)

All Waste Management Activities are regulated by the National Environmental Management Waste Act, 2008 (Act No. 59 of 2008) (NEM:WA) and the regulations thereunder. Owing to the nature and composition of the ash that is generated by the combustion of coal, it is considered to be hazardous waste and as such also falls within the ambit of the National Environmental Management Waste Act, 2008 (Act No. 59 of 2008) (NEM:WA[4]). A number of the project activities associated with the KPS Continuous Ash Disposal Facility project are regarded as Waste

[2] R544: Environmental Impact Assessment Regulations Listing Notice 1 of 2010 published in Government Notice R544 in Government Gazette 33306 dated 18 June 2010.
[3] R545: Environmental Impact Assessment Regulations Listing Notice 2 of 2010 published in Government Notice R545 in Government Gazette 33306 dated 18 June 2010
[4] NEMWA: National Environmental Management Waste Act, 2008 (Act No. 59 of 2008).

Management Activities. As such these activities are governed by the NEM:WA[5] (2008) and must conform to the provisions of the Act.

In order to regulate waste management activities and to ensure that they do not adversely impact on human health and the environment, the NEM:WA (2008) introduced the licensing of waste management activities. All waste management activities which are listed in Government Notice 921[6] (2013) in terms of the NEM:WA (2008) requires licensing from the Competent Authority before these activities may proceed. Prior to the implementation of any waste management activity listed in Category A, of Government Notice 921 (2013), a Basic Assessment Process as set out in the Environmental Impact Assessment Regulation made under Section 24(5) of the NEMA (1998) must be carried out as part of the Waste Management License Application Process. However, prior to the implementation of any Waste Management Activities listed in Category B of Government Notice 921 (2013), a Scoping and Environmental Impact Reporting Process must be carried out as part of the Waste Management License Application Process. An Integrated Environmental Impact Assessment Process was undertaken in 2013/2014 and the Integrated Environmental Authorisation was issued on the 28 July 2018 for the Continuous ADF project.

### 4.3.1 National Waste Management Strategy

The National Waste Management Strategy (NWMS) is a legislative requirement of NEMWA and the purpose of the NWMS is to achieve the objects of the Waste Act. Organs of state and affected persons are obliged to give effect to the NWMS (DEA, 2011). NEMWA is structured around the steps in the waste management hierarchy, which is the overall approach that informs waste management in the Republic of South Africa (RSA). The waste management hierarchy consists of options for waste management during the lifecycle of waste, arranged in descending order of priority: waste avoidance and reduction, re-use and recycling, recovery, and treatment and disposal as the last resort.

In terms of the NWMS Eskom is obligated to implement the principles of the waste management hierarchy, and therefore must develop and implement strategies to reduce the disposal of ash produced by its power stations to landfill, and to develop strategies to increase the recycling, re-use and recovery of its ash into beneficial uses that will address waste avoidance and stimulation of economic opportunities at the same time.

[5] NEMWA: National Environmental Management Waste Act, 2008 (Act No. 59 of 2008)
[6] Government Notice 921: Government Notice 921 List of Waste Management Activities that have, or are likely to have, a detrimental effect on the environment, published in Government Gazette 37083, 29 November 2013

### 4.3.2 Waste Management Regulations and Norms and Standards

On 23 August 2013, the DEA promulgated the following regulations and norms and standards for the management, classification and disposal of waste:

- NEMWA: Waste Classification and Management Regulations (GN R.634)
- NEMWA: National norms and standards for the assessment of waste for landfill disposal (GN R. 635)
- NEMWA: National norms and standards for disposal of waste to landfill (GN R. 636)

These regulations replaced the Minimum Requirements waste classification system developed by the Department of Water Affairs and Forestry (DWAF), currently known as the Department of Water and Sanitation, in the 1990s that was used to classify the Eskom ash for disposal purposes.

Subsequent to the coming into effect of the NEMWA and leading up to the publication of the NEMWA: Waste Classification and Management Regulations (Government Notice No. R.634), the classification of waste was subject to interpreting the definition of waste provided in the Act. The Regulations and Norms and Standards marked a significant shift in the waste classification and associated management regime which came before it, under which wastes were classified and regulated with reference to the Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste and for Waste Disposal by Landfill, published by the erstwhile Department of Water Affairs and Forestry.

The new waste classification system focuses on the long-term storage (in excess of 90 days) and long-term disposal of waste on land or waste disposal facilities. The system is based on the Australian State of Victoria’s waste classification system for disposal, which uses the Australian Standard Leaching Procedure (ASLP) to determine the Leachable Concentrations (LCs) of pollutants (DEA, 2013a).

These Regulations and Norms and Standards are key aspects of NEMWA developed for the management of waste classification and categorisation of all substances that is included in the definition of waste in the Waste Act. A waste is classified as either a hazardous or general waste, after which a particular class is assigned in accordance with the GHS protocol (SANS 10234:2008) for the classification of chemical products. This takes cognisance of any detrimental physical or health issues as well as any hazard a substance may pose to the aquatic environment. NEMWA considers:

- Total Concentration (TC) as well as Leachable Concentration (LC) of a stored or disposed substance;
- The status of the receiving environment;
- Changes in waste, or the behaviour of constituent elements, once the substance is disposed.

Besides establishing whether a waste is hazardous or not, classification also determines the severity of the hazard. This proposed classification system has three levels of categorisation for reporting: Level 1, either Hazardous or General; Level 2, the Major waste type and Level 3 the

Specific waste type. The waste categorisation system states that pulverised coal fired boiler ash could either be classified as hazardous or general waste in terms of the Globally Harmonised System (GHS) (Kruger & Thomson, 2011).

The waste hazard classes assess physical properties of the substance (Classes 1 to 4), health impacting properties (Classes 5 to 11), and environmental impacts (Class 12). The latter is specifically aimed towards aquatic environments since this has globally been proven to be an adequate indicator of environmental impact. A substance may be allocated to more than one hazard category. Each hazard category is associated with a hazard statement and a corresponding hazard code which will help to determine the hazard classification of the substance (Kruger & Thomson, 2011).

All waste management facilities are required to register under specific codes:

- R1 - R6 for recycling and recovery of waste;
- T1 - T4 for treatment of waste not for disposal i.e. final treatment;
- D1 - D5 for disposal of waste.

For the purpose of disposal, waste generators must ensure that their waste is assessed in accordance with the Standard for Assessment of Waste for Landfill prior to placing the waste on a landfill. To assess the level of risk associated with the disposal of waste to landfill, the contaminants present in the waste must be identified along with their total concentration (TC) and leachable concentration (LC).

In GN R. 635, the TC and LC values of the contaminants in the waste must be compared to three specified levels of threshold limits for total concentration, i.e. Total Concentration Threshold (TCT) values, and four specified levels for leachable concentration, i.e. Leachable Concentration Threshold (LCT) values, of the specific contaminant. Based on the TC and LC values of the contaminants in the waste exceeding the corresponding TCT and LCT values respectively, the level of risk associated with the disposal to landfill is assigned. The TC of all the contaminants specified in section 6(1) and 6(2) of GN R. 635 that are known or are likely to occur or can reasonably be expected to occur in the waste must be determined.

Once the waste has been classified, the containment barrier that will be required for each waste type is given in GN R. 636. The containment barrier is designed to take cognisance of the properties and leaching potential of the waste itself. There are four classes of landfill design (Class A to D) with stringent liner requirements specified for more hazardous waste, while liner requirements decrease as the waste is classified as less hazardous or inert (Kruger & Thomson, 2011).

**Table** 4-1 presents the liner type designation to waste classification. The information in the column for the Landfill Disposal Requirements has been truncated for brevity purposes to show only the liner type designation for the type of waste.

**Table 4-1: Designated liner types for waste classes identified in terms of GN R.636**

| Waste Type | Landfill Disposal Requirements |
|---|---|
| Type 0 Waste | Disposal of Type 0 waste to landfill is **not allowed**. The waste must be treated and re-assessed in terms of the *Norms and Standards for Assessment of Waste for Landfill Disposal*. |
| Type 1 Waste | Type 1 waste may only be disposed of at a **Class A** landfill designed in accordance with the Norms and Standards [extra conditions omitted]. |
| Type 2 Waste | Type 1 waste may only be disposed of at a **Class B** landfill designed in accordance with the Norms and Standards [extra conditions omitted]. |
| Type 3 Waste | Type 1 waste may only be disposed of at a **Class C** landfill designed in accordance with the Norms and Standards [extra conditions omitted]. |
| Type 4 Waste | Type 1 waste may only be disposed of at a **Class D** landfill designed in accordance with the Norms and Standards [extra conditions omitted]. |

The standardized liner types were developed based on liner design requirements for landfills contained in the Minimum Requirements for Waste Disposal by Landfill (2nd Edition, 1998: Department of Water Affairs and Forestry). The minimum requirements document defines all components that constitute a liner type. **Table 4-2** displays all the layer components of liner systems.

**Table 4-2: Liner Layer Components**

| Layer Component | Description and Function |
|---|---|
| O Layer | A desiccation protection layer consisting of 150mm of soil, gravel, rubble or other similar material that completely covers the B layer and protects it from desiccation and cracking until it is covered by waste. |
| A Layer | A leachate collection layer comprising of 150mm thick layer of single-sized gravel or crushed stone having size of between 38mm and 50mm. |
| B Layer | A 150mm thick compacted clay liner layer. This must be compacted to a minimum density of 95% Standard Proctor maximum dry density at water content of Proctor optimum to optimum +2%. Maximum permeabilities for the layer as specified. |
| C Layer | A layer of geotextile laid on top of any D layer to protect it from contamination by fine material from above. |
| D Layer | A leakage detection and collection layer. This is always below a C layer and above a B layer in hazardous waste landfills. |
| E Layer | A cushion of 100mm of fine to medium sand or similar suitable material which is placed immediately above any F layer to protect it from mechanical damage. |
| F Layer | A geomembrane or flexible membrane liner (FML) which must be laid in direct contact with the upper surface of a compacted Clay B layer. |
| G Layer | A base preparation layer consisting of a compacted layer of reworked in-situ soil with a minimum thickness of 150mm and constructed to the same compaction standards as a B layer. If the permeability of the G layer can be similar to a B layer, it can replace the lowest B layer in a liner system. |

The build-up of a Class A liner which is required for Type 1 waste is given in **Figure 4-1**. The liner is built from bottom upwards as follows:

- 150mm base preparation on top of In-situ material (G layer)
- Under drainage and monitoring system (D layer) constructed on top of the G layer

- Two layers of 200mm thick compacted clay layers. Total thickness is 400mm (B layer)
- 1.5mm HDPE geomembrane (F layer)
- 100mm protection layer of silty sand. This can be replaced by a geotextile of equivalent performance (E layer)
- 150mm leakage detection system of granular material. This can be replaced with an equivalent geosynthetic (D layer)
- Geotextile filter layer (C layer)
- Four layers of 150mm thick compacted clay layers. Total thickness is 600mm (B layer)
- 1.5mm HDPE geomembrane (F layer)
- 100mm protection layer of silty sand. This can be replaced by a geotextile of equivalent performance (E layer)
- 200mm stone leachate collection system (A layer)
- Geotextile that receives the waste body (C layer).

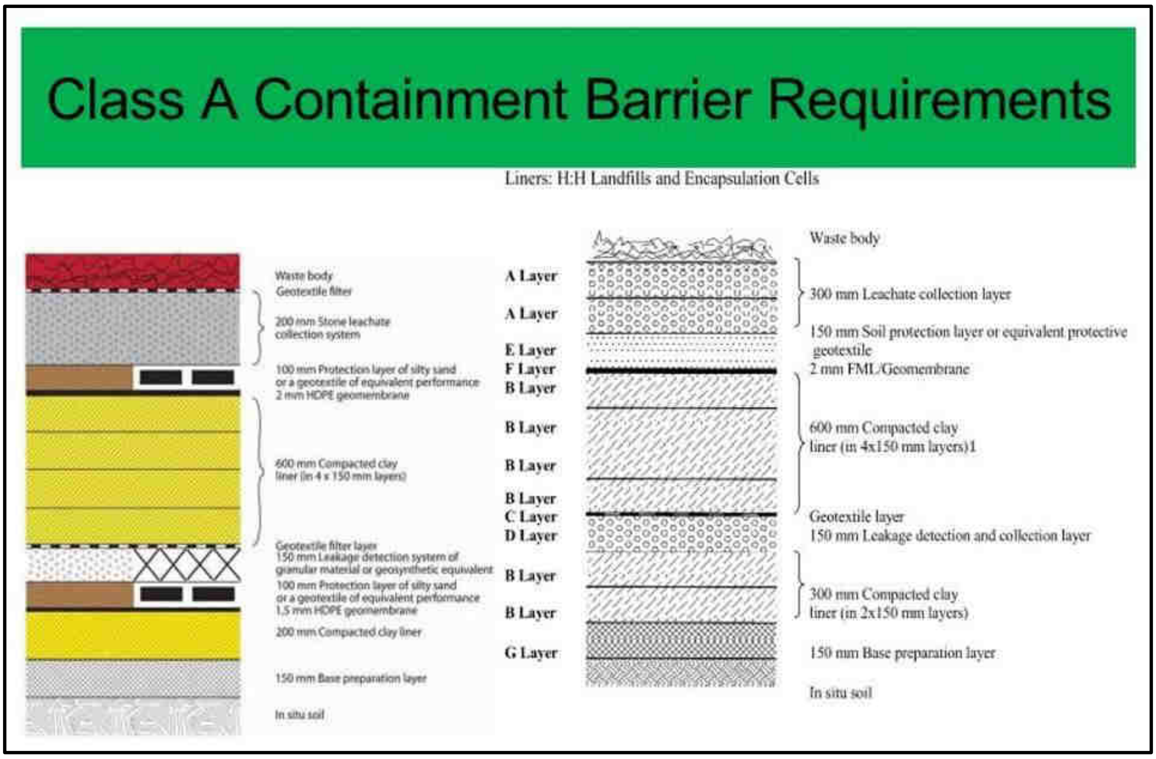


**Figure 4-1: Class A Liner Type i.t.o. GN R.636**

The build-up of a Class B liner which is required for Type 2 waste is given in **Figure 4-2**. The liner is built from bottom upwards as follows:

- 150mm base preparation on top of In-situ material (G layer)
- Under drainage and monitoring system (D layer) constructed on top of the G layer
- Four layers of 150mm thick compacted clay layers. Total thickness is 600mm (B layer)

- 1.5mm HDPE geomembrane (F layer)
- 100mm protection layer of silty sand. This can be replaced by a geotextile of equivalent performance (E layer)
- 150mm stone leachate collection system (A layer)
- Geotextile that receives the waste body (C layer).

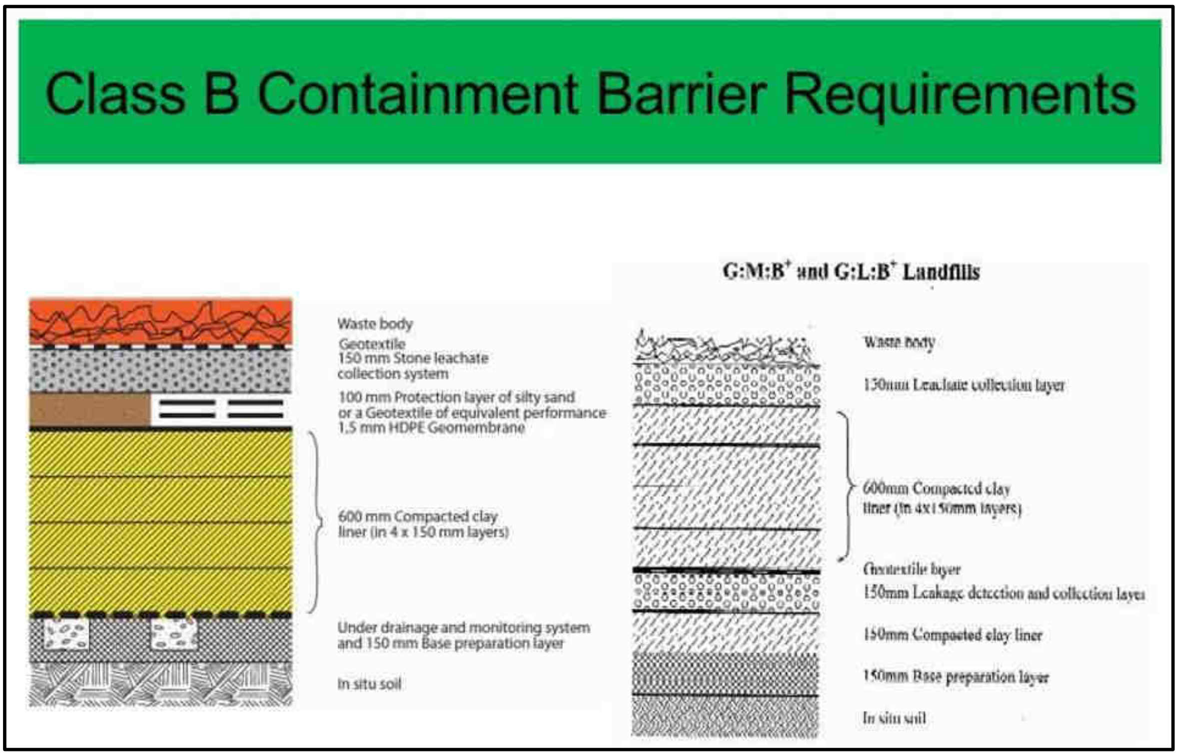


**Figure 4-2: Class B Liner Type i.t.o. GN R.636**

The build-up of a Class C liner which is required for Type 3 waste is given in **Figure 4-3**. The liner is built from bottom upwards as follows:

- 150mm base preparation on top of In-situ material (G layer)
- Under drainage and monitoring system (D layer) constructed on top of the G layer
- Two layers of 150mm thick compacted clay layers. Total thickness is 300mm (B layer)
- 1.5mm HDPE geomembrane (F layer)
- 100mm protection layer of silty sand that receives the waste body. This can be replaced by a geotextile of equivalent performance (E layer)
- 300mm finger drain of aggregate covered by geotextile (A layer)

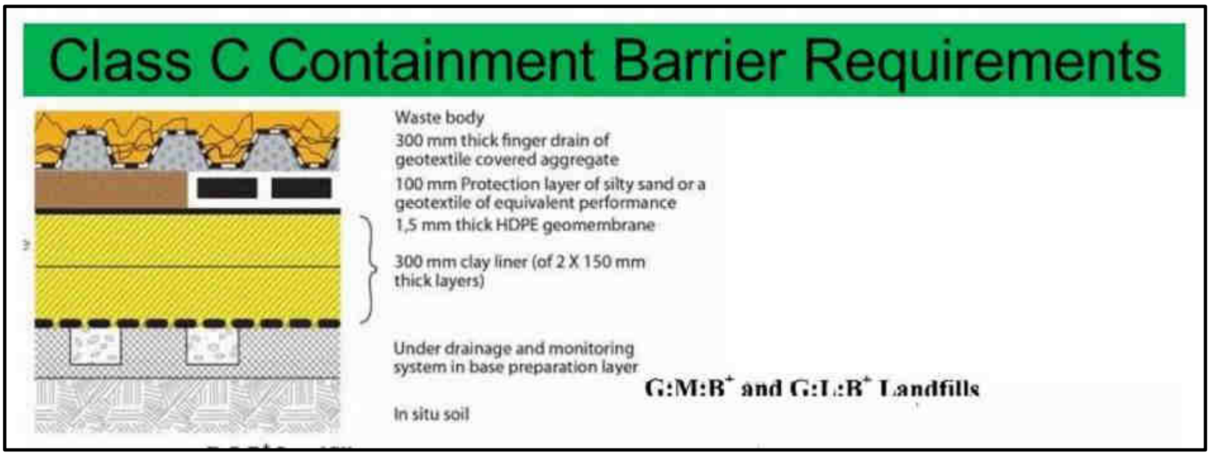


**Figure 4-3: Class C Liner Type i.t.o. GN R.636**

A Class D liner which is required for Type 4 waste is given in Figure 4. The liner is built by only 150mm base preparation on top of In-situ material (G layer) that receives the waste body

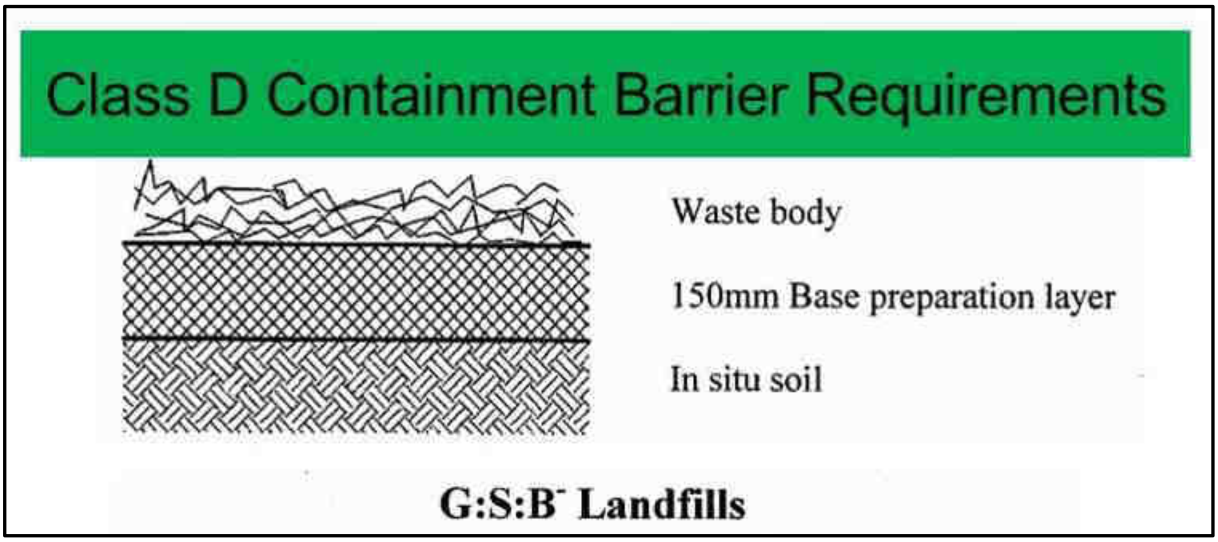


**Figure 4-4: Class D Liner Type i.t.o. GN R.636**

### 4.4 The National Water Act, 1998 (Act No. 36 of 1998)

The activities associated with the KPS Continuous Ash Disposal Facility project triggered a number of Water Uses that are defined in Section 21 of the National Water Act, 1998 (Act No. 36 of 1998) (NWA) (refer to Table 3-3). Accordingly, these Water Uses may not be undertaken without being granted a Water Use License from the DWA7. In accordance with Sections 40 and 41of the NWA (1998), a Water Use License Application Process was carried out. Section 21 (a), (b), (c), (e), (g) and (i) waster uses was applied for through the WULA. The resultant documents from the WULA process include completed WULA forms, as well as a Technical Report. These documents were submitted to DWA for review and decision making and the WUL was issued on the 18 December 2015.

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[7] DWA: Department of Water Affairs

# 5 DESCRIPTION OF THE RECEIVING ENVIRONMENT

For this SPR study, the description of the receiving environment focusses on the elements that will, or is likely to, be impacted as receptors, as a result of pollution entering the groundwater system, which acts as the pathway, emanating from the source of the contaminants, which in this case represents the potential leakage of water that has infiltrated through the ADF waste body or runoff water from the continuous ADF into the groundwater.

## 5.1 Regional Climate

The climate of the study area is typical of the South African Highveld climatic zone with summer rainfall and cold winters. Recent rainfall data (1/06/2001 to 10/05/2013) collected at the Middelburg EDE farms (0516/232LO) suggest a Mean Annual Precipitation (MAP) of 735 mm per annum (**Figure 5-2**). This confirms the long-term precipitation recorded at the station of Ogies (number 0478093_W), 8km west of KPS, which suggests mean annual rainfall of 736 mm, based on a 50 years dataset. The area receives the lowest average monthly rainfall in July (2.69 mm) and highest average monthly rainfall in January (160 mm) (**Figure 5-2**). The average minimum and maximum monthly temperatures are shown in **Figure 5-1**. Temperature extremes range from 28.37°C in summer to -1.89°C in winter.

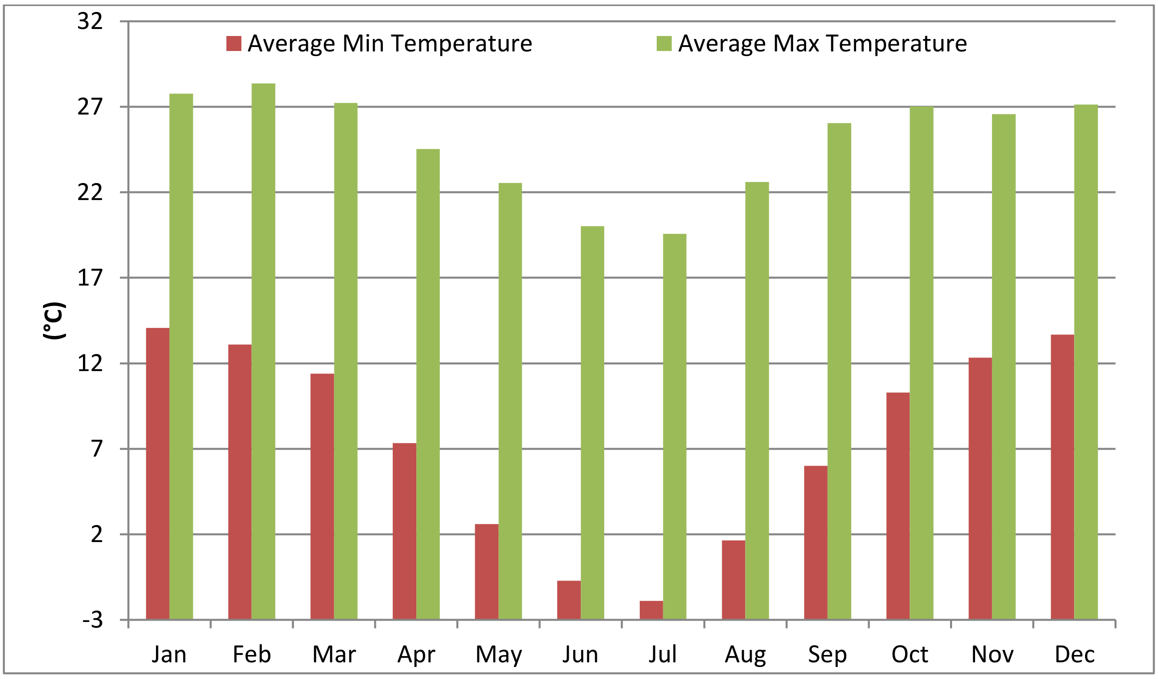



**Figure 5-1: Daily average temperatures**

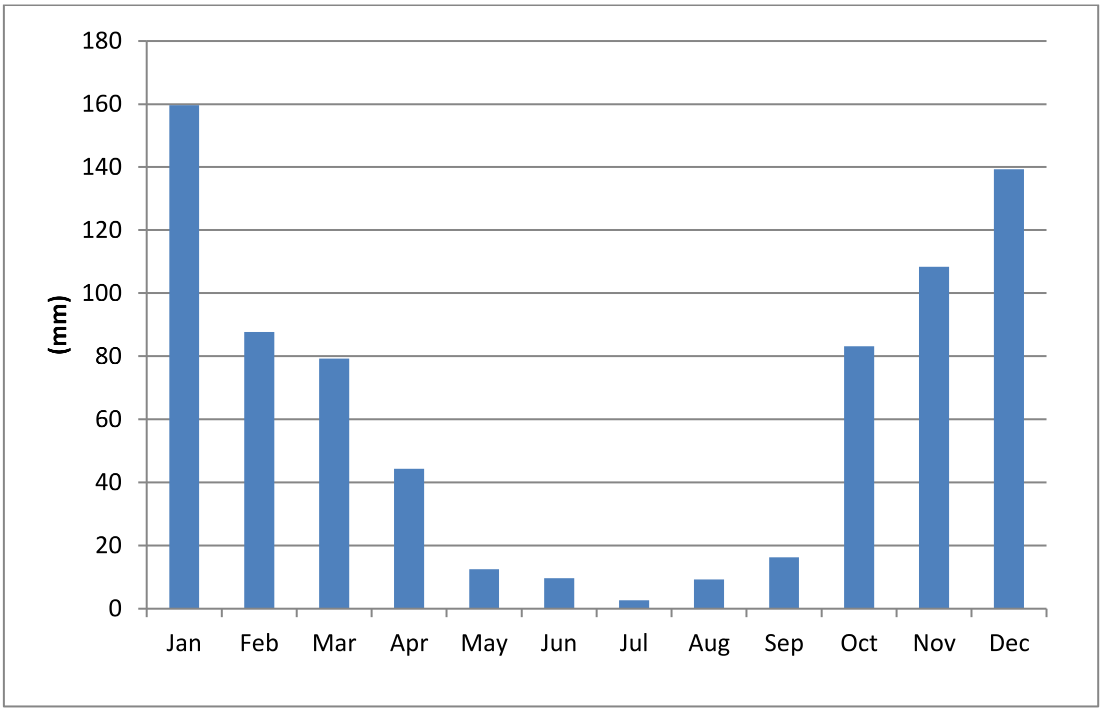



**Figure 5-2: Average monthly rainfall**

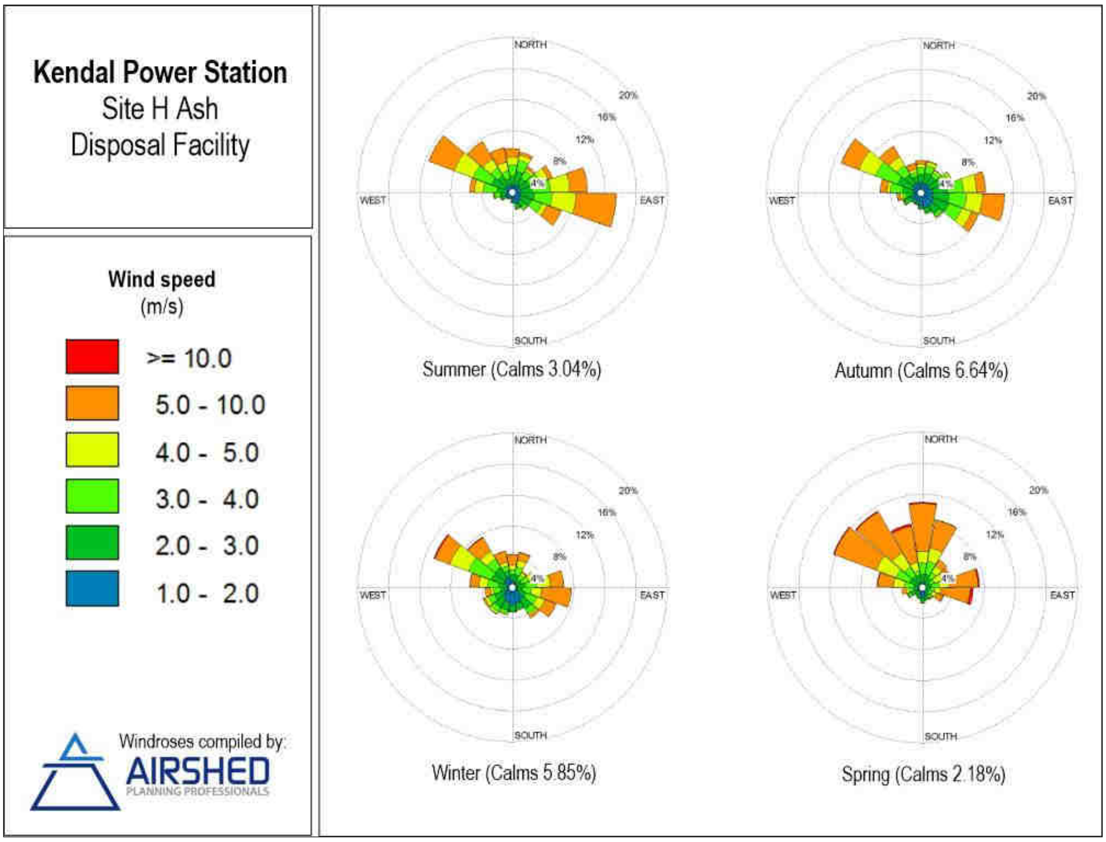



**Figure 5-3: Seasonal wind roses for Kendal monitoring station (January 2009 – October 2012)**

The dominant wind direction (**Figure 5-3**), based on wind data collected during the period January 2009 to October 2012, is west-north-west with a frequency of occurrence approaching 12%. Easterly sector winds are the next dominant with a frequency of 10%.

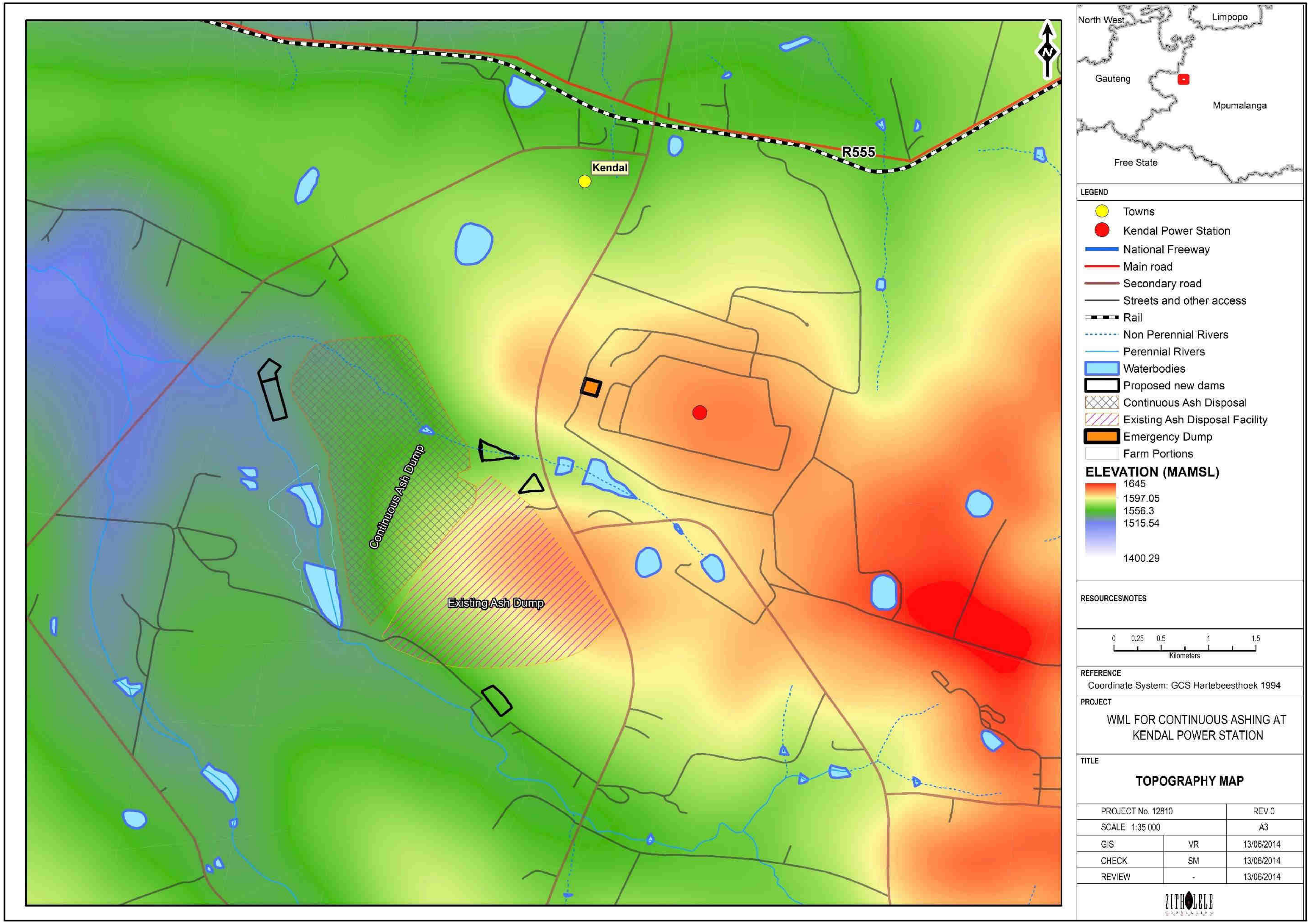



**Figure 5-4: Topography of development area**

## 5.2 Topography and drainage

The Kendal Power Station is located on a water divide between 3 quaternary catchments, i.e. B20F, B20E and B11F (**Figure 5-5**). These quaternary catchments form part of the Limpopo–Olifants primary drainage region. The continuous ADF is located on quaternary catchment B20E, which is mainly drained by the perennial Wilge River. In the catchment, the Wilge River flows from North (1696 mamsl) to South (1501 mamsl) over a distance of approximately 41 km (**Figure 5-4** and **Figure 5-6**). The topography drops gently SE-NW and SW-NE toward the Wilge River. The site of the continuous ADF is drained by 2 tributaries westward into the Wilge River. The Leeuwfontein Spruit, and an unnamed tributary drain from the south of the facility. Schoongezight Spruit, a non-perennial stream drains the north eastern site of the ash disposal facility into the Leeuwfontein Spruit. Schoongezight Spruit will be diverted upstream during the construction of the continuous ADF (GHES, 2018).

## 5.3 Geology

### 5.3.1 Regional geology

The description of general geology (**Figure 5-7**) and geohydrology are based on the analysis of the:

- “1/250 000 Geological Series: 2628 East Rand” published in 1986 by the Government Printer; and
- “Exploration of the 1:500 000 general hydrogeology map done by Barnard (2000).

The prevailing formations in the region are:

- Ecca, Dwyka (found at the base in the pre-Karoo topography), and Vryheid of the Karoo Sequence;
- Rayton, Magaliesberg, Sylverton, Daspoort, and Strubenkop of the Pretoria Group; and
- Loskop of the Rooiberg Group.

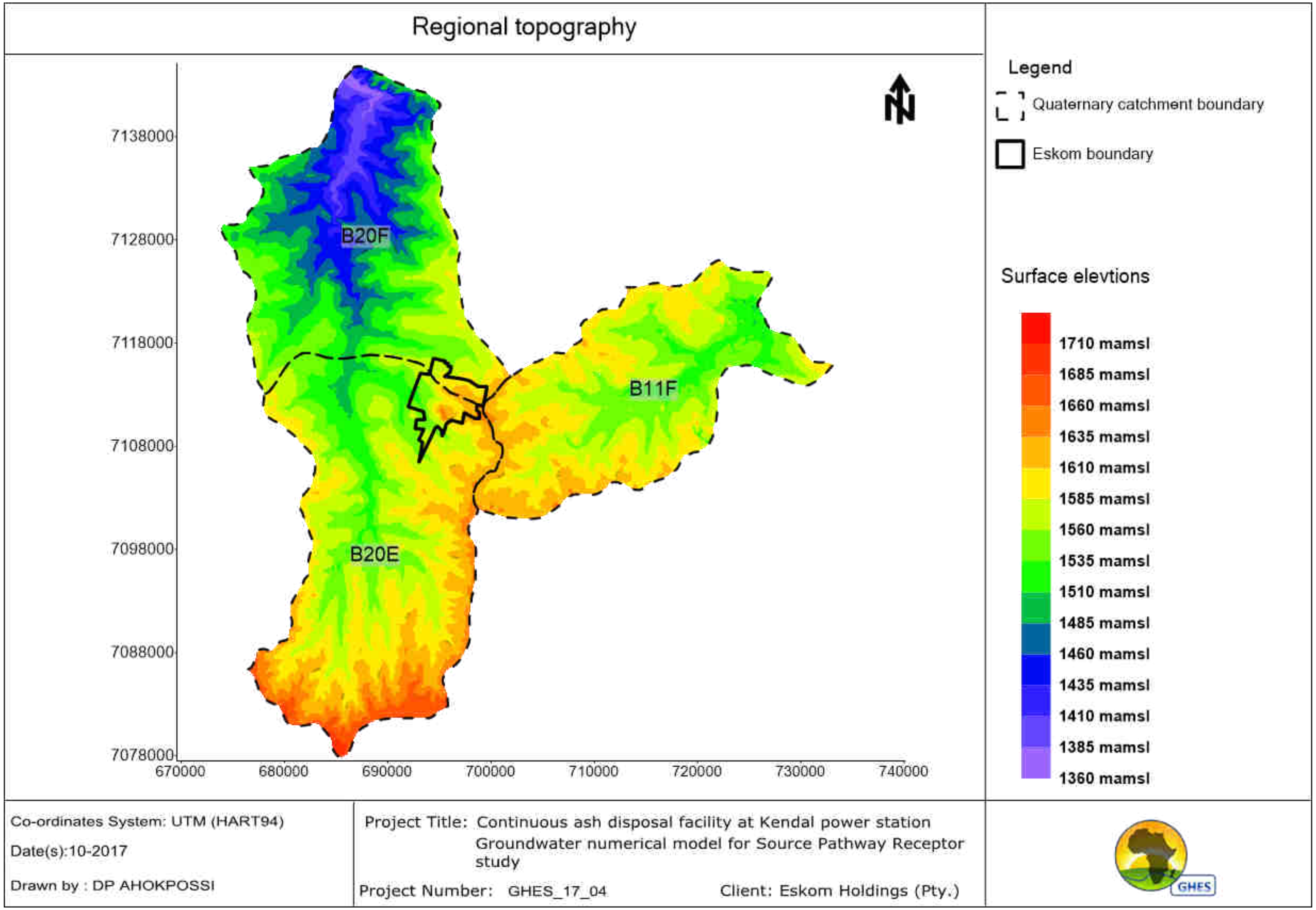



**Figure 5-5: Catchment B20E topography**

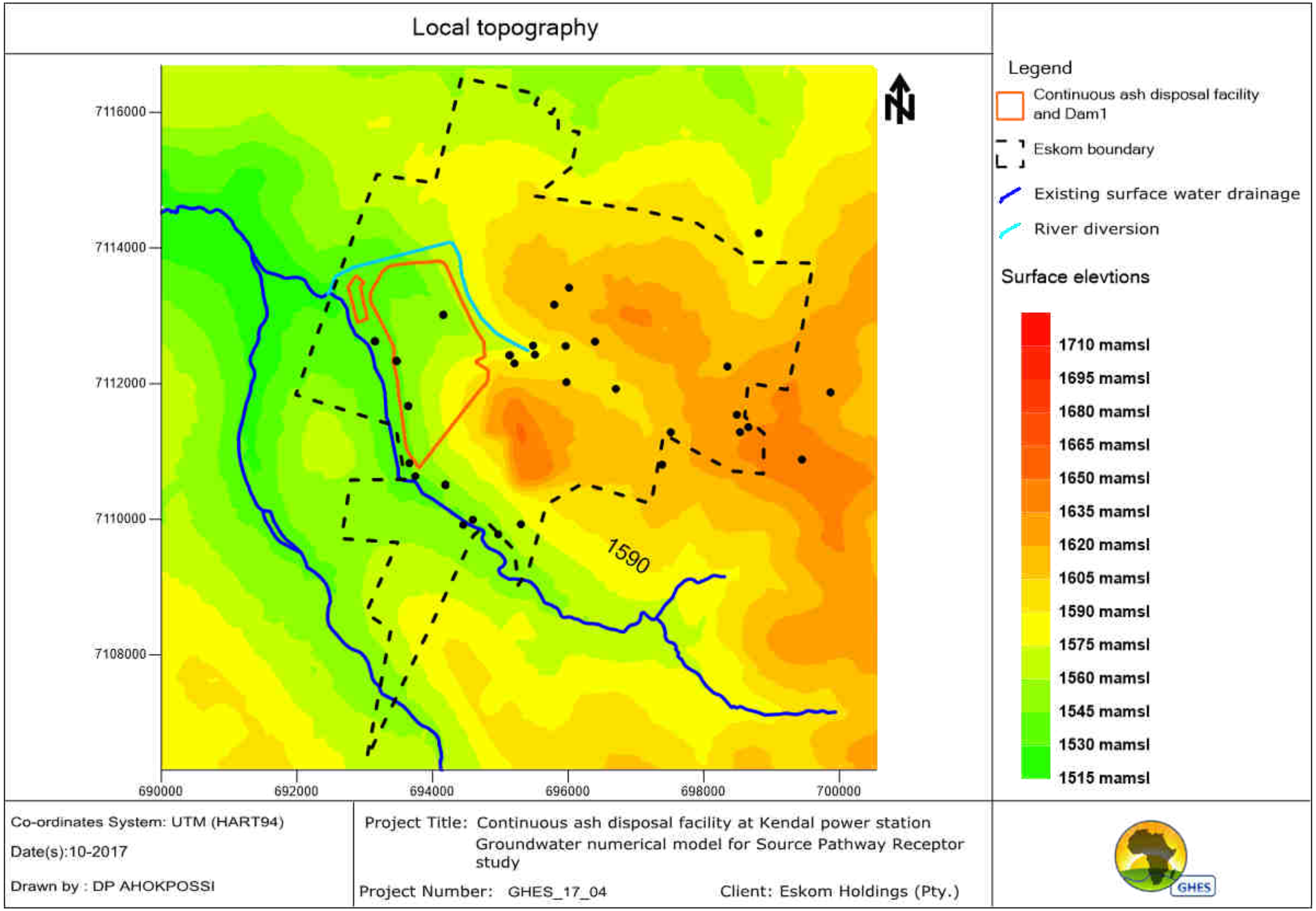
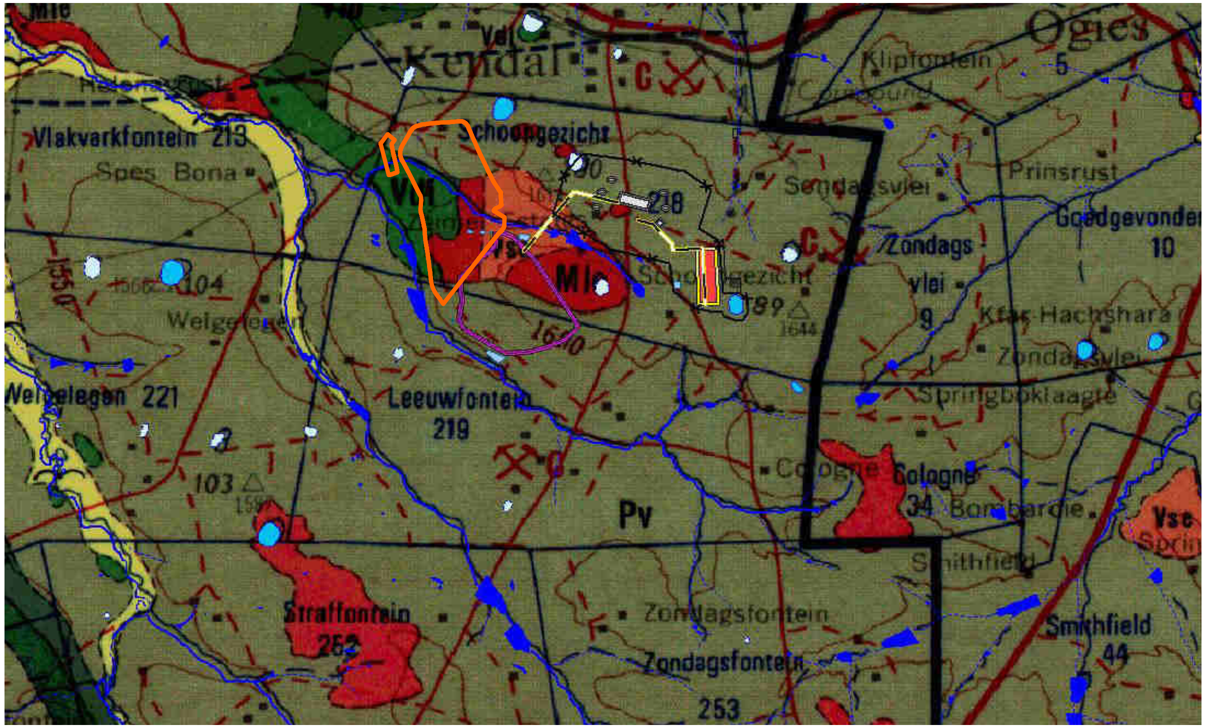



**Figure 5-6: Local topography at the Kendal Power Station**

General geology




N

Legend

Continuous ash disposal facility and Dam1

Mle : Granite suite

Jd : Dolorite

Pv : Vryheid Formation Sandstone, Mudstone, Shale, and Coal

Vse : Selons River Formation Porphyritic Rhyolite, Mudstone, and Sandstone

Vle : Loskop Formation Agglomerate, Lava

Vdi : Loskop Formation Diabase

Co-ordinates System: UTM (HART94)

Date(s):10-2017

Drawn by : DP AHOKPOSSI

Project Title: Continuous ash disposal facility at Kendal power station Groundwater numerical model for Source Pathway Receptor study

Project Number: GHES_17_04

Client: Eskom Holdings (Pty.)

GHES

**Figure 5-7: General geology of the study area**

### 5.3.2 Local geology at the KPS ADF

Based on the regional geological map for the Kendal Power Station area that the local geological sequence comprises of, soil, clay, shale, siltstone, mudstone and sandstone. This local lithological sequence for the Kendal Power Station Area is presented in **Table 5-1**.

**Table 5-1: Local lithological make up for the Kendal Power Station area (GHT Consulting Scientists, 2016b)**

| Age | Sequence | Group | Formation | Symbol | Rock types | |
|---|---|---|---|---|---|---|
| | | | | | Sedimentary and Volcanic Rocks | Intrusive Rocks |
| Quaternary | | | | Q | Alluvium Sands | |
| Jurassic | | | | Jd | | Dolerite |
| Permian | Karoo | Ecca | Vryheid | Pv | Sandstone, Mudstone, Shale and Coal Beds | |
| Mokolian | | | | Mle | | Granite suite (Bushveld complex) |
| Vaalian | Transvaal | Rooiberg | Loskop | Vlo | Agglomerate, Lava | |
| Vaalian | Transvaal | Rooiberg | Loskop | Vdi | | Diabase |
| Vaalian | Transvaal | Rooiberg | Selons River | Vse | Porphyritic rhyolite with interbedded Mudstone and Sandstone | |

GHT Consulting Services undertook a numerical pollution plume model update at the KPS Continuous ADF site in 2016 (GHT Consulting Scientists, 2016b). The study produced 47 geological borehole logs with representative data and information of the geology underlying the Continuous ADF site.

Based on the geological borehole logs presented in the study, (GHT Consulting Scientists, 2016b) concluded that the main geological features (lithology) encountered during drilling on the site consisted of clay, granites and dolerites of the Karoo Supergroup:

- Clay: The clay is very fine texture with a soft and silty feature, and varies between approximately 6 – 19 m thick within the alluvium layer directly underlying the existing KPS ADF;
- Granite: Reddish brown to brownish white fine to coarse grained and weathered to hard, massive granites, which varies between approximately 3 – 36 m (or more) thick;
- Dolerite: The dolerites are mainly massive hard and fresh, no prominent weathered zones were intersected during the drilling.

This study undertaken by (GHT Consulting Scientists, 2016b) also developed a conceptual geohydrological model of the Kendal Power Station area. The conceptual geology on which the conceptual geohydrological model was based is presented as a 3-dimentional diagram in **Figure 5-8**. The 3-D conceptual geology representation suggests that the current KPS ADF is underlain firstly by an alluvium layer containing clay, amongst others, followed by an impervious aquitard intrusion consisting of granite, dolerite and diabase. The relative position of the Continuous ADF site is indicated by the yellow dashed oval shape in **Figure 5-8**, which is suggesting that the Continuous ADF may be characterised by the same lithological sequence as shown underlying the existing KPS ADF.

The study undertaken by GHT Consulting Scientists (2016b) reported on geological borehole logs that was investigated during an earlier study by GHT Consulting Scientists that investigated the lithological sequence of boreholes in the area northwest of the existing KPS ADF, and was located in the area where the Continuous ADF was proposed to extend to (GHT Consulting Scientists, 2015b). The boreholes in this area are represented by boreholes AB60 – AB67 as indicated in **Table 5-2**. These 8 additional boreholes are represented geographically in relation to the Continuous ADF footprint in **Figure 5-10**.

**Table 5-2: Boreholes located in close proximity to the Continuous ADF footprint (GHT Consulting Scientists, 2015b)**

| BH No. | Site description | BH depth | Coordinates | | Underlying lithological sequence from shallow to deep (width of layer in meters) | | | Depth of water strike (m) |
|---|---|---|---|---|---|---|---|---|
| | | | Long (°E) | Lat (°S) | 1st | 2nd | 3rd | |
| AB60 | Deep borehole west of ash stack. Nearby Leeuwfontein Spruit. | 36 | 28.93634 | -26.10117 | Clay (19) | Dolerite (17) | - | 22 |
| AB61 | Shallow borehole west of ash stack. Nearby Leeuwfontein Spruit. | 17 | 28.93633 | -26.10121 | Clay (17) | - | - | - |
| AB62 | Deep borehole north west of ash stack. In old cultivated land next to nearby Leeuwfontein Spruit. | 36 | 28.93452 | -26.09522 | Granite (3) | Clay (8) | Dolerite (25) | 12 |
| AB63 | Shallow borehole north west of ash stack. In old cultivated land nearby Leeuwfontein Spruit. | 12 | 28.93455 | -26.09522 | Granite (3) | Clay (8) | Dolerite (1) | - |
| AB64 | Deep borehole north west of ash stack. Nearby Leeuwfontein Spruit. | 36 | 28.93129 | -26.09264 | Granite (36) | - | - | - |
| AB65 | Shallow borehole north west of ash stack. Nearby Leeuwfontein Spruit. | 6 | 28.93128 | -26.09264 | Granite (6) | - | - | - |
| AB66 | Deep borehole north of ash stack. Next to Schoongezicht Spruit. | 36 | 28.94131 | -26.08899 | Clay (6) | Dolerite (30) | - | - |
| AB67 | Shallow borehole north west of ash stack. Next to Schoongezicht Spruit. | 6 | 28.94129 | -26.08899 | Clay (6) | - | - | - |

Results from the geological borehole logs for the 8 additional boreholes drilled in close proximity to the Continuous ADF footprint (Figure 5-10) indicate that the local lithology generally occur in the sequence Clay-Granite-Dolerite for the borehole samples analysed. In boreholes where no clay was encountered, granite was encountered, while dolerite was encountered underlying either the clay or granite lithologies. It is therefore inferred that a strong likelihood exists that most of the area that will be covered by the Continuous ADF is either directly underlain by clay or granite.

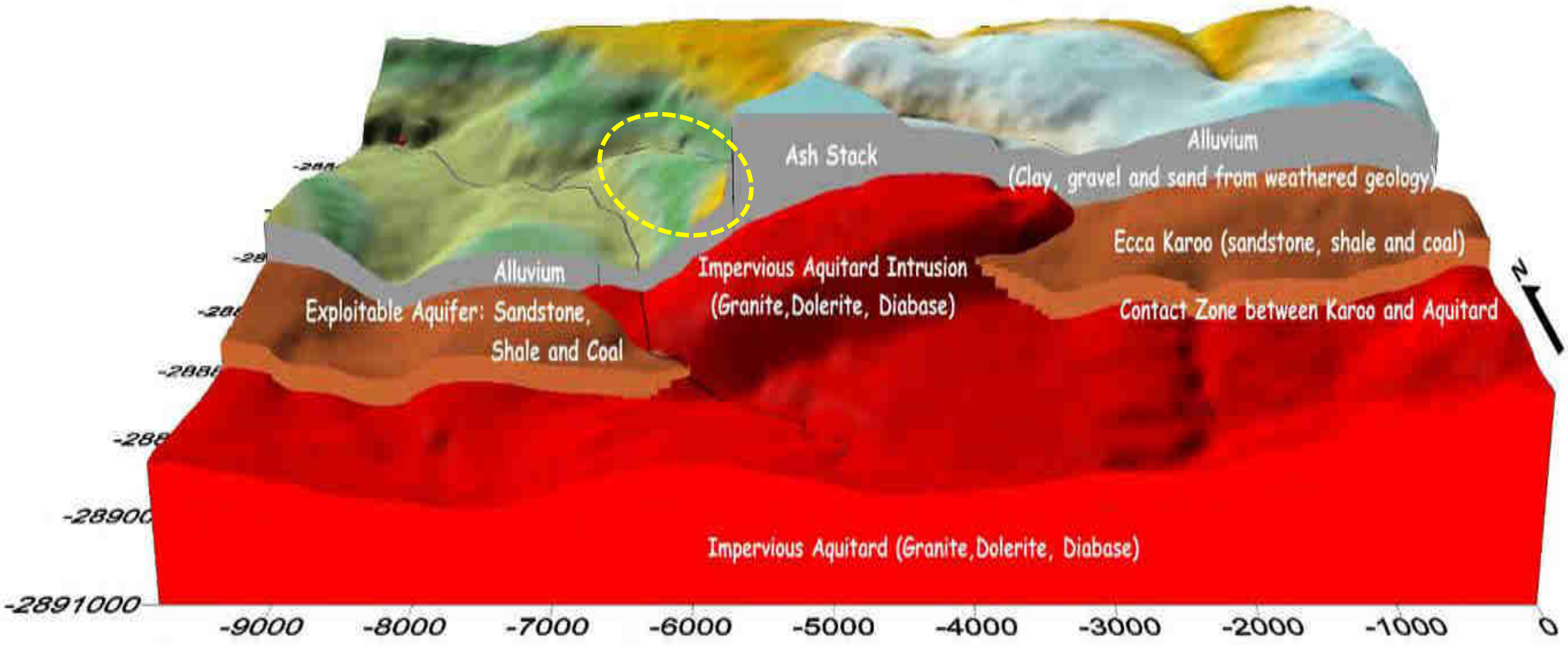



**Figure 5-8: Conceptual local geology at Kendal Power Station (GHT Consulting Scientists, 2016b) and relative position of Continuous ADF**

## 5.4 Geohydrology

### 5.4.1 General geohydrology

Two main water-bearing rock type formations control the storage, flow (movement), recharge, and withdrawal of groundwater: Fractured aquifer system (Class B), and inter-granular and fractured aquifer (Class D). The predominant formations at the site are Vryheid; Loskop; and Selons Rivier. The site is generally associated with one or combined forms of the following:

- Fractures associated with the intrusion of acidic lava, contact zones between different sediments;
- Weathered and/or fractured sedimentary rocks not associated with dolerite intrusion,
- Indurated and jointed sedimentary rocks alongside dykes,
- Narrow weathered and fractured dolerite dykes,
- Weathered dolerite sills and jointed sedimentary rocks,
- Weathered and fractured upper contact-zones of dolerite sills,
- Weathered and fractured lower contacts-zones and coal seams.

Key aquifer characteristics that are associated with such aquifers are summarized in **Table 5-3**. In Vryheid formation, the recharge is estimated by Vegter et al (1995) at 4 to 5% of the mean annual rainfall.

**Table 5-3: Geological sequence with selected aquifer characteristics**

| Formation/Group | Maximum borehole yield (l/s) | Range of water level (mbgl) |
|---|---|---|
| **Loskop** | 6.40 | 10 and 30 |
| **Vryheid** | 12.60 | 5 – 25 |
| **Ecca** | 9.20 | -- |

### 5.4.2 Existing hydrocensus surveys

A review of the existing hydrocensus information and data was undertaken by Geo Hydraulic and Engineering Services in early 2018 (GHES, 2018). GHES reported that two independent hydrocensus was undertaken for the Kendal Power Station in 2013 and 2016 by Golder Associates and GHT Consulting Scientists, respectively.

Golder Associates conducted a hydrocensus during February 2013 (Golder Associates, 2014a) and identified privately owned boreholes (Kendal1/FBB39, and Kendal2/ FBB56) within less than 1 km to the Continuous ADF site. The 2 boreholes were equipped with submersible pumps and were used for domestic purposes. With the exception of elevated concentrations of Nitrate ($NO_3$) and Manganese (Mn), and the lower pH (<6) at sampled site Kendal1, the groundwater quality at these two sampling points are generally of good quality when compared to South African National Standard (SANS), SANS_241_2011 and South

African Water Quality Guidelines (SAWQG), Volume1_Domestic Use. Fertilizer which is used for cropping was suggested as probable source for elevated concentrations of $NO_3$ and Mn on the groundwater quality at sampled site Kendal1 (FBB39). Kendal2 was found to represent unpolluted groundwater.

Another hydrocensus was conducted by GHT Consulting Scientists in February 2016 (GHT Consulting Scientists, 2016a), and confirmed that these 2 boreholes are the closest privately-owned boreholes to the Continuous ADF site. The quality and the uses of these boreholes were confirmed to be the same as in 2013. The Mn concentration in the water from FBB39 improved from 0.099 mg/l in 2013 to 0.001 mg/l in 2016, but the $NO_3$ remained at 17.40, which is above the South African National Standard (SANS_241_2015) for drinking water.

In addition to these 2 boreholes, 36 groundwater sites (**Figure 5-10**) were identified in the area, 19 of which are in catchment B20E. The uses of groundwater and surface water, as recorded during hydrocensus in the area, are illustrated in Figure 5-9, below

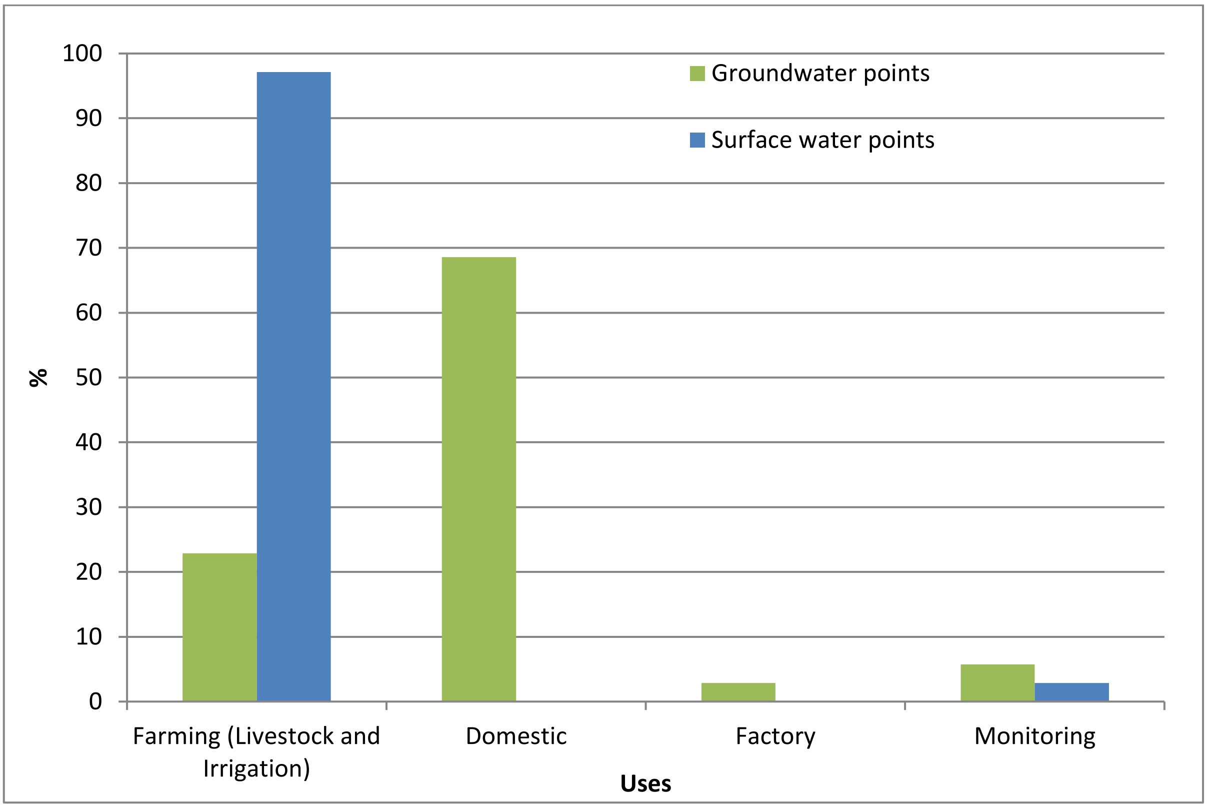



**Figure 5-9: Groundwater uses in the study area**

The boreholes that were sampled during the hydrocensus in the catchment B20E were classified in Class 1 water quality and suitable for human consumption according to SANS_241_2011, except for high concentrations of $NO_3$ (FBB35, and FBB54), Na and $SO_4$ (FBB40), and F (FBB38) in 4 boreholes. These 4 boreholes were all located more than 2.5 km south east of the ADF site and the potential sources of these high concentrations of solutes in groundwater were not associated with any activity of the Kendal Power Station as all these sites are located upstream of the KPS and its ADF.

### 5.4.3 Groundwater quality

Surface water and groundwater monitoring is conducted at KPS according to and in compliance with its WUL requirements. Monitoring data (quality and quantity) from 86 sites has been collected quarterly and captured by GHT Consulting Services since 2011. Among these monitoring sites, 69 are in catchment B20E, specifically in the Schoongezicht Spruit (44 sites) and Leeuwfontein Spruit (25) drainage systems respectively (**Figure 5-10**). Currently, a total of 41 surface water sampling points and 45 groundwater sampling points are sampled around the potential sources of pollution at the power station.

The main groundwater chemical constituents exceeding the SANS 241_2011's limits in the catchment B20E include Manganese (at sites AB07, AB08, AB16, AB22, AB51, AB52, CB55, AB57, and WB18S), Sulphate (at site AB08), Fluoride (at sites PB04, PB06, PB23, and CB54), and Iron (at site AB08 and AB48). It was not possible to concluded from the groundwater monitoring samples which proportion of the contamination could be apportioned to Kendal Power station as constituents from other potential pollution sources could not be quantified. When compared to the SAWQG, Manganese (PB04 and PB05), Fluoride (PB04, PB06, PB23, and CB54), and Iron (AB08 and AB48) are of concern. The locations of the contaminated monitoring boreholes in the project area are shown in **Figure 5-11**.

Sites AB51 and AB52 are located at the downstream footprint of the continuous ADF site, at the northern extent of the existing ash disposal facility (**Figure 5-11**). AB07, AB08, AB16, AB57, are located north of the existing ashing area drainage, and south east of the continuous ash disposal facility's site (Schoongezicht Spruit).

Borehole sites PB04, PB05, PB06, PB23 are located at the south of the power station area drainage, at more than 500m east of the Continuous ADF site, along the Schoongezicht Spruit, while borehole site AB22 and AB48 are located to the south of the existing ADF area drainage, and south east of the Continuous ADF site, along the Leeuwfontein Spruit. Borehole sites CB54, CB55, and WB18S are located west of the coal stockyard area drainage along the Schoongezicht Spruit (**Figure 5-11**), more than 2.5 km south-south east of the continuous ADF site (GHES, 2018).

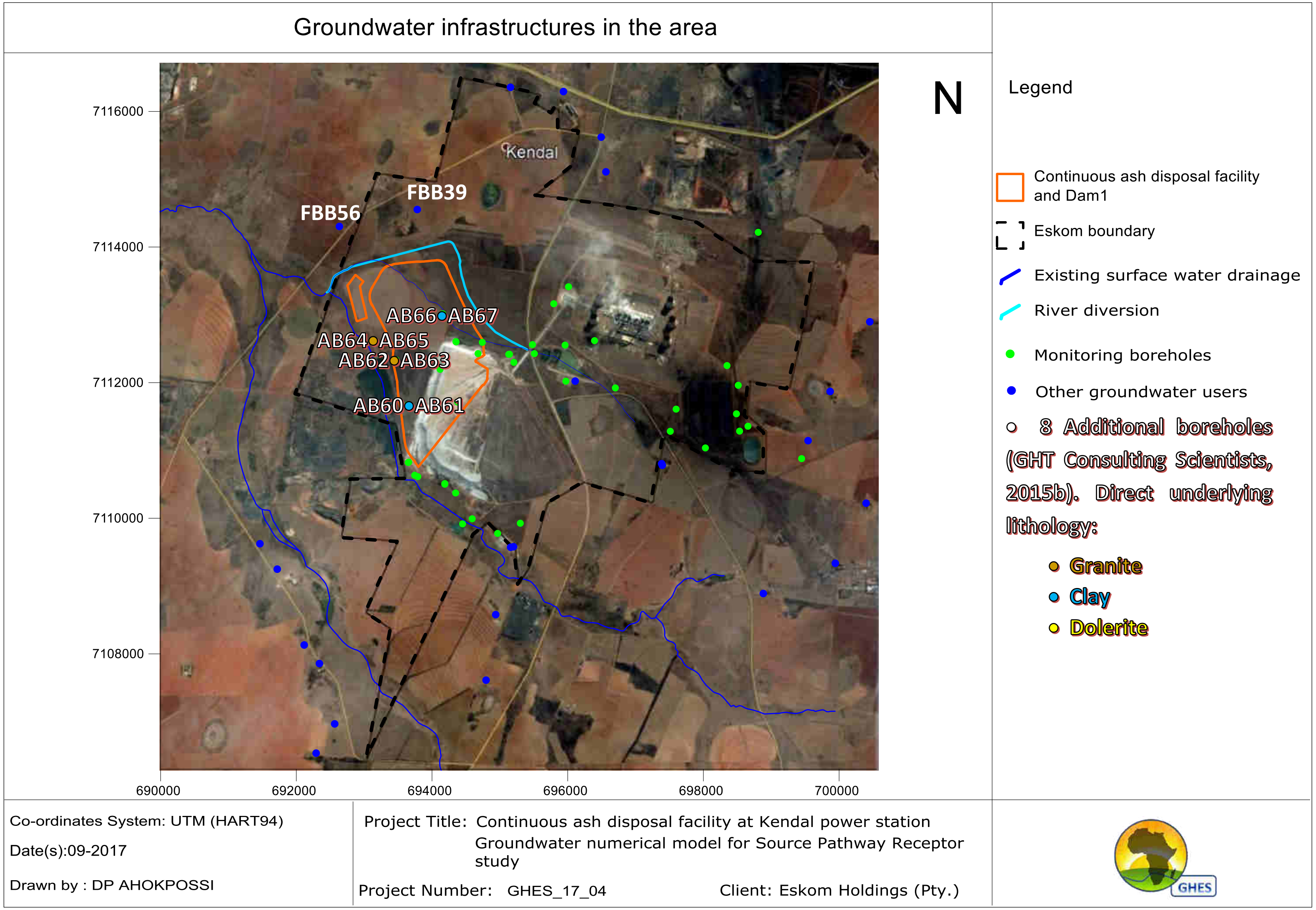



**Figure 5-10: Overview of borehole resources in the area (GHES, 2018)**

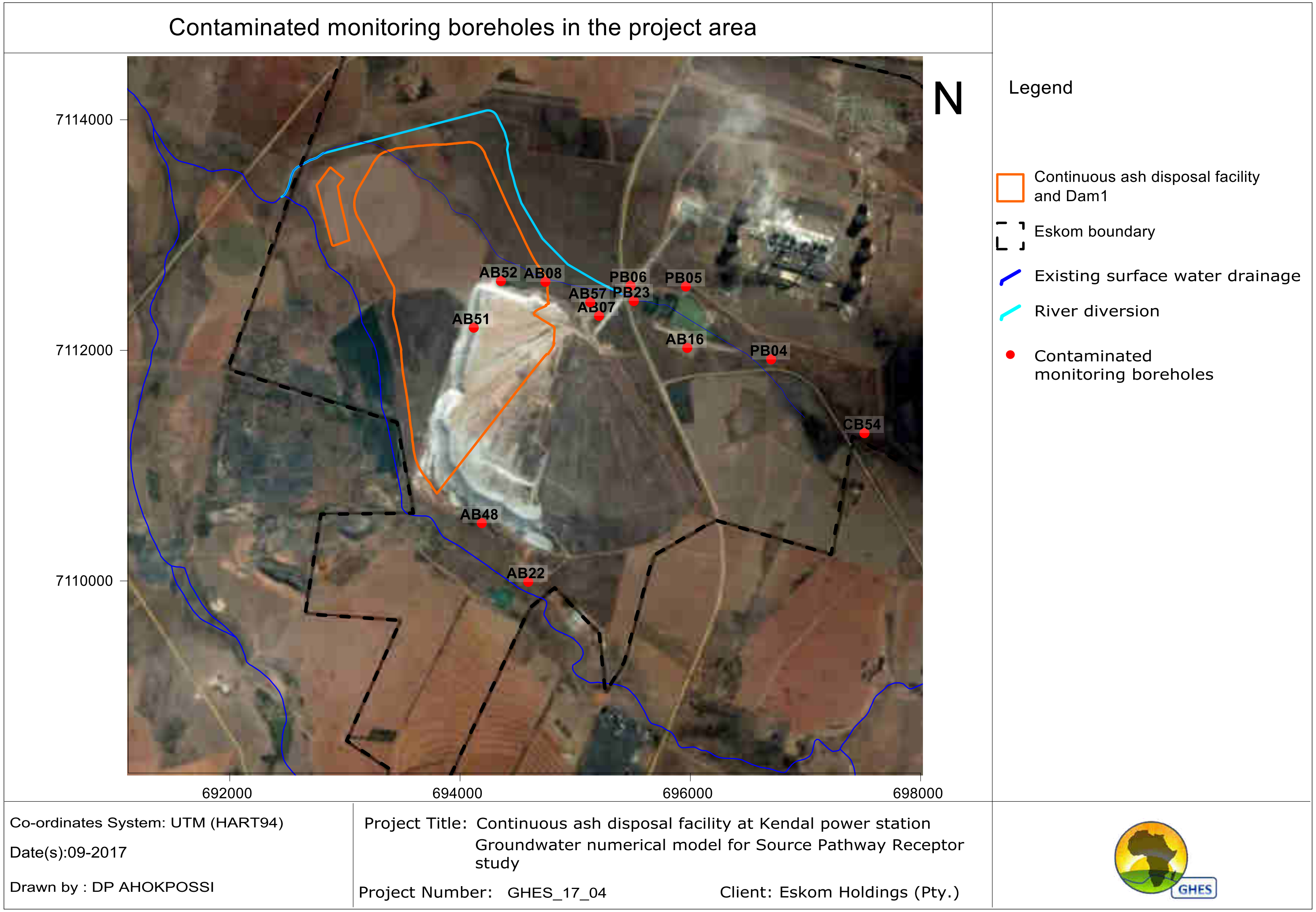
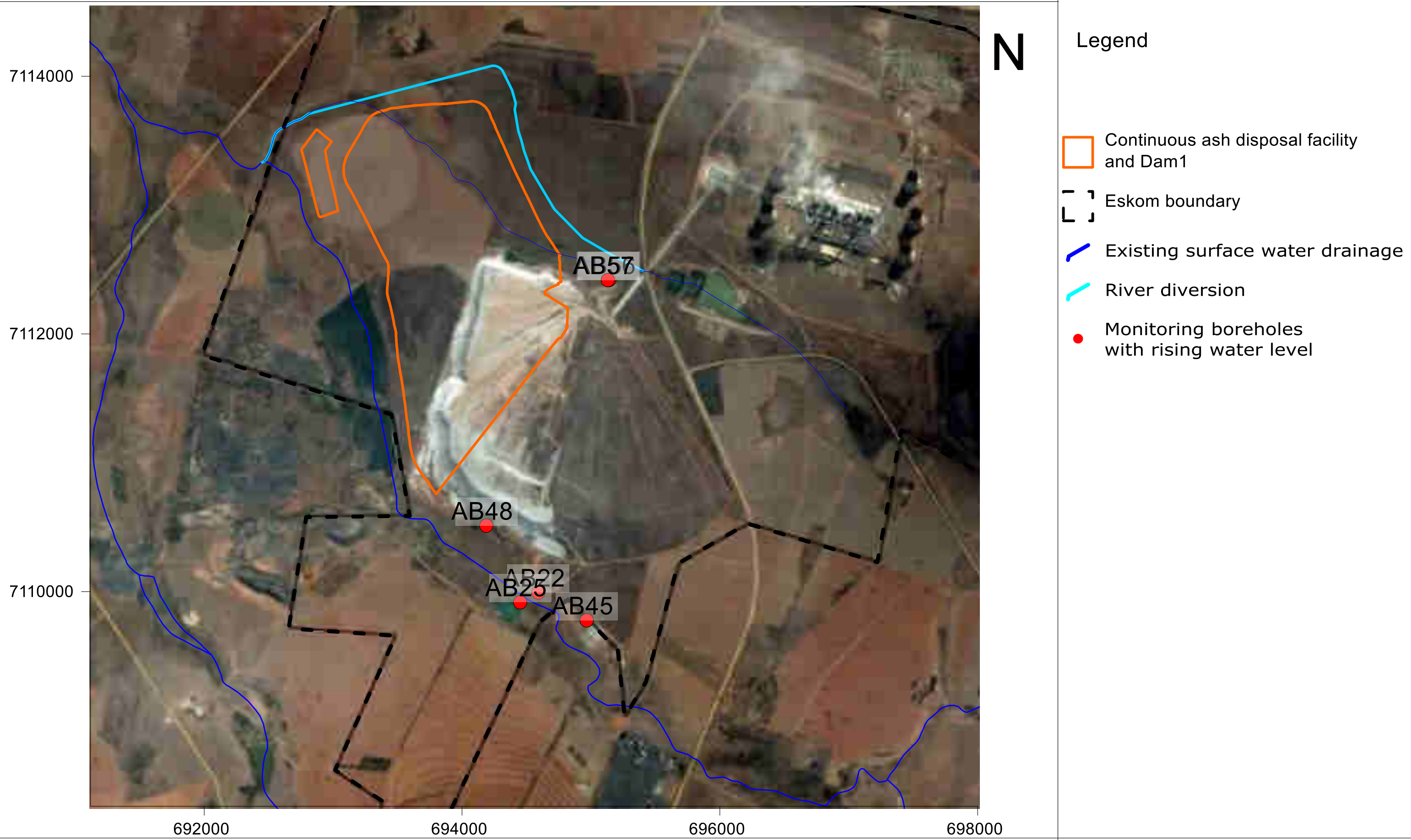



**Figure 5-11: Contaminated monitoring boreholes in the project area (GHES, 2018)**

Monitoring boreholes with rising water levels in the project area




Co-ordinates System: UTM (HART94)

Date(s):09-2017

Drawn by : DP AHOKPOSSI

Project Title: Continuous ash disposal facility at Kendal power station Groundwater numerical model for Source Pathway Receptor study

Project Number: GHES_17_04

Client: Eskom Holdings (Pty.)

**Figure 5-12: Monitoring boreholes with rising water level (GHES, 2018)**

### 5.4.4 Groundwater levels

Seasonal fluctuating water levels are observed in the majority of the boreholes, and the highest annual decreases of depths to groundwater (rise of water elevations) in the monitoring boreholes, are generally observed between January and March. This decrease in the depths to groundwater levels during the wettest months of the year, alternate with an increase (drop of water elevations) during the dry period of the year.

This suggests that the groundwater in the study area is being recharged by the infiltration of summer rainfall starting from November. The groundwater elevations in monitoring boreholes AB22, AB25, AB45, AB48, AB56, AB57, and WB12, show a continuous increasing trend, especially from July 2012 (**Figure 5-12** and **Figure 5-13**). The increased groundwater elevations in these boreholes result in relative steep groundwater gradients towards these boreholes and may be associated with existing continued seepage from the existing ADF.

In February 2016 the depths of groundwater at the boreholes in the study area ranged from 0.9 to 35mbgl (**Figure 5-14**). The highest frequency (mode) of the recorded depths to groundwater levels is from 0.9 to 2.9 mbgl, and a decrease in frequency is observed as the depth of groundwater level increase. 85% of the overall recorded groundwater levels are shallower than 10 mbgl, and approximately 54% are less than 5 mbgl. **These observations confirm the general shallow water level (limited unsaturated zone) across the ash disposal area.**

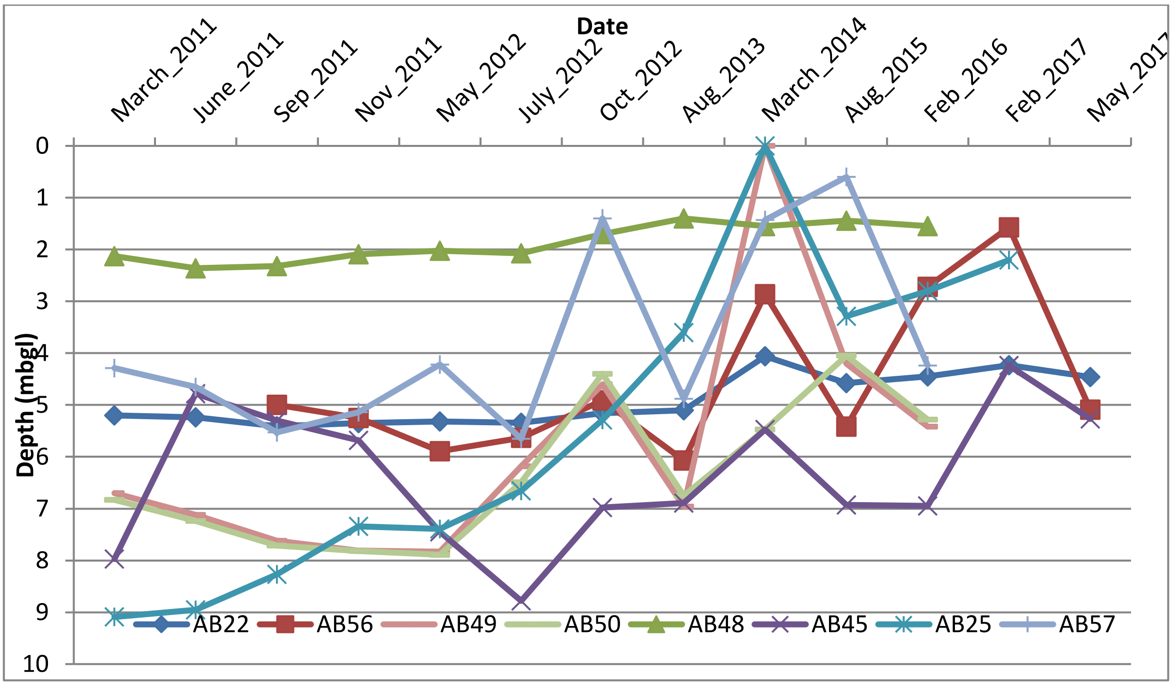



**Figure 5-13: Monitoring boreholes with rising water level**

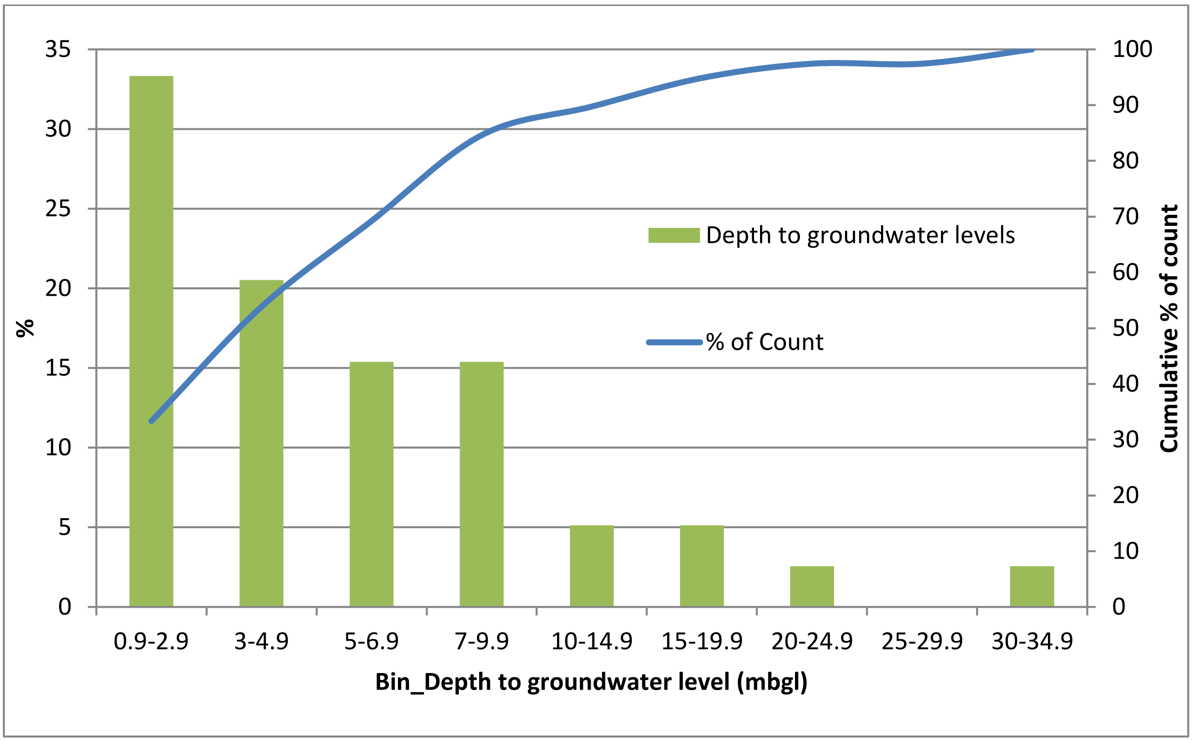



**Figure 5-14: Frequency distribution of recorded depths to water levels (GHES, 2018)**

Using the ground surface elevations retrieved from digital elevations models (SRTM), groundwater elevations were calculated and plotted against surface elevations. A correlation of 99% was observed between the two elevations, suggesting that the groundwater level will mimic the topography. The Bayesian interpolation was then used to compile the groundwater heads contour map and assess the groundwater drainage in the study area (**Figure 5-15**).

The groundwater heads contour map indicates that groundwater drainage at the Continuous ADF footprint is generally in a westward direction.

### 5.4.5 Existing geophysical survey and drilling data

In April 2012, preliminary geophysical surveys were conducted south of the continuous ash disposal facility's site, by GHT Consulting Services as part of "aquifer classification for vulnerability and Risk assessment at KPS" (GHT Consulting Scientists, 2012). The magnetic method was used on 24 traverses (T1 to T24) to detect geological features (dolerite dykes, sills, hidden faults) that may be associated with preferential pathways for groundwater migration and contaminant transport from the existing ADF and other potential pollution sources (e.g. Coal stack yard, emergency stack, dirty water dams) at the power station. These geophysical investigations suggested presence of relatively highly magnetised rocks (dolerites) around the existing ADF. A dolerite dyke is probably crossing the south of the existing ash disposal facility as shown by magnetic anomalies on traverses T1, T2 and T12 (**Figure 5-16)**. The size, depth, strike, and the shape of the dyke were not determined.

GHT Consulting Services conducted other magnetic geophysical surveys (Trav1 to Trav4) on the Continuous ADF site, in 2015 (GHT Consulting Scientists, 2015b). The magnetic data were collected to site boreholes for the extension of groundwater monitoring network at KPS. The results of the magnetometer survey **suggested the presence of dolerite sill underlying the continuous ADF site**. Five pairs of deep and shallow monitoring boreholes were subsequently drilled for monitoring purpose on the Continuous ADF site.

In addition to the geophysical and drilling reports (Reports Number: RVN 601.12/1311, and RVN 716.6/1581), 47 geological borehole logs information were reviewed from the numerical pollution plume model update, compiled by GHT Consulting Services in 2016 (GHT Consulting Scientists, 2016b). The drilled borehole depths ranged from 1 to 60 meters, while water was encountered before 10 mbgl in 47% of boreholes, and before 20 mbgl in 80% of boreholes.

When lithological sequence of some of the borehole logs were considered, it was found that dolerite sill depth ranged between 6 and 19 mbgl, which correlate well with the fact that water strikes were observed below 20 mbgl in 80% of the boreholes drilled. **The results therefore suggest that** t**he thickness and the geometry of the impermeable granite sills in the area control the groundwater flow and associated solute transport, especially possible pollution emanating from ground surface.**

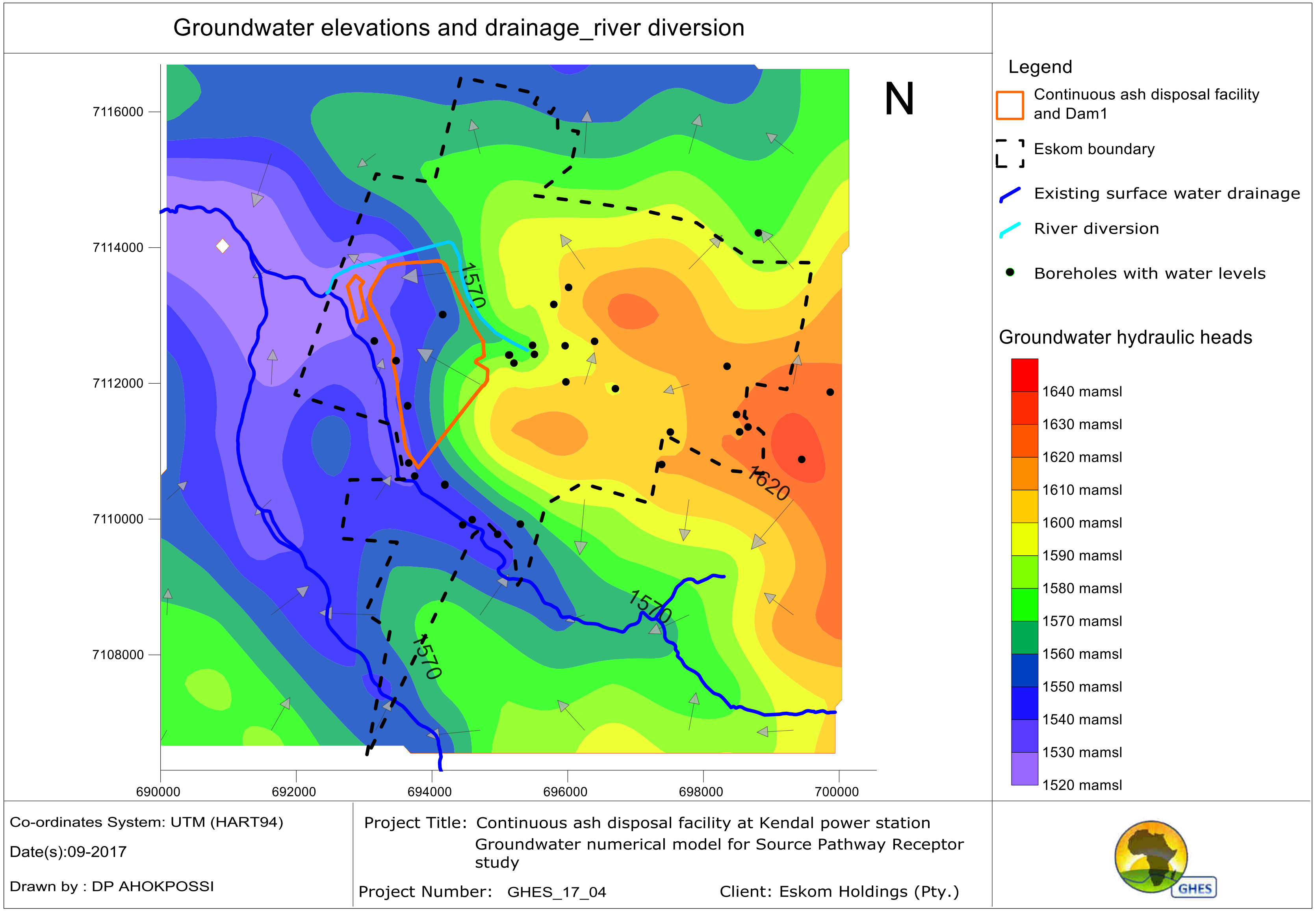



**Figure 5-15: Groundwater elevations and drainage (GHES, 2018)**

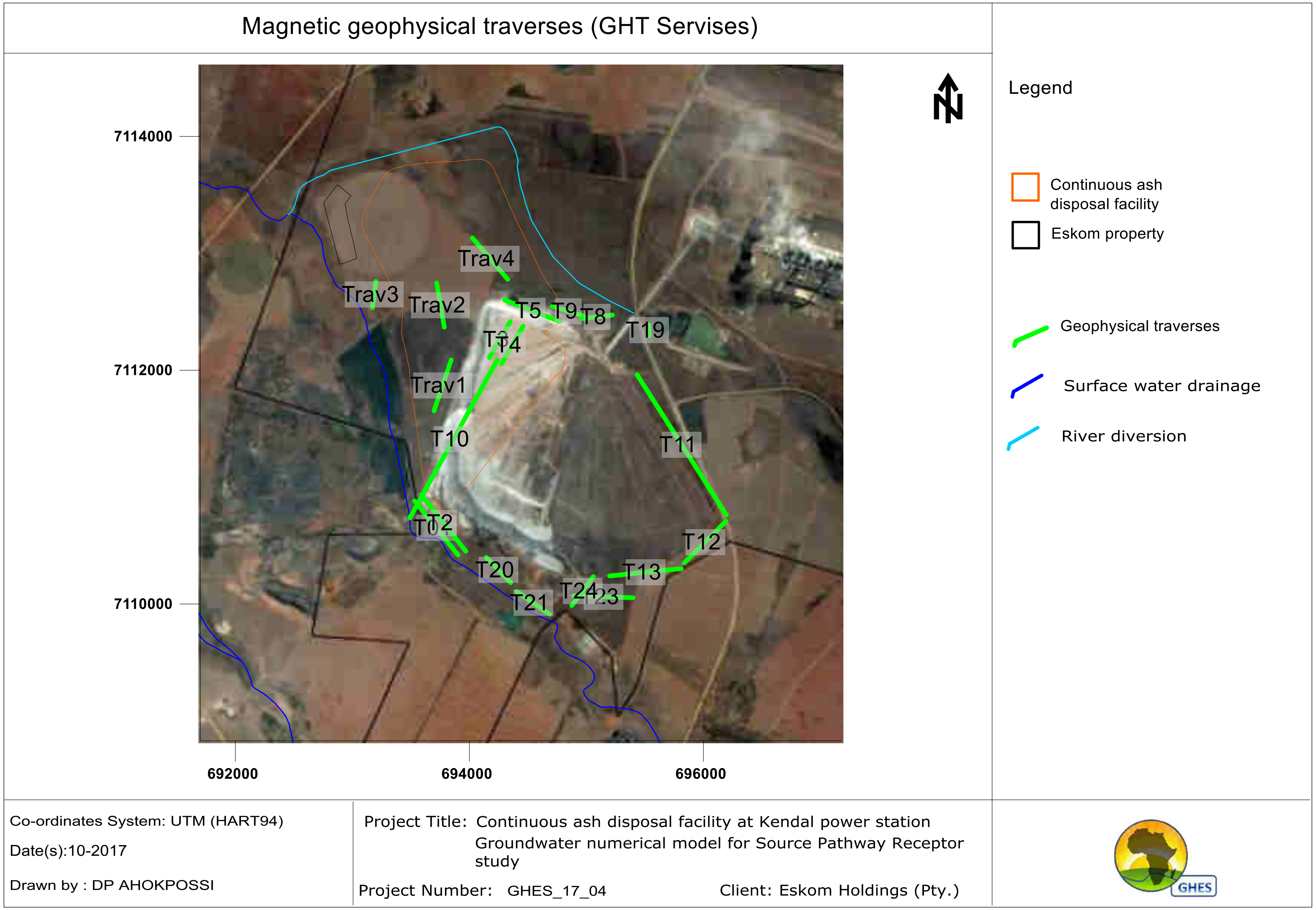



**Figure 5-16: Traverses identified during previous geophysical survey's (GHES, 2018)**

## 5.5 Surface Water

### 5.5.1 Catchment description

Kendal Power Station is located in the Upper Olifants Catchment which falls within the Olifants Water Management Area (WMA4), specifically in the B20E and B20F quaternary catchments within the Wilge River sub-catchment. The Wilge River catchment principally includes the towns of Bronkhorstspruit and Delmas as well as the Ezemvelo Game Reserve to the north. The catchments in the Olifants are further divided into Management Units (MU) and Kendal is located within MU 22. The Wilge catchment incorporates four rivers/streams including the Grootspruit, Saalboomspruit, Bronkhorstspruit and the Wilge River (Golder Associates, 2016b).

The project area lies mainly within the Wilge Water Management Unit. The Wilge River is the main drainage feature of the area draining northwards to the west of KPS and ADF. Tributaries near the KPS ADF drain westwards into the Wilge River (**Figure 5-17**). Except for the Leeuwfontein Spruit, most tributaries in this area are unnamed.

### 5.5.2 Classification of the water resources

The Department of Water and Sanitation (previously Department of Water Affairs (DWA)) has completed the classification process for the significant water resources of the Olifants WMA (DWA, 2013). The process included stakeholder engagement for input in recommending the classes for the Integrated Units of Analysis (IUA) defined for the WMA.

The Bronkhorstspruit, Saalboomspruit and Upper Wilge rivers are in a moderately modified state (category C) with less developed areas present in the catchment (DWA, 2013) (DWS, 2018b). Impacts within the catchment are related to urban areas, agriculture, dams and some mining. The importance of the resources is moderate especially in terms of good water quality that they contribute to the main stem Olifants River above Loskop Dam.

The management class for the Wilge River has been set as a Class II with an overall ecological category of a C for the IUA (DWA, 2013) (DWS, 2018b). This class implies that moderate usage of the water resource in future and the status quo in the river system has to be at least maintained.

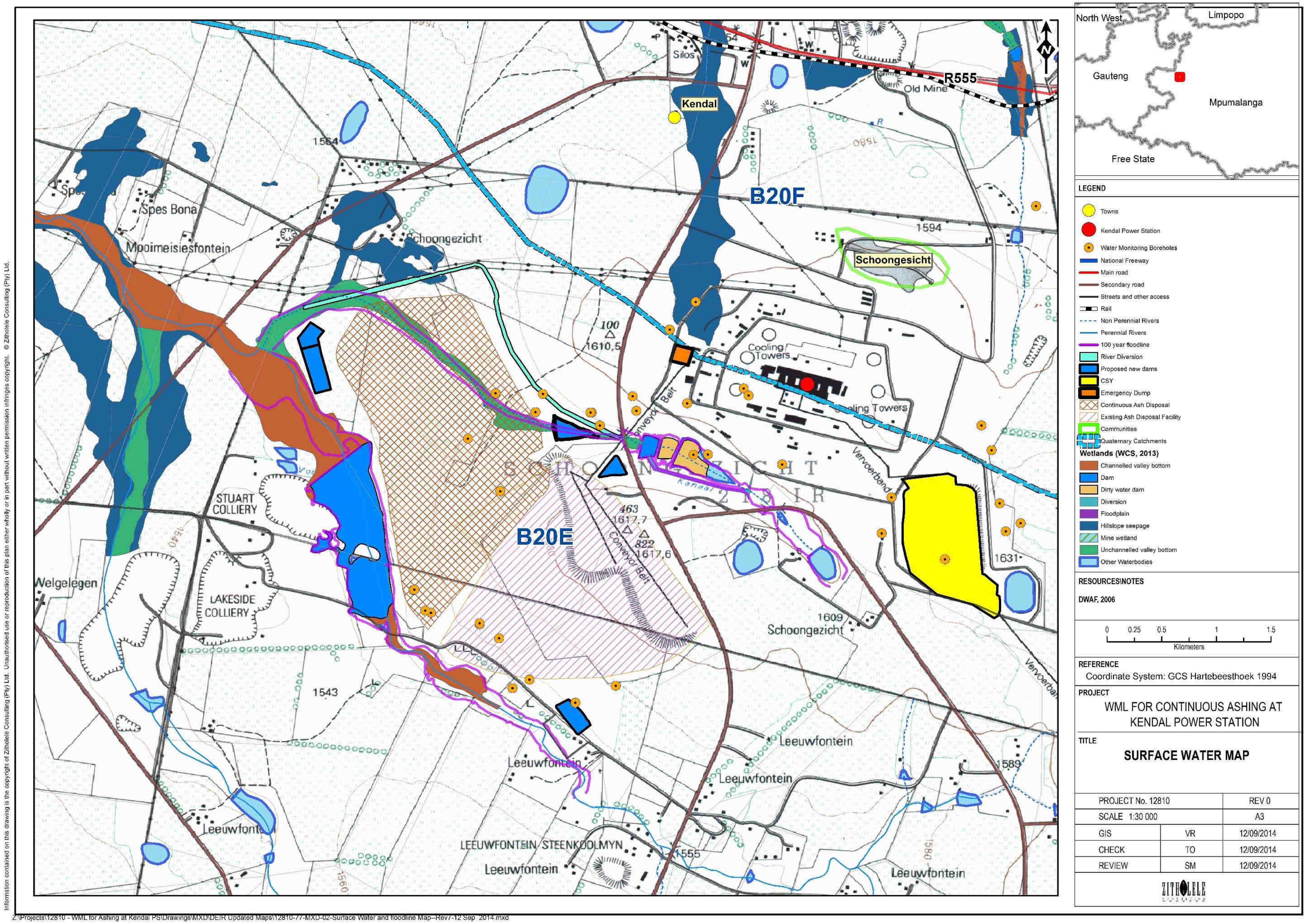



**Figure 5-17: Surface water and drainage features associated with the KPS ADF**

### 5.5.3 Present Ecological State and Ecological Importance and Sensitivity

The Present Ecological State (PES) is defined as the current state or condition of a water resource in terms of its biophysical components (drivers) such as hydrology, geomorphology and water quality and biological responses, viz. fish, invertebrates and riparian vegetation. The degree to which ecological conditions of an area have been modified from the natural condition and the Ecological Importance and Sensitivity (EIS) relate to the presence, representativeness and diversity of species of biota and habitat. Ecological Sensitivity relates to the vulnerability of the habitat and biota to modifications that may occur in flows, water levels and physico-chemical conditions.

PES and EIS were determined during the recently completed classification study (DWS, 2014). **The Wilge River was found to be in a moderately modified state (category C)** and with less developed areas present in the catchment. The importance of the resource is moderate especially in terms of good water quality contributed to the main stem Olifants River above Loskop Dam. Therefore, it was proposed to maintain the current PES category within the catchment. A Management Class II was recommended. As defined in the Water Resource Classification process this means that the area can be moderately used and that the water resource could be moderately altered from its pre-development condition (Golder Associates, 2016b).

### 5.5.4 Class and Resource Quality Objectives

During 2010 a study was undertaken to develop an integrated water resources management plan for the Upper and Middle Olifants catchments. As part of this study the catchment was divided into management units (MU). Interim Resource Water Quality Objectives (RWQOs) were set for each of the management units identified in the study. KPS falls within MU 22 (Golder Associates, 2014b). Following on from the establishment of the Interim RWQOs, a report setting out classes and resource quality objectives for water resources in the Olifants catchment (DWS, 2014) was gazetted in April 2016. This report determined and set the Resource Quality Objectives (RQO) for the Olifants catchment to ensure comprehensive protection of water resources so that they can be used in a sustainable manner. RQOs was set for river resources, wetlands, dams and groundwater resources.

Subsequent to the gazetting of the RQOs for the Olifants catchment, DWS identified the need to develop an overarching Integrated Water Quality Management Plan (IWQMP) for the Olifants WMA in order to manage the water resources. The IWQMP needed to take cognisance of and align to a number of studies and initiatives that have been completed to date, while furthermore establishing clear goals relating to the quality of the relevant water resource in order to facilitate a balance between protection and use of water resources (DWS, 2018b). This study included the development of Water Quality Planning Limits (WQPL) and monitoring programmes (DWS, 2018a).

**Table 5-4: Proposed WQPLs for the Wilge catchment Management Unit 22**

| Variable | Units | WQPL |
|---|---|---|
| **WQPLs for MU 22 Wilge catchment of the Upper Olifants** | | |
| Calcium (dissolved) | mg/L | 32 |
| Chloride (dissolved) | mg/L | 20 |
| Total Dissolved Solids | mg/L | 260 |
| Electrical Conductivity (EC) | mS/m | 40 |
| Fluoride (dissolved) (F) | mg/L | 0.75 |
| Potassium (dissolved) (K) | mg/L | 10 |
| Magnesium (dissolved) (Mg) | mg/L | 20 |
| Sodium (dissolved) (Na) | mg/L | 30 |
| Ammonium ($NH_4$-N) | mg/L | 0.05 |
| Nitrate ($NO_3$-N) | mg/L | 0.5 |
| Total Phosphorus | mg/L | 0.25 |
| pH | | 6.5-8.4 |
| Ortho-phosphate ($PO_4$) | mg/L | 0.025 |
| Sulphate (dissolved) ($SO_4$) | mg/L | 70 |
| Total Alkalinity | mg/L | 120 |
| Dissolved Organic Carbon (DOC) | mg/L | 10 |
| Dissolved Oxygen (DO) | mg/L | 9 |
| Sodium Absorption Ratio | | 2 |
| Suspended Solids | mg/L | 5 |
| Chlorophyll a | µg/L | 1.5 |
| *Escherichia coli* | CFU/ 100mL | 130 |
| Faecal coliforms | CFU/ 100mL | 130 |
| Aluminium (Al) | mg/L | 0.02 |
| Boron (B) | mg/L | 0.5 |
| Chromium (VI) (Cr) | µg/L | 7 |
| Iron (Fe) | mg/L | 0.1 |
| Manganese (Mn) | mg/L | 0.02 |
| **Additional WQPLs for the Upper Olifants sub-catchment** | | |
| Antimony (Sb) | mg/L | 0.01 |
| Arsenic (As) | mg/L | 0.01 |
| Barium (Ba) | mg/L | 0.02 |
| Beryllium (Be) | mg/L | 0.02 |
| Bromide (Br) | mg/L | 0.02 |
| Cadmium (Cd) | mg/L | 0.01 |
| Cobalt (Co) | mg/L | 0.02 |
| Lead (Pb) | mg/L | 0.01 |
| Mercury (Hg) | mg/L | 0.01 |
| Nickel (Ni) | mg/L | 0.02 |
| Selenium (Se) | mg/L | 0.01 |
| Thallium (Th) | mg/L | 0.01 |
| Uranium (U) | mg/L | 0.02 |
| Vanadium (V) | mg/L | 0.02 |

The objectives of the monitoring programmes are to assess the current monitoring requirements at various levels throughout the WMA in respect of variables of concern, location and frequency in relation to users and impacts in the various management units (DWS, 2018b).

Water Quality Planning was set for each management unit within the Upper Olifants catchment. The KPS is located in MU 22 within the Wilge catchment. The proposed WQPLs for MU 22 are provided in **Table 5-4**.

### 5.5.5 Baseline water quality

Historical agricultural and mining practices over the past few decades have had detrimental effects on the surface water environment in the area. This is mainly attributed to fertilizer application, erosion, siltation and point-source discharges by Wastewater Treatment Works to the surrounding watercourses. The presence of several industrial and mining activities within one catchment may have severe effects on the surface water environment.

DWA monitoring point (B20_188173) upstream of the ADF on Leeuwfontein was sampled only once in 2004. Sampling points CSW01, CSW02 and CSW03, which are on the Wilge River, indicate high total alkalinity ($CaCO_3$), sodium (Na), magnesium (Mg) and aluminium (Al) concentrations. Samples taken along the Leeuwfontein Spruit and the unnamed tributary north of the ash disposal facility indicate high pH, electrical conductivity (EC) and total dissolved solids (TDS) concentrations. These concentrations were above the RWQOs limits for MU 22.

### 5.5.6 Existing surface water monitoring at KPS

Thirteen surface water monitoring sites form part of the Kendal water monitoring network. Of the 13 surface water sites visited in the catchment B20E during the hydrocensus, only 2 (FBR13 and R05) were found dry. All the surface water sites surrounding the ADF site were found to have the required minimum level of water and were sampled. Sampled sites FBP16 and FBR18, located upstream of Leeuwfontein Spruit from the ADF (**Figure 5-18**), were classified as Class 1 water quality and were considered representative of the natural surface water quality.

Leeuwfontein Spruit water quality at site FBR15 did not comply with the recommended standard due to high concentrations of F, Mn, and $SO_4$. The site is located upstream of Leeuwfontein Spruit from the ash stack but might have been affected by run-off water from the coal conveyor belt upstream.

Sampled site R01 located upstream of the Leeuwfontein Spruit, but much closer to the ADF site, showed very high concentrations of Ca (570 mg/l), Mg, $SO_4$ (2911 mg/l), and Mn (37.1 mg/l). The close proximity of coal mining to the sampling site was suspected to be the source of such negative change of the surface water at this site.

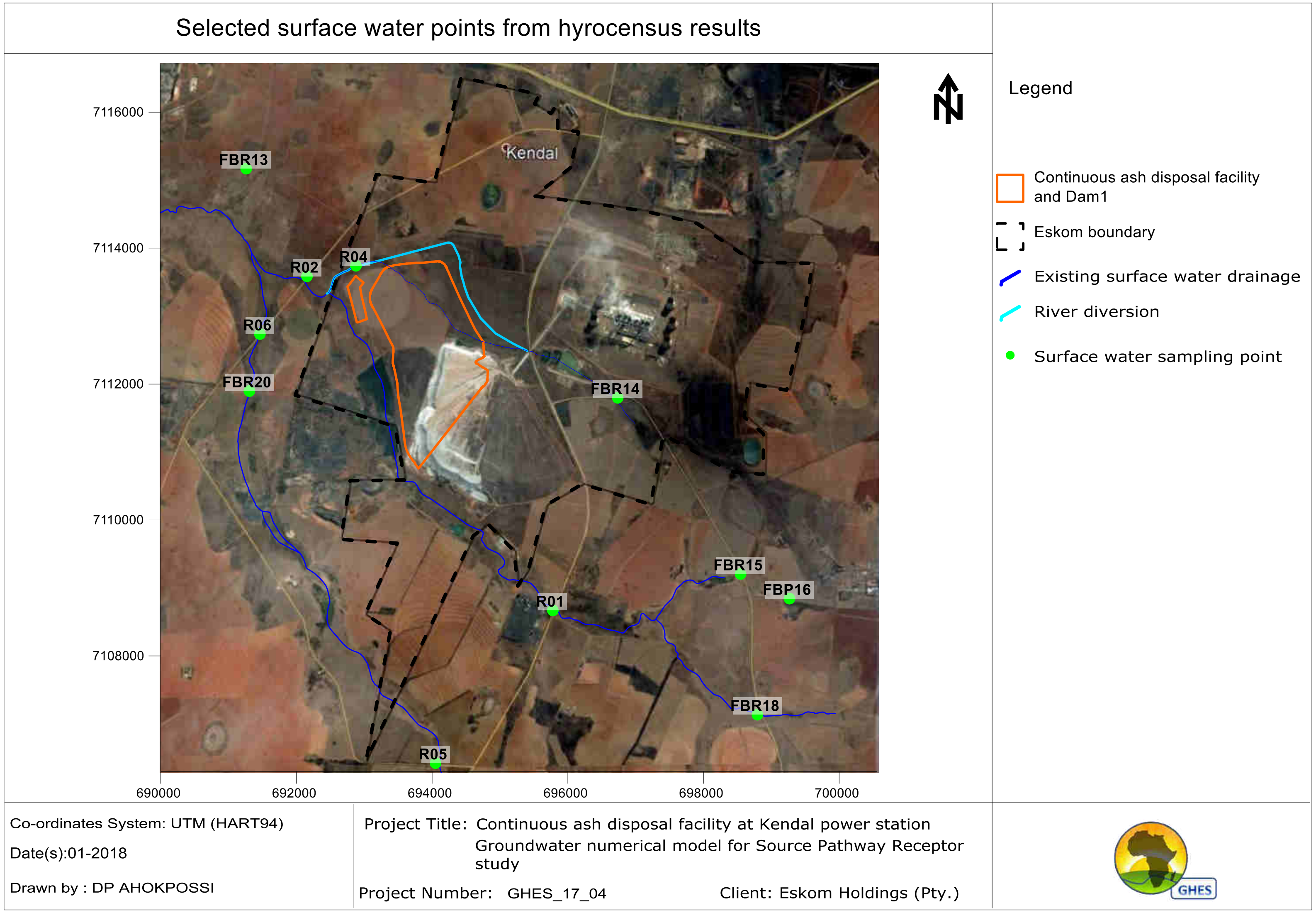



**Figure 5-18: Selected surface water points from hydrocensus results (GHES, 2018)**

The Schoongezicht Spruit, represented by sampling site FBR14, upstream of the ADF site is classified Class 1 water quality. Schoongezicht Spruit was affected by Kendal Power Station, as it was shown by the poor water quality (increase in EC, Na, Ca, Mg, Cl and $SO_4$ concentrations) observed at sampled site R04.

At the sampled sites R02 and R06 on the Leeuwfontein Spruit the observed water quality was under recommended standard limits. The factors that influence the improvements of the water quality at these points despite them receiving water, from R01 and R04, and FBR20, respectively, have not been investigated. Site FBP18 on Leeuwfontein Spruit showed high fluoride concentration, which might be representative of the natural surface water quality or impact from only agricultural activities, which is generally associated with increased fluoride levels. Such potential pollution sources could however not be confirmed as this has not been quantified in a focussed study to determine the origin of constituents of concern.

## 5.6 Aquatic Environment

A dry and wet season assessment of the aquatic environment was undertaken by Golder Associates in September 2013 (Golder Associates, 2013) and May 2016 (Golder Associates, 2016c), respectively. The aquatic assessment included an assessment of the *in-situ* water quality, habitat availability for aquatic macroinvertebrates, aquatic macroinvertebrate and ichthyofauna diversity within the aquatic ecosystems associated with proposed KPS ADF.

Conclusions from the aquatic assessment at the Kendal Power Station include:

### 5.6.1 In situ water quality

*In situ* water quality was a limiting factor to aquatic biota at the time of the dry season, primarily due to low dissolved oxygen concentrations and percentage saturations. Both of these parameters were below the Target Water Quality Range (TWQR) guideline at the majority of the sites in the tributaries of the Wilge River, including two of the upper sites on the Wilge River. The low values may be attributed to the large amount of decaying organic matter on the stream beds and limited flow conditions at the time of the survey. Furthermore, it was noted that the alkaline pH values on the upper Wilge River exceeded those values recorded during previous surveys conducted further downstream on the river. The turbidity levels were relatively low due to the time of year, with the exception of four sites in the tributaries of the Wilge River which demonstrated high turbidity levels. The rest of the water quality parameters (pH, Electrical Conductivity (EC), Temperature and Clarity) were within the guideline values and thus not considered to be a limiting factor to the aquatic ecosystem. During the follow-up survey during the wet season, conducted in May 2016, the water quality was adequate at the selected sites monitored however, the turbidity levels remained high in the study area at selected sites.

### 5.6.2 Habitat integrity

Overgrazing and trampling by cattle were evident in the vicinity of the project area. The overgrazing of the ground cover results in higher runoff velocities that transport particulates and result in erosion, increased turbidity and sedimentation. A further concern is the level of nutrient input into the river systems due to the high level of agricultural activities within the project area. High levels of nutrient inputs, together with long residence time/standing water/slow flowing water, are contributing to algal blooms at various sites, a clear sign of eutrophic conditions (Golder Associates, 2016c). In addition to the agricultural activities in the project area, four (4) of the monitoring sites are further impacted by raw sewage, inadequate municipal waste water treatment works and poor waste management. This is further contributing to eutrophication.

Based on the IHAS results obtained in August/September 2013, in-stream habitat availability ranged from Adequate to Poor. A general description of the habitat integrity showed that the vegetation and sand and mud habitats were the dominant habitat elements in the Wilge River and adjoining tributaries draining the Kendal project area during both surveys. The limited habitat availability observed was largely due to a lack of the stones biotope and limited flow velocities at the time of the surveys (Golder Associates, 2016c).

### 5.6.3 Aquatic macroinvertebrates

Based on the assessment of the aquatic macroinvertebrate communities, the biotic integrity in the tributaries in the project area ranged from unmodified to seriously modified (Class A to E) during the dry season and seriously modified (Class E) at the four sites surveyed during the follow up survey (Golder Associates, 2016c).

### 5.6.4 Fish communities

During the dry season (2013), the fish biotic integrity in the project area ranged from Largely to Critically Modified (PES Class D to F). The exotic and invasive fish species *Gambusia affinis* and *Cyprinus carpio* were recorded in the lower reaches of the Leeufontein and consequently at two sites in the Wilge River downstream from the Leeufontein. Some fish species in the Wilge River showed signs of external parasites, a sign of increased physiological stress. Owing to low fish diversity recorded during the follow-up survey, the biotic integrity was critically modified. The low biotic integrity recorded in the tributaries was primarily attributed to limited habitat availability and low flow conditions.

### 5.6.5 Concluding remarks

The findings of the aquatic assessment show that the aquatic systems in close proximity of the Kendal Power Station is significantly impacted by existing activities in the catchment, including KPS. It is therefore difficult to assign impacts to specific activities in the catchment. Continued long term bio-monitoring at strategic locations, informed by potential pollution point sources, is therefore required to track the integrity of the aquatic communities in the catchment.

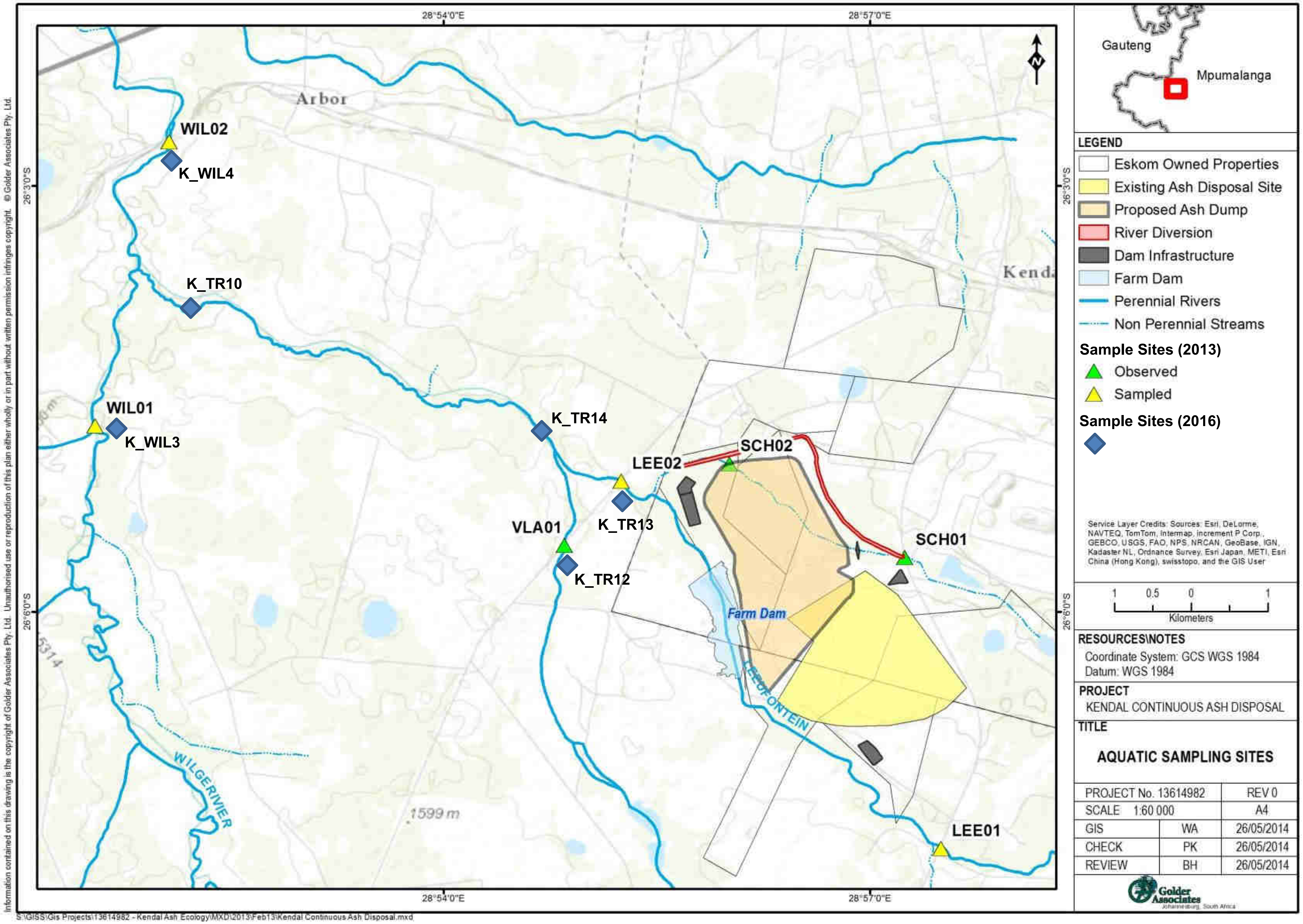



**Figure 5-19: Aquatic monitoring sites associated with and downstream of the KPS ADF**

### 5.7 Wetlands

Field work for the wetland delineation and assessment for the KPS Continuous ADF was undertaken in May and November 2013 by Wetland Consulting Services. Extensive wetland areas were identified and delineated on site and included Channelled valley bottom wetlands, Hillslope seepage wetlands, and Weakly/Unchannelled valley bottom wetlands (Wetland Consulting Services, 2014).

In total, surveyed wetland areas within and around the project area cover approximately 248 hectares. The ecological integrity of wetland areas around the Continuous ADF site ranges from moderately to largely modified with PES of C and D, respectively, although HGM Unit 2 may be considered critically, although not irreversibly, modified due to the influence of the large farm dam located to the west of the Continuous ADF footprint (see blue water body in **Figure 5-20**). All the wetlands on site have moderate or low/marginal ecological sensitivity status.

A number of wetlands are located to the West, South-west and South of the KPS Continuous ADF site, as is evident from **Figure 5-20**. No wetland FEPA falls within or around the project area, although extensive wetland habitat is indicated. An important wetland cluster (Wetcluster) is indicated immediately downstream of the Kendal Continuous ADF (**Figure 5-20**).

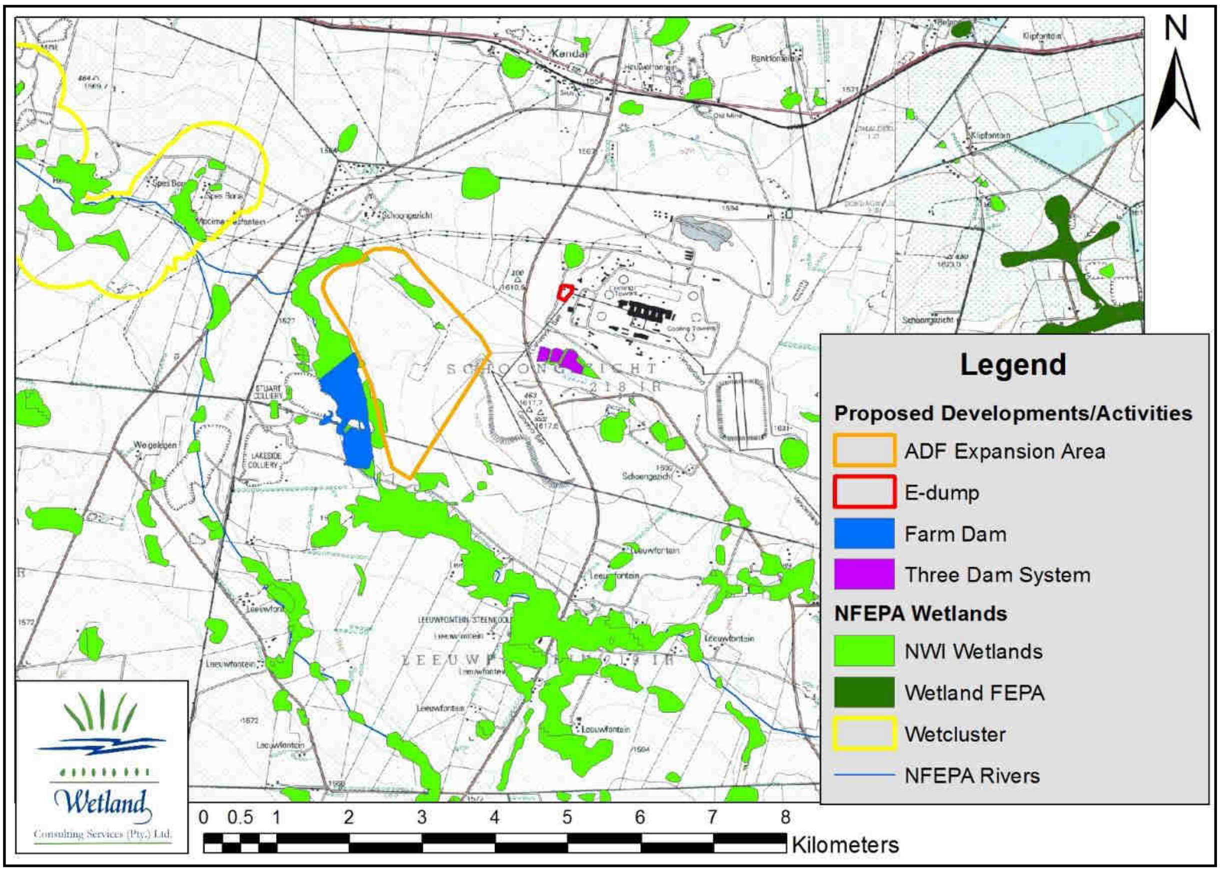



**Figure 5-20: Extract of the Atlas of Freshwater Ecosystem Priority Areas in South Africa (Nel et al., 2011)**

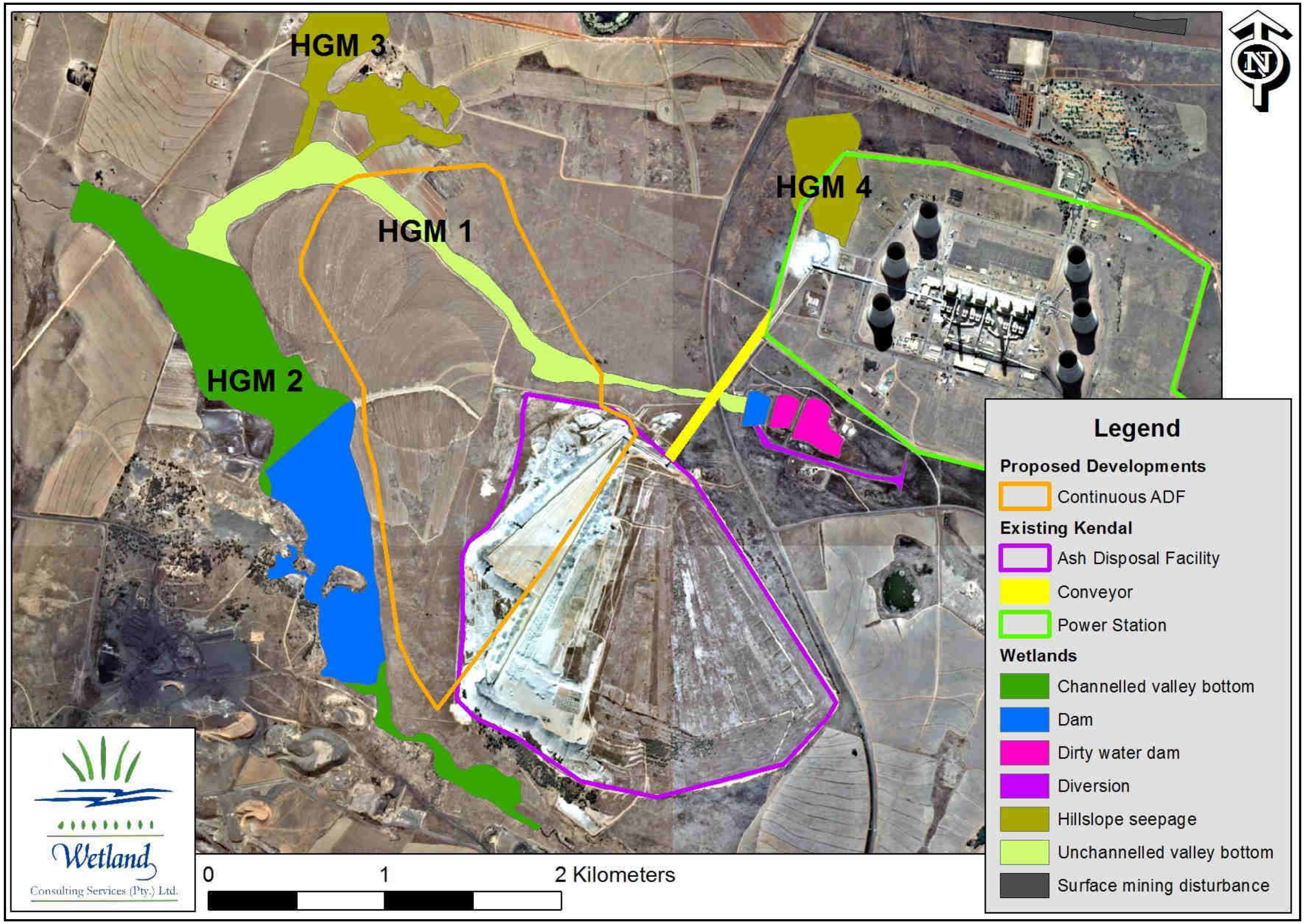



**Figure 5-21: Map of the delineated wetlands within and surrounding the Kendal Continuous ADF**

### 5.7.1 Wetland Delineation

Field work for the wetland delineation and assessment was undertaken in May and November 2013. Two valley bottom wetland systems were recorded on site; one traverses the site to the north and the other bordering the western boundary of the proposed development footprint. These were associated with a number of lateral hillslope seepage wetland areas. A further hillslope seepage wetland, draining in a northerly direction, was delineated to the north of the proposed emergency ADF (E-dump) location (just north of the transfer station along the existing conveyor route).

**Table 5-5: Identified wetland types and delineated areas**

| HGM Unit | Wetlands (ha) | HGM No |
|---|---|---|
| Unchannelled Valley Bottom | 43.4 | HGM 1 |
| Channelled Valley Bottom | 142.6 | HGM 2 |
| Hillslope seepage | 38.9 | HGM 3 |
| Hillslope seepage | 23.1 | HGM 4 |
| **Total** | **248.0** | |

In total, surveyed wetland areas within and around the project area cover approximately 248 hectares. From the functional assessment of the wetlands on site it is clear that the wetlands have the ability to provide various ecosystem services such as biodiversity support, maintenance of water quality, flood attenuation and sediment trapping.

The ability of the wetlands to perform these functions has, however, been compromised by disturbances such as alien invasive vegetation encroachment, impoundments, farms dams, road crossings, mining activities and associated mine dumps, cut off trenches along the roads and eroded channels. The ecological integrity of wetland areas on site ranges from moderately to largely modified with PES of C and D, respectively (although HGM Unit 2 may be considered critically, although not irreversibly, modified due to the influence of the large dam). All the wetlands on site have moderately sensitive status.

In light of the considerable wetland loss that has already occurred in the greater catchment area (Upper Olifants) and which is likely to continue with planned mining activities, it is important that the proposed activities are planned sensitively around the remaining wetland areas to minimise further deterioration of the remaining systems and the water resources they represent.

## 5.8 Faunal biodiversity and vegetation communities

The terrestrial ecology study was undertaken by Golder (2014d). This section contains a description of the faunal diversity in the study area.

### 5.8.1 Mammals

Five mammal species were recorded in the study area during the 2013 field study. These are the Reddishgrey musk shrew (*Crocidura cyanea*), Multimammate mouse (*Mastomys* sp.), Serval

(*Leptailurus serval*), Black-backed jackal (*Canis mesomelas*), Cape clawless otter (*Aonyx capensis*), Water mongoose (*Atilax paludonosus*), Steenbok (*Raphicerus campestris*) and Warthog (*Phacochoerus africanus*). Previous studies conducted in areas surrounding KPS and the nearby Kusile Power Station have recorded an additional ten mammal species, which include Lesser red musk shrew, Yellow mongoose, Blesbok, Chestnut climbing mouse, Porcupine, Scrub hare, Aardvark, Angoni vlei rat, Striped mouse and Common duiker (Golder Associates, 2013).

### 5.8.2 Birds

Forty-one bird species were recorded in the study area during the 2013 field survey, which include Malachite kingfisher, Egyptian goose, Yellow-billed duck, Darter, Black-headed heron, Marsh owl, Hadeda ibis, African sedge warbler, Cattle egret, Spotted thick knee, Red-capped lark, Burchell's coucal, Whiskered tern, Diederik's cuckoo, Rock pigeon, Pied crow, Golden bishop, Red bishop, Long-tailed widow, Swainson's francolin, Red-knobbed coot, African fish-eagle, White throated swallow, Greater striped swallow, European swallow, Grey-headed gull, Sabota lark, Anteating chat, Helmeted guineafowl, Cape sparrow, Reed comorant, Flamingo sp., Masked weaver, Red-billed quelea, Secretary bird, African pied starling, Cape turtle dove, Laughing dove, Blacksmith plover and Pin-tailed whydah. Most of these are common and widespread species typical of grassland and wetland habitats in Mpumalanga (Golder Associates, 2013).

### 5.8.3 Herpetofauna

Three amphibians were recorded in the study area, i.e. Common river frog (*Afrana angolensis*), Striped stream frog (*Strongylopus fasciatus*) and Red toad (*Schismaderma carens*). These are all common species with widespread distributions. In terms of reptiles only the Striped skink (*Mabuya striata punctatissima*) was observed in the study area during the 2013 field survey. Seventeen other species of herpetofauna have been recorded in the general area in which the study area is located. These include ten reptile species (Puff adder, Rhombic egg eater, Rinkhals, Brown house snake, Marsh terrapin, Green water snake, Striped skaapsteker, Variable skink and Water monitor) and seven amphibian species (Cape river frog, Guttural toad, Bubbling kassina, African red toad, Tremolo sand frog and Common platanna). All recorded species are common and not restricted in terms range or habitat.

### 5.8.4 Vegetation communities

The site of the continuous ADF comprises five vegetation communities. These were recognised based on physiognomy, moisture regime, slope, species composition and disturbance characteristics. Vegetation communities include:

- Transformed land;
- Cultivated land (current and former);
- *Themeda triandra* mixed grassland;
- *Hyparrhenia hirta* grassland; and
- Moist grass and sedge community.

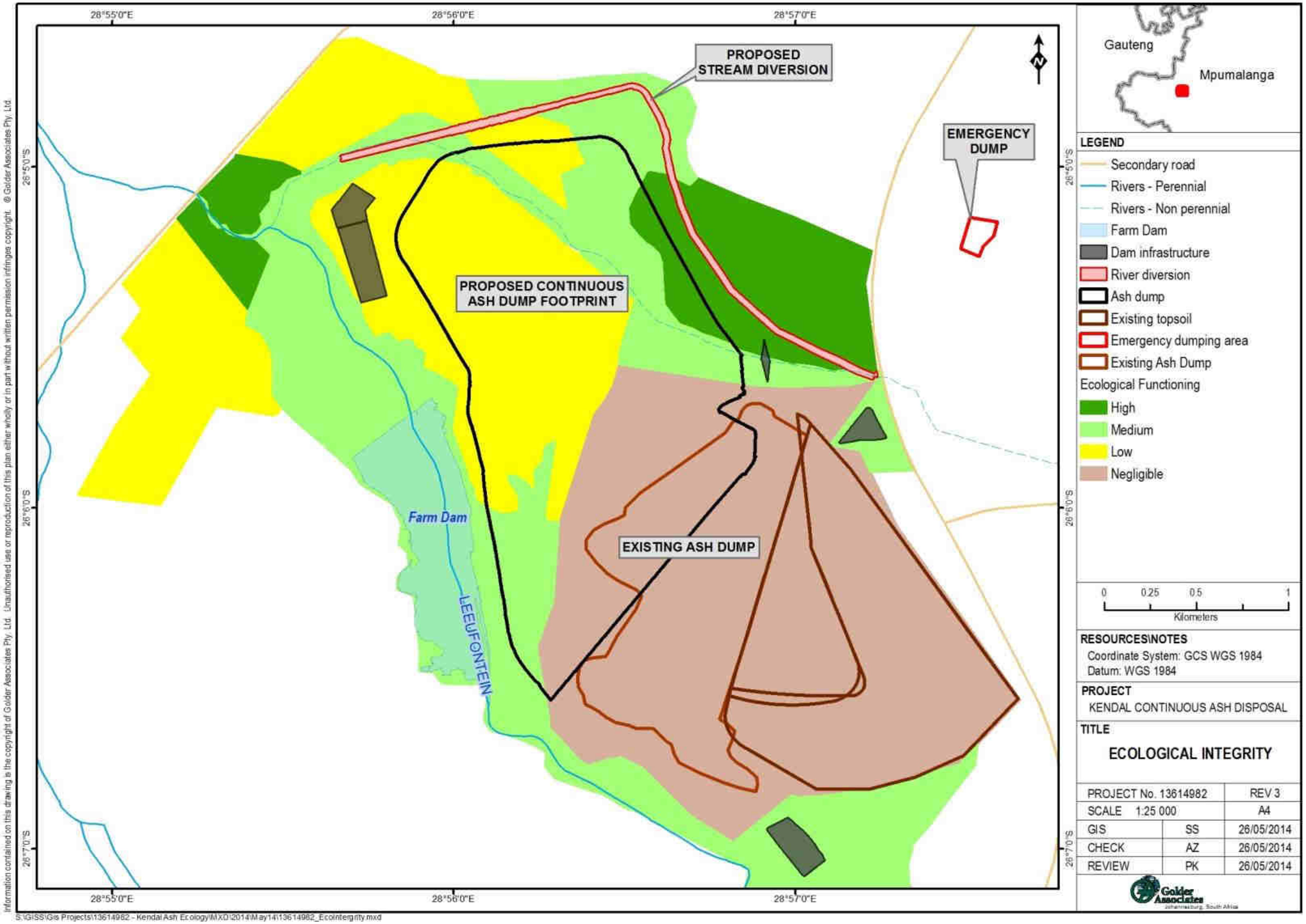



**Figure 5-22: Ecological Integrity of the study area (Golder Associates, 2013)**

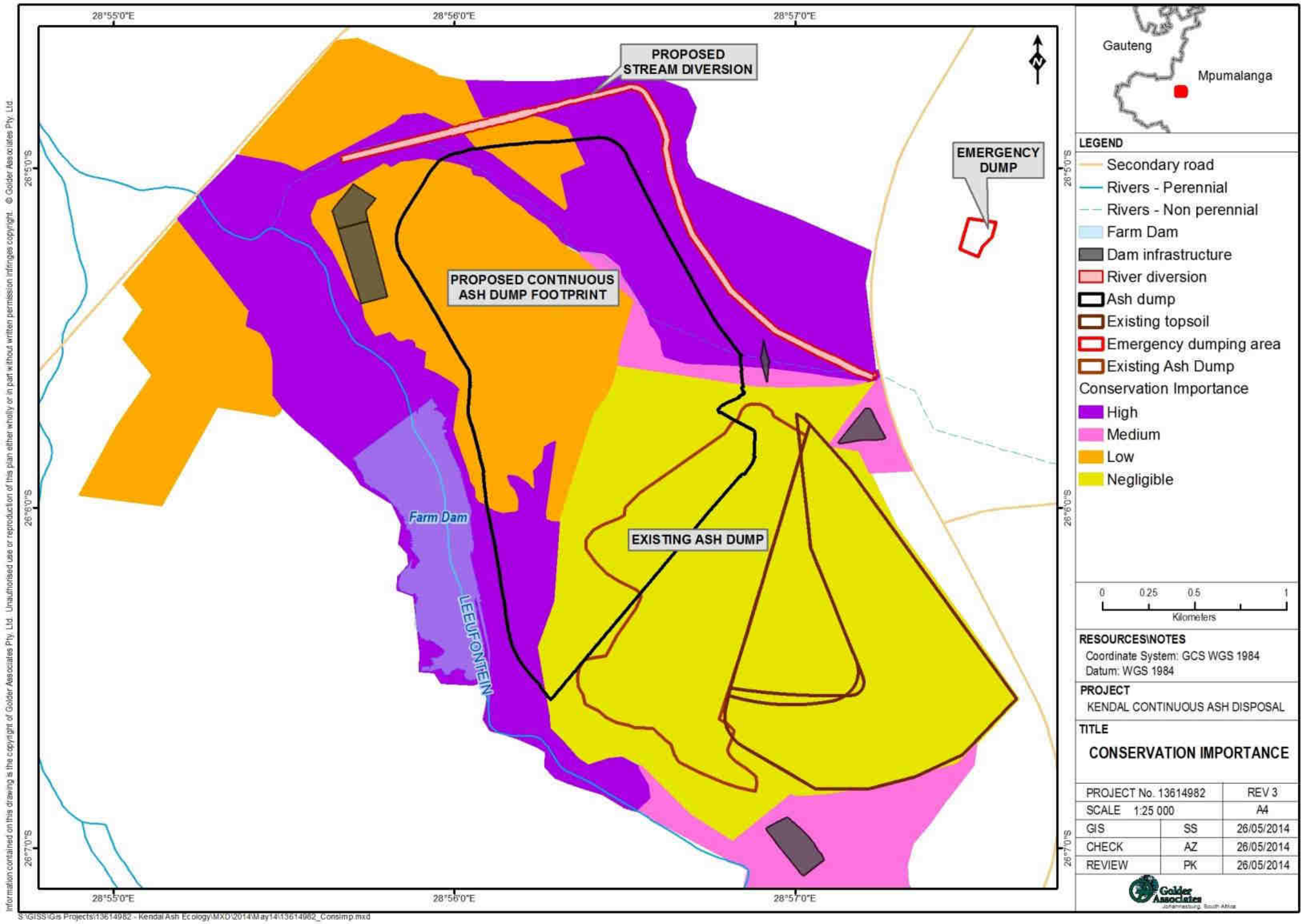



**Figure 5-23: Conservation importance of the study area (Golder Associates, 2013)**

The ecological integrity and conservation importance of vegetation in the study site is represented in Figure 5-22 and Figure 5-23, respectively.

## 5.9 Land Use

The land use data was obtained from the Council for Scientific and Industrial Research Land Cover database (2006) and supplemented with visual observations on site. From **Figure 5-24** it is evident that the Continuous ADF site is surrounded by unimproved grassland areas. Two agricultural pivot irrigation systems were also operated within the footprint of the Continuous ADF site in the past. It is therefore evident that the ADF site is largely located in and surrounded by high potential arable land. Mining activities are also found to the south-east of the ADF site. The land use in the area is dominated by maize cultivation and grazed fields (mostly cattle). The site is leased to a farmer for agricultural use by means of centre pivots with an agreement between Eskom and the farmer that the lease will be terminated once development of the ADF moves onto the additional continuous footprint area (Zitholele Consulting, 2014a).

## 5.10 Social Environment

The KPS and associated infrastructure is located approximately 40 km south-west of Emalahleni in the Mpumalanga Province. The Power Station falls within the jurisdiction of the Emalahleni Local Municipality which forms part of the Nkangala District Municipal. The Kendal Continuous Site falls within the Emalahleni Local Municipality (ELM) which is situated in the Nkangala District Municipality (NDM) in the Mpumalanga.

Several stakeholders that are likely to impact or be impacted by the development of the Continuous ADF at KPS were identified, which includes Residential communities, Agriculture groups, Government, Mining groups and Parastatal organisations.

Five residential communities were identified within a 1km radius of the proposed Kendal 30-year ADF. Refer to **Table 5-6**.

**Table 5-6: Residential communities within 1km radius of the KPS**

| Residential Community | Description |
|---|---|
| Eskom Triangle community | The Triangle community consist of 12 families (approximately 68 people) that occupy 14 units on a piece of land that is owned by Eskom. According to the residents, some of them have been living there for 60 years and have living rights on the property. |
| Khayalethu Village | Homeland Mining and Energy SA (Pty) Ltd (Homeland) relocated the people residing in Khayalethu Village in 2008. There are 15 houses in the village, each with a water tank. The village rely on the harvesting of rainwater and a borehole operated by a windmill for water. If there is no wind, they struggle with water supply. |
| Olympic community | The Olympic community is situated south of the old Ogies Road (R555) and west of the R545 intersection, about 700m north from the boundary of the proposed site. It consists of approximately 60 to 80 houses, both formal and informal. |
| Makhosi community | The Makhosi Village consists of two parts. The first part is the “Blue Houses”; a few houses situated a small distance from the rest of the community at the northern entrance to the community. Makhosi Village is located on the north-eastern side of the old Ogies |

| | |
|---|---|
| | (R555) and R545 junction, about 900m from the boundary of the proposed site. There are approximately 200 to 250 structures, both formal and informal. |
| Van Biljon Residence | The Van Biljon Residence is about 600m north-east of the boundary of the proposed site on the western side of the old Ogies (R555) and R545 crossing. Mr van Biljon's father owned one of four portions of the farm Leeuwfontein. The rest of the properties where owned by the Shill family. Mr van Biljon's father died in 1978, and Mr van Biljon claims that he is a life tenant on the property (meaning he received the right to live at or use the property during his lifetime). |

Agriculture, together with mining, is the predominant land use in the area. Commercial farmers operate in the directly affected area. The area around the proposed Continuous ADF site has historically been exposed to mining activities, and large sections of land are under-mined.

**Table 5-7: Description of land user groups in the vicinity of Kendal Power Station**

| Land use | Properties | Description |
|---|---|---|
| **Agricultural Groups** | Commercial farmers | The two commercial farming enterprises that will be affected by the proposed Kendal 30 year ADF are Truter Boerderye and Torero Investments. Farming commodities include cattle, maize, soya and potatoes. |
| | AFGRI | AFGRI is an agricultural services and processing company, with grain commodities as a core focus. The company owns 69 grain silos across South Africa, of which the Kendal silo is one. The Kendal silo is situated approximately 450m north-east of the boundary of the proposed site. |
| **Mining groups** | Eyethu Coal/Kusile Mining | Eyethu Coal/Kusile Mining applied for prospecting rights on portions of Site H and Portion 20 of Schoongezicht. Prospecting revealed that Site H does not have coal resources, and Kusile Mining undertook to change their mining right application to exclude the areas required by Eskom. The Mpumalanga Department of Economic Development, Environment and Tourism (MDEDET) authorised the Heuvelfontein Colliery in September 2014. Ferret Coal, owned 51% by Kusile Mining, owns Heuvelfontein Portion 20, a piece of land that is also affected by the proposed Site H. Eyethu Coal/Kusile Mining is an important stakeholder as future neighbour and current rights holder. |
| | Other mining groups in the area | There are a significant number of mines active in or planned for the area, including Khanyisa, Intibane, Mbuyelo (Rirhandzu Colliery), Zibulo, New Largo, Khutuka, Leeuwfontein, Bankfontein, Lakeside and Klipspruit amongst others. These mines share access roads and cumulatively contribute to the existing impacts experienced in the area. |

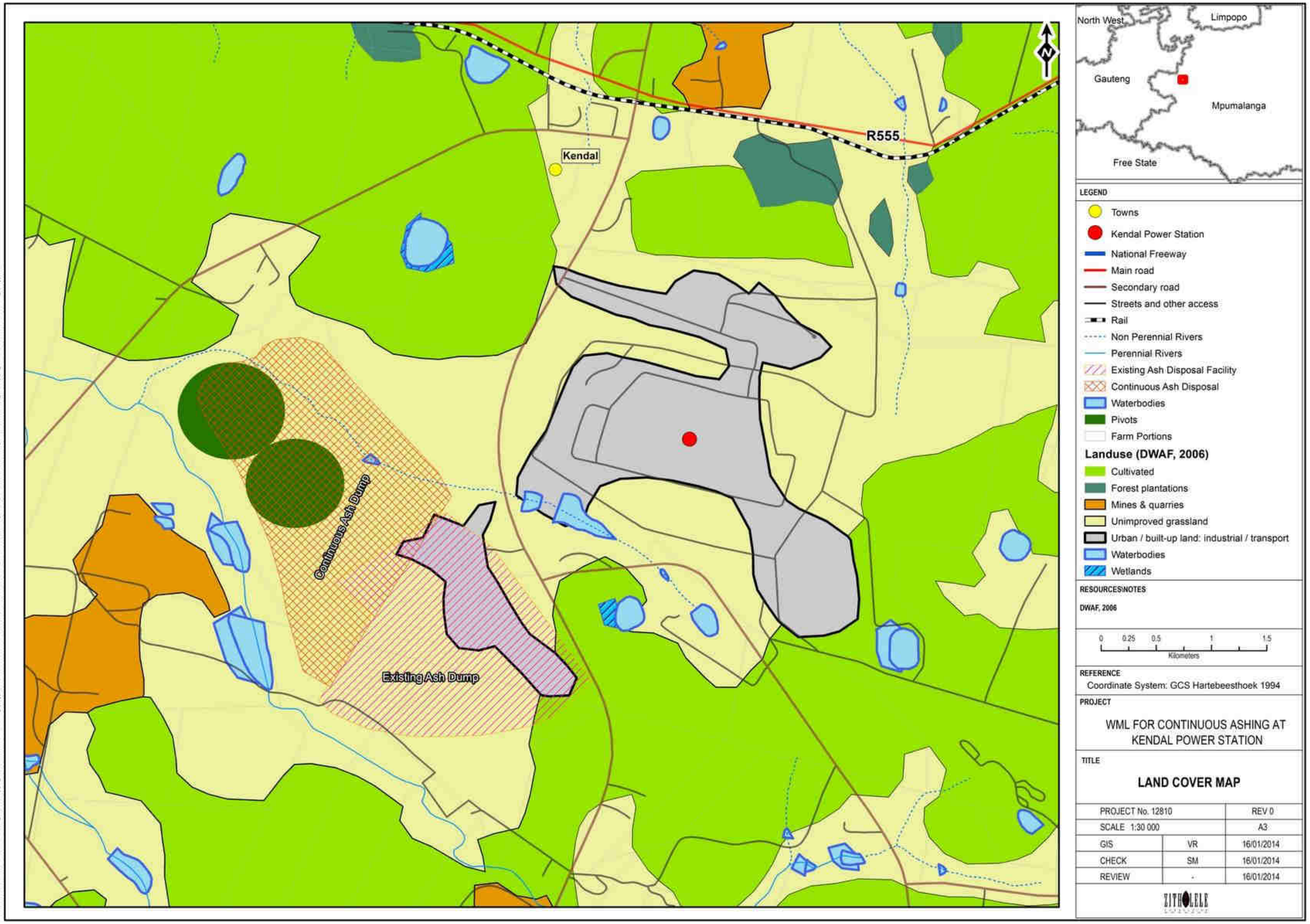



**Figure 5-24: Land use identified around KPS Continuous ADF**

# 6 ALTERNATIVE LINER DESIGNS

## 6.1 Liner System Alternatives

The liner types that were assessed for this SPR study were selected on the following basis:

- Only liner alternatives that have a proven track record of implementation or have been scientifically assessed and tested were considered. Therefore, the effectiveness of these liner systems as well as accepted estimated leakage rates comes with a high degree of confidence.
- The Class C liner system, promulgated in terms of GN R.636, is the regulated liner for Type 3 waste. Therefore, inclusion of the Class C liner was the base alternative for an ADF.
- The study itself aims at investigating opportunities for optimising applicable liner designs while taking the characteristics of the receiving environment into consideration.
- Substitution of existing layers in approved liner systems with other material, e.g. a GCL layer, was also considered. However, suitability of such substitution layers was considered against the success of such layers being approved by the regulator due to the possible chemical reaction of the liner system with the leachate via the ash body.
- Class A and Class B liners are excluded from the study because they have more structural components for a high level of protection.

The Class C and Class D liner systems were included in the assessment. Other options that lie within the range between Class C and Class D were considered. The following liner systems were therefore considered in the SPR study:

1. **Class C:** Standard Class C liner type as per GN R.636 (Refer to **Figure 6-1**).
2. **Class C – Variation 1** (Refer to **Figure 6-2**) – This is a Class C liner with variation on the protection layer between the waste body and the HDPE geomembrane. The Norms and Standards stipulates an alternative geotextile to replace the 100mm sand layer.
3. **Class C – Variation 2** (Refer to **Figure 6-3**) – This is a Class C liner with a 300mm thick course ash as protection layer between the waste body (ash) and the lining system.
4. **Intermediate Liner** (Refer to **Figure 6-4**) – This liner type is mainly used for lagoons and it constitutes two 1.5mm HDPE geomembrane that sandwich a 750micron cuspated sheet. The cusps are installed facing downwards. Geotextiles are installed at the bottom and top of the double geomembrane system to protect them. This liner system although used for Type 3 waste, has not been utilized under such loading as for ash disposal facilities, therefore the behaviour of the cuspated sheets under such loading is unknown.
5. **Class D**: Standard Class D liner type as per GN R.636 (Refer to **Figure 6-5**).

It should be noted that the level of protection offered by each liner type is not necessarily equivalent to the sum of each layer component. Therefore, accepted leakage rates determined for a specific liner type was determined for the liner as a whole. This is the reason why compiling an alternative liner option from selected layers was not feasible. Alternative liner designs should be assessed and tested to determine specific leakage rates.

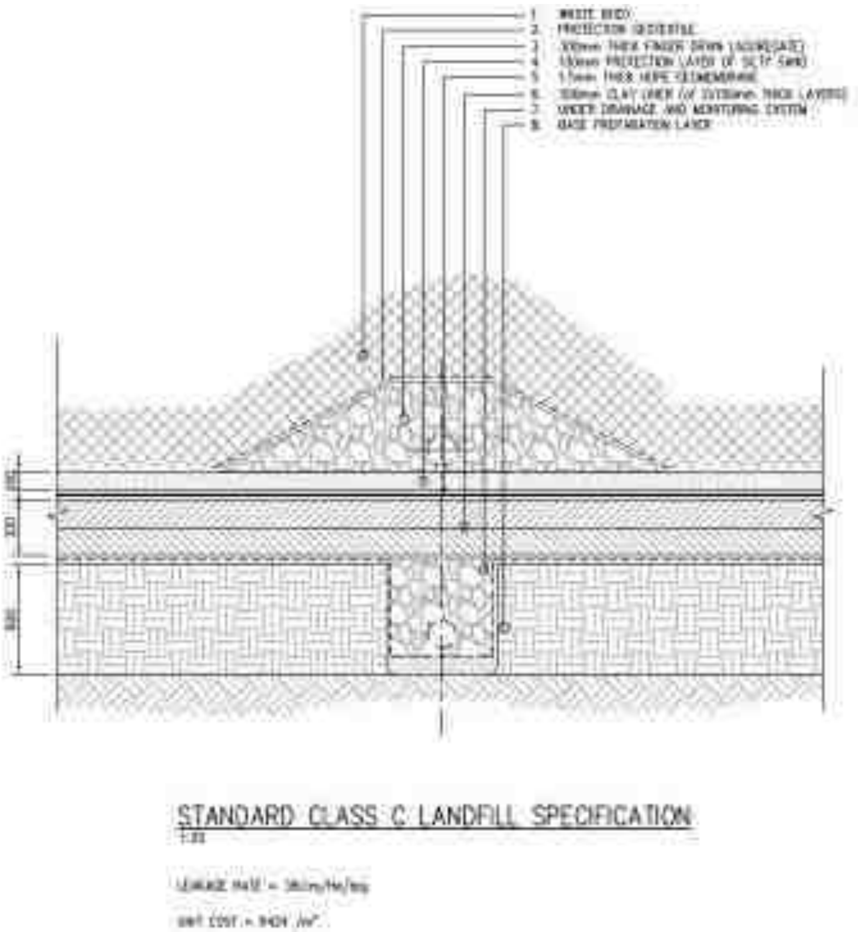



**Figure 6-1: Class C – Standard Liner Type**

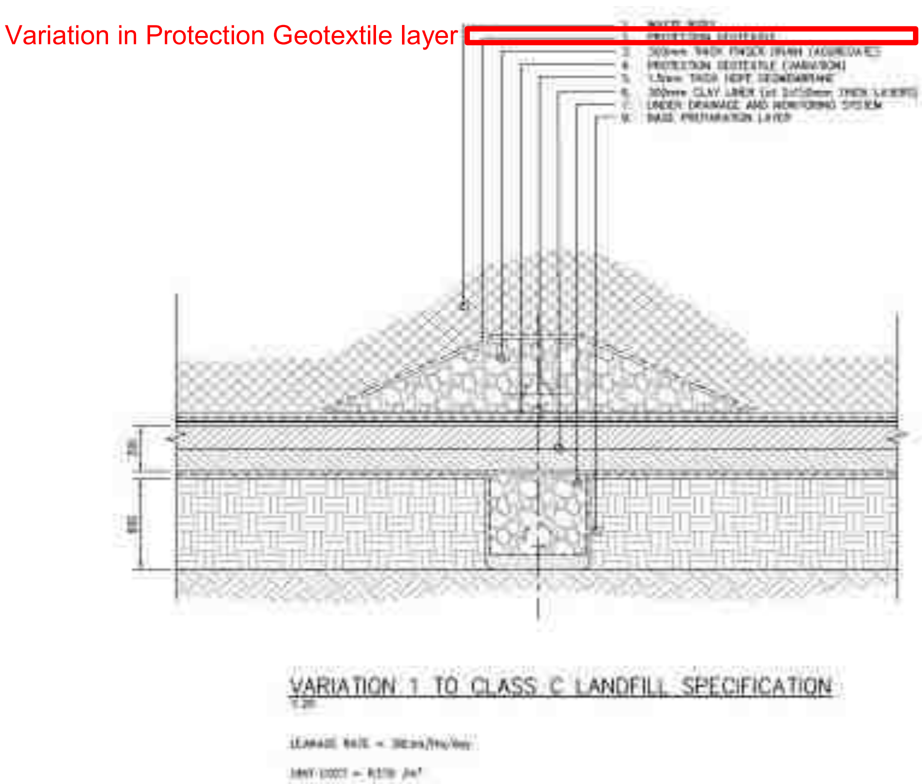



**Figure 6-2: Class C - Variation 1 Liner Type**

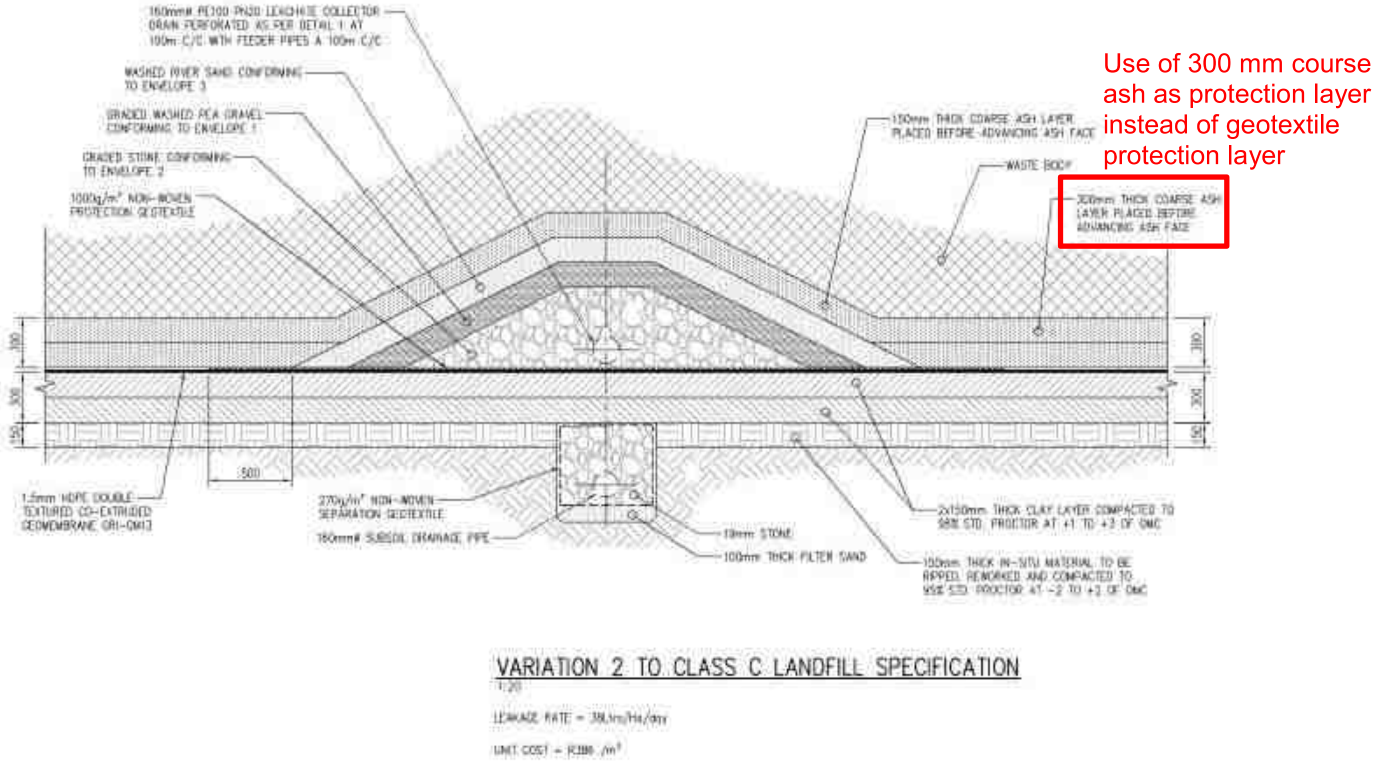



**Figure 6-3: Class C - Variation 2 Liner Type**

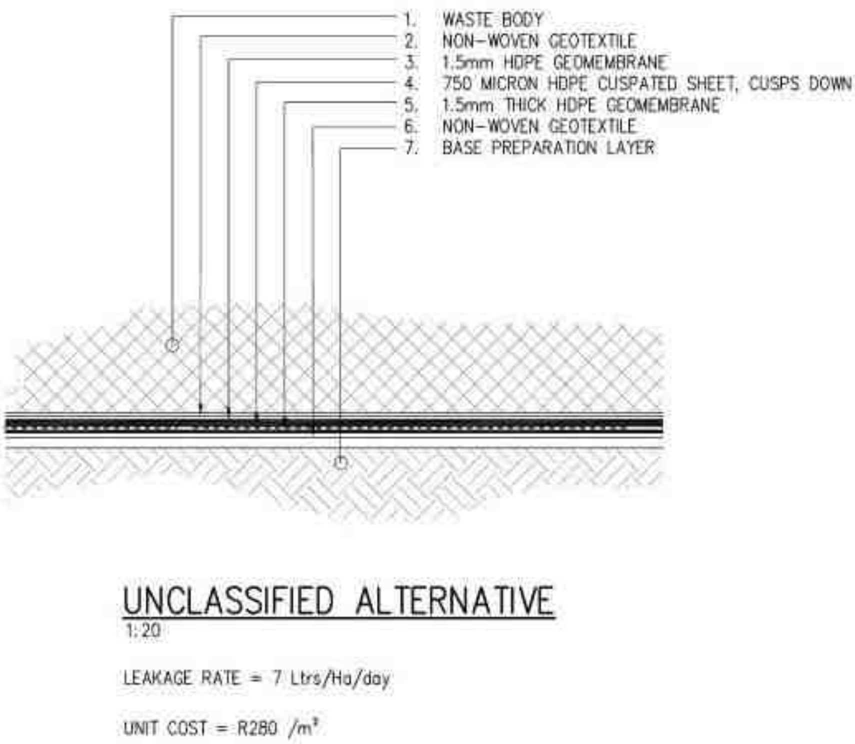



**Figure 6-4: Intermediate - Lagoon Liner Type**

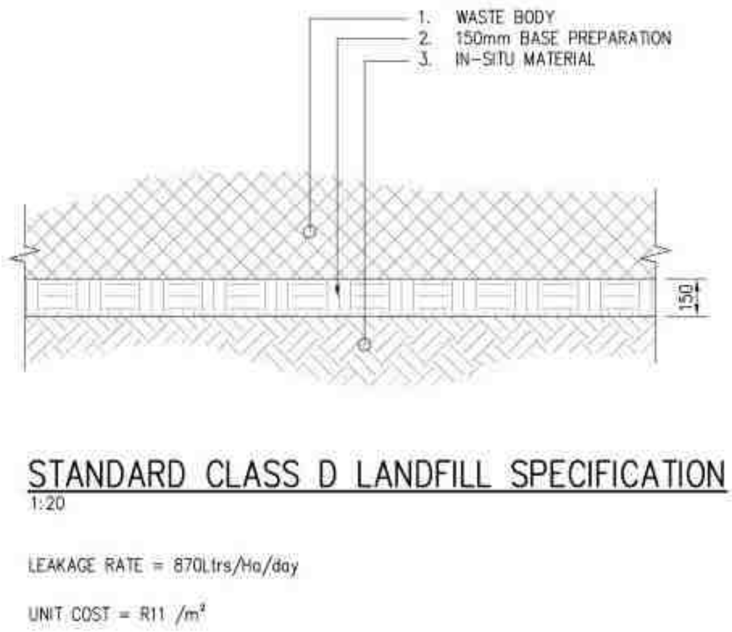



**Figure 6-5: Class D Liner Type**

## 6.2 Leakage Rates

The infiltration rates are based on leakage rates through different types of accepted alternative liner systems. Giroud & Touze-Foltz (2005) presented a methodology to compute leakage rates through liners with defined defects. These equations were utilized to compute the leakage rates through liner systems that incorporate geomembranes. The following factors are essential to using the computation methods:

- The rate of liquid flow is through potential defects in the geomembrane component of a composite liner that may result after deposition of the ash body
- Assumptions are made on quantity and size of defects in the geomembrane in the system
- Equations are based on a hydraulic head above the geomembrane
- Equations are set up for geomembrane resting on low permeability material
- Interface conditions taken into consideration are interface flow, contact conditions and interface transmissivity
- Defects considered are; cuts, tears and defective seams.

Table 6-1: Defined leakage rates used in SPR study indicate the leakage rates through the different liners. It should be noted that all variation to the Class C liner yield the same leakage rate because the barrier components are the same.

**Table 6-1: Defined leakage rates used in SPR study**

| Liner Type | Leakage Rate |
|---|---|
| Class C Liner (Including Class C variations) | 38 Litres/Ha/day |
| Intermediate – Lagoon Liner | 7 Litres/Ha/day |
| Class D Liner | 870 Litres/Ha/day |

### 6.3 Unit Costs for Liner Alternatives

Unit costs were computed for each liner type based on the current industry unit costs presented in **Table 6-2**. **Table 6-3** to **Table 6-6** indicate the unit rates for the liner options. **Figure 6-6** is a summary of unit costs for all the liners systems considered.

**Table 6-2: Liner Component Costs**

| Layer | Description | Rate (R/m$^2$) |
|---|---|---|
| O Layer | Desiccation Layer | 10.61 |
| A Layer | Stone – Leachate Collection | 133.88 |
| B Layer | Clay Layer | 118.47 |
| C Layer | Geotextile | 29.82 |
| D Layer | Stone – Leakage Detection | 133.88 |
| E Layer | Cushion – Sand | 75.87 |
| F Layer | Geomembrane | 69.80 |
| G Layer | Base Preparation | 10.61 |
| | Coash Ash Filter | 3.84 |
| | Washed Filter Sand | 75.87 |
| | Graded and Washed Pea Gravel | 104.88 |
| | Cuspated Sheets | 68.37 |
| | Graded Stone | 133.88 |

**Table 6-3: Class C – Standard Liner Unit Cost**

| Layer | Description | Rate (R/m$^2$) |
|---|---|---|
| E Layer | Cushion – Sand | 75.87 |
| F Layer | Geomembrane | 69.80 |
| D Layer | Stone – Leakage Detection | 133.88 |
| D Layer | Stone – Leakage Detection | 133.88 |
| G Layer | Base Preparation | 10.61 |
| | **Total** | **424.04** |

**Table 6-4: Class C – Variation 1 Liner Unit Cost**

| Layer | Description | Rate (R/m$^2$) |
|---|---|---|
| C Layer | Geotextile | 29.82 |
| F Layer | Geomembrane | 69.80 |
| D Layer | Stone – Leakage Detection | 133.88 |
| D Layer | Stone – Leakage Detection | 133.88 |
| G Layer | Base Preparation | 10.61 |
| | **Total** | **377.99** |

**Table 6-5: Class C – Variation 2 Liner Unit Cost**

| Layer | Description | Rate (R/m$^2$) |
|---|---|---|
| C Layer | Geotextile | 29.82 |
| | Coash Ash Filter | 3.84 |
| | Coash Ash Filter | 3.84 |
| F Layer | Geomembrane | 69.80 |
| D Layer | Stone – Leakage Detection | 133.88 |
| D Layer | Stone – Leakage Detection | 133.88 |
| G Layer | Base Preparation | 10.61 |
| | **Total** | **385.67** |

**Table 6-6: Intermediate – Lagoon Liner Unit Cost**

| Layer | Description | Rate (R/m$^2$) |
|---|---|---|
| C Layer | Geotextile | 29.82 |
| F Layer | Geomembrane | 69.80 |
| | Cuspated Sheets | 68.37 |
| F Layer | Geomembrane | 69.80 |
| C Layer | Geotextile | 29.82 |
| G Layer | Base Preparation | 10.61 |
| | **Total** | **278.22** |

Since the Class D liner is built by only 150mm base preparation on top of In-situ material (G layer) that receives the waste body, costs associated with Class D liner amounts to **R10.61**, as per the value for Base preparation in **Table 6-2**.

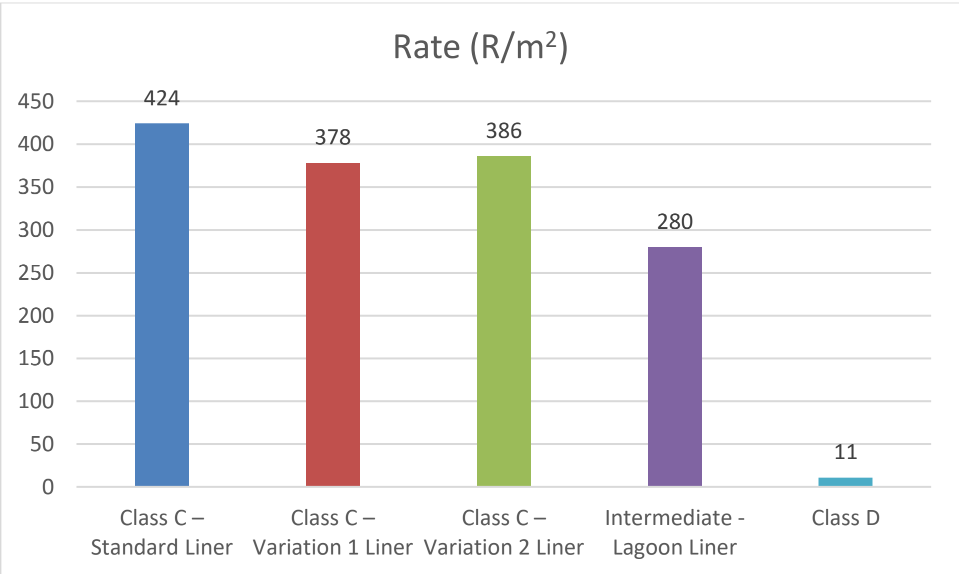



**Figure 6-6: Summary – Liner Unit Costs (Rounded)**

# 7 SOURCE PATHWAY RECEPTOR MODELLING AND ANALYSIS

It is fundamental to construct a simple conceptual process that defines the potential contaminants linkage to the potential environmental receptor. The process that leads to the establishment of such linkage is referred to as the source-pathway-receptor model. Three essential elements need to be understood so that the contaminants of concern (CoC) can be defined, and the associated risk to receptors can be quantified. The chevron list in **Figure 7-1** illustrates how source-term characterisation is linked to groundwater and receptor study.

The sources and the unsaturated pathway are discussed together as source-term analysis. The prevailing groundwater's characteristics are then discussed as aquifer pathway. The users and sensitive environmental components that depend on the groundwater that is flowing from the continuous ash disposal facility's site are also analysed. Note that we did not consider in the present study the Aquifer as receptor but rather as pathway to groundwater users (boreholes) and sensitive environmental components (river and wetland).

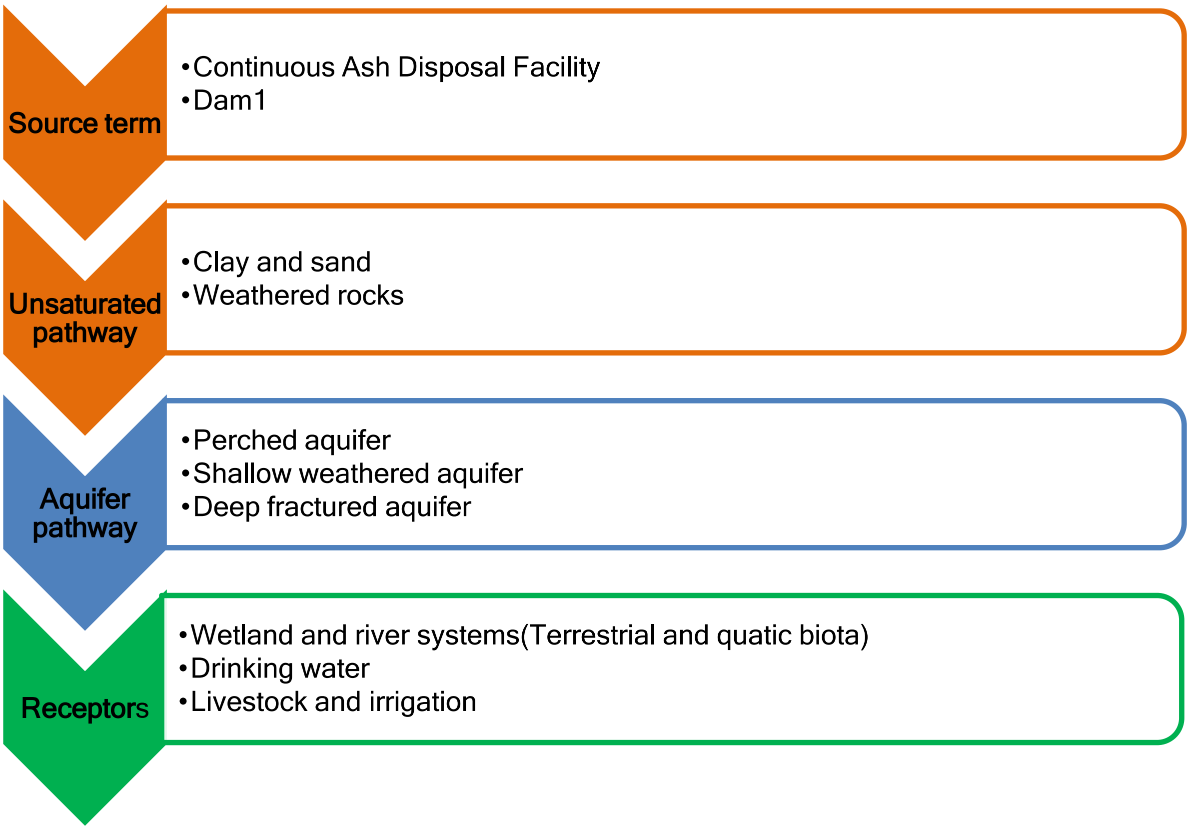



**Figure 7-1: Link between source-term, groundwater and receptor studies**

## 7.1 Groundwater pollution source-term analyses

### 7.1.1 Defining existing pollution source

Sources of the current and potential contaminations were identified mainly around the existing ash facility. They form part of the overall delineated pollution sources of contamination to groundwater as delineated at KPS by GHT Consulting Scientists in 2012 (GHT Consulting Scientists, 2012).

Five main pollution sources (ash stack, coal stockpile, dirty water dams, station drain dams, and emergency ash dump) were identified in the overall power station. These pollutions sources are not lined and may leach into the surrounding water resources either by infiltration and percolating through the unsaturated soil zone to reach the water table, or surface water runoff and reach surface water features (streams, wetlands). The rising groundwater elevations found in boreholes located directly north (AB56, and AB57) and south (AB22, AB25, AB48) of the existing ash disposal facility, as is evident in **Figure 5-12**, are probably the indications of water seepage into the ground, as demonstrated by in water samples collected from the boreholes shown in **Figure 5-11.** The high concentration of Manganese (AB07, AB08, AB16, AB22, AB51, AB52, and AB57), Sulphate (AB08), and Iron (AB08 and AB48) furthermore confirms such a probability (GHES, 2018).

### 7.1.2 Continuous ash disposal facility (source)

The continuous ash disposal facilities with its associated dirty water management infrastructures (Dam 1 and Dam 2) are to be lined according to regulatory and design requirements. However, these lining systems are susceptible to leak at certain specific rates (Giroud & Touze-Foltz, 2005) and at predisposed points or areas such as drains, leachate drains, or finger drains. Hence such areas constitute potential pollutions sources.

Therefore, certain leakage rates are considered according to different lining design alternatives. Based on 3 different lining scenarios (Class C (including Class C Variations 1 and 2), Intermediate (Lagoon Liner), and Class D), the leakage rates were calculated for input into the numerical groundwater model developed to model the impact and extent of these leakage rates. As the sources of the contaminant leakage would be continuous the calculated leakage rate (s) assumed the ADF would always contain sufficient water to allow continuous percolation into the subsurface within the continuous ADF area. Assuming a groundwater recharge rate of 3 % to such available water, the annual recharge to saturated groundwater was determined for each scenario (**Table 7-1**) (GHES, 2018).

The static leachate test conducted on four ash samples at Kendal Power Station indicated a maximum concentration of 133 mg/l for sulphate. However, considering the observed concentrations of sulphate in the groundwater at AB08 and AB57 (586 and 480 mg/l respectively), and at dirty water monitoring points AP10, AC05, AP32, and AP33 (621, 611, 720 and 598 mg/l, respectively) (GHT Consulting Scientists, 2012), a sulphate concentration on 600 mg/l was assumed to be a reasonable concentration in any leachate that may leak from the continuous ash disposal facility into the underlying lithology (GHES, 2018). The corresponding mass flux (source term) of the contamination (Sulphate) was then calculated for each alternative scenario (**Table 7-1**). The percolation of contaminated water through the unsaturated soil will mainly be controlled by soil characteristics, as referenced in **Table 7-2**.

**Table 7-1: Source characteristics**

| Pollution sources | Volumes/weigh | Contaminants of concern | Leakage rate $m^3$/ha/day | Recharge to saturated groundwater mm/$m^2$/year | Concentrations of Sulphate for mg/l | Max flux g/$m^2$/day |
|---|---|---|---|---|---|---|
| **Pollution Control Dam 1** | 120 Ml | Mn<br>SO4<br>Fe<br>F | Class C: 0.038<br>Intermediate: 0.007<br>Class D: 0.87 | Class C: 1.387<br>Intermediate: 0.2555<br>Class D: 31.755 | 600 | Class C: 2.28 x $10^{-3}$<br>Inter C: 0.42 x $10^{-3}$<br>Class D: 52.2 x $10^{-3}$ |
| **Continuous ADF** | 6 200 000 t/a<br>or<br>5 300 000 $m^2$ x 70 m | | | | | |

**Table 7-2: Unsaturated zone characteristics**

| | Hydraulic Conductivity m/day | Thickness mbgl | Material |
|---|---|---|---|
| **Unsaturated pathway** | 0.5 – 18 | 1.5 – 5 | Clay, sand, weathered rocks (granite, dolerite), gravel |

Water strikes were recorded before 20 mbgl in 80% of boreholes, and a dolerite sill is present below the continuous ash disposal facility's site, at a depth generally between 6 and 19 mbgl. Hence, it is inferred that contaminations from the pollution sources associated with the continuation of disposing of ash will be limited to the shallow weathered aquifer (GHES, 2018).

## 7.2 Defining the pathway

The pathway is the route from the source to any given receptors. Therefore, if a contaminant is to cause harm, it must reach a receptor. Each receptor is identified and their sensitivity to the specific contaminant assessed. In this study the underlying aquifers acted as the pathway for potential contaminant transport.

### 7.2.1 Aquifer pathway

Two dominant hydro-stratigraphic units (aquifer system) were identified within the Kendal power station area. These include (GHES, 2018):

- **Shallow weathered and fractured aquifer system:** this aquifer is unconfined to semi-confined and is recharged by rainfall. The shallow weathered aquifer is formed of lower permeable rock material. According to previous investigations (percussion drilling logs), the local thickness of the shallow aquifer was estimated to be between 5 m – 25 m. The water-bearing fractures occur from 15 to 25 m below ground surface. The weathered and fractured horizon consists mainly of clay, granites and dolerites of the Karoo Supergroup. It is important to note that this is not an absolute thickness value for the entire study area. Different thicknesses can occur from the competent hard rock outcropping in places.

  Although most of groundwater strikes are recorded in this shallow aquifer because of weathering conditions, the recorded borehole yields in this aquifer are generally low. The static groundwater water level is often naturally perched (0.9 and 3.0 mbgl). The occurrence of natural wetlands in the area is probably associated with lower permeable underlying rock material in the unsaturated zone, which allows static groundwater level to even be artesian in places. Prevailing boreholes yields range between 0.1 and 0.9 l/s. Hydraulic conductivities vary considerably in the area, and are generally estimated between 0.01 and 0.9 m/day.

- **Deeper Localized fractured to fresh aquifer system:** the deeper fractured to fresh aquifer rock aquifer formed by competent rock of the Vryheid Formation that has been subjected to fracturing associated with tectonic movements, is developed below the shallow and fractured weathered aquifer. This aquifer is semi-confined and is controlled by geological structures (dolerite intrusions and fault zones) and horizontal conductive layers (coal seam) contact zones. Groundwater flows in the deeper aquifer along discrete pathways associated with the fractures. Although occasional high yielding boreholes may be intersected, the deeper aquifer does not constitute an extensive aquifer able to sustain excessive pumping.

The recharge to the shallow aquifer in the area is directly from rainfall, and is estimated to be between 2 % (7.35 mm) and 6 % (22.05 mm) of the Mean Annual Precipitation (735 mm). In typical unconfined system, groundwater divides develop approximately beneath the major surface water divides, as a result of local recharge and discharge.

The deeper fractures aquifer is assumed to be interconnected to the shallower one, and is also recharged mainly by rainfall recharge, and groundwater seeps from the perched aquifer into the fractured rock aquifer. Direct recharge from rainfall or surface stream can also occur where the fractured, competent rock outcrops, or from the base of perennial rivers.

Most of the groundwater recharge that is occurring within the study area may discharge internally to the base of perennial Wilge River drainage system and the surrounding mining pit.

### 7.3 Defining the receptors

Based on the existing literature and data assessed, the sensitive receptors indented include potential contamination of:

- **Boreholes:** Contamination of boreholes could result in the adverse health impacts on humans/residents living in the area or on livestock and wildlife consuming water pumped from these boreholes; and
- **Rivers:** Contaminants transported through the groundwater pathway could daylight in adjacent river systems, thereby impacting of the water quality of these river systems. Such contamination could also have an indirect impact on aquatic and terrestrial biodiversity associated with these systems.

**Wetlands near the ADF site was not considered as a sensitive receptor**. The wetland study conducted by Wetland Consulting Services (Wetland Consulting Services, 2014) in October 2013, for the continuous ash disposal facility do not suggest any clear dependence of the local wetland on shallow saturated groundwater flow. Surface runoff inflow and interflow inflow are likely to be the main hydrological drivers supporting the overall wetness within a wetland. The most significant likely impacts on local wetlands are: the direct loss of wetland habitat falling within the footprint of the continuous ash dam facility; the risk of water quality deterioration posed mainly by spills, leaks (construction) seepage, and runoff from the ash disposal facility (GHES, 2018). The degree or interdependence of surface water-groundwater interactions between wetlands and shallow saturated groundwater flow have however not been determined through a focused study.

#### 7.3.1 Boreholes

As confirmed by different borehole surveys (hydrocensus) the closest (less than 1 km radius) privately owned water supply boreholes (FBB56, FBB39 see Figure 24) to the continuous ash disposal facility's site are equipped with submersible pumps and are in use. They both may constitute receptors of any migration through the aquifer, of contamination from the continuous ash disposal facility. FBB39 falls under Eskom's property but FBB56 does not. The continuous abstraction of water from those boreholes will locally draw down the groundwater levels and create local and dynamic cone of depression. The details of the baseline groundwater quality at these boreholes for contaminants of concerns are summarised in **Table 7-3**.

**Table 7-3: Sensitive Receptors - Boreholes**

| | | FBB56 | FBB39 |
|---|---|---|---|
| Coordinates (Decimal Degrees) | Long | 28.92523 | 28.93734 |
| | Lat | -26.07738 | -26.07506 |
| Owner/Farm | | JG Prinsloo Vlakvarkfontein 213/4 | Kendal Power Station, but used by JG Prinsloo / Schoongezicht 218/24 |
| Use(s) | | Domestics and farming/ Submersible pump | Domestics and farming/ Submersible pump |
| Signs of Pollution | | No | Yes |
| pH | | 8.11 | 5.98 |
| EC | | 21.70 | 26.10 |
| Mn (mg/l) | | <0.001 | 0.001 |
| $SO_4$ (mg/l) | | 0.41 | 9.36 |
| Fe (mg/l) | | <0.004 | <0.004 |
| F (mg/l) | | 0.22 | <0.142 |
| $NO_3$ (mg/l) | | 4.35 | 17.40* |
| *Above SANS_241_2011 Limit | | | |

### 7.3.2 Rivers

Water quality at monitoring point R04 is the only baseline quality information on surface water receptor that is available. The details of such quality in light of contaminants of concerns are summarised in **Table 7-4**.

A map indicating the identified pollution source, pathways, and sensitive receptors are provided in **Figure 7-2**.

**Table 7-4: Sensitive Receptors-Rivers**

| Monitoring Point | | R04 |
|---|---|---|
| Coordinates | Long | 28.92840 |
| | Lat | -26.08260 |
| Owner/Farm | | Public Stream/ Schoongezicht218/20 |
| Use(s) | | Monitoring, Livestock |
| Signs of Pollution | | |
| pH | | 7.70 |
| EC | | 113.00 |
| Mn (mg/l) | | <0.001 |
| $SO_4$ (mg/l) | | 507.00* |
| Fe (mg/l) | | <0.004 |
| F (mg/l) | | 0.29 |
| $NO_3$ (mg/l) | | 0.23 |

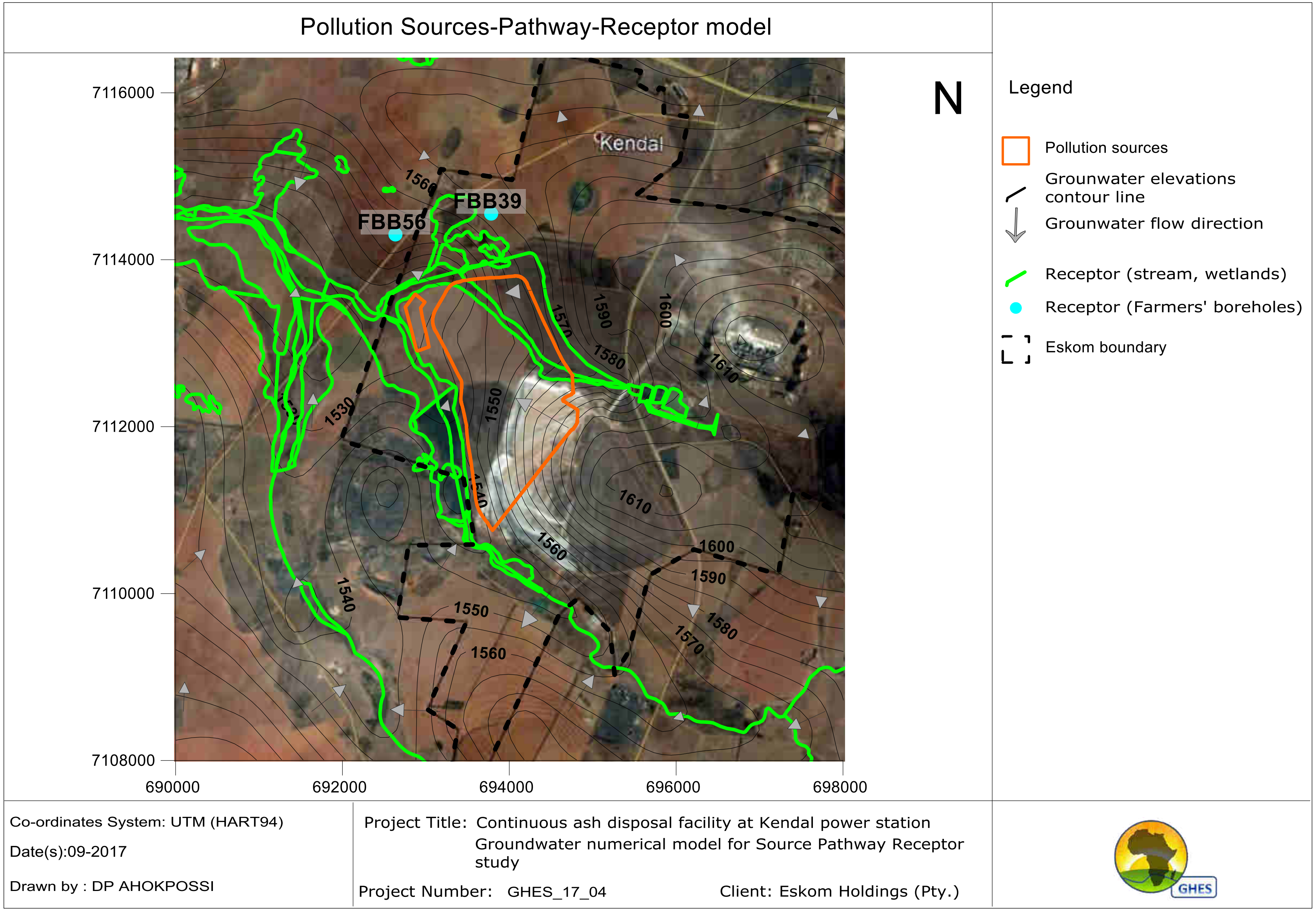



**Figure 7-2: Pollution Source-Pathway-Receptor map (GHES, 2018)**

### 7.4 Aquifer Vulnerability and Risk Assessment

An assessment of the vulnerability of the groundwater aquifer underlying the Kendal Power Station to potential pollution sources was undertaken for the power station in 2012 (GHT Consulting Scientists, 2012).

The concept of aquifer vulnerability derives from the assumption that the physical environment may provide some degree of protection of groundwater against human impacts, especially with regard to pollutants entering the subsurface. Aquifer vulnerability thus combines the hydraulic inaccessibility of the saturated zone to the penetration of pollutants, with the attenuation capacity of the strata overlying the saturated zone (Foster, 1998), as cited (GHT Consulting Scientists, 2012). The vulnerability of the underground water source is related to the distance that the contaminant must flow to reach the water table, and the ease with which it can flow through the soil and rock layers above the water table (GHT Consulting Scientists, 2012).

#### 7.4.1 Potential impact sources considered from KPS infrastructure

GHT Consulting Scientists (2012) identified several potential pollution sources associated with the Kendal Power Station and associated infrastructure only that could impact on the underlying groundwater aquifer. Taking the topology and ungerlying geology into account, study area was divided into three different effected major drainage regions receiving possible contamination from different pollution sources (**Figure 7-3**). These include:

1. **Heuwelfontein Spruit Drainage System**: Identified pollution sources include Emergency Ash Dump and Coal Stockpile
2. **Schoongezicht Spruit Drainage System**: Identified pollution sources include existing ADF, Coal Stockpile, Dirty water dams and Station Drain dams
3. **Leeuwfontein Spruit Drainage System**: Identified pollution sources include the existing ADF

From Figure 7-3 it is clear that the existing and Continuous ADF extension fall partly within the Schoongezicht Spruit Drainage System and partly within the Leeuwfontein Spruit Drainage System.

#### 7.4.2 Sample locations and soil profiles

The study further determined the hydraulic parameters of the unsaturated zone. 19 auger holes were drilled across the entire study area close to the identified pollution sources. The aim was to drill each auger hole 2 meters deep, but due to underlining rock and very hard clay, the depth was rarely reached.

Locations of the auger holes are provided in Figure 7-3. Auger holes located in the vicinity of the Continuous ADF footprint include AD12 (2), AD13 (0.5), AD15 (2) and AD16 (0.5). The depth to which the auger holes could be drilled is included in brackets next to each auger hole number.

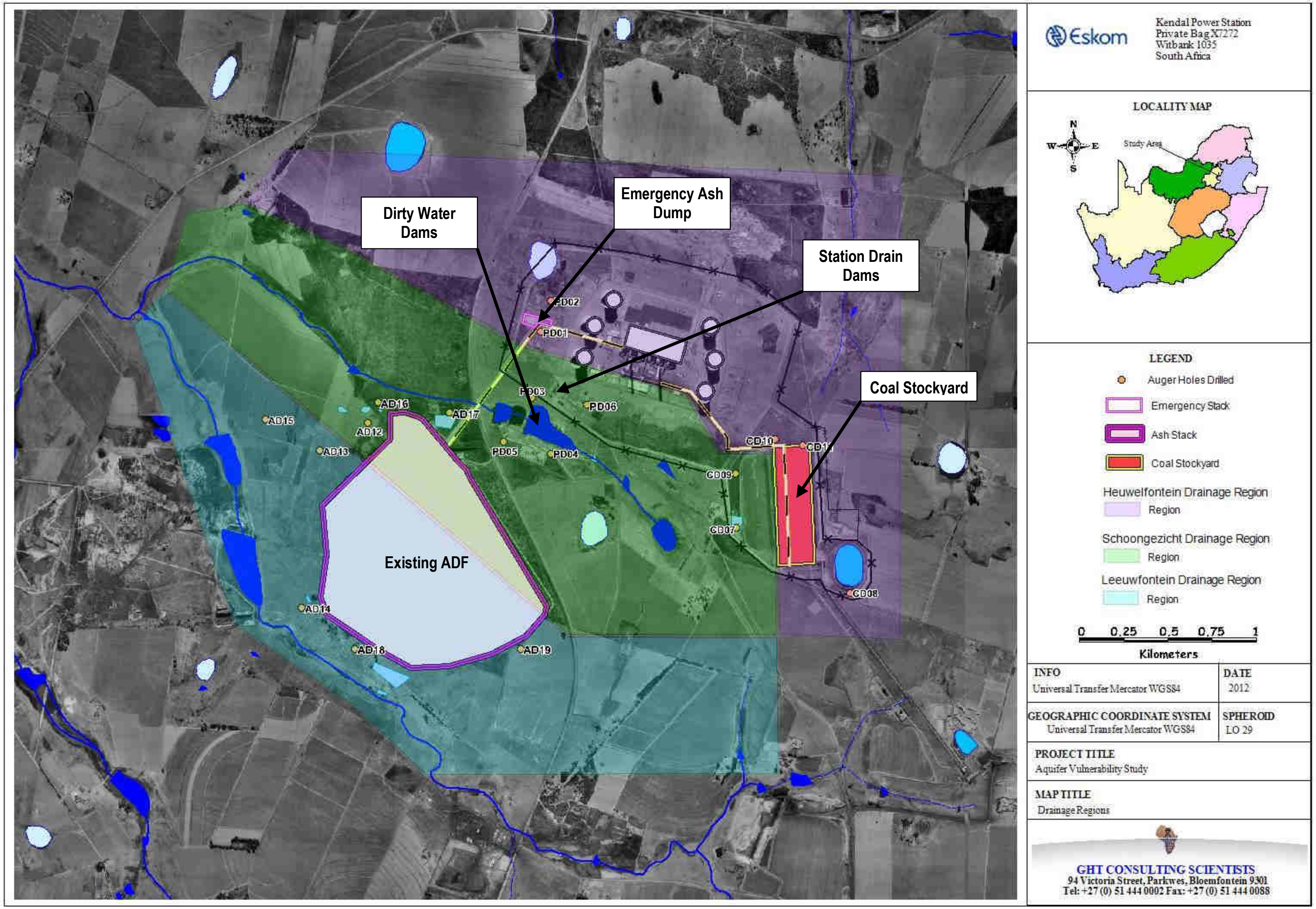



**Figure 7-3: Location of pollution source identified within drainage regions at KPS (GHT Consulting Scientists, 2012)**

### 7.4.3 Aquifer vulnerability

Aquifer vulnerability was assessed through a risk assessment undertaken by GHT Consulting Scientists (2012). Since the exiting ADF and Continuous ADF footprints are located within the Schoongezicht Spruit and Leeuwfontein Spruit drainage regions, aquifer vulnerability for only these 2 drainage regions were considered in this SPR report. The vulnerability of groundwater aquifer due to hydrogeological conditions was considered using risk parameters shown in **Table 7-5**.

**Table 7-5: Vulnerability of groundwater aquifer due to hydrological conditions (Groundwater protocol version 2, 2003)**

| Vulnerability Class | Measurements | Definition |
|---|---|---|
| **Extreme** (usually highly fractured rock and/or high ground water table) | High risk and short distance (< 2m) to water table | Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface |
| **High** (usually gravely or fractured rock, and/or high water table) | High risk and medium distance (2-5m) to water table | Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed |
| **Medium** (usually fine sand, deep loam soils with semisolid rock and average water table (>10m) | Low risk and medium to long distances to water table | Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants |
| **Low** (usually clay or loam soils with semi-solid rock and deep water table (>20m) | Minimal and low risk, and long to very long distance to water table | Only vulnerable to the most persistent pollutants in the very long term |
| **Negligible** (usually dense clay and/or solid impervious rock with deep water table) | Minimal risk with confining layers | Confining beds present with no significant infiltration from surface areas above aquifer |

### 7.4.4 Consideration of aquifer vulnerability test results

The study concluded, based on consideration of the results of all the soil augers locations that the Schoongezicht Spruit drainage region aquifer has a **high vulnerability** due to a thin, permeable unsaturated zone, while the Leeuwfontein Spruit drainage region aquifer has a **medium vulnerability** due to a medium to long distance from the surface to the water table, clays and soils with a low hydraulic conductivity for attenuation to occur.

It should be noted that the study results were variable and no results logs or raw data was presented in the report to consider potential vulnerability of auger hole results associated with auger holes located around the existing ADF and Continuous ADF footprint.

In fact, when additional boreholes were drilled a number of years later in a different study (GHT Consulting Scientists, 2015b) at different locations within and close to the Continuous ADF, the shallow borehole data indicated the occurrence of thick clay layers, or granite followed by clay layers (see section 5.3.2 and Table 5-2) were observed at the borehole locations.

## 7.5 Numerical Geohydrological Model and Impact Scenarios

### 7.5.1 Model construction

The ultimate goal of the numerical groundwater model is to simulate the contamination migration scenarios (Pollution plume) for each contamination barrier (lining) alternative.

An updated finite-element 2D/3D numerical groundwater model was developed by GHES (GHES, 2018) using modelling software package Feflow (Diersch, 1979). The numerical model is built with 3 layers (**Table 7-6**).

**Table 7-6: Details of model layers**

| Layer number | Hydro-stratigraphic unit | Top of the layer m (below Static water elevations) | Type of Aquifer |
|---|---|---|---|
| Layer 1 | Weathered fractured sandy clay | 0 | Unconfined |
| Layer 2 | Weathered fractured sandy clay, granite, dolerite | 10 | Confined/ Unconfined |
| Layer 3 | fractured rock | 30 | Confined/ Unconfined |

By default initial concentration of 0 mg/l was assigned to fresh water in the aquifer system. The contamination sources are represented by a higher initial concentration in the areas of the continuous ash disposal facility and associated dams in the top aquifer. For each alternative, the mass flux (source term) of the contaminant (Sulphate) was assigned accordingly.

Sulphate is generally used as the indicator element for modelling purposes. It is introduced into the system through oxidation of sulphides in ash stack when the ash comes into contact with water. Sulphate is a convenient constituent to study the movement of pollution, because: sulphate is readily soluble, does not adsorb readily onto clay particles in soil or the aquifer and it does not decay over time (GHT Consulting Scientists, 2015a).

### 7.5.2 Results and findings from the Numerical Geohydrological Model

The simulation of scenarios of the contamination migration scenarios (Pollution plume) for each contamination barrier (lining) alternative was conducted using the calibrated model. The simulated increases in the concentrations of sulphate in the aquifer, for each alternative for 5, 10, and 40 years after closure, are provided in **Figure 7-4** to **Figure 7-12**. All these figures were taken from the groundwater numerical model for Source Pathway Receptor study report (GHES, 2018).

Simulated increase in concentrations of sulphate at the pollution source, i.e. ADF, and borehole FBB56 40 years after closure of the ADF is provided in **Table 7-7**. These simulate concentrations of sulphate are also compared to the South Africa Water Quality Guidelines (SAWQG) for

Domestic Use (DWAF, 1996), SANS 241-2: 2015 (SABS, 2015), and the recent Water Quality Planning Limits set for the Olifants WMA, Wilge sub-catchment (DWS, 2018a).

**Table 7-7: Simulated increase in concentrations of sulphate at FBB56 after 40 years**

| | **Current Background concentration @FBB56** | **Increase in concentration @FBB56** | **Increase in concentration @Source** | **SAWQG TWQR for domestic use** (DWAF, 1996) | **SANS 241-2: 2015 Limit** | **WQPLs for Wilge catchment** (DWS, 2018a) |
|---|---|---|---|---|---|---|
| **Units** | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) |
| **Class C,** including Class C variations | 0.41 | 0.02 | 10.6 | ≤ 200 | ≤ 500 | ≤ 70 |
| **Intermediate Class C** | | <0.01 | 1.80 | | | |
| **Class D** | | 22 | 125 | | | |

The groundwater specialist reached the following conclusions:

- The predicted increase of concentration of contaminant in the aquifer at the source (continuous ash dam facility area) is lowest for “Intermediate” (1.8 mg/l), then increases for “Class C” and “Class D”. “Class D” would induce the worse contamination scenario with a predicted increase in the concentration of contaminant of 125 mg/l after 40 years of simulation.
- The Class C and Intermediate Class C liner alternatives pose less contamination risk than the Class D liner alternative. One of the advantages of the Class C and Intermediate Class C liner alternatives is the presence of finger drains, which have the function to drain (collect) any water that may leak through barrier system, toward water management infrastructure. Leakage is therefore likely to be concentrated to the dirty water containment infrastructure.
- From a groundwater impact perspective, the Intermediate Class C liner alternative is the preferred alternative, since the induced sulphate’s concentration after 40 years of simulation at borehole FBB56, is less than 0.01 mg/l, compared to an increase of 0.02 mg/l and 22 mg/l, respectively, for “Class C” and “Class D”.

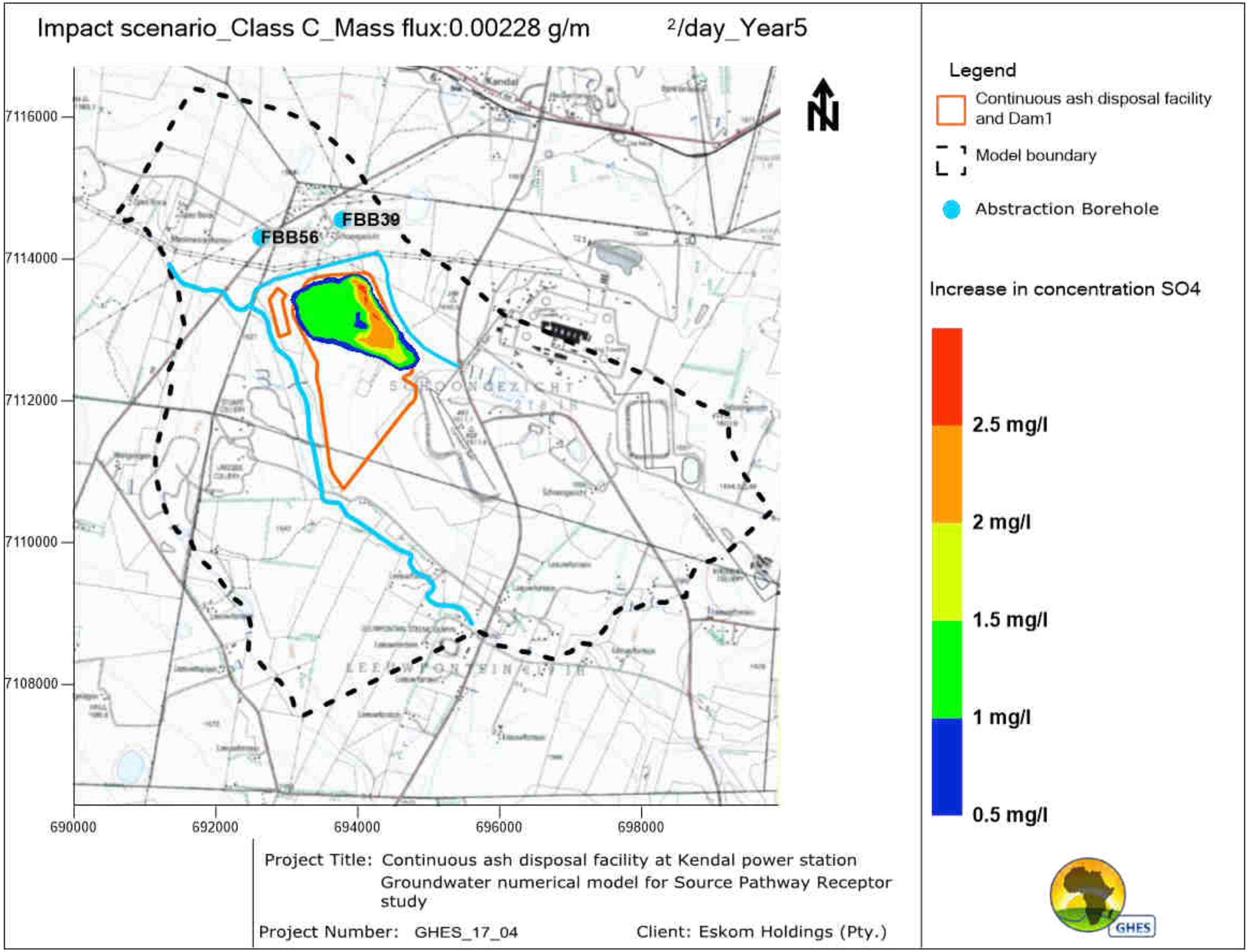



**Figure 7-4: Simulated pollution plume impact for Class C liner after 5 years**

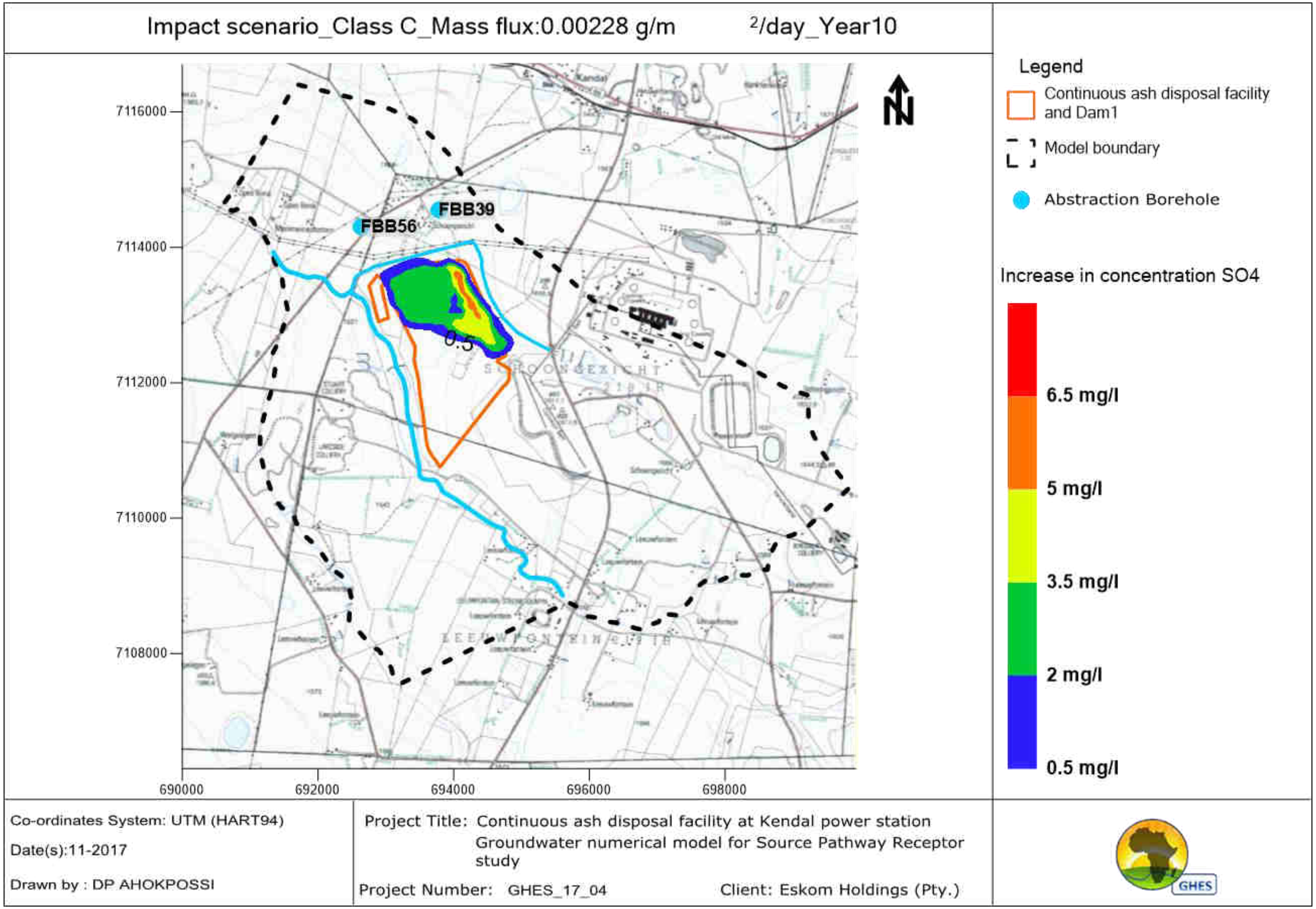



**Figure 7-5: Simulated pollution plume impact for Class C liner after 10 years**

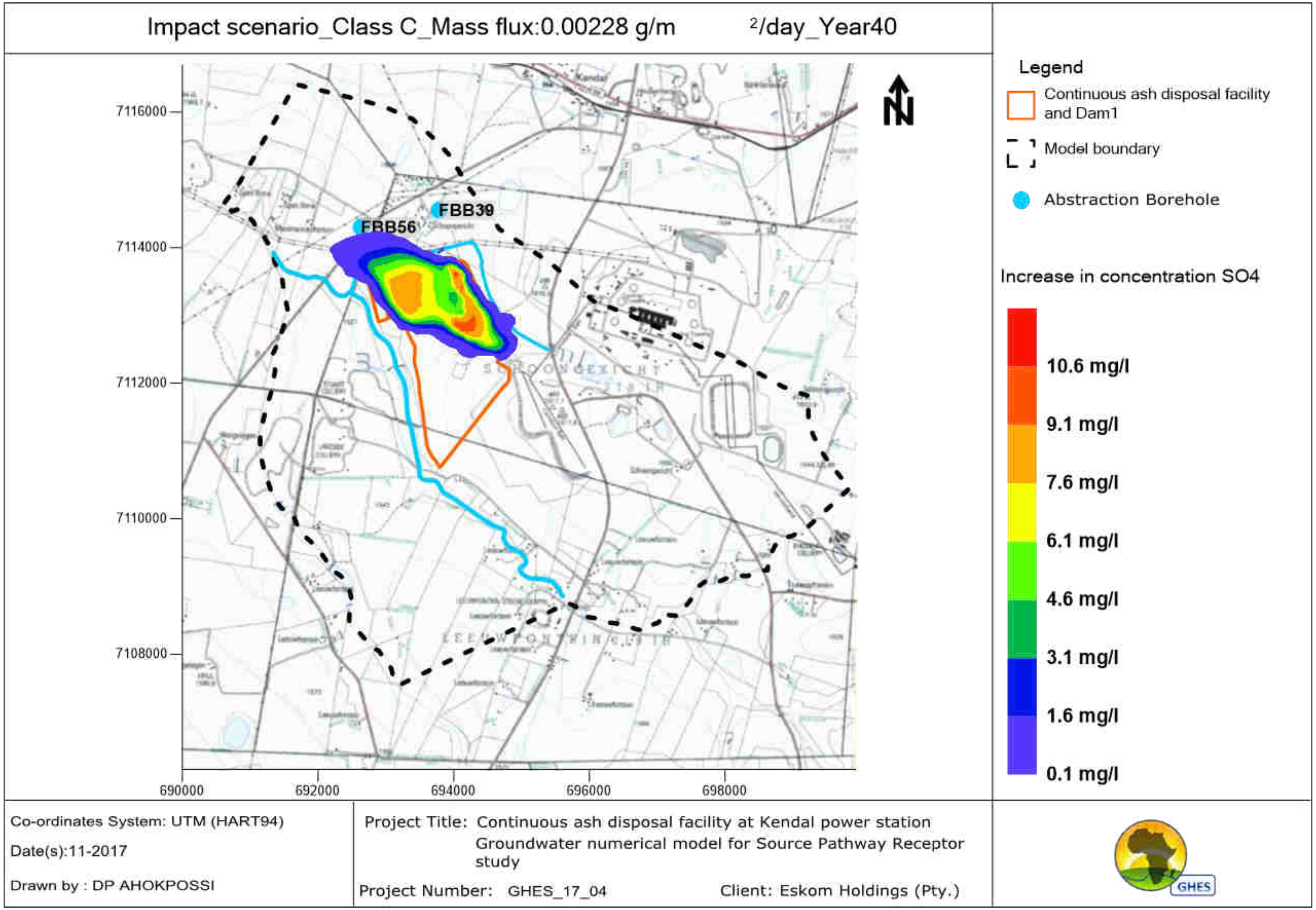



**Figure 7-6: Simulated pollution plume impact for Class C liner after 40 years**

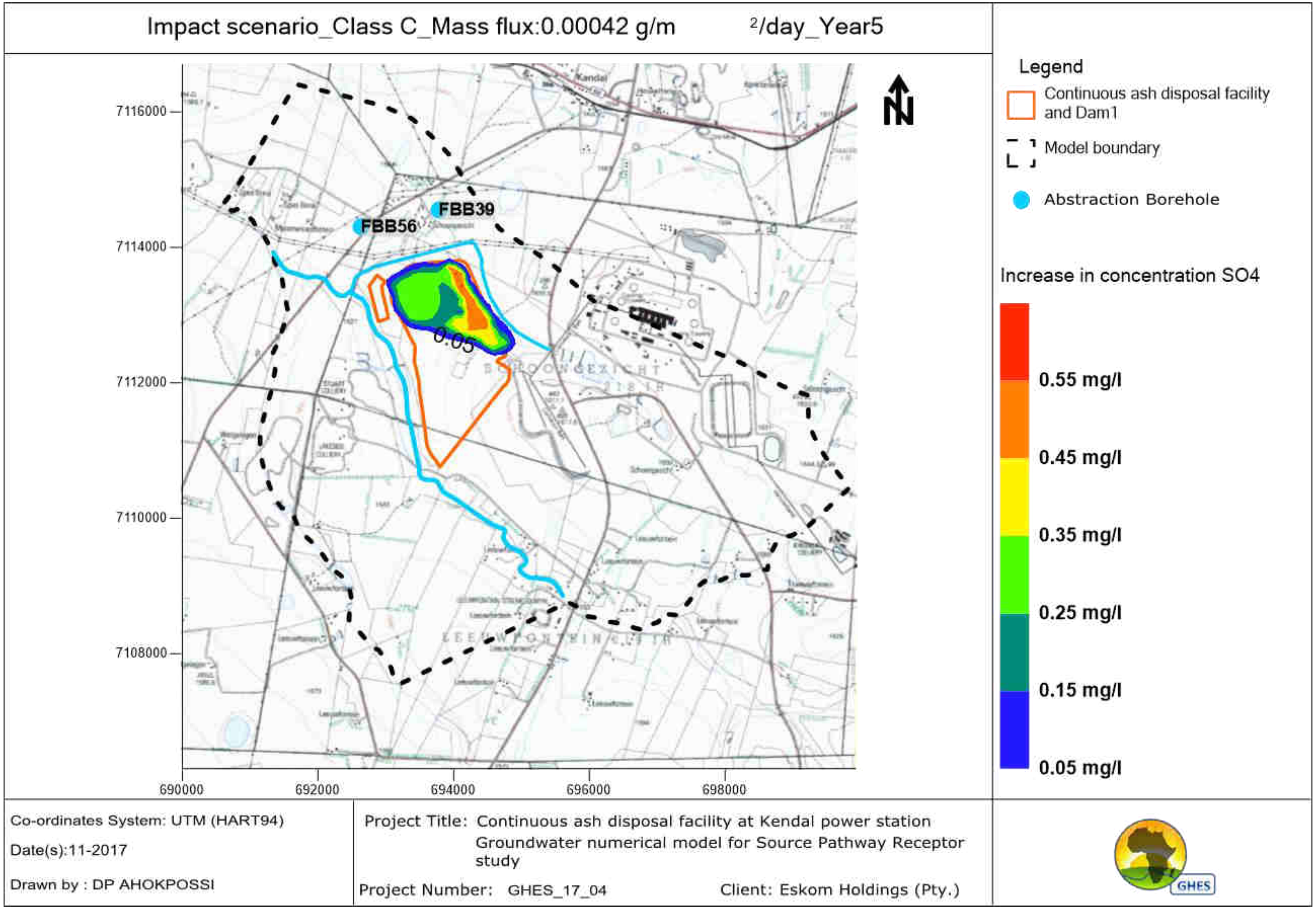



**Figure 7-7: Simulated pollution plume impact for Intermediate Class C liner after 5 years**

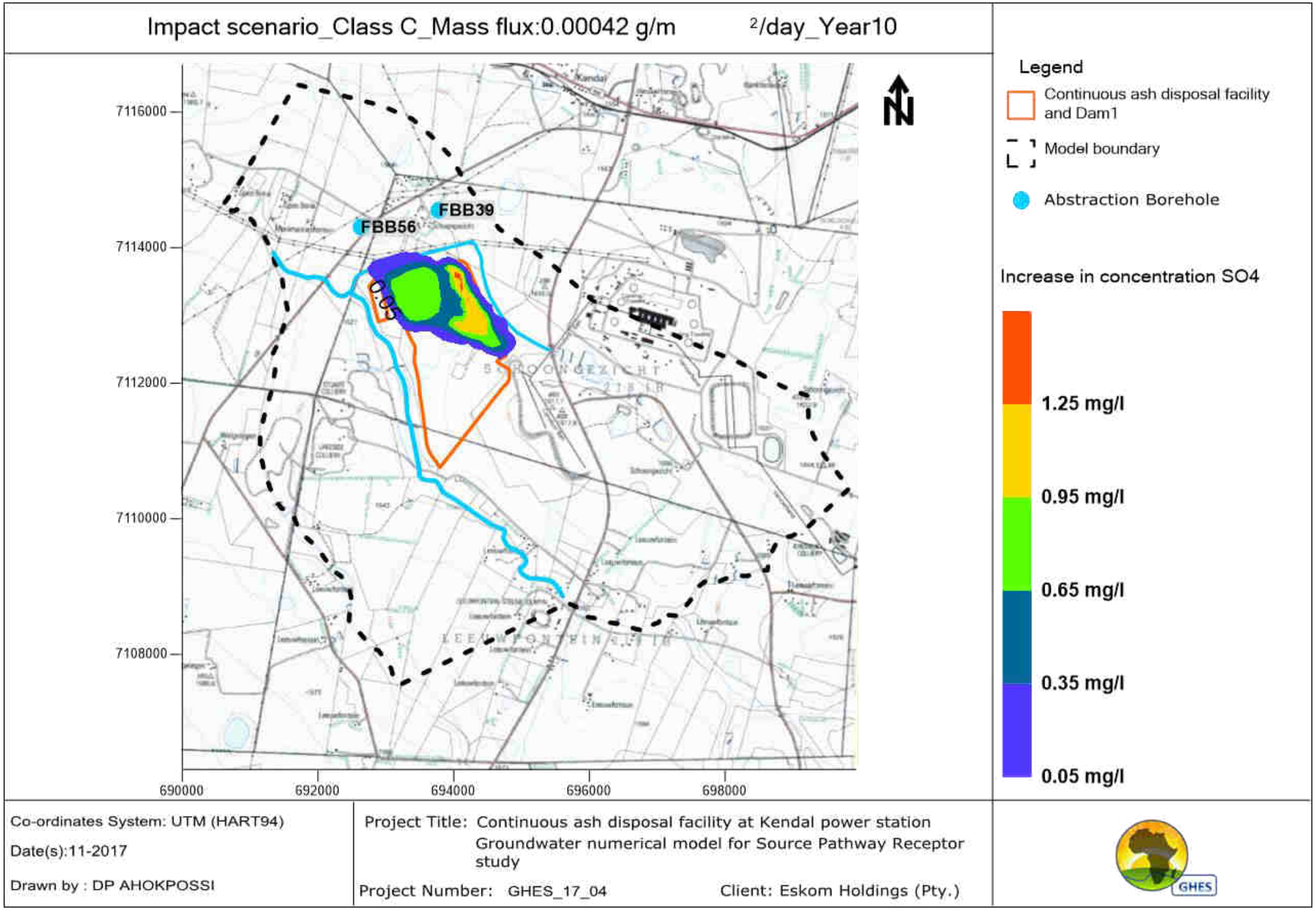



**Figure 7-8: Simulated pollution plume impact for Intermediate Class C liner after 10 years**

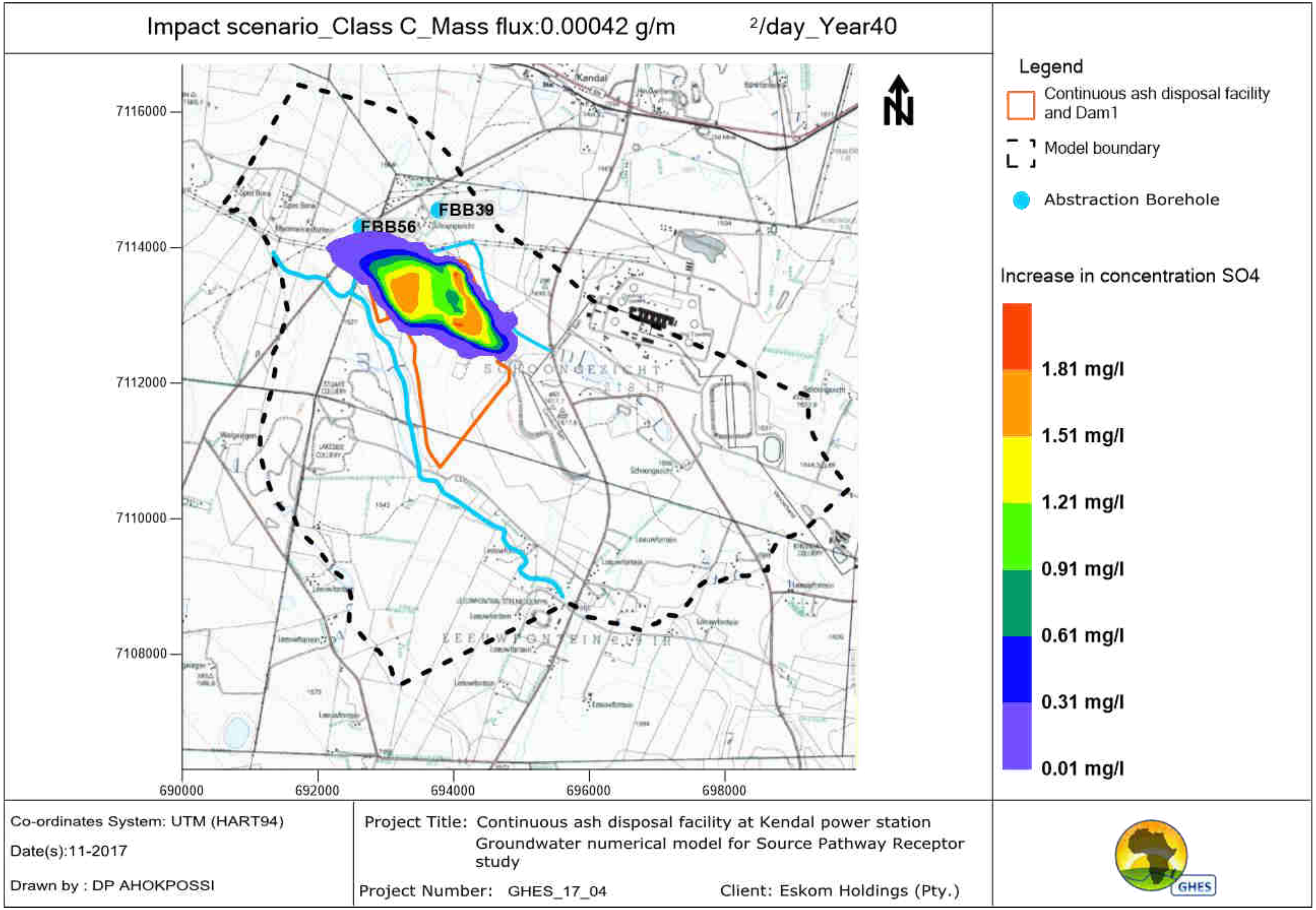



**Figure 7-9: Simulated pollution plume impact for Intermediate Class C liner after 40 years**

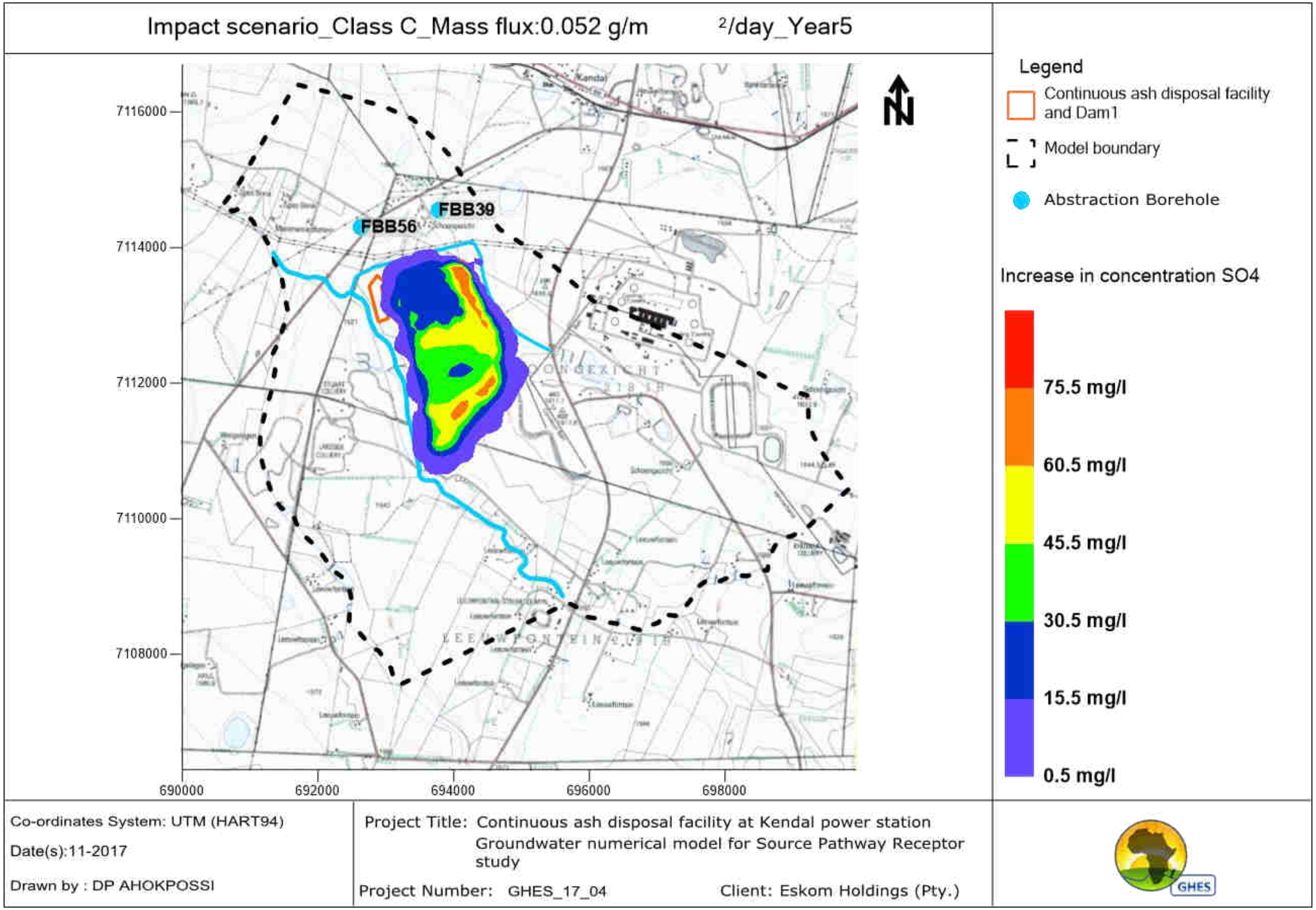



**Figure 7-10: Simulated pollution plume impact for Class D liner after 5 years**

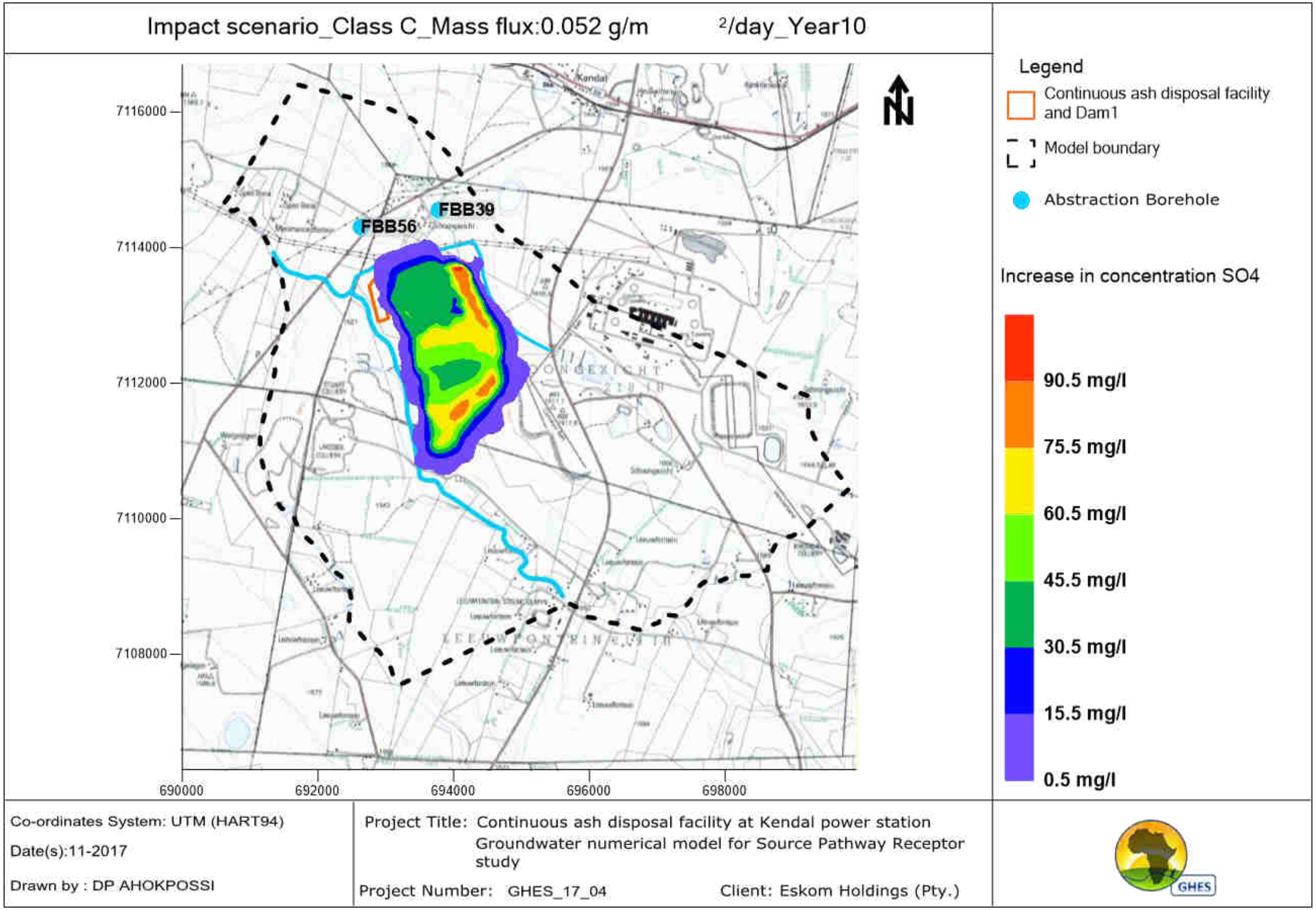



**Figure 7-11: Simulated pollution plume impact for Class D liner after 10 years**

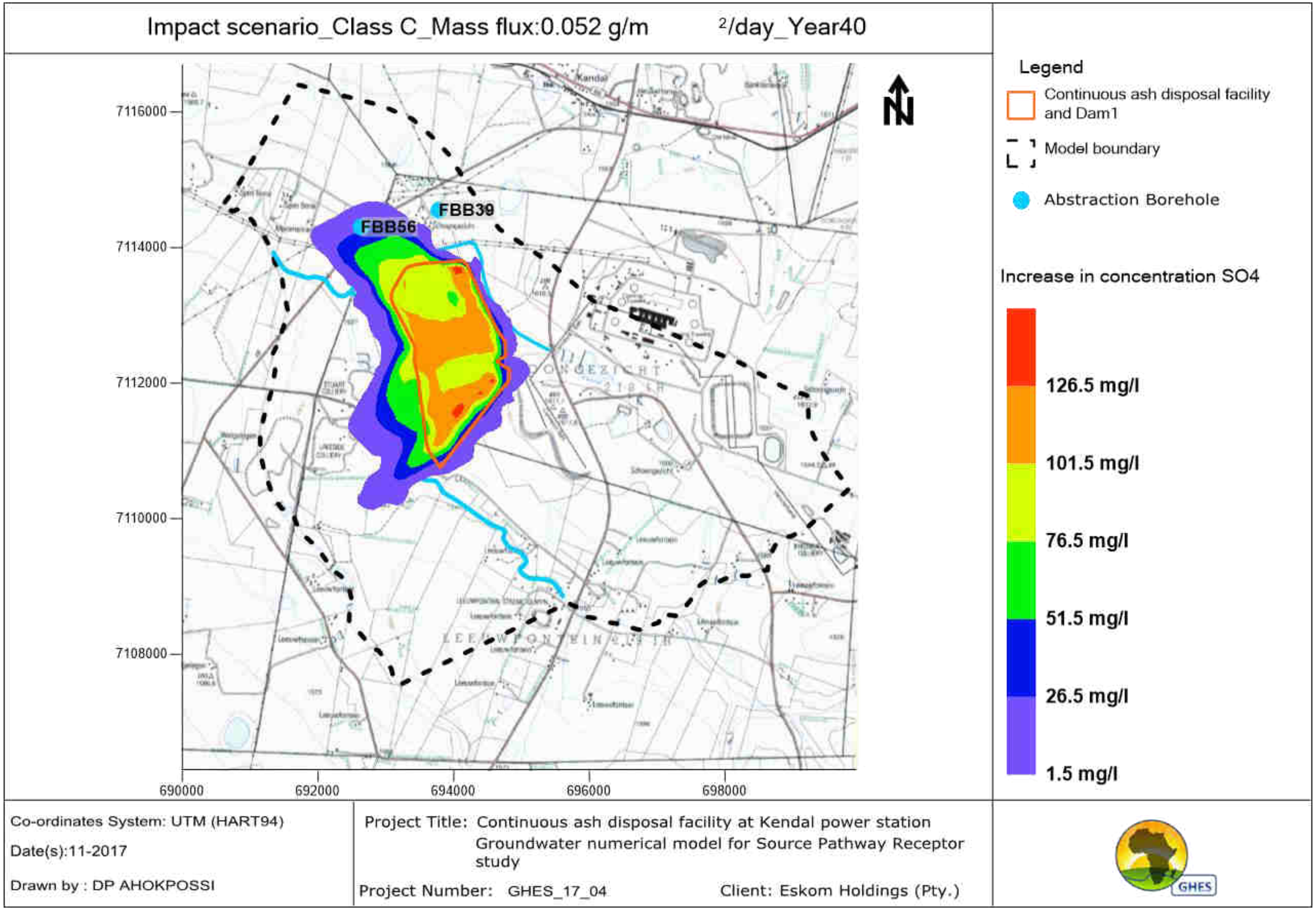



**Figure 7-12: Simulated pollution plume impact for Class D liner after 40 years**

# 8 DISCUSSION

The Source-Pathway-Receptor (SPR) study considered the characteristics of the potential pollution source, the potential pathway Contaminants of Concern (CoC) would follow including the direction, rate and concentration dilution effect, as well as the potential sensitive receptors downstream of the pollution plume the CoCs could impact. Discussion around the SPR findings are therefore also done in this order to aid understanding of the SPR concept and conceptualise the impacts and potential consequences that could results from the KPS ADF.

## 8.1 Source of Contaminants of Concern (CoCs)

The objective of this SPR study was to assess the potential impacts that the reduction in the authorised Class C liner requirements could have on sensitive receptors located around the KPS ADF if an alternative liner system was approved for implementation. The source of the potential pollution was therefore identified as the Continuous Ash Disposal Facility (ADF), which represent the continuation of ashing from the existing ADF in a north-westward direction, as shown in **Figure 3-2**.

Besides the obvious benefits of ash, as mentioned in Section 2.1, pulverised coal fired boiler ash is still considered a waste product in South Africa. The high-level human health risk assessment (Golder Associates, 2016a), undertaken for Eskom's pulverised coal-fired fly ash in 2016 (see Section 2.6**)**, concluded that concentrations of **all CoCs in groundwater of an on-site borehole will be within acceptable levels, i.e. less than South African Water Quality Guidelines for Domestic use, even after a simulated period of 100 years**.

When the dynamics and characteristics of the ash body itself was considered (see Chapter 2), it is evident that when ash deposited on the ADF comes into contact with water for extended periods of time, the **pozzolanic properties of the ash would create a cementitious effect, hardening the ash body and thereby making it less permeable**, which has also been listed by some studies (Ahmaruzzaman, 2010) as one of the benefits for the use of ash in brick-making and the cement industry. This pozzolanic effect has been reported by some power stations when the ash dumps were inspected. This pozzolanic effect can also be increased by the addition of lime to increase the self-hardening properties of the ash. Therefore, it is expected that the exposure of the ash body to water would result in a less permeable ash body thereby resulting in less water accumulating at the base of the ADF.

The operational and maintenance philosophy underpinning the management of the ADF structures must also be considered. Best practice for managing developing ADFs is to undertake concurrent rehabilitation a number of shifts behind the advancing face of the ADF. This results in the **ash body being reshaped to appropriate angles that will allow drainage of storm water to the natural environment, therefore limiting the infiltration of water into the ash body beneath**.

Furthermore, the main geological features (lithology) encountered during drilling on at the Continuous ADF site consisted of clay, granites and dolerites of the Karoo Supergroup. Clay, for example, was found to vary from between 6 – 19 m thick at the ADF. This clay layer will therefore tend to form a natural impermeable barrier that could help explain why no significant impacts from the operation of the existing unlined ADF has not picked up in routine surface and groundwater monitoring.

## 8.2 Identified Pollution Pathway

The numerical groundwater modelling undertaken by GHES investigated potential groundwater pathways that could transport CoCs to sensitive downstream receptors (GHES, 2018). The modelling identified two dominant hydro-stratigraphic units (aquifer system) within the Kendal power station area, which include a shallow weathered and fractured aquifer system and deeper localized fractured to fresh aquifer system (see Section 7.2). Plume formation was generally in a north-west and westerly direction towards lower lying areas. Geophysical surveys that was undertaken at the ADF site suggested the presence of dolerite sills underlying the continuous ADF site at a depth generally between 6 and 19 mbgl. The thickness and the geometry of such sill in the area is expected to control the groundwater flow and associated solute transport, especially possible pollution emanating from ground surface (see Section 5.4.5 and **Figure 5-16**). This suggests that a preferential pathway exists below the Continuous ADF site toward the confluence of the Schoongezicht Spruit and Leeuwfontein Spruit located north-west of the ADF site.

Kendal Power Station's existing ADF was not lined with any barrier system at the time the power station commenced operations. Construction on KPS was completed in 1993. KPS has therefore been disposing ash on an unlined footprint for about 25 years. It can therefore be reasoned that CoCs from the unlined ADF would have been identified in groundwater monitoring results by now. Granted that for this assumption to hold true factors such as the composition of leachable constituents, the source of coal and ashing operations would have to remain stable or unchanged. Nonetheless, no major pollution of groundwater around the existing KPS ADF have been documented even considering the potential impacts from upstream point sources such as active mining and agriculture. Even though the apportionment of contaminant loads originating from potential upstream point sources could not be quantified in the SPR study, groundwater monitoring results does suggest that other contaminants not generally associated with coal-fired power stations are present in the groundwater at KPS. This is therefore a strong indication that upstream point sources are contributing to the observed contaminant loads characterising the groundwater resources at KPS.

Furthermore, given the fact that the new ADF is largely a continuation of the existing ashing operation in a north-westward direction, it can be inferred that the groundwater flow through the underlying aquifers from the existing ADF would behave in the same manner as predicted by the numerical groundwater model simulations undertaken by the groundwater specialist for this SPR study (GHES, 2018). The baseline groundwater quality data complied during the various studies undertaken for the KPS, and routine groundwater and surface water monitoring should therefore be representative of any pollutions emanating from the existing ADF. This, however, does not seem to be the case as **groundwater at boreholes downstream of the ADF was found to generally be of good quality when compared to South African National Standard (SANS), SANS 241: 2011 and South African Water Quality Guidelines (SAWQG), Volume1 Domestic Use** (see Section 5.4.2).

Furthermore, boreholes that were sampled during the previous hydrocensus undertaken in catchment B20E were classified in Class 1 water quality and suitable for human consumption according to SANS_241_2011, except for high concentrations of $NO_3$ (FBB35, and FBB54), Na and $SO_4$ (FBB40), and F (FBB38) in 4 boreholes. These 4 boreholes were all located more than 2.5 km upstream of the ADF site and therefore the potential sources of these high concentrations of solutes in groundwater were not associated with any activity of the Kendal Power Station. **It is therefore reasonable to expect that the impact of the existing ADF on groundwater quality is insignificant.** The CoCs that was identified include Mn, $SO_4$, Fe and F (**Table 7-1**).

## 8.3 Identified Sensitive Receptors

The results obtained from the numerical groundwater modelling identified the potential pollution plumes, directions of plume movement and expected concentrations 5 years, 10 years and 40 years after completion of the Continuous ADF. These results were then used to identify the likely sensitive receptors that could be impacts by the CoCs.

Two boreholes (FBB56 and FBB39) located approximately 1km north-west of the Continuous ADF site (see **Figure 5-10** and **Figure 7-2**) was identified as sensitive receptors that would likely be impacted by plume development as simulated through the numerical groundwater modelling. FBB39 falls within Eskom's property but FBB56 is privately owned. The continuous abstraction of water from those boreholes will locally draw down the groundwater levels and create a local and dynamic cone of depression.

Wetlands were **not** identified as potential sensitive receptors. The wetland study conducted by Wetland Consulting Services (Wetland Consulting Services, 2014) in October 2014, for the continuous ADF do not suggest any clear dependence of the local wetlands on shallow saturated groundwater flow. Surface runoff inflow and interflow inflow are likely to be the main hydrological drivers supporting the overall wetness within a wetland. The most significant likely impacts on local wetlands are: the direct loss of wetland habitat falling within the footprint of the continuous ash dam facility; the risk of water quality deterioration posed mainly by spills, leaks (construction) seepage, and runoff from the ash disposal facility.

## 8.4 Consideration of appropriate liner alternative

The assessment of alternative liner systems largely hinges on the level of protection these liners offer by acting as a physical barrier between the ash body and CoCs and the underlying groundwater resources. The degree of protection a specific liner system offer is related to the component layers making up the whole. Five alternative liner systems (Class C liner, 2 variations to the Class C liner, an intermediate liner and Class D liner) were modelled with simulations run over a 5, 10 and 40-year period after the ADF is decommissioned.

The main difference between the alternative liner systems is the composition of the liner systems (see Section 6.1), cost associated with each composite liner system (see Section 6.3) and associated leakage rate (see Section 6.2) as calculated from literature (Giroud & Touze-Foltz, 2005). The liner alternatives that were simulated were considered against the findings of the SPR study in the sections below.

### 8.4.1 Class C liner and variations alternatives

The Class C liner system has been authorised for installation for the Continuous ADF in terms of Kendal Power Station's Environmental Authorisation (EA) and Water Use Licence (WUL). It therefore represents the default liner system against which the other liner alternatives has been considered. It is furthermore also the most costly liner system of the 5 alternative liner systems to implement at an expected unit price of R424/$m^2$.

When the simulated leakage rates are considered, it is evident from **Figure 7-6** that when the pollution plume is simulated at a 40-year period after completion of the Continuous ADF the pollution plume would have migrated north-westward across the 2-dimentional footprint of the Schoongezicht Spruit tributary. It is unclear whether the groundwater pollution plume would interact with the surface water carried by the tributary, however the simulated $SO_4$ concentrations, which is in the range of 1.5 – 2 mg/l at the 2-D interface with the Schoongezicht Spruit, is well below the SANS, SAWQG and WQPLs stipulated for the Wilge catchment (see **Table 7-7**). The pollution plume does not extend across the 2-dimentional interface of the Leeuwfontein Spruit located to the south-west of the Continuous ADF.

The simulation furthermore calculated that the $SO_4$ concentration does not reach borehole FBB56, which is the privately-owned borehole. The simulated $SO_4$ concentration representative of this borehole is provided in **Table 7-7**.

The Class C variation 1 and 2 liners offer the same protection as the Class C liner system. However, these two variations demonstrate minor differences in liner component make-up which is reflected in the differences in unit cost per liner alternative. **The Class C liner, including the 2 variations to the Class C liner, is therefore effective in providing sufficient protection to the groundwater resources.**

### 8.4.2 Intermediate liner

The intermediate Class C liner alternative represents a reduction in the Class C liner requirements, but does introduce a cuspated sheet layer, which together with the geomembrane layers effectively increases the permeability of the composite liner system. The removal of some of the Class C layers reduces the unit cost for the composite liner by approximately 35% to

R278.22/$m^2$, while furthermore decreasing the anticipated leakage rate to approximately 7 litres/ha/day.

When the simulated leakage rates are considered, it is evident from **Figure 7-9** that the plume formation pattern is very similar to that Class C liner plume. When the pollution plume is simulated at a 40-year period after completion of the Continuous ADF the pollution plume would have migrated north-westward across the 2-dimentional footprint of the Schoongezicht Spruit tributary as in the case with the Class C liner plume. It is unclear whether the groundwater pollution plume would interact with the surface water carried by the tributary, however as in the case of the Class C Liner, the simulated $SO_4$ concentrations, which is in the range of 0.6 mg/l at the 2-D interface with the Schoongezicht Spruit, is well below the SANS, SAWQG and WQPLs stipulated for the Wilge catchment (see **Table 7-7**). The pollution plume does not extend across the 2-dimentional interface of the Leeuwfontein Spruit located to the south-west of the Continuous ADF.

The simulation calculated that the $SO_4$ concentration also does not reach borehole FBB56. The simulated $SO_4$ concentration representative of this borehole is provided in **Table 7-7**.

**The Intermediate Class C liner alternative is therefore also effective in providing sufficient protection to the groundwater resources.**

### 8.4.3 Class D liner

The Class D liner alternative has the lowest liner component requirements and largely represent rip and decompaction of a base preparation layer. This alternative is also the least costly alternative with a unit cost of R10.61/$m^2$ as shown for the base preparation layer in **Table 6-2**.

It is evident from **Figure 7-12** that the simulated $SO_4$ plume for the Class D liner alternative is more pronounced than those of the other liner alternatives. Even within 5 years the pollution plume would reach the 2-dimentional footprint of the Schoongezicht Spruit and Leeuwfontein Spruit (**Figure 7-10** and **Figure 7-11**), albeit at concentrations probably in the range of 0.5 – 5 mg/l.

When the pollution plume is simulated at a 40-year period the pollution plume would have migrated north-westward and westward across the 2-dimentional footprint of the Schoongezicht Spruit and Leeuwfontein Spruit as is evident from **Figure 7-12**. As with the Class C and Intermediate liner, it is unclear whether the groundwater pollution plume would interact with the surface water carried by the tributary.

It is also clear that the simulated pollution plume will reach the privately-owned borehole FBB56 within 40 years. **Table 7-7** however indicated that the **simulated $SO_4$ concentrations in FBB56 after 40 years would still be below the SANS, SAWQG and WQPLs stipulated for the Wilge catchment** (see **Table 7-7**).

The simulated data therefore suggest that the implementation of the Class D liner alternative is expected to result in CoCs migrating through the groundwater pathway to reach the identified receptors, but levels of the CoCs will be within acceptable limits. **It is therefore argued that based on the SPR study and underlying geological conditions the Class D liner can be implemented without exceeding the set water quality limits of the SANS, SAWQG and WQPLs stipulated for the Wilge catchment.**

#### 8.4.4 Proposed mitigation measures and recommendations

Appropriate mitigation can be considered for implementation regardless of what liner alternative is installed. Such mitigation measures can include:

- Implementation of existing water and storm water management measures that would effectively manage controlled runoff of storm water from the rehabilitated ADF and which is already approved through the EA and relevant EMPrs for the power station.
- Intensify monitoring of water levels and quality along surface drainage to better characterise the local interactions between surface and ground waters.
- Should pollution be detected through monitoring, a deep mitigation trench or curtain could be dug between the ADF and the stream to the west of the ADF. This trench will assist in capturing polluted groundwater before it poses risk to surface water and groundwater resources west of the facility.
- Some of the existing monitoring boreholes directly adjacent to the existing and proposed Continuous ADF could be utilised to pump contaminated water for treatment at the station's waste water treatment plant, prior to release back into the groundwater environment. The feasibility of such measures would have to be determined however.
- Addition of lime to the top layers of ash body prior to top-soiling would strengthen the pozzolanic effect in the upper layers of the ash body. This would have a hardening effect causing the top layers of the ADF to become less permeable. A less permeable ADF body would result in lower water infiltration through the ash body and reduce build-up of water at the base of the ADF, and ultimately lower leakage rates. The feasibility and impact of this would also have to be investigated first.
- Field Kinetic tests should be conducted on site to model and predict leachate water quality.
- Develop a geochemical model to predict leachate water quality, using suitable software such PREEQC or equivalent.

# 9 CONCLUSION

Zitholele Consulting and GHES completed the SPR study and numerical groundwater investigation for the Continuous Ash Disposal Facility of the Kendal Power Station, and the following conclusions are reached:

- The continuous ADF with its associated dirty water management infrastructures, constitutes the potential sources of contaminants which are specifically associated with this SPR study. The potential contaminants of concern include Mn, $SO_4$, Fe, and F;
- Local groundwater is one of the potential pathways for the migration of the contaminants to receptors (borehole water users and receiving surface water). Potential contamination from ground surface will mostly impact on the shallow weathered and fractured aquifer system;
- The thickness of the local shallow aquifer was estimated to be between 5 and 25 m, and consists mainly of clay, granites and dolerites of the Karoo Supergroup;
- The thickness and the geometry of local sill and lineaments in the area are expected to control the groundwater flow and possible pollution emanating from ground surface;
- One privately owned borehole (Kendal2/ FBB56) is located within less than 1 km to the north-west of the Continuous ADF site, and risks to be impacted by potential contaminants from the project. The background water quality at the borehole represents unpolluted groundwater.
- The wetland study conducted by Wetland Consulting Services for the continuous ash disposal facility suggest that surface runoff inflow and interflow inflow are likely to be the main hydrological drivers supporting the overall wetness within a wetland, and that minor dependence of the local wetlands on shallow saturated groundwater flow may be expected.
- The increases in the concentrations of sulphate in the local aquifer were simulated for each alternative over 40 years after closure using a finite element numerical model. Intermediate Class C is preferred above the other alternatives if only the migration of contaminants into the aquifer is considered since the induced increase of sulphate's concentration after 40 years of simulation at FBB56, is less than 0.01 mg/l, compare to an increase of 0.02 mg/l and 22 mg/l, respectively, for "Class C" and "Class D".
- However, when characteristics of the underlying lithology, geology and aquifer are considered, the implementation of the Class D liner will not result in contaminant levels in groundwater quality at identified receptors above the legislated standards of SANS 241-2:2015, SAWQG and WQPLs. **From this perspective implementation of the Class D liner is recommended.**

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# APPENDIX A : NUMERICAL GROUNDWATER MODELLING REPORT