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GROUNDWATER ASSESSMENT

FOR

HARTSWATER LANDFILL SITE

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Compiled for:

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Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at address: http://www.gptglobal.com/feedback.htm.

EXECUTIVE SUMMARY

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by SE Solutions as a sub-contractor to do groundwater assessments for unlicensed landfill sites. Hartswater landfill site is one of the landfill sites requiring a groundwater assessment which is detailed in this report. Within the scope of work the groundwater assessment aims to address the following:

- Note the land use, topographic features, natural and man-made drainage features and the position of underground services (if any).
- Determine receptors of concern. All potential receptors of any contamination that might emanate from the site and the different identified pollution sources on the site will be noted, if any.
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey.
- Submit recovered water samples to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses.
- Aquifer classification
- Aquifer Vulnerability
- Based on the above complete the groundwater assessment

Completed Work

The following was done to address the above:

- Based on a site visit all potential groundwater receptors of any contamination that might emanate from the landfill site was noted. A potential receptor may be any person or place. Examples of receptors include proximate residential areas, schools, parks, and play grounds, as well as surface water bodies and private boreholes supplying water for human consumption. Workers on the site might also be receptors, depending on the identified pathway(s)
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey. Groundwater samples were collected from one upstream & one downstream borehole (if present). The visited points were recorded via GPS coordinates of these sample points. The National Groundwater Archive (NGA) was also be consulted to identify any boreholes.
- Two (2) recovered water samples two (2) was submitted to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses.
- Aquifer classification was performed based on available information.
- Aquifer Vulnerability was performed to indicate the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction of a contaminant at some location above the uppermost aquifer

Site visit & Hydrocensus observations

During the hydrocensus and site visit the following observations were made:

- The landfill site was found to be unlined;
- No storm water trenches were observed during the site visit;
- No groundwater monitoring network was found to be present for the landfill;

- Groundwater is used by the residents of Hartswater for domestic purposes as well as irrigation;
- During rainfall events excess water collects in the centre of the landfill and a wetland is starting to form;

Water quality

Based on the available hydrocensus information the water quality can be described as follows:

- None of the analysed constituents were found to be above the DWA guidelines for agricultural use: irrigation.
- If the upstream (HART3) and downstream (HART6) boreholes are compared to each other it can be seen that HART3 is more mineralised and has higher concentrations of most constituents especially Na, Cl and NO_3. These elevated concentrations most likely a result of irrigation and fertilizers being applied to the school fields and not related to contamination from the landfill site.
- No noticeable concentration of targeted petroleum hydrocarbon compounds (diesel range organics, Poly Aromatic Compounds and gasoline range organics) were detected in the water collected from the hydrocensus boreholes HART3 and HART6.

Aquifer Sensitivity

The aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process. The following information was obtained during the investigation:

- The underlying aquifer(s) can be regarded as a Major Aquifer System;
- The aquifer vulnerability can be regarded as Medium;
- The aquifer protection classification is High;

Source-Pathway-Receptor

- Sources – Landfill Site –Unlined and a potential source of leachate. No berms or trenches to capture leachate.
- Pathways – Possible exposure through groundwater and surface water runoff. No berms or trenches to capture or route runoff. No lining to capture leachate to groundwater.
- Receptors – Boreholes surrounding the site or the Phokwane River

Based on the observations made during the site visit and the data collected during the hydrocensus it can be seen that there is a potential linkage between the sources, pathways and receptors for the site. The unlined landfill (source) may leach contaminated water into the underlying aquifer (pathway) during rainfall events. This contaminated groundwater may then move downgradient towards private boreholes surrounding the site or the Phokwane River (receptors).

Water management options

With reference the Department of Water Affairs and Forestry Minimum (Second Edition 1998), Requirements for Waste Disposal by Landfill, Republic of South Africa. The following measures should be implemented during decommissioning:

- The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement. Capping should be implemented on all areas where no further waste deposition will take place, and vegetation should commence as soon as possible. Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the 'rising green wall' approach.

- All final levels and slopes must be in accordance with the landfill design and the End-use Plan. Slopes should not be steeper than 1 in 2.5, as this will promote erosion.
- Immediately on completion of an area, the final cover must be applied. The thickness of the final cover must be consistent and in accordance with the design. The final cover must comprise material capable of supporting the vegetation called for in the End-use Plan. In order to prevent erosion and improve aesthetics, re-vegetation should commence as soon as possible after applying the final cover.
- All covered surfaces on the landfill must be so graded as to promote run-off to prevent ponding. Re-vegetation must commence as soon as is practically possible after the final cover has been placed, in order to rehabilitate on an ongoing basis.
- Assuming that ongoing rehabilitation has taken place at the site, as stipulated in the minimum requirements, the cover of the landfill must be inspected regularly to ensure that uniform subsidence occurs and no cracks and fissures form. Cracks and fissures may act as preferential pathways for surface water into the landfill, generating additional leachate and contaminating groundwater.
- It is essential to ensure that drains are not excessively eroded or filled with silt or vegetation. They must function in order to ensure that excess surface water does not enter the waste body.
- Any subsidence or cracks, due to settlement or any other cause, must be identified and rectified by infilling.
- Any gas or water monitoring systems must be maintained and monitored on an ongoing basis, after the landfill site has closed.
- Post closure monitoring may be carried out under the auspices of a Monitoring Committee. Where this is the case, the results of ongoing monitoring should be submitted to the Monitoring Committee and made available for public scrutiny.
- The public may, through the Monitoring Committee, also monitor the landfill and report any problems that are observed to the Responsible Person.

Recommendations

The following recommendations are put forward:

- Compile an end use plan for the site. Based on the end use plan a closure plan should also be compiled.
- As a minimum at least one upstream and one downstream borehole should be constructed for detection monitoring of the landfill site as detailed in the report. Site the proposed monitoring boreholes (see section on Monitoring Programme) using geophysical methods, drill and install these boreholes according to the Minimum Requirements for Water Monitoring at Waste Management Facilities.
- Monitoring of groundwater upstream and downstream of the landfill site is imperative. Depending on the water, quality results of dedicated groundwater monitoring boreholes, consideration can be given to storm water trenches and leachate collection systems.

- Water levels and quality data should be collected on a bi annual basis during the landfill operations. This data should be used to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
Km^2	Square Kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
Ml/d	Megalitres per day
m	meter
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Karst (Karstic)	The type of geomorphological terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing groundwater.

Definition	**Explanation**
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

GROUNDWATER ASSESSMENT FOR HARTSWATER LANDFILL SITE

1. INTRODUCTION

Sustainable Environmental Solutions (Pty) Ltd (SE Solutions) was appointed as the main contractor by the Department of Environmental Affairs in connection with Waste Management License Applications for unlicensed municipal waste disposal facilities in various provinces. As such, Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by SE Solutions as a sub-contractor to conduct groundwater assessments for these unlicensed landfill sites. Hartswater landfill site is one of the landfill sites requiring a groundwater assessment and is detailed in this report.

1.1 Project Objectives

Within the scope of work the groundwater assessment aims to address the following:

- Note the land use, topographic features, natural and man-made drainage features and the position of underground services (if any).
- Determine receptors of concern. All potential receptors of any contamination that might emanate from the site and the different identified pollution sources on the site will be noted, if any.
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey.
- Submit recovered water samples to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses.
- Aquifer classification
- Aquifer Vulnerability
- Based on the above complete the groundwater assessment

2. PROJECT METHODOLOGY

The groundwater assessment methodology is based on defining and understanding the three basic components of the risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is therefore aimed at describing and defining the relationship between cause and effect. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist.

- Source:
    - Ability of the contaminant sources at the landfill site to produce and release contaminant leachate into the sub-surface.
- Pathway:
    - Ability of the groundwater pathway to transport the contaminant leachate from the sources.
- Receptor:
    - Whether the contaminant leachate has or will reach receptors such as streams, wetlands and privately owned boreholes.

In order to do the above the following work was conducted in phased approach which is discussed in the headings below.

2.1.1 Phase 1 - Site Visit & Fieldwork

Phase 1 consisted out of the following:

- Based on a site visit all potential groundwater receptors of any contamination that might emanate from the landfill site were noted. A potential receptor may be any person or place. Examples of receptors include proximate residential areas, schools, parks, and play grounds, as well as surface water bodies and private boreholes supplying water for human consumption. Workers on the site might also be receptors, depending on the identified pathway(s)
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey. Groundwater samples were collected from one upstream & one downstream borehole (if present). The visited points were recorded via GPS coordinates of these sample points. The National Groundwater Archive (NGA) was also be consulted to identify any boreholes.
- Two (2) recovered water samples two (2) was submitted to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses.

2.1.1.1 Groundwater sampling

Groundwater was sampled in accordance with the GPT's Standard Operating Procedure for groundwater sampling[1] by bailing. Before the bailed sample is collected a electrical conductivity (EC) profile down the hole is considered to detect changes in EC. EC profiles, compared with the construction logs of monitoring wells are then used to determine the optimum sampling depth of each hole. The sample was taken at a depth where the EC reaches a maximum. The bailer is then lowered to the prescribed depth and the sample taken.

2.1.1.2 Groundwater analysis

The following groundwater cation/anion parameters as listed in Table 1 were analysed by an accredited laboratory for interpretation.

Table 1: Groundwater Parameters Analysed

Methodology	Parameter
LPM 2	Total Dissolved Solids
LPM 1	Suspended Solids
LPM 32/76	Nitrate & Nitrite as N
LPM 30/76	Chlorides as Cl
LPM 11/81	Total Alkalinity as CaCO3
LPM 27/76	Fluoride as F
LPM 28/76	Sulphate as SO4

[1] Available on request from morne@gptglobal.com

Methodology	Parameter
LPM 85	Total Hardness as CaCO3
LPM 85	Calcium Hardness as CaCO3
LPM 85	Magnesium Hardness as CaCO3
LPM 15	Calcium as Ca
LPM 15	Magnesium as Mg
LPM 15	Sodium as Na
LPM 15	Potassium as K
LPM 15	Iron as Fe
LPM 15	Manganese as Mn
LPM 51/82	Conductivity at 25° C in mS/m
LPM 51/82	pH-Value at 25 ° C
Calculation	pHs by 21° Celsius

2.1.1.3 Quality Assurance and Quality Controls (QA/QC)

Geo Pollution Technologies (Pty) Ltd, comply with the Quality Management System and the requirements of ISO 9001:2000. The methodology followed by GPT for groundwater sampling is in accordance with the American Environmental Protection Agency (EPA). On request of the Client, GPT can supply Chain of Custody forms, field notes as well as standard operating procedures outlining the methodology followed for groundwater sampling,

Furthermore GPT uses SANAS accredited laboratories that are competent to carry out specific tasks in terms of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006). SANAS's purpose is to instil confidence and peace of mind to companies and individuals through accreditation which is required for economic and social well-being for all.

2.1.2 Phase 2 - Data Interpretation & Reporting

Phase 2 consisted out of the following:

Aquifer Classification: Aquifer classification was performed based on the aquifer classification map of South Africa[2], which entails the following regional aquifer systems:

- Major aquifer region which is a high-yielding system of good water quality;

[2] Andiswa Matoti, Julian Conrad and Susan Jones, CSIR, 22 March 1999.

- Minor aquifer region which is a moderately-yielding aquifer system of variable water quality; and
- Poor aquifer region which is a low to negligible yielding aquifer system of moderate to poor water quality.

Aquifer Vulnerability: The South African Groundwater Decision Tool (GDT) and aquifer vulnerability map of South Africa (CSIR, March 1999) was used to indicate the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction of a contaminant at some location above the uppermost aquifer. The landfill sites will be classified into the following 3 categories:

- Least vulnerable to conservative contaminants in the long term when continuously discharged or leached;
- Moderately vulnerable to some contaminants, but only when continuously discharged or leached; and
- Most vulnerable to many contaminants except those strongly absorbed or readily transformed in many contamination scenarios.

The vulnerability of groundwater is a relative, non-measurable and dimensionless property which is based on the concept that some land areas are more vulnerable to groundwater contamination than others. Maps showing groundwater vulnerability assist with the identification of areas more susceptible to contamination than others.

2.1.2.1 Aquifer Classification

The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification document[3]. The aquifers were classified by using the following definitions:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

[3] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

2.1.2.2 Aquifer Vulnerability

Aquifer vulnerability is the intrinsic characteristics that determine the aquifer's sensitivity to the adverse effects resulting from the imposed pollutant[4]. It is determined to indicate the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction of a contaminant at some location above the uppermost aquifer

The following factors have an effect on groundwater vulnerability:

- Depth to groundwater: Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- Recharge: The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- Aquifer media: The rock matrices and fractures which serve as water bearing units.
- Soil media: The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- Topography: Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- Impact of the vadose zone: The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants [4].

The Groundwater Decision Tool (GDT) was used to quantify the vulnerability of the aquifer underlying the site. Please note that vulnerability of groundwater is a relative, non-measurable and dimensionless property which is based on the concept that some areas are more vulnerable to groundwater contamination than others.

2.2 Mitigation and Management Measures

The groundwater management measures were developed by taking in consideration the National Water Act, Act 36 of 1998 (NWA) and the Department of Water Affairs and Forestry Minimum (Second Edition 1998), Requirements for Waste Disposal By Landfill, Republic of South Africa.

3. GROUNDWATER ASSESSMENT REGIONAL INFORMATION

A description of the site information is described under the headings below.

3.1 Site Location

The Hartswater Landfill site is situated approximately 18 km north of the town of Jan Kempdorp in the Northern Cape Province (see figure Figure 2). It is situated approximately 110 km north of Kimberly, and 85 km south of Vryburg in the Frances Baard District Municipality (DC9), Phokwane Local Municipality (NC094), in the Eastern Cape Province.

3.2 Regional water Management Setting and Sensitivity

The sites are situated in the Harts sub area of the Lower Vaal Water Management Area (WMA), in quaternary catchment C33A (Figure 2). The Harts Sub Area is divided into thirteen quaternary

[4] The South African Groundwater Decision Tool (SAGDT), Manual Ver. 1 (Department of Water Affairs and Forestry)

catchments namely C31A – C31F, C32A – C32D and C33A – C33C. The Lower Vaal Water management area is divided into 3 sub-catchments, that is the Vaal Downstream/Bloemhof, Harts and Molopo Sub Catchment Areas.

3.3 Climatic Conditions

Climatic data was obtained from the DWA weather station Nazareth @ Vaalharts Sto.Weir (rainfall data and evaporation data) for the Hartswater area (Table 2)[5]. The landfill site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 65 years) is approximately 493 mm, with the high rainfall months between November and March.

Table 2: Climatic Data

Month	Average monthly rainfall (mm)	Mean monthly evaporation
January	83.29538462	257.7861538
February	76.26969697	200.9123077
March	73.83636364	180.1138462
April	43.71343284	128.4060606
May	18.82941176	99.125
June	9.217910448	75.41641791
July	5.753030303	85.61538462
August	8.512307692	120.5125
September	14.02153846	170.0523077
October	37.27424242	217.7203125
November	55.8030303	239.8953125
December	66.47575758	263.32
Annual	493.002107	2038.875604

5 Department of Water Affairs (DWA): www.dwa.gov.za

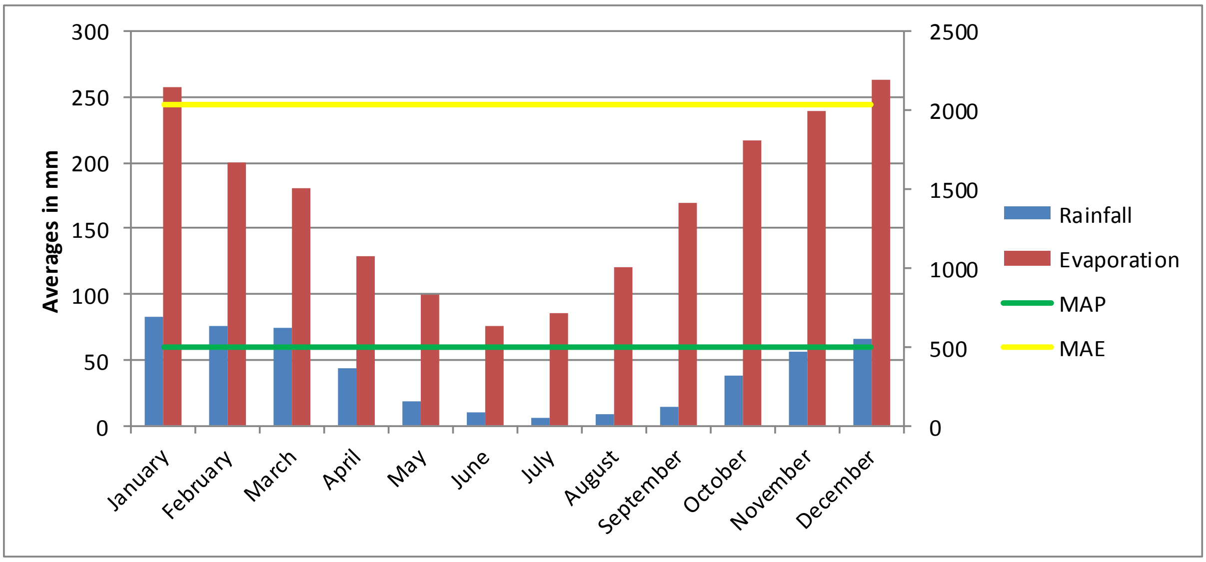

Figure 1:Climatic data representation

3.4 Regional Geology

The investigated area falls within the 2724 Christiana 1:250 000 geology series maps and is situated approximately 110 km north of Kimberly, Nothern Cape. An extract of these maps is shown in Figure 4.

The landfill site falls within the Allanridge, Bothaville, Rietgat and Kameeldorns Formations of the Ventersdorp Supergroup. Also present in the area are Quaternary sediments in the form of aeolian sands.

The Allanridge Formation consists of Tholeiitic and calc alkaline basalt and andesite as well as tuff and andesitic breccia. The Allanridge Formation is underlain by the Bothaville Formation which consists of Quartzite, grit, conglomerate, pyroclastic breccia, tuffacious sediments and can be cherty or calcareous in places.

Underlying these two formations is the Rietgat Formation of the Platberg Group (Ventersdorp Supergroup) which consists of alternation sedimentary and volcanic rocks. This Formation is comprised of light green tholeiitic alkaline basalt and andesite as well as tuff, pyroclastic breccia, carbonate rocks with chert layers, conglomerate, sandstone and tuffacious sediments.

The rocks of the Kameeldorns Formation are also present in the area. This Formation forms part of the Platberg Group of the Ventersdorp Supergroup and consists of conglomerate, greywacke, limestone, chert, cherty shale and granite boulder conglomerate. This formation unconformably overlies the Klipriversberg Group (does not present in the area of the landfill).

3.5 Regional Hydrogeology

According to the 1:500 000 General Hydrogeological Map[6] the rocks of the sedimentary and volcanic rocks of the Ventersdorp Supergroup that underlie the site form fracture and weathered aquifers while the quaternary sediments in the form of aeolian sands that underlie the site form intergranular primary aquifers.

[6] Haupt, C.J., (1995). An explanation of the 1:500 000 General Hydrogeological Map. Rustenburg 2526. DWAF.

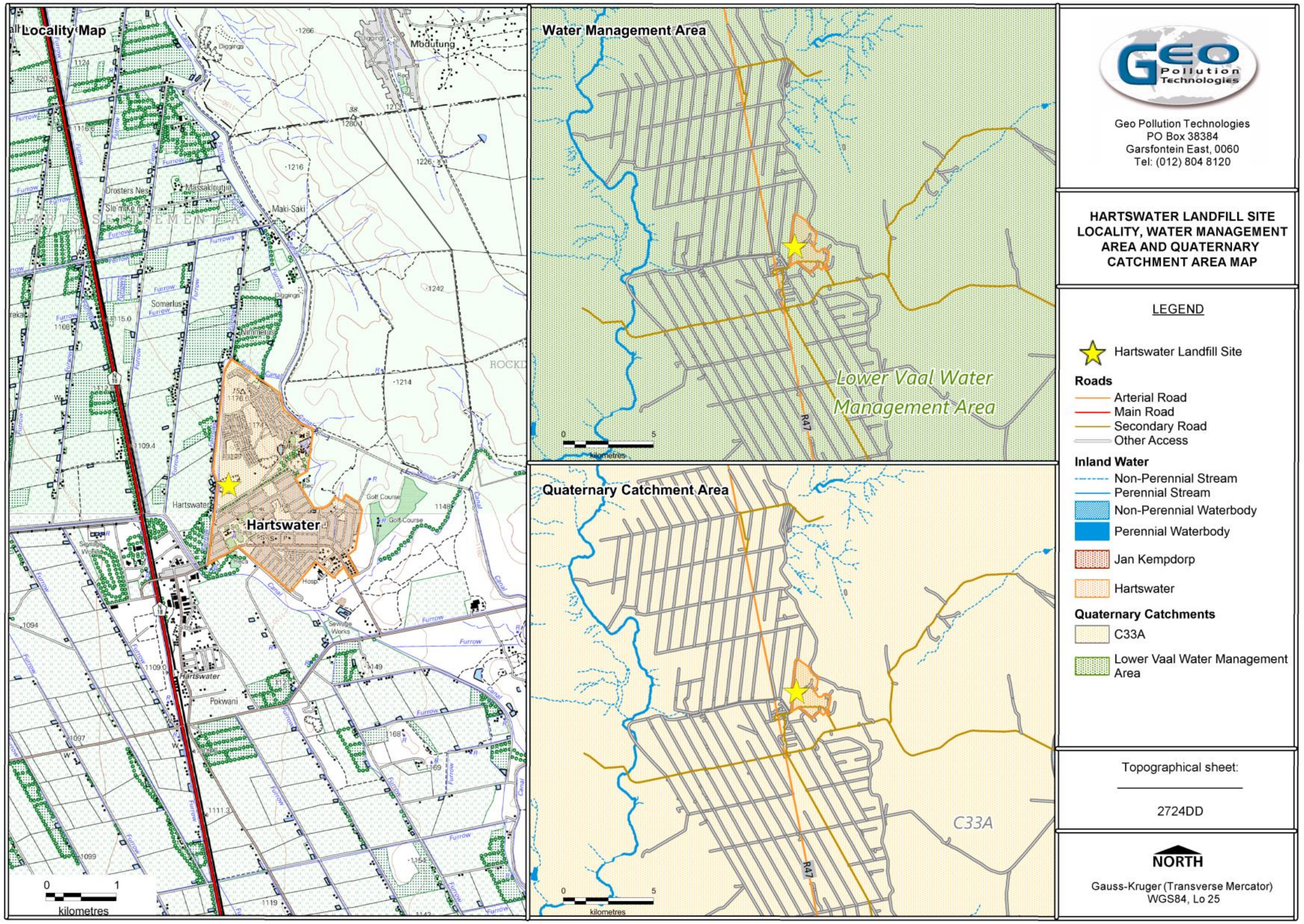

Figure 2: Site Location and Quaternary Catchment Boundaries

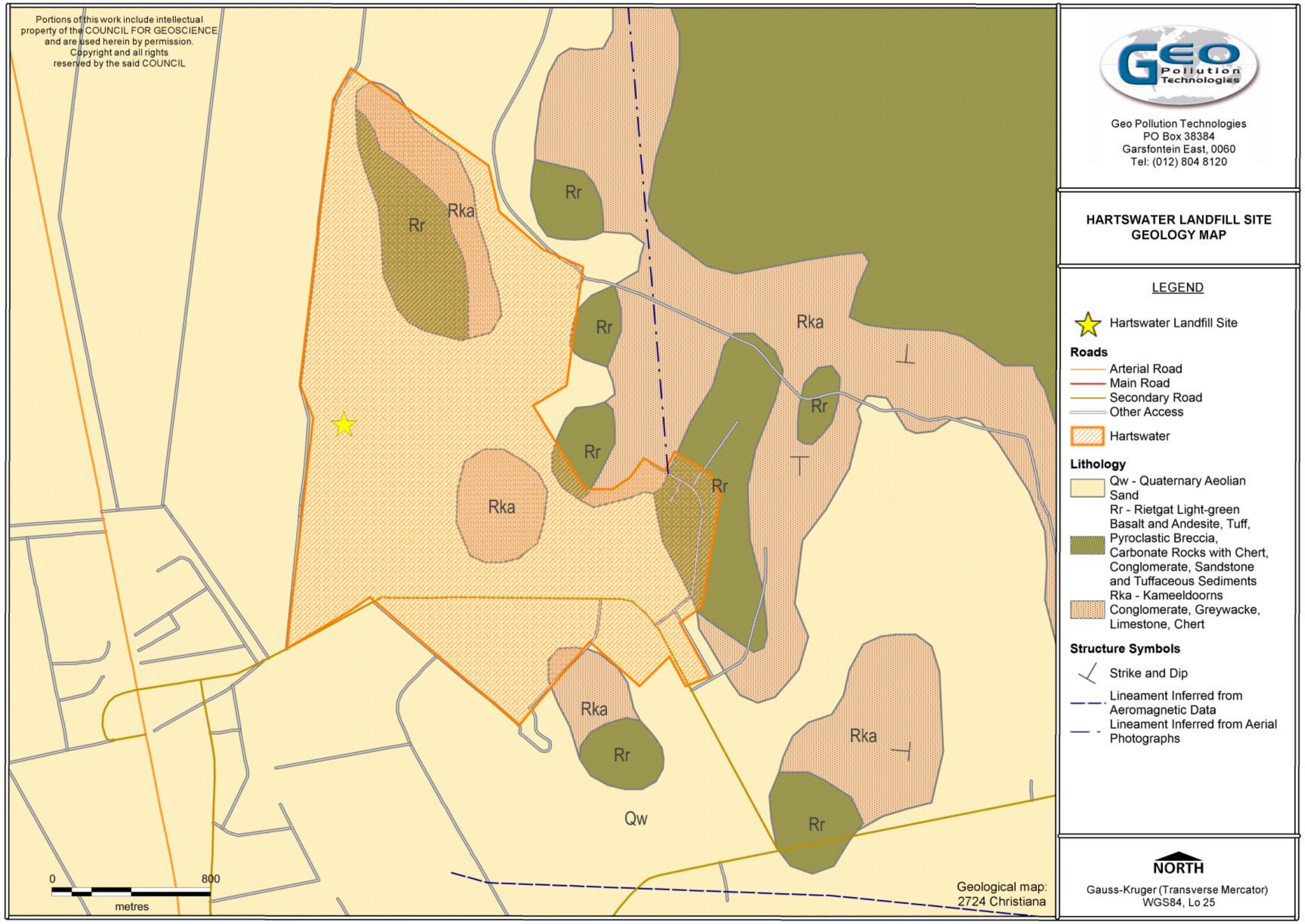

Figure 3: Regional Geology Map (1:250 000 geology series map)

4. GROUNDWATER ASSESSMENT

The hydrogeological setting is described under the headings below.

4.1 Site Topography and Drainage

The topography (shown in Figure 6) can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer. This discussion will focus on the slope and direction of fall of the area under investigation, features that are important from a groundwater point of view.

Regionally the area is gently undulating (sloping towards the Harts River to the west of the site) and in the area of the landfill site the slope is more or less in the order of 1:45 (0.02).

Locally drainage is towards the Phokwane River, a tributary of the Hartsrivier that flows in a westerly direction to the south of the site. Regionally the drainage is towards the Hartsrivier approximately 8km to the west of the site.

4.2 Hydrocensus

A hydrocensus was conducted within a 2 km radius as a site familiarisation exercise and collection of essential groundwater related data from the study area and surrounding environments. The hydrocensus was conducting 6 October 2015. The following features were found to exist within the 2 km radius and are discussed under the headings below. A summary of the groundwater information gathered during the hydrocensus is detailed in Table 4 with the hydrocensus points depicted in Figure 7. The detailed information can be seen in Appendix A: Hydrocensus Information.

4.2.1 Boreholes

Ten (10) boreholes were found during the hydrocensus of which (see Figure 7):

- Five (5) were privately owned boreholes used for irrigation purposes
- Three (3) were privately owned boreholes used for domestic purposes;
- One (1) borehole was not in use
- One (1) owner could not be contacted
- HART1, HART2, HART3 and HART6 were found to be in use and downgradient of the landfill site. Therefore these boreholes could be impacted by migration of contamination in the aquifer from the site

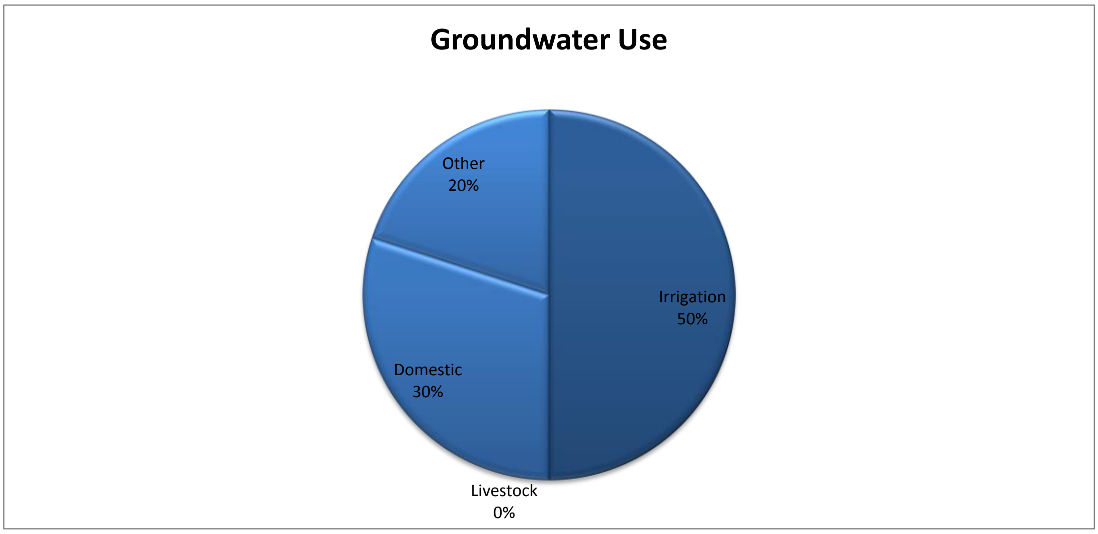

Figure 4: Groundwater distribution % use of the boreholes found during the hydrocensus

4.2.2 Access restrictions and other issues

The following access restrictions were encountered during the hydrocensus:

- The owner of borehole HART5 was not home and could not be contacted.

4.3 Water Levels

During the hydrocensus, five (5) boreholes were available for groundwater level measurement. The groundwater levels varied between a minimum of 2.5 m to the north of the landfill to a maximum of 10.5 m below ground level to the south east of the landfill (Table 4). The relationship, using the boreholes from the hydrocensus, is shown in Figure 5 below.

This general relationship is useful to make a quick calculation of expected groundwater levels at selected elevations, or to calculate the depth of to the groundwater level (unsaturated zone):

Groundwater level = m. Elevation x C

Depth to the groundwater level = Elev (1-m) - c

= Elevation x 0.00419

In general a good relationship should hold between topography and static groundwater level. This relationship can be used to distinguish between boreholes with water levels at rest, and boreholes with anomalous groundwater levels due to disturbances such as pumping or local hydrogeological heterogeneities.

However, due to the heterogeneity of the subsurface, these relationships should not be expected to hold everywhere under all circumstances, and deviations could thus be expected. A poor correlation between groundwater levels and topography can be seen from the correlation graph in Figure 5.

Table 3: Available groundwater level statistics

Groundwater level statistics	
Number of boreholes available	5
Number of boreholes with anomalous water levels	0
Min water level (mbgl)	2.5
Max water level (mbgl)	10.5
Mean water level (mbgl)	6.37

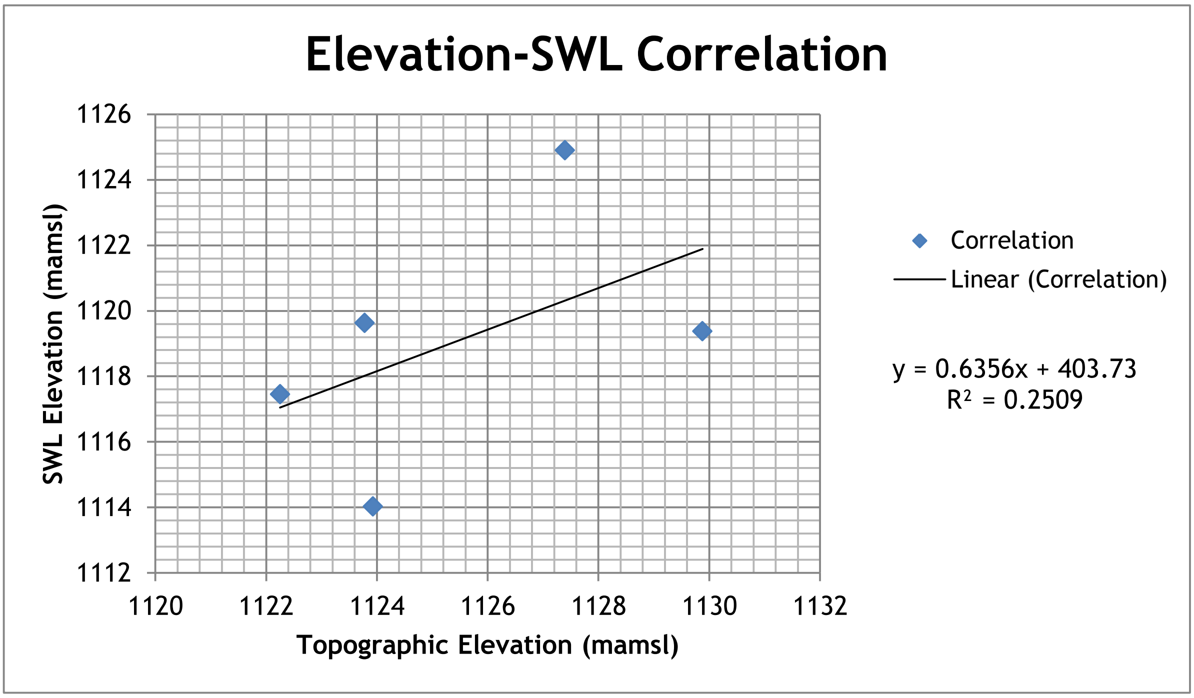

Figure 5: Correlation Graph of topography vs available groundwater levels

4.4 Water quality

Two (2) water samples were collected from 2 boreholes around the site during the investigation. The samples were submitted for major cation and anion analyses to determine water quality in the area. The groundwater and surface water results are compared with the maximum recommended concentrations for domestic use (Table 5) as defined by the DWAF Water Quality Guidelines. For Agricultural Use: Irrigation was considered the most appropriate standard to use as it is shown in this report that this is the main groundwater use in the area. The DWAF guidelines are classified as:

- Target water quality range
- Acceptable/ tolerable water quality range
- Water quality that exceeds the acceptable/tolerable water quality range.

The results from these analyses were plotted as Pie diagrams (circular graphs as in Figure 9).The laboratory certificate of analyses and monitoring data can be seen attached as Appendix II.

The pie diagrams show both the individual ions present in a water sample and the total ion concentrations in meq/L or mg/L. The scale for the radius of the circle represents the total ion concentrations, while the subdivisions represent the individual ions. It is very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection.

4.4.1 General groundwater quality

From the tables and figures the following can be deduced:

- The major cations in the groundwater samples are sodium, calcium and magnesium
- The major anions in the groundwater samples are chloride, sulphate and bicarbonate
- The groundwater quality can be described as unpolluted Calcium Bicarbonate waters

4.4.2 Groundwater quality vs DWA Guidelines

From the tables and figures the following can be deduced:

- None of the analysed constituents are found to be above the DWA guidelines for irrigation
- Cl (HART3), NO_3 (HART3) and Na (HART3 and HART6) are found to be within the tolerable limits for irrigation

The elevation of the constituents described above can be interpreted as follows:

- Cl, NO_3 and Na may be within the tolerable limits as a result of irrigation and agricultural activities

4.4.3 Water quality-Organic results

The collected samples were stored below 4°C prior to be submitted to the laboratory for the analysis of targeted petroleum hydrocarbon compounds with GC-MS screening. The results of water laboratory analysis are summarized in Table 6 below, while the laboratory certificates are attached under Appendix III.

Based on the results (Table 6), it can be seen that no noticeable concentration of targeted petroleum hydrocarbon compounds (diesel range organics, Poly Aromatic Compounds and gasoline range organics) were detected in the water collected from the hydrocensus boreholes HART3 and HART6.

Table 4: Hydrocensus Information

ID	Latitude	Longitude	Elevation	Owner	Property	Casing height	Static water level (mbgl)	Static water level (mamsl)	Sampled (Y/N)	Use			
										Irrigation	Livestock	Domestic	Other
Groundwater													
HART1	-27.7502	24.80221	1119.609	Laerskool Hartswater	Hartswater	0.000	0	1119.609009	No	X			
HART2	-27.7526	24.80396	1121.989	Learskool Hartswater	Hartswater	0.000	0	1121.989014	No	X			
HART3	-27.75264	24.80375	1120.157	Learskool Hartswater	Hartswater	0.000	0	1120.156982	Yes	X			
HART4	-27.7398	24.81002	1152.396	Learskool Kies	Hartswater	0.000	0	1152.395996	No	X			
HART5	-27.74562	24.7976	1124.95	Unknown	Hartswater	0.040	0	1124.949951	No				X
HART6	-27.75021	24.79728	1122.252	M.C van Niekerk	16I4	0.000	4.8	1117.451953	Yes			X	
HART7	-27.7359	24.7982	1123.777	D.L Saunderson	Hartswater	0.000	4.15	1119.626978	No			X	
HART9	-27.7498	24.80102	1123.927	W.J v.d Merwe	18 Anderson str	0.035	9.9	1114.027002	No				X
HART8	-27.7387	24.79787	1127.396	M.J Taljaard	Hartswater	0.000	2.5	1124.895996	No			X	
HART10	-27.74821	24.80405	1129.879	Lucas Matsiwa	Hartswater	0.030	10.5	1119.379028	No	X			

Table 5: Water qualities compared to DWA drinking water quality guidelines

Water Quality Constituents		HART3	HART6	TWQR	Acceptable	Exceeding TWQR
Total Alkalinity	M Alk. [mg/l CaCO3]	358.00	195.00	*Not available*		
Calcium	Ca [mg/l]	152.00	47.90	*Not available*		
Chloride	Cl [mg/l]	248.00	49.10	0 - 100	100 - 350	> 350
Chromium	Cr^{6+} [mg/l]	0.00	0.00	0 - 0.1	0.1-1	> 1
Electrical Conductivity	EC [mS/m]	192.00	70.70	*Not available*		
Fluoride	F [mg/l]	0.66	0.14	0 - 2.0	2.0 - 15	> 15
Iron	Total Fe [mg/l]	0.00	0.00	0 - 5	5.0-20	> 20
Magnesium	Mg [mg/l]	139.00	28.30	*Not available*		
Manganese	Mn [mg/l]	0.00	0.00	0 - 0.02	0.02 - 10	> 10
Mercury	Hg [mg/l]	0.00	0.00	*Not available*		
Nitrate	NO_3 as N [mg/l]	6.33	0.72	0-5.0	5.0-30	> 30
pH	pH units	7.34	7.36	6.0 - 9.0		<6, >9
Potassium	K [mg/l]	2.14	4.41	*Not available*		
Sodium	Na [mg/l]	107.00	73.20	0 - 100	100 - 200	> 200
Sulphate	SO_4 [mg/l]	310.00	109.00	Not available		
Total Dissolved Solids	TDS [mg/l]	1340.00	495.00	*Not available*		
Cation/Anion Balance %		8.74	7.01	Error should not exceed 5%		

Notes:A value of zero indicates that the analysis was below the detection limit

TWQR- Target water quality range

Maximum acceptable concentration for certain soil types

Exceeding TWQR- Acceptable for irrigation only over the short term on a site specific basis basis

Table 6: Organic Water analysis results (mg/l)

Sample no.		HART3	HART6
Sample depth (mbgl)			
Gasoline Range Organics	Benzene	BDL	BDL
	Toluene	BDL	BDL
	Ethylbenzene	BDL	BDL
	Xylenes	BDL	BDL
	MTBE	BDL	BDL
	TAME	BDL	BDL
	Naphthalene	BDL	BDL
	1,2,4 Trimethyl benzene	BDL	BDL
	1,3,5 Trimethyl benzene	BDL	BDL
Poly Aromatic Compounds	Acenapthene	BDL	BDL
	Acenaphthylene	BDL	BDL
	Fluorene	BDL	BDL
	Phenanthrene	BDL	BDL
	Anthracene	BDL	BDL
	Fluoranthene	BDL	BDL
	Pyrene	BDL	BDL
Diesel Range Organics	TPH Aliphatic C_{10}-C_{12}	BDL	BDL
	TPH Aliphatic C_{12}-C_{16}	BDL	BDL
	TPH Aliphatic C_{16}-C_{20}	BDL	BDL
	TPH Aliphatic C_{10}-C_{14}	BDL	BDL
Total VPHs Identified		BDL	BDL
Estimated VPHs Unidentified		BDL	BDL
Estimated TOTAL VPHs		BDL	BDL

* Assuming unidentified compounds fall in this range

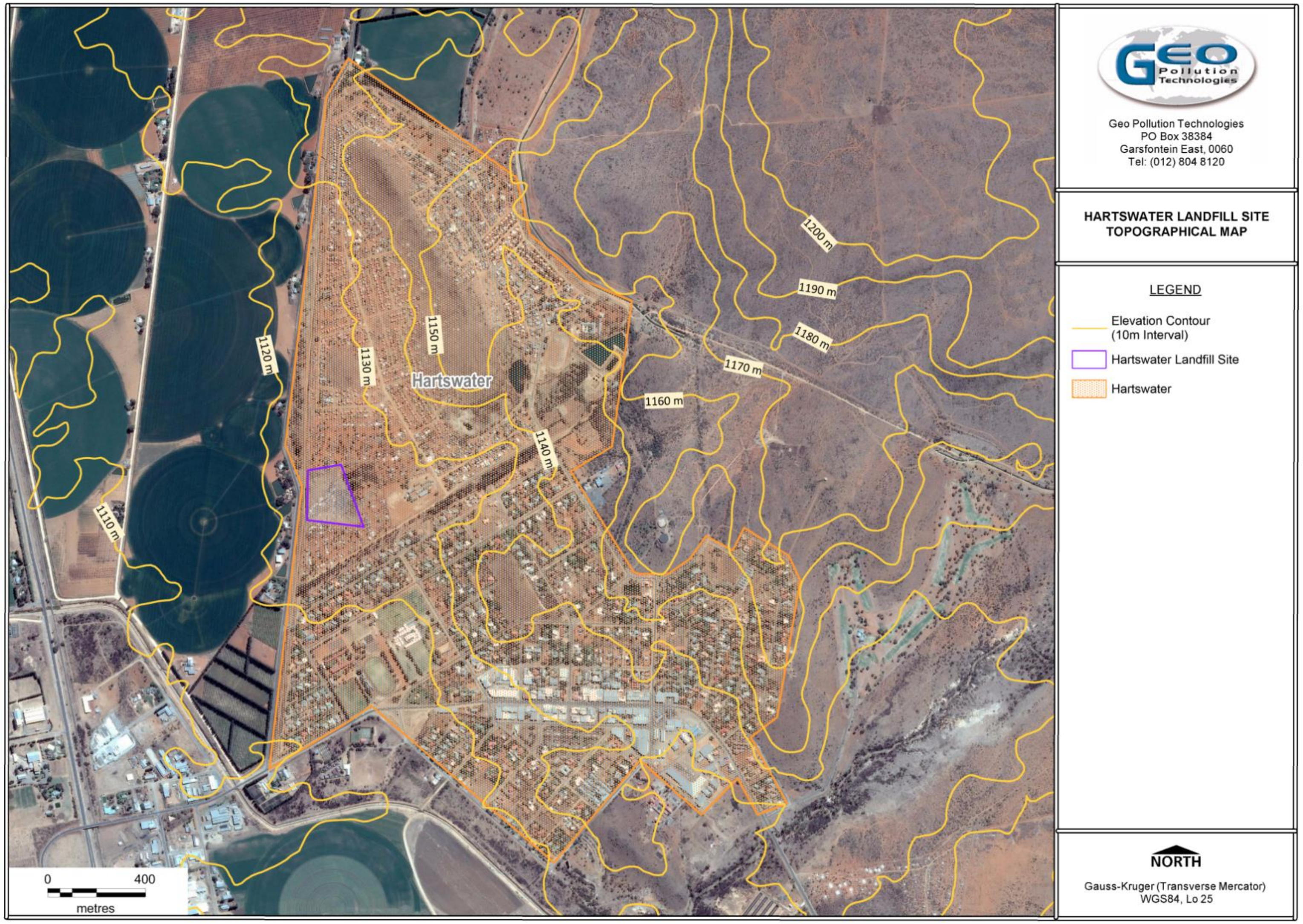

Figure 6: Site Topography

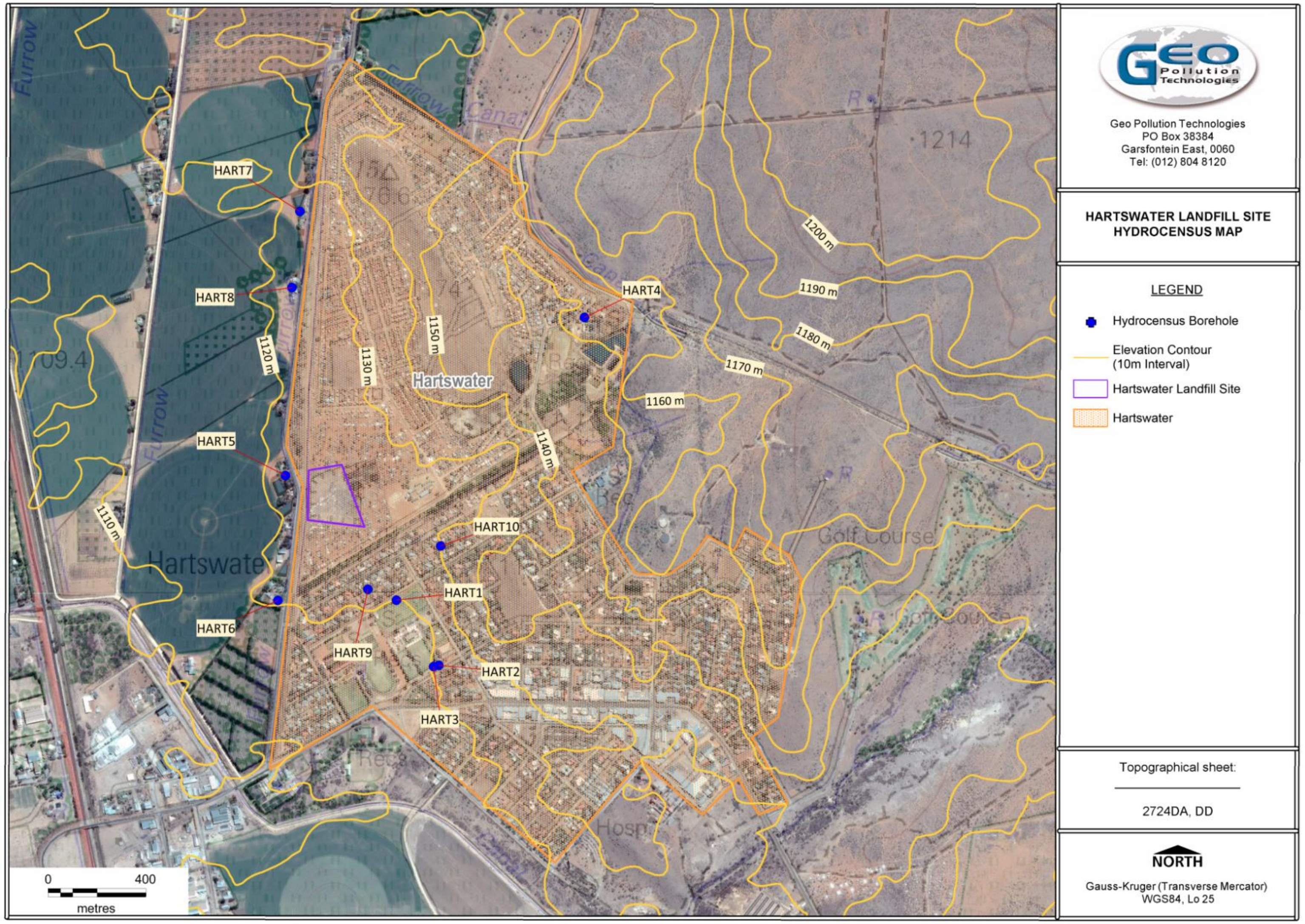

Figure 7: Hydrocensus points

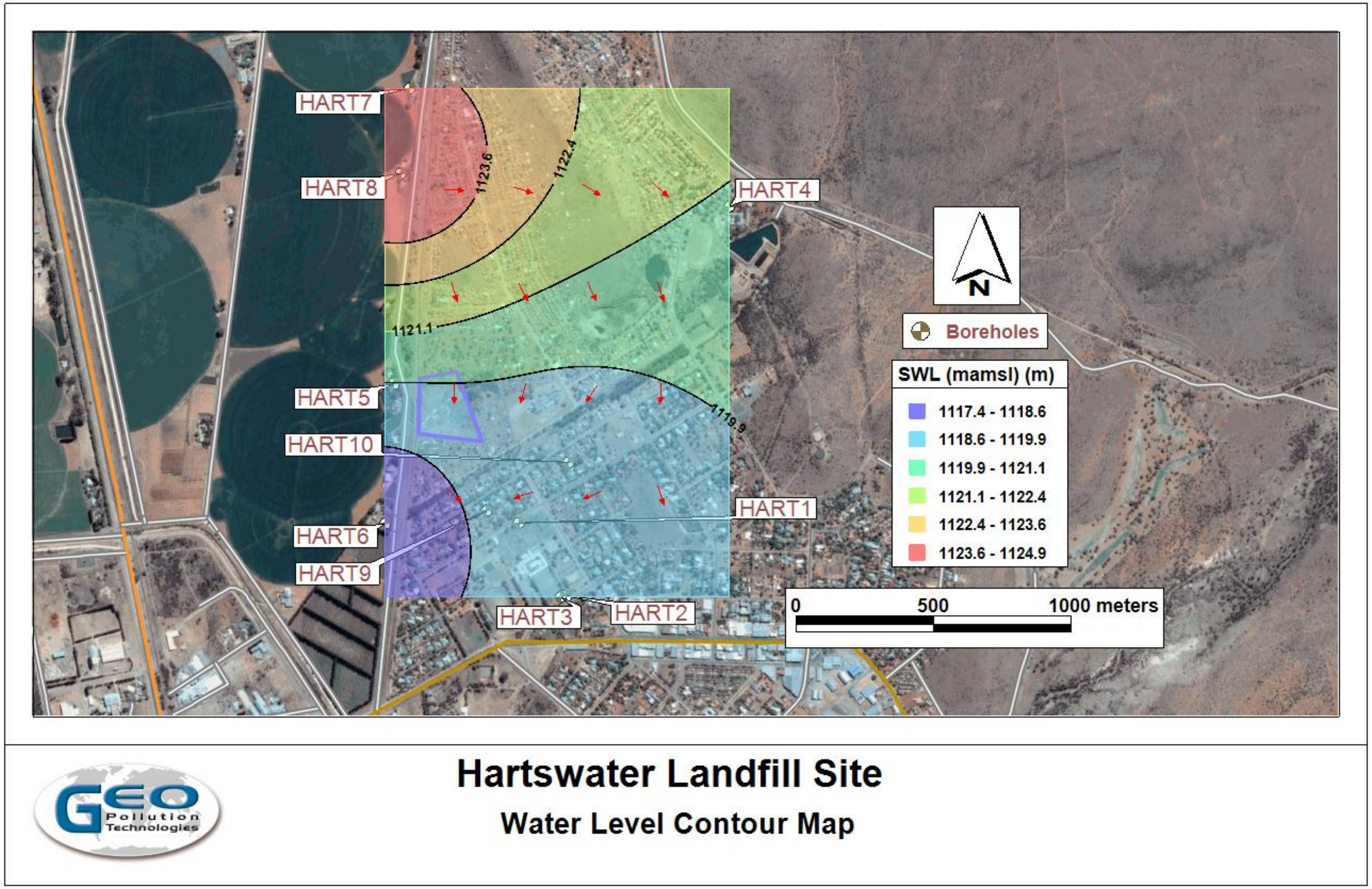

Figure 8: Contoured water levels of the water table aquifer (unconfined aquifer)

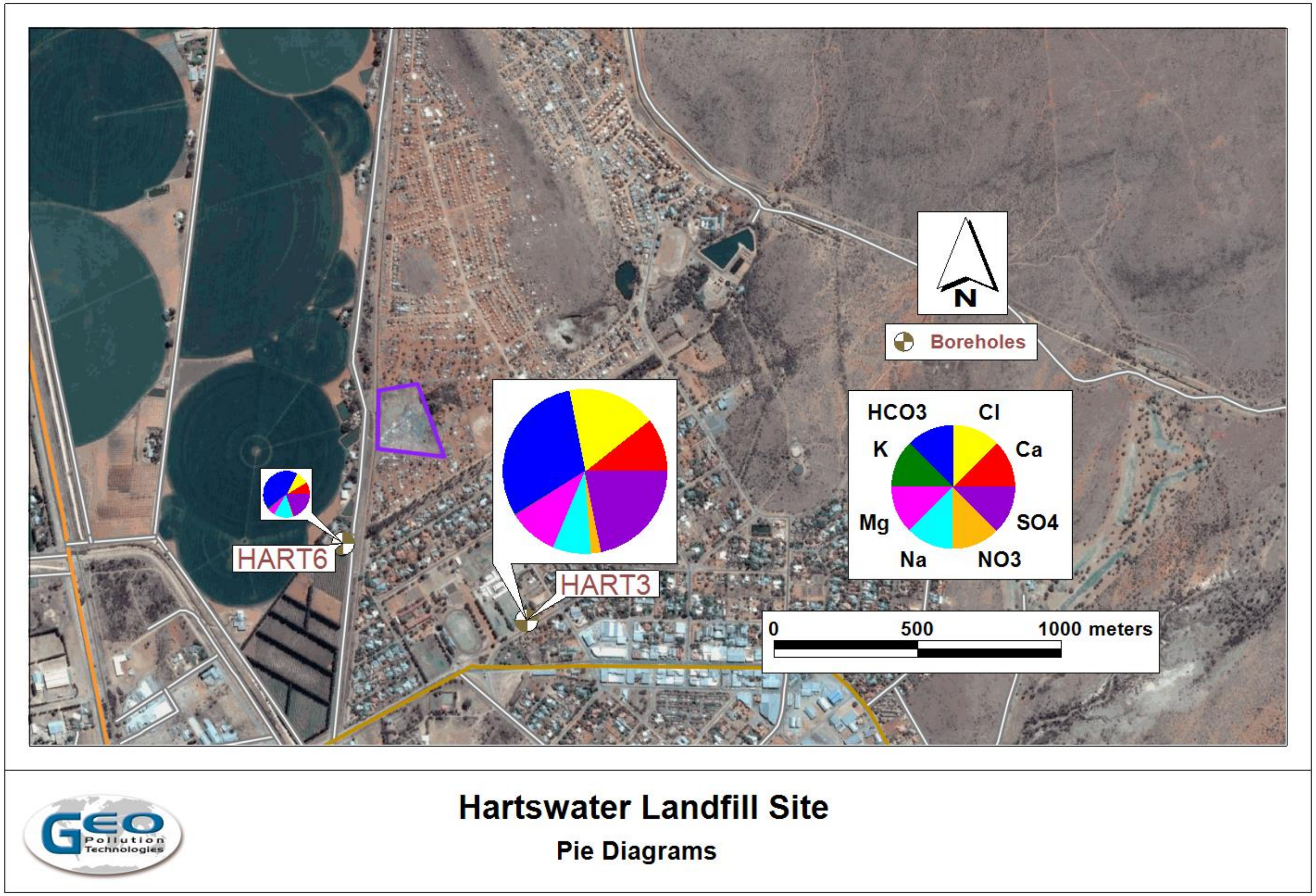

Figure 9: Pie diagrams for the Hydrocensus points

5. AQUIFER SENSITIVITY

The term aquifer refers to a strata or group of interconnected strata comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes and /or springs (Vegter, 1994). In the light of South Africa's limited water resources it is important to discuss the aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process.

5.1 Aquifer Classification

The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification document[7]. The aquifer classification map of South Africa is shown in Figure 10. The aquifer is classified by using the following definitions:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

According to the Aquifer classification map of South Africa the site is underlain by a minor aquifer system. However, based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a "Major Aquifer System", based on the fact that the local population is dependent on groundwater.

In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a points scoring system is shown in Table 7 and Table 8.

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[7] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

Table 7: Ratings – Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	4
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

Table 8: Ratings - Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	4
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 - 6	
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. The GQM index for the study area is presented in Table 9.

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **medium.**

The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 4 x 2 = 8

Table 9: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	
3 - 6	Medium Level	
6 - 10	High Level	8
>10	Strictly Non-Degradation	

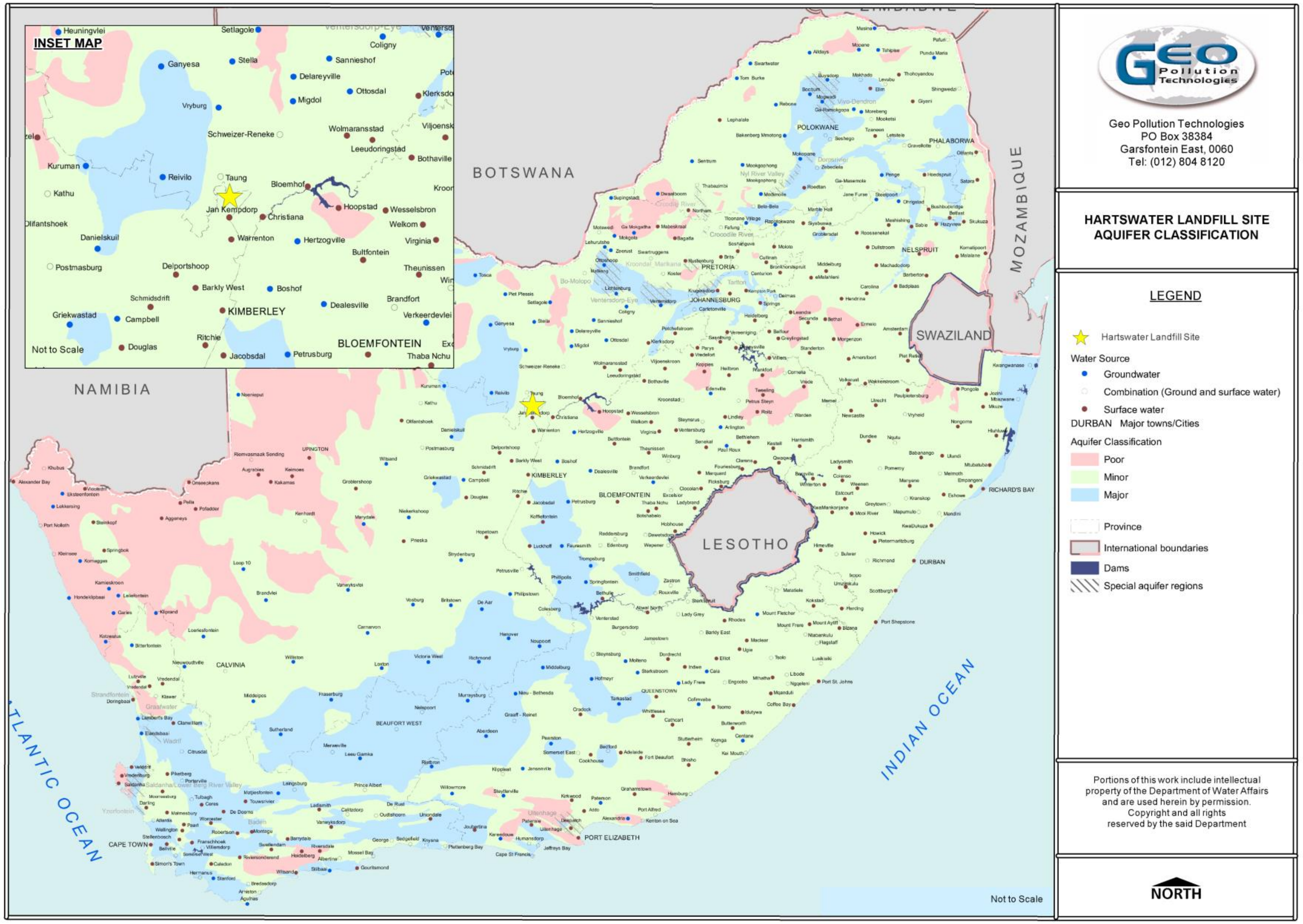

Figure 10: Hartswater Landfill Site Aquifer Classification

5.2 Aquifer Vulnerability

Aquifer vulnerability assessment indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Stated in another way, it is a measure of the degree of insulation that the natural and manmade factors provide to keep contamination away from groundwater.

- Vulnerability is high if natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Vulnerability is low if natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

The following factors have an effect on groundwater vulnerability:

- Depth to groundwater: Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- Recharge: The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- Aquifer media: The rock matrices and fractures which serve as water bearing units.
- Soil media: The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- Topography: Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- Impact of the vadose zone: The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants.

The Groundwater Decision Tool (GDT) along with the aquifer vulnerability map of South Africa (Figure 11) was used to quantify the vulnerability of the aquifer underlying the site using the below assumptions.

- Depth to groundwater below the site was estimated from water levels measured during the hydrocensus inferred to be at mean of ~6.4 mbgl.
- Groundwater recharge of ~20 mm/a (4% recharge),
- Sandy clay loam soil vadose zone
- Gradient of 2% were assumed and used in the estimation.

The aquifer vulnerability for a contaminant released from surface to a specified position in the groundwater system after introduction at some location above the uppermost aquifer was determined using the criteria described below and assuming a worst case scenario:

- Highly vulnerable (> 60), the natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Medium Vulnerable = 30 to 60%, the natural factors provide some protection to shield groundwater from contaminating activities at the land surface, however based on the contaminant toxicity mitigation measures will be required to prevent any surface contamination from reaching the groundwater table.

- Low Vulnerability (< 30 %), natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation
- The GDT calculated a vulnerability value of 52%, which is medium.

5.3 Aquifer Protection Classification

A Groundwater Quality Management Index of 8 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a **high level groundwater protection** is required for the aquifer. Reasonable and sound groundwater protection measures based on the modelling will therefore be recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

DWA's water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that measures must be taken to limit the risk to the following environments.

- The protection of the underlying aquifer.
- The Hartswater and its tributaries.

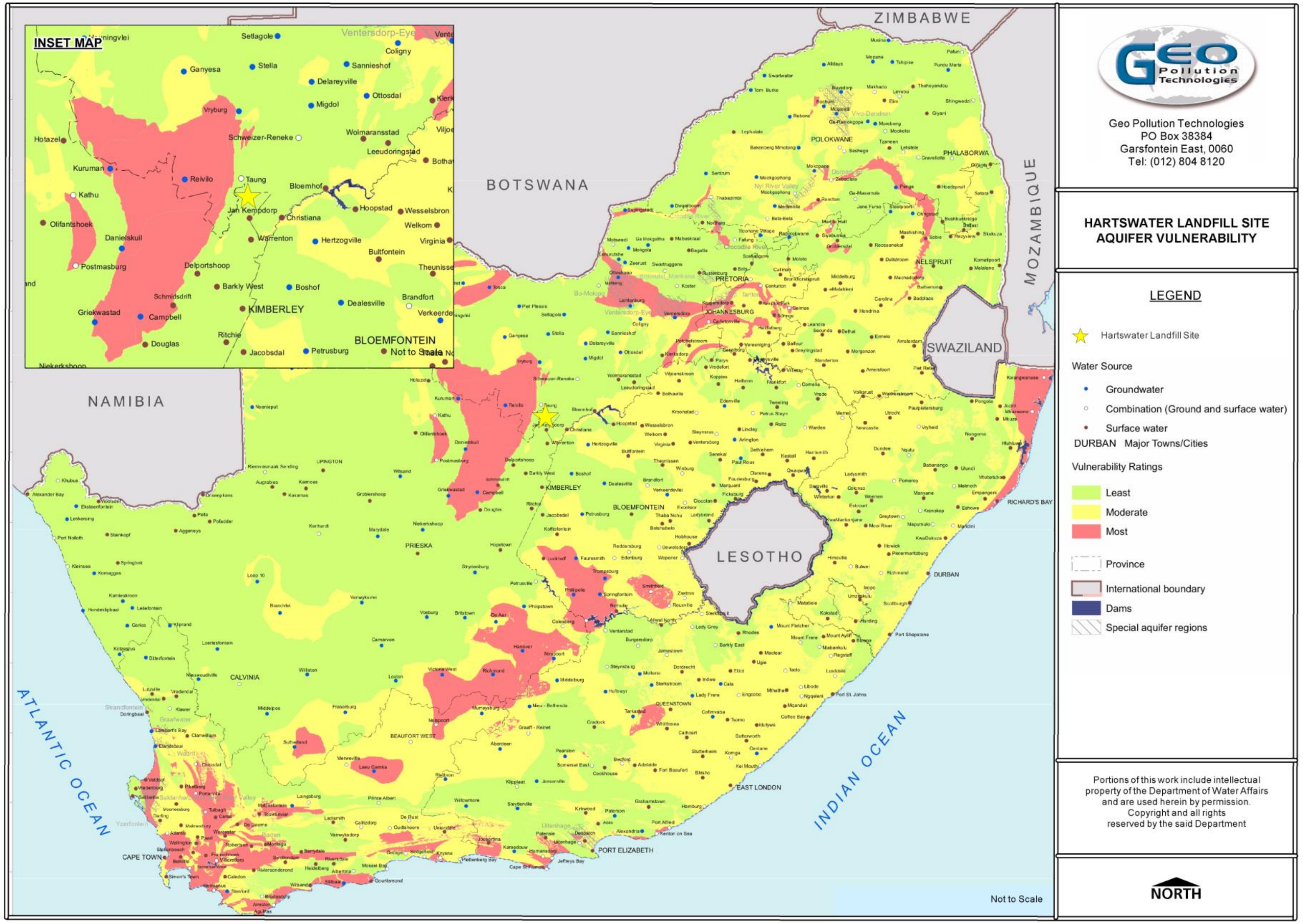

Figure 11: Hartswater Landfill Site Aquifer Vulnerability

6. IMPACT ASSESSMENT AND GROUNDWATER MANAGEMENT PROGRAMME

6.1 Assessment Criteria

The criteria for the description and assessment of groundwater impacts were drawn from the EIA Regulations, published by the Department of Environmental Affairs and Tourism (April 1998) in terms of the NEMA[8].

In order to determine the significance of an impact, the following criteria would be used: extent, duration, intensity and probability. The extent and probability criteria have five parameters, with a scaling of 1 to 5. Intensity also has five parameters, but with a weighted scaling.

The assessment of the intensity of the impact is a relative evaluation within the context of all the activities and other impacts within the framework of the project. The intensity rating is weighted as 2 since this is the critical issue in terms of the overall risk and impact assessment (thus the scaling of 2 to 10, with intervals of 2). The intensity is thus measured as the degree to which the project affects or changes the environment.

The level of detail as depicted in the EIA regulations was fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes each aspect was assigned a value, ranging from one (1) to five (5), depending on its definition. This assessment is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. An explanation of the impact assessment criteria is defined below in

The criteria used for the assessment of the potential impacts of the project are described in Table 10. Cumulative impacts will be included as part of the impact assessment process.

Table 10: Impact Assessment Criteria

Criteria	Description
Nature	Includes a description of what causes the effect, what will be affected and how it will be affected.
Extent	The physical and spatial scale of the impact.
Duration	The lifetime of the impact is measured in relation to the lifetime of the proposed development.
Intensity	Examining whether the impact is destructive or benign, whether it destroys the impacted environment, alters its functioning, or slightly alters the environment itself.
Probability	This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the lifecycle of the activity, and not at any given time.
Status	Description of the impact as positive, negative or neutral.
Significance	A synthesis of the characteristics described above and assessed as low, medium or high. A distinction will be made for the significance rating without the implementation of mitigation measures and with the implementation of mitigation measures.

[8] Guideline document EIA regulations (April 1998): Implementation of sections 21, 22 and 26 of the environment conservation act.

Criteria	Description
Confidence	This is the level of knowledge/information that the environmental impact practitioner or a specialist had in his/her judgement.
Reversibility	Examining whether the impacted environment can be returned to its pre-impacted state once the cause of the impact has been removed.
Replaceability	Examining if an irreplaceable resource is impacted upon
Cumulative	Synthesis of different impacts in concert, considering the knock-on impacts thereof.

6.2 Nature and Status

The nature of the impact is the consideration of what the impact will be and how it will be affected. This description is qualitative and gives an overview of what is specifically being considered. That is, the nature considers 'what is the cause, what is affected, and how is it affected. The status is thus given as being positive, negative or neutral, and is deemed to be either direct or indirect in impact.

6.3 Extent

The physical and spatial scale of the impact is classified in Table 11below.

6.4 Duration

The lifetime of the impact is measured in relation to the lifetime of the proposed project, as per Table 12

6.5 Intensity

This will be a relative evaluation within the context of all the activities and the other impacts within the framework of the project, as per Table 13

6.6 Probability

This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the lifecycle of the activity, and not at any given time. The probability classes are rated in Table 14.

6.7 Level of Significance

The level of significance is expressed as the sum of the area exposed to the risk (extent), the length of time that exposure may occur over in total (duration), the severity of the exposure (intensity) and the likelihood of the event occurring (probability). This leads to a range of significance values running from 'no impact' to 'extreme'.

The significance of the impacts has been determined as the consequence of the impact occurring (reflection of chance of occurring, what will be affected (extent), how long will it be affected, and how intense is the impact) as affected by the probability of it occurring, this translates to the following formula:

Significance value = (Extent + Duration + Intensity) x Probability

Each impact is considered in turn and assigned a rating calculated using the results of this formula, and presented as a final rating classification according to Table 15. A distinction will be made for the significance rating of (a) without the implementation of mitigation measures, and, (b) with the implementation of mitigation measures.

6.8 Identifying the Potential Impacts without Mitigation Measures (WOM)

Significance without mitigation is rated on the following scale as contemplated in Table 15:

Low (L): Impacts with little real effect and which should not have an influence on or require modification of the project design or alternative mitigation. No mitigation is required.

Medium (M): Where it could have an influence on the decision unless it is mitigated. An impact or benefit which is sufficiently important to require management. Of moderate significance - could influence the decisions about the project if left unmanaged.

High (H): Impact is significant, mitigation is critical to reduce impact or risk. Resulting impact could influence the decision depending on the possible mitigation. An impact which could influence the decision about whether or not to proceed with the project.

6.9 Identifying the Potential Impacts with Mitigation Measures (WM)

In order to gain a comprehensive understanding of the overall significance of the impact, after implementation of the mitigation measures, it will be necessary to re-evaluate the impact. Significance with mitigation is rated on the following scale as contemplated in Table 16 below.

Low (L): The impact is mitigated to the point where it is of limited importance.

Medium (M): Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.

High (H): The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.

6.10 Impacts Assessment and Management Options

Based on the impact assessment criteria as detailed in the preceding paragraph an impact rating is given in Table 11 to Table 15. The table also summarises all the groundwater related EMP's and should be implemented post closure of the landfill site.

Table 11: Impact Extent (post closure phase)

Criteria	Description	Scoring	Hartswater Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)			
Footprint	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.	1	3
Site	The impact could affect the whole, or a significant portion of the site.	2	
Local	Impact could affect the adjacent landowners.	3	
Regional	Impact could affect the wider area around the site, that is, from a few kilometres, up to the wider Council region	4	
National	Impact could have an effect that expands throughout a significant portion of South Africa – that is, as a minimum has an impact across provincial borders.	5	
With Mitigation (WM)			
Footprint	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.	1	2
Site	The impact could affect the whole, or a significant portion of the site.	2	
Local	Impact could affect the adjacent landowners.	3	
Regional	Impact could affect the wider area around the site, that is, from a few kilometres, up to the wider Council region	4	
National	Impact could have an effect that expands throughout a significant portion of South Africa – that is, as a minimum has an impact across provincial borders.	5	

Table 12: Impact Duration (post closure phase)

Criteria	Description	Scoring	Hartswater Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)			
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than any of the development phases (i.e. less than 2 years).	1	4
Short to Medium term	The impact will be relevant through to the end of the construction phase (i.e. less than 5 years).	2	
Medium term	Impact will last up to the end of the development phases, where after it will be entirely negated (i.e. related to each phase development thus less than 10 years).	3	
Long term	The impact will continue or last for the entire operational lifetime of the development, but will be mitigated by direct human action or by natural processes thereafter (i.e. during decommissioning) (i.e. more than 10 years, or a maximum of 60 years).	4	
Permanent	This is the only class of impact that will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient (i.e. will remain once the site is closed).	5	
With Mitigation (WM)			
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than any of the development phases (i.e. less than 2 years).	1	4
Short to Medium term	The impact will be relevant through to the end of the construction phase (i.e. less than 5 years).	2	
Medium term	Impact will last up to the end of the development phases, where after it will be entirely negated (i.e. related to each phase development thus less than 10 years).	3	
Long term	The impact will continue or last for the entire operational lifetime of the development, but will be mitigated by direct human action or by natural processes thereafter (i.e. during decommissioning) (i.e. more than 10 years, or a maximum of 60 years).	4	
Permanent	This is the only class of impact that will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient (i.e. will remain once the site is closed).	5	

Table 13: Impact Intensity (post closure phase)

Criteria	Description	Scoring	Hartswater Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)			
Low	The impact alters the affected environment in such a way that the natural processes or functions are not affected.	2	6
Low-Medium	The impact alters the affected environment in such a way that the natural processes or functions are slightly affected.	4	
Medium	The affected environment is altered, but functions and processes continue, albeit in a modified way.	6	
Medium-High	The affected environment is altered, and the functions and processes are modified immensely.	8	
High	Function or process of the affected environment is disturbed to the extent where the function or process temporarily or permanently ceases.	10	
With Mitigation (WM)			
Low	The impact alters the affected environment in such a way that the natural processes or functions are not affected.	2	4
Low-Medium	The impact alters the affected environment in such a way that the natural processes or functions are slightly affected.	4	
Medium	The affected environment is altered, but functions and processes continue, albeit in a modified way.	6	
Medium-High	The affected environment is altered, and the functions and processes are modified immensely.	8	
High	Function or process of the affected environment is disturbed to the extent where the function or process temporarily or permanently ceases.	10	

Table 14: Impact Probability (post closure phase)

Criteria	Description	Scoring	Hartswater Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)			
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience (less than 24% chance of occurring).	1	4
Possible	The possibility of the impact occurring is very low, either due to the circumstances, design or experience (25 – 49%).	2	
Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made (50 – 69%).	3	
Highly likely	It is most likely that the impacts will occur at some stage of the Development. Plans must be drawn up before carrying out the activity (70 – 89%).	4	
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied upon (90 – 100%).	5	
With Mitigation (WM)			
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience (less than 24% chance of occurring).	1	3
Possible	The possibility of the impact occurring is very low, either due to the circumstances, design or experience (25 – 49%).	2	
Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made (50 – 69%).	3	
Highly likely	It is most likely that the impacts will occur at some stage of the Development. Plans must be drawn up before carrying out the activity (70 – 89%).	4	
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied upon (90 – 100%).	5	

Table 15: Impact Significance (post closure phase)

Criteria	Description	Scoring	Hartswater Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)			
No Impact	There is no impact.	0-9	52
Low	The impacts are less important, but some mitigation is required to reduce the negative impacts.	10 - 24	
Medium	The impacts are important and require attention; mitigation is required to reduce the negative impacts.	30 - 49	
Medium to High	The impacts are of medium to high importance; mitigation is necessary to reduce negative impacts.	50 - 74	
High	The impacts are of high importance and mitigation is essential to reduce the negative impacts	75 - 89	
Extreme	The impacts present a fatal flaw, and alternatives must be considered.	90 - 100	
With Mitigation (WM)			
No Impact	There is no impact.	0-9	30
Low	The impacts are less important, but some mitigation is required to reduce the negative impacts.	10 - 24	
Medium	The impacts are important and require attention; mitigation is required to reduce the negative impacts.	30 -49	
Medium to High	The impacts are of medium to high importance; mitigation is necessary to reduce negative impacts.	50 - 74	
High	The impacts are of high importance and mitigation is essential to reduce the negative impacts	75 - 89	
Extreme	The impacts present a fatal flaw, and alternatives must be considered.	90 - 100	

Table 16: Water Management Options (post closure phase)

Hartswater Landfill Site (Degradation of Groundwater Quality)			
Significance Rating (WOM)	**Impact**	**Management Options**	**Significance Rating (WM)**
52	Leaching/Seeping of contaminants into sub-surface	Determine/reassess End-use Requirements and obtain and confirm end use design	30
		Design for upgrade/ rehabilitation, final shaping and landscaping, final cover or capping, permanent storm water diversion and anti-erosion measures.	
		Compile a closure report. The Closure Report compares the current status of the landfill with the Closure Design and End-use requirements. Based on this comparison, recommendations are made regarding measures to upgrade the existing condition of the landfill to that desired.	
		Leachate management as well as gas management should be continued post closure of the landfill site.	
		Ongoing inspections of the cover intergrety should take place at the landfill. If any issues with cover intergrety are found during inspection. Maintenance of the cover should also take place post closure in order to prevent breaches and settlement.	
		Compact of the landfill site prior to installation of the cover will ensure even settlement and discourage the formation of cracks or depressions in the cover	
		Ponding should be controlled by ensuring that all drainage systems are working correctly and are maintained post closure. Inspections should be carried out in order to assess the drainage systems	
		Vegetation planted for the purposes of rehabilitation, erosion control, beautification or the end-use must be maintained to ensure that it achieves its purpose. Monitoring should be carried out inorder to assess the state of the above vegetation.	
		The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement.	
		Illegal dumping should be prevented on the site as this could lead to increased contamination. Security measures should be put in place in order to prevent illegal dumping	
		Groundwater quality and water level monitoring should be continued during the post closure phase using the monitoring network that was setup during the operational phase.	
		In the case of some B– sites, most B+ sites and all hazardous waste disposal sites, post-closure water quality monitoring must continue for 30 years after site closure, unless otherwise agreed with the Department.	

7. SOURCE PATHWAY RECEPTOR MODEL

7.1 Source

The relevant potential contaminants related to the operations at the Hartswater Landfill site include nitrogen in the form of nitrate, nitrite or ammonium, phosphate, sulphate, potassium, chloride, magnesium and calcium as well as organic contaminants (hydrocarbons). The primary source of the above listed contaminants is:

- The unlined landfill site

A photograph showing the unlined landfill site can be seen in Figure 12 and a photograph showing the "wetland" formed at the centre of the landfill after rainfall events due to poor drainage of the landfill can be seen in Figure 13. The hydraulic characteristics of the source and the geochemical properties of the subsurface will determine the behaviour of the contaminants emanating from the source. In addition, the location and extent of the pollution source will have an effect on the extent of the contaminant plume

7.2 Pathway

The pathway along which contaminants may be mobilized and migrate toward groundwater receptors include:

- The aquifer underlying and downstream of the site;

For an accurate prediction of the behaviour of a contaminant plume along its pathways, it is critical that the monitoring and field measurements are representative of the physical environment. It is also important to keep seasonal and annual trends in mind, as it affects the water quality.

7.3 Receptors

Any user of a groundwater or surface water resource that is affected by pollution from any of the above mentioned sources is defined as a receptor. Furthermore, a borehole or river may also be a receptor. The following possible receptors may be found:

- Phokwane River, a tributary of the Hartsrivier that flows in a westerly direction to the south of the site
- Boreholes HART1, HART2, HART3 and HART6 which are located down gradient of the site and are used for irrigation purposes.

Based on the observations made during the site visit and the data collected during the hydrocensus it can be seen that there is a potential linkage between the sources, pathways and receptors for the site. The unlined landfill (source) may leach contaminated water into the underlying aquifer (pathway) during rainfall events. This contaminated groundwater may then move downgradient towards private boreholes surrounding the site or the Phokwane River (receptors).

Figure 12: Harstwater unlined landfill site

Figure 13: Hartswater unlined landfill site- "wetland"

8. WATER MANAGEMENT OPTIONS

With reference to the Department of Water Affairs and Forestry Minimum (Second Edition 1998), Requirements for Waste Disposal by Landfill, Republic of South Africa, various water management options available to the Hartswater landfill site during operations and post-closure are discussed. The objectives of the Minimum Requirements for Waste Disposal by Landfill are:

- To improve the standard of waste disposal in South Africa.
- To provide guidelines for environmentally acceptable waste disposal for a spectrum of landfill sizes and types. Limit the ingress of surface water and groundwater into the pits, and
- To provide a framework of minimum waste disposal standards within which to work and upon which to build.

The general objective of environmentally acceptable landfilling, therefore, is:

- To avoid both short or long term impacts or any degradation of the environment in which the landfill is located.
- Prevent pollution of the surface and ground water.

Pollution prevention is the foundation of the hierarchy of decision taking used by DWS with the purpose of protecting the water resource from waste impacts. This hierarchy is based on a precautionary approach using the following order of priority for waste water:

- Pollution Prevention;
- Minimisation of Impacts though water reuse, reclamation and treatment;
- Discharge or disposal of waste water through a site specific risk based approach whereby the polluter pays.

The core of integrated water management in the first instance is to seek to optimally implement pollution prevention measures. If these measures do not address all the water management issues, then the operation should secondly develop and implement appropriate water reuse and reclamation strategies. These strategies may include a greater or lesser degree of water treatment in order to render the water suitable for reuse. If there is still a residual water management problem, then the operation could evaluate and negotiate options with DWA for the discharge of such water to the water resource. The above-mentioned fundamental principle of pollution prevention can be elaborated upon by way of defining a number of secondary principles:

- Prevention is better than cure and good planning reduces the environmental and financial liabilities.
- Sustainability is a key principle, as it would ensure a positive legacy for future generations, not a liability.
- Use and impact on as little water as is practically possible.
- The closer a pollution prevention system is to the source, the more effective it is likely to be.
- Pollution prevention is a planning and design process that is considered and applied for each life-cycle phase of the operation through to post-closure.
- Pollution prevention measures must be considered and applied throughout the entire operation process chain to waste disposal.
- Passive pollution prevention systems are preferred to active systems due to their generally more robust nature, often with a lower risk of failure.

- If measures are properly applied during the full life cycle, post-closure risks and liabilities are reduced.
- Pollution prevention is not the end point and minimisation of residual impacts through recycling, treatment and/or safe and secure disposal will most likely be required.
- Apply closure pollution prevention measures during the operational phase and monitor the performance in order to validate pollution prevention performance.
- Continuous improvement, pollution prevention systems should be monitored, assessed and improved on an ongoing basis.

Pollution source management should be based on passive management principles, i.e. the need for ongoing intervention and active management is minimal, but not zero. Examples of passive measures include storm water diversion berms and drains, lining of pollution control dams, finger drains under ash disposal facilities and toe paddocks around such facilities, etc. Passive pollution prevention measures are essentially based on good planning and design to prevent a pollution problem from arising, rather than relying on active intervention to intercept and treat contaminated water. However, situations are often encountered where active impact minimisation management measures are required to supplement the passive pollution prevention measures. The management/mitigation options with reference to groundwater are discussed in the headings below. Rehabilitation and Closure

8.1 Rehabilitation

- The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement. Capping should be implemented on all areas where no further waste deposition will take place, and vegetation should commence as soon as possible. Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the ‘rising green wall’ approach.
- All final levels and slopes must be in accordance with the landfill design and the End-use Plan. Slopes should not be steeper than 1 in 2.5, as this will promote erosion.
- Immediately on completion of an area, the final cover must be applied. The thickness of the final cover must be consistent and in accordance with the design. The final cover must comprise material capable of supporting the vegetation called for in the End-use Plan. In order to prevent erosion and improve aesthetics, re-vegetation should commence as soon as possible after applying the final cover.
- All covered surfaces on the landfill must be so graded as to promote run-off to prevent ponding. Re-vegetation must commence as soon as is practically possible after the final cover has been placed, in order to rehabilitate on an ongoing basis.

8.2 Closure

Closure is the final step in the operation of a landfill. In order to close a landfill properly, however closure must be preceded by rehabilitation, to ensure that the site is environmentally acceptable. The site must also be rendered suitable for its proposed end-use, as determined during permitting and set out in the End-use Plan. The objectives of landfill closure are:

- To ensure public acceptability of the implementation of the proposed End-use Plan.
- To rehabilitate the landfill so as to ensure that the site is environmentally and publicly acceptable and suited to the implementation of the proposed end-use.

After determination of the end-use requirements, closure requirements, closure design, closure report and written acceptance of the closure plan for the landfill property, the following actions must be performed with regards to post-closure maintenance:

- Assuming that ongoing rehabilitation has taken place at the site, as stipulated in the minimum requirements, the cover of the landfill must be inspected regularly to ensure that uniform subsidence occurs and no cracks and fissures form. Cracks and fissures may act as preferential pathways for surface water into the landfill, generating additional leachate and contaminating groundwater.
- It is essential to ensure that drains are not excessively eroded or filled with silt or vegetation. They must function in order to ensure that excess surface water does not enter the waste body.
- Any subsidence or cracks, due to settlement or any other cause, must be identified and rectified by infilling.
- Any gas or water monitoring systems must be maintained and monitored on an ongoing basis, after the landfill site has closed.
- Post closure monitoring may be carried out under the auspices of a Monitoring Committee. Where this is the case, the results of ongoing monitoring should be submitted to the Monitoring Committee and made available for public scrutiny.
- The public may, through the Monitoring Committee, also monitor the landfill and report any problems that are observed to the Responsible Person.

9. MONITORING PROGRAMME

9.1 Groundwater Monitoring Network

A groundwater monitoring system has to adhere to the criteria mentioned below. As a result the system should be developed accordingly. The objectives of water quality monitoring are:

- To enable the Permit Holder to comply with the relevant Permit conditions and legislation.
- To indicate any escape of leachate into the water environment.
- To serve as an early warning system, so that any pollution problems that arise can be identified and rectified.
- To quantify any effect that the landfill has on the water regime.

9.1.1 Source, plume, impact and background monitoring

A groundwater monitoring network should contain monitoring points (boreholes and surface water) which can assess the groundwater status at certain areas. The boreholes can be grouped according to the following purposes:

- **Source monitoring:** Monitoring boreholes are placed close to or in the source of contamination to evaluate the impact thereof on the groundwater chemistry.
- **Plume monitoring:** Monitoring boreholes are placed in the primary groundwater plume's migration path to evaluate the migration rates and chemical changes along the pathway.
- **Impact monitoring:** Monitoring of possible impacts of contaminated groundwater on sensitive ecosystems or other receptors. These monitoring points are also installed as early warning systems for contamination break-through at areas of concern.

- **Background monitoring:** Background groundwater quality is essential to evaluate the impact of a specific action/pollution source on the groundwater chemistry.

9.2 System Response Monitoring Network

Groundwater levels: Static water levels are used to determine the flow direction and hydraulic gradient within an aquifer. Where possible all of the above mentioned borehole's water levels need to be recorded during each monitoring event.

9.3 Monitoring Frequency

In the operational phase and closure phase, bi-annual abbreviated analyses monitoring of groundwater quality and groundwater levels is recommended, as listed below. Quality monitoring should take place before after and during the wet season, i.e. during September and March. It is important to note that a groundwater-monitoring network should also be dynamic. This means that the network should be extended over time to accommodate the migration of potential contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

Since a landfill can continue to pollute the ground and surface water regime long after the site has been closed, post-closure water quality monitoring must be ongoing or the site has been proven to have limited risk in the long term.

9.4 Monitoring Parameters

The identification of the monitoring parameters is crucial and depends on the chemistry of possible pollution sources. They comprise a set of physical and/or chemical parameters (e.g. groundwater levels and predetermined organic and inorganic chemical constituents). Once a pollution indicator has been identified it can be used as a substitute to full analysis and therefore save costs. The use of pollution indicators should be validated on a regular basis in the different sample position. The parameters should be revised after each sampling event; some metals may be added to the analyses during the operational phase, especially if the pH is lowered.

9.4.1 Analysis (pollution indicators)

Physical Parameters:

- Groundwater levels

Suggested Parameters for Background and Investigative Monitoring:

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Ammonia (NH3 as N), Electrical Conductivity (EC), Alkalinity (Total Alkalinity), Free and Saline Ammonia as N, (NH4-N), Lead (Pb), Magnesium (Mg), Boron (B), Mercury (Hg) Cadmium (Cd), Nitrate (as N) (NO3-N), Calcium (Ca) pH, Chemical Oxygen Demand (COD), Phenolic Compounds (Phen), Chloride (Cl), Potassium (K), Chromium (Hexavalent) (Cr6+), Sodium (Na), Chromium (Total) (Cr), Sulphate (SO4), Cyanide (CN), Total Dissolved Solids (TDS), Other parameters (EC, COD, TDS)

Suggested Parameters for Detection Monitoring:

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Bi-annually for:Alkalinity (Total Alkalinity), Ammonia (NH3 - N), Chemical Oxygen Demand (COD), Chlorides (Cl), Electrical Conductivity (EC), Nitrate (NO3 - N), pH, Potassium (K), Total Dissolved Solids (TDS
  - Annually for: Calcium (Ca), Fluoride (F), Magnesium (Mg), Sodium (Na), Sulphate (SO4)

9.4.2 Landfill Site Monitoring

DWAF (1998) states that "A monitoring hole must be such that the section of the groundwater most likely to be polluted first, is suitably penetrated to ensure the most realistic monitoring result."[9]

Currently a monitoring network does not exist for the site. The recommended boreholes are listed in Table 17 and Table 18 and the areas to site these monitoring boreholes is shown in Figure 14. These boreholes can be utilised for water level monitoring during the operation of the landfill, as well as groundwater quality monitoring after decommissioning of the landfill.

However, a monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources. An audit on the monitoring network should be conducted annually.

9.4.3 Monitoring Borehole Placement and Construction

The objective of monitoring boreholes is to provide both geological and geohydrological information. This information is used to assess the risk and site complexity. Where possible, boreholes should be sited by geophysical means so that they can be used for water quality monitoring.

The number of boreholes as per the Minimum Requirements for Water Monitoring at Waste Management Facilities is shown in Table 17 below. The geological data required includes stratigraphy, lithology, structure and permeability. The geohydrological data required includes depth to the regional ground water phreatic surface, perched surfaces, seepages and the importance of the ground water resource. The latter involves aquifer characteristics and sustainable yield.

9.4.3.1 Location

The preliminary location of the boreholes (Figure 14) is based on the experience and assisted by available geological and geohydrological data. However the final positions should be based on geophysics.

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[9] Department of Water Affairs and Forestry (DWAF). (1998). Minimum Requirements for the Water Monitoring at Waste Management Facilities. CTP Book Printers. Cape Town.

9.4.3.2 Depth of Drilling

Boreholes must be so sited, drilled and constructed that they do not unnecessarily penetrate impermeable layers or create conduits for the migration of leachate pollution to ground water bodies.

In general, boreholes should extend to at least twice the depth of the base level of the proposed cover excavation, in order to disclose any unfavourable zones which may affect the stability of the sideslopes. In areas of unfavourable geology, such as areas underlain by dolomitic bedrock and areas underlain by faulted bedrock or highly permeable soils, the boreholes should be drilled to a minimum depth of 25m below the base level of the proposed excavation. Unless one requires to prove the underlying geology, this depth is sufficient if no ground water is encountered.

9.4.3.3 Construction

The boreholes should be drilled with a starting diameter in the order of 150mm to 165mm and with a minimum diameter of 125mm. This diameter allows for the installation of casing with an internal diameter of more than 110mm, which is the minimum required for the installation of a conventional submersible pump.

Slotted Class 9 PVC casing should be installed in boreholes which are to be included in the ground water monitoring system. A concrete slab, 750mm square and 150mm thick, should be cast at the top of the borehole. It is essential that a locking mechanical cap be fitted to all monitoring boreholes, to avoid vandalism and contamination. For the construction of boreholes in various geological settings, refer to the Minimum Requirements for Monitoring at Waste Management Facilities.

Table 17: Recommended monitoring distances and frequencies for different landfill environments.

Waste Sites	Number of Boreholes	Distance from Waste Site	Frequency	Analytical Variables
General Waste Sites				
Large (>500 t/d)	3 to 6	20-200 m surrounding	Samples from boreholes every 6 months or as specified in permit. Sample water-supply boreholes 1-5 km radius initially and when problems are expected. Sample surface water as specified in permit. Sample monthly for Leachate, if any.	Bi-annually for:Alkalinity (Total Alkalinity), Ammonia (NH3 - N), Chemical Oxygen Demand (COD), Chlorides (Cl), Electrical Conductivity (EC), Nitrate (NO3 - N), pH, Potassium (K), Total Dissolved Solids (TDS)
Medium (150 – 500 t/d)	2 to 3	20-200 m downstream		
Small (25 – 149 t/d)	1 to 2	20-200 m downstream		Annually for: Calcium (Ca), Fluoride (F), Magnesium (Mg), Sodium (Na), Sulphate (SO4)
Communal (<25 t/d)	0 to 1	20 m downstream		
Private boreholes	2 to 3	Within 1-5 km from waste		

Table 18: Proposed Monitoring Positions (New boreholes to be site by geophysics)

ID	Latitude (South)	Longitude (East)	Owner	Property	Borehole Depth (mbgl)	Reasoning	Requirement	Frequency	Existing/New
Groundwater									
HWU	-27.746385	24.801646	Hartswater Landfill site	Hartswater	40	Upstream	Background monitoring	Biannual	New
HWD	-27.747316	24.798166	Hartswater Landfill site	Hartswater	40	Downstream	Plume monitoring	Biannual	New

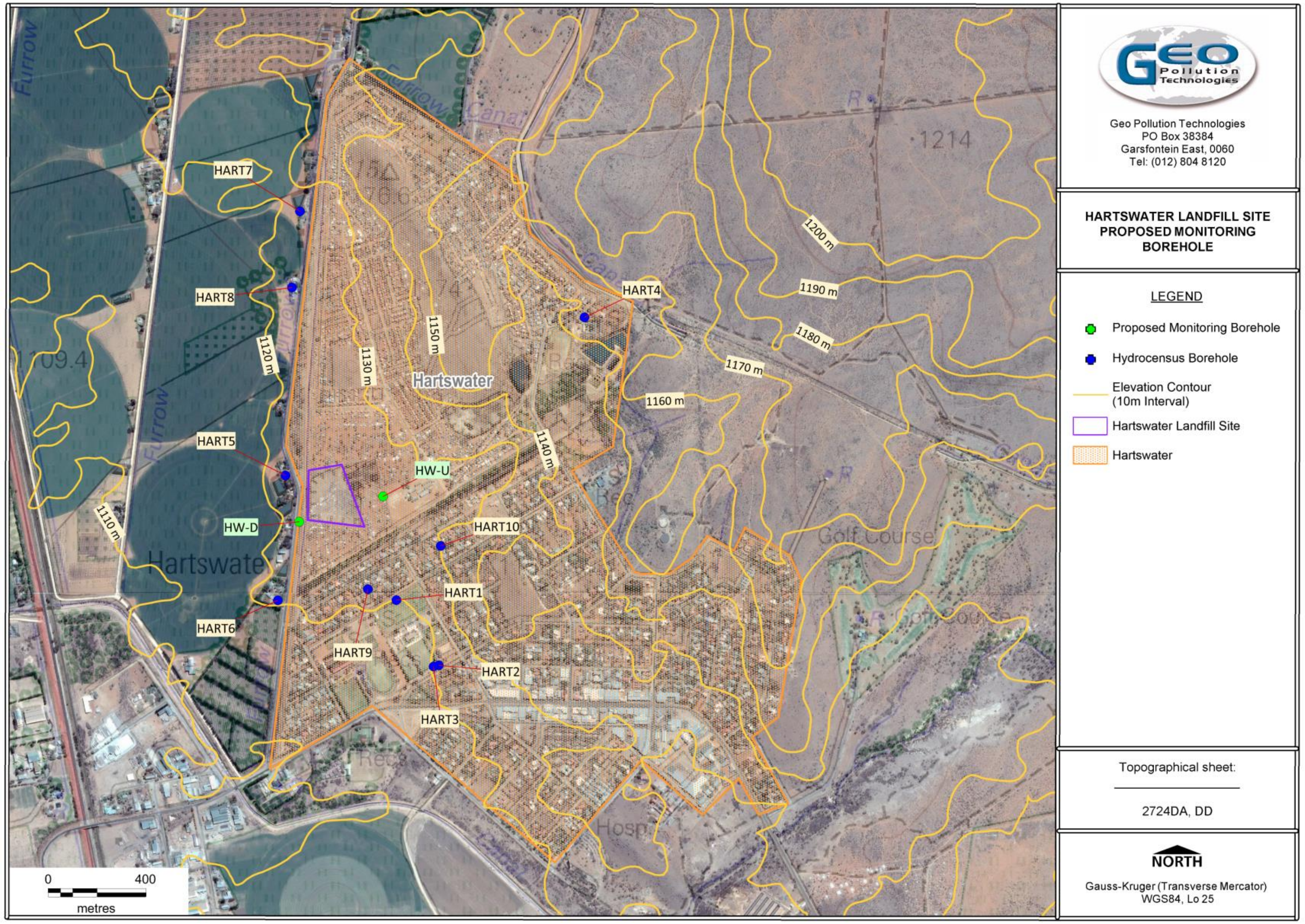

Figure 14: Proposed monitoring positions (new boreholes to be sited by geophysics)

10. ENVIRONMENTAL CONSEQUENCES OF FAILURE: GROUNDWATER

Following the assessment of the adverse impact of the landfill on the receiving groundwater environment, the landfill design will have to be adjusted to reduce or eliminate these potential impacts. Thereafter, it is also necessary to consider the environmental consequences of the failure of any of the environmental defence measures, such as the liner or leachate collection system.

It is necessary to follow the chart (Figure 15) through for the design of a particular landfill and, to justify the design, its environmental defence measures and its backup measures in the event of failure. In other words, it must be demonstrated that any consequences of a failure of the first line of environmental defences will not have an unacceptably adverse effect on the environment, either in the short or long term

10.1 Response Action Plan

In the event of failure in the design and/or operation, it is appropriate in certain instances, specifically for hazardous waste disposal sites, to have a Response Action Plan to deal with the situation rapidly and efficiently. While this is a procedure which must be addressed in the Operating Plan it should also be included in the Environmental Impact Control Report.

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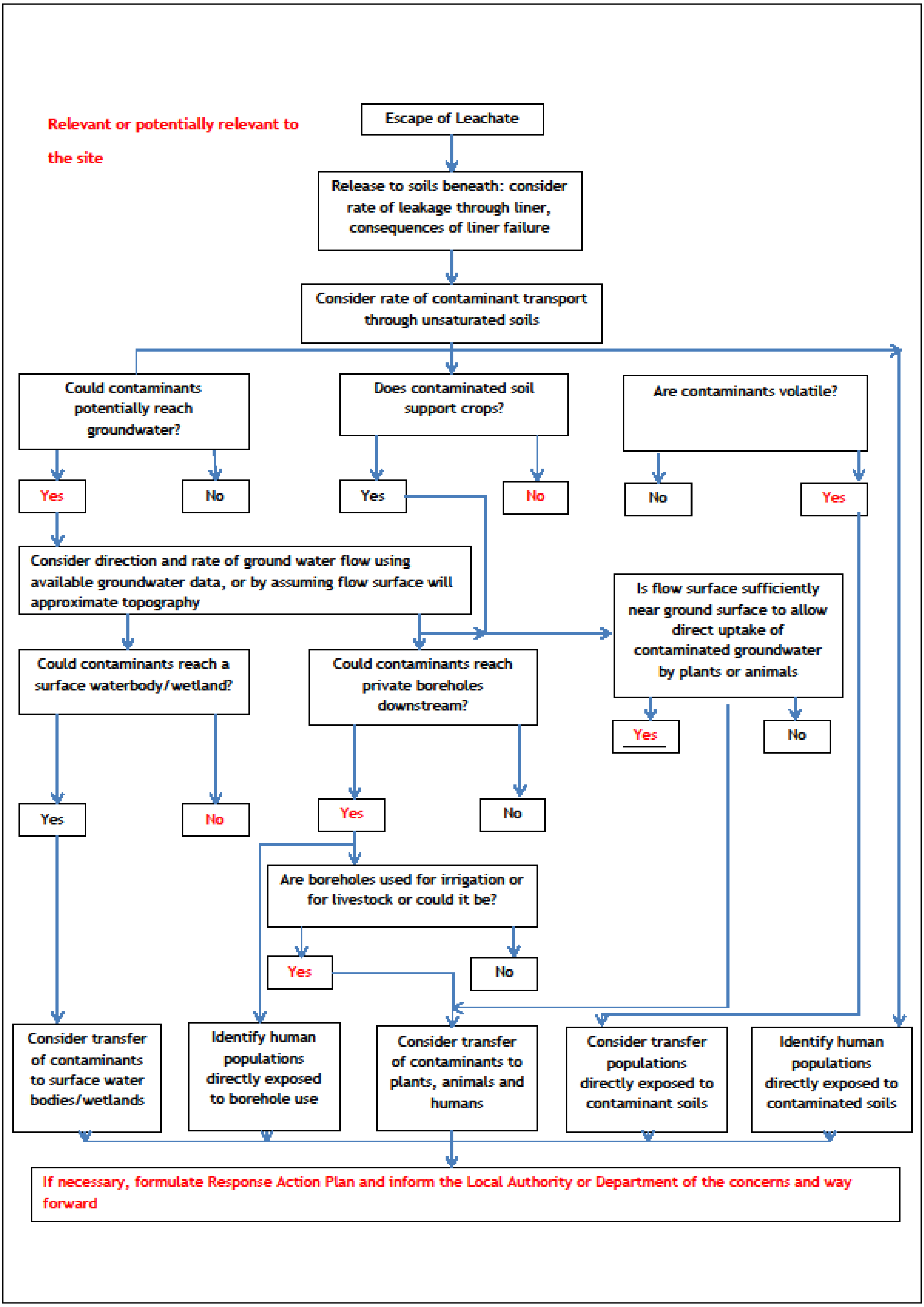

Figure 15: Environmental Consequences of Failure for Groundwater

11. CONCLUSIONS AND RECOMMENDATIONS

This section will briefly summarise the current groundwater conditions in the area of the landfill site and the potential impacts of the landfill on the receiving environment as well as the recommendations to minimise the effect of the landfill on the groundwater.

This report was not intended to be an exhaustive description of the project, but rather as a specialist interim hydrogeological study to evaluate the hydrogeological impact the landfill might have on the receiving groundwater environment.

11.1 Project Objectives

- Note the land use, topographic features, natural and man-made drainage features and the position of underground services (if any).
- Determine receptors of concern. All potential receptors of any contamination that might emanate from the site and the different identified pollution sources on the site will be noted, if any.
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey.
- Submit recovered water samples to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses.
- Aquifer classification
- Aquifer Vulnerability
- Based on the above complete the groundwater assessment

11.2 Desk Study

A desk study was done on all available information pertaining to groundwater situation at Hartswater Landfill site. The key findings are listed below

Based on available information received the landfill is situated in Hartswater, Eastern Cape Province

11.3 Regional Information

A description of the regional area information is given below:

- The site is situated approximately 110 km north of Kimberly, and 85 km south of Vryburg in the Frances Baard District Municipality (DC9), Phokwane Local Municipality (NC094), in the Eastern Cape Province
- The sites are situated in the Harts sub area of the Lower Vaal Water Management Area (WMA), in quaternary catchment C33A
- The average annual rainfall (measured over a period of 65 years) is approximately 493 mm, with the high rainfall months between November and March.
- The landfill site falls within the Allanridge, Bothaville, Rietgat and Kameeldorns Formations of the Ventersdorp Supergroup. Also present in the area are Quaternary sediments in the form of aeolian sands.
- Ventersdorp Supergroup rocks typically act as secondary aquifers (intergranular and fractured rock aquifers) while the aeolian sand form intergranular primary aquifers.

11.4 Hydrogeological Setting

11.4.1 Topography and drainage

- Regionally the area is gently undulating (sloping towards the Harts River to the west of the site) and in the area of the landfill site the slope is more or less in the order of 1:45 (0.02).
- Locally drainage is towards the Phokwane River, a tributary of the Hartswater, that flows in a westerly direction to the south of the site. Regionally the drainage is towards the Hartsrivier approximately 8km to the west of the site

11.4.2 Hydrocensus

A hydrocensus was conducted within a 2 km radius as a site familiarisation exercise and collection of essential groundwater related data from the study area and surrounding environments. The hydrocensus was conducting from 6 October 2015. The following features were found to exist within the 2 km radius:

- Ten (10) boreholes were found during the hydrocensus of which (see Figure 7):
- Five (5) were privately owned boreholes used for irrigation purposes
- Three (3) were privately owned boreholes used for domestic purposes;
- One (1) borehole was not in use
- One (1) owner could not be contacted
- HART1, HART2, HART3 and HART6 were found to be in use and downgradient of the landfill site. Therefore these boreholes could be impacted by migration of contamination in the aquifer from the site.

11.4.3 Water levels

During the hydrocensus, five (5) boreholes were available for groundwater level measurement.

- The groundwater levels varied between a minimum of 2.5 m to the north of the landfill to a maximum of 10.5 m below ground level to the south east of the landfill

11.4.4 Water quality

Two (20) water samples were collected from 2 boreholes around the site during the investigation. The samples were submitted for major cation and anion analyses to determine water quality in the area:

- The major cations in the groundwater samples are sodium, calcium and magnesium
- The major anions in the groundwater samples are chloride, sulphate and bicarbonate
- The groundwater quality can be described as unpolluted Calcium Bicarbonate waters
- None of the analysed constituents were found to be above the DWA guidelines for agricultural use: irrigation
- No noticeable concentration of targeted petroleum hydrocarbon compounds (diesel range organics, Poly Aromatic Compounds and gasoline range organics) were detected in the water collected from the hydrocensus boreholes HART3 and HART6.

11.5 Aquifer Sensitivity

The aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process. The following information was obtained during the investigation:

- The underlying aquifer(s) can be regarded as a Major Aquifer System
- The aquifer vulnerability can be regarded as Medium
- The aquifer protection classification is High

11.6 Source-Pathway-Receptor

Source:

The primary source of contamination from the site is:

- The unlined landfill site

Pathways:

Pathways along which contaminants may be mobilized and migrate toward groundwater receptors include:

- The aquifer underlying and downstream of the site

Receptors

Any user of a groundwater or surface water resource that is affected by pollution from any of the above mentioned sources is defined as a receptor. Furthermore, a borehole or river may also be a receptor. The following possible receptors may be found:

- Phokwane River, a tributary of the Hartsrivier that flows in a westerly direction to the south of the site
- Boreholes HART1, HART2, HART3 and HART6 which are located down gradient of the site and are used for irrigation purposes.

Based on the observations made during the site visit and the data collected during the hydrocensus it can be seen that there is a potential linkage between the sources, pathways and receptors for the site. The unlined landfill (source) may leach contaminated water into the underlying aquifer (pathway) during rainfall events. This contaminated groundwater may then move downgradient towards private boreholes surrounding the site or the Phokwane River (receptors).

11.7 Water Management Options

In this section various water management options available to Hartswater Landfill site during rehabilitation and post-closure are discussed. The objectives of the Minimum Requirements for Waste Disposal by Landfill are:

- To improve the standard of waste disposal in South Africa.
- To provide guidelines for environmentally acceptable waste disposal for a spectrum of landfill sizes and types. Limit the ingress of surface water and groundwater into the pits, and
- To provide a framework of minimum waste disposal standards within which to work and upon which to build.

11.7.1 Rehabilitation and Closure

- The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement. Capping should be implemented on all areas where no further waste deposition will take place, and vegetation should commence as soon as possible. Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the 'rising green wall' approach.
- All final levels and slopes must be in accordance with the landfill design and the End-use Plan. Slopes should not be steeper than 1 in 2.5, as this will promote erosion.
- Immediately on completion of an area, the final cover must be applied. The thickness of the final cover must be consistent and in accordance with the design. The final cover must comprise material capable of supporting the vegetation called for in the End-use Plan. In order to prevent erosion and improve aesthetics, re-vegetation should commence as soon as possible after applying the final cover.
- All covered surfaces on the landfill must be so graded as to promote run-off to prevent ponding. Re-vegetation must commence as soon as is practically possible after the final cover has been placed, in order to rehabilitate on an ongoing basis.
- Assuming that ongoing rehabilitation has taken place at the site, as stipulated in the minimum requirements, the cover of the landfill must be inspected regularly to ensure that uniform subsidence occurs and no cracks and fissures form. Cracks and fissures may act as preferential pathways for surface water into the landfill, generating additional leachate and contaminating groundwater.
- It is essential to ensure that drains are not excessively eroded or filled with silt or vegetation. They must function in order to ensure that excess surface water does not enter the waste body.
- Any subsidence or cracks, due to settlement or any other cause, must be identified and rectified by infilling.
- Any gas or water monitoring systems must be maintained and monitored on an ongoing basis, after the landfill site has closed.
- Post closure monitoring may be carried out under the auspices of a Monitoring Committee. Where this is the case, the results of ongoing monitoring should be submitted to the Monitoring Committee and made available for public scrutiny.
- The public may, through the Monitoring Committee, also monitor the landfill and report any problems that are observed to the Responsible Person.

11.8 Recommendations

The following recommendations are put forward:

- Compile an end use plan for the site. Based on the end use plan a closure plan should also be compiled.
- Site the proposed monitoring boreholes using geophysical methods, drill and install these boreholes according to the Minimum Requirements for Water Monitoring at Waste Management Facilities.
- Monitoring of groundwater upstream and downstream of the landfill site is imperative. Depending on the water, quality results of dedicated groundwater monitoring boreholes, consideration can be given to storm water trenches and leachate collection systems.

- Water levels and quality data should be collected on a bi annual basis during the landfill operations. This data should be used to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA

APPENDIX I: HYDROCENSUS INFORMATION

APPENDIX II: LABORATORY CERTIFICATE OF ANALYSIS –INORGANIC

APPENDIX III: LABORATORY CERTIFICATE OF RESULTS-ORGANIC