



GROUNDWATER ASSESSMENT
FOR
NONDWENI LANDFILL SITE

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SUSTAINABLE ENVIRONMENTAL SOLUTIONS (PTY) LTD



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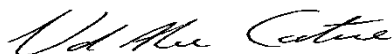


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Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website 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. Nondweni landfill site is one of these 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 was collected from one upstream & one downstream borehole (if present). The visited points was recorded via GPS coordinates of these sample points. The National Groundwater Archive (NGA) was also be consulted to identify any boreholes.
- No samples could be collected and submitted to a SANAS accredited laboratory for the analysis of hydrocarbon compounds by GC-MS screening and inorganic major cation/anion analyses, as no boreholes could be identified.
- 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

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 Minor Aquifer System

- The aquifer vulnerability can be regarded as Medium
- The aquifer protection classification is Medium to Low

Source-Pathway-Receptor

The sources, pathways and receptors identified can be described as follows:

- Sources - Landfill Site -Unlined and a potential source of leachate. No berms or trenches to capture leachate.
- Pathways - Possible exposure through surface water runoff. No berms or trenches to capture or route runoff. No lining to capture leachate to groundwater.
- Receptors - Potential surface water users in the local village.

Based on the site visit, the groundwater pathway is currently not complete, as no boreholes were encountered, which can be used for groundwater abstraction. However, should contaminants from the landfill (source) travel through the vadose zone to the aquifer (pathway) it is likely that groundwater may be affected, as the uppermost geology on site is highly permeable. Additionally, the surface water body (receptor) to the southwest of the site is likely to be affected. Therefore, storm water trenches and leachate collection systems should be considered.

Water management options

The following surface water management options are recommended during operations:

- In Class G:C and G:S landfills, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation.
- Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a Minimum Requirement, as spoil from the excavation makes this possible.
- The basic landfill unit is a cell of compacted waste which, when completed at the end of each day, is entirely contained by cover material. The sides are usually formed by 1,5m to 2,0m high berms, constructed from soil, rubble, or sloped waste covered by daily cover.
- Regardless of the co-disposal ratio used or the amount of leachate generated, it is a Minimum Requirement that there are no free liquid surfaces on the landfill and that the fill is trafficable.
- Upslope run-off water must be diverted away from the waste, to prevent water contamination and to minimise leachate generation.
- Where contaminated water or leachate does arise on a site, it must be managed. This means that it must be kept out of the environment. This also applies to the drainage from wash bays and spills at hazardous waste landfills.
- Clean, uncontaminated run-off water must not be permitted to mix with, and increase the volume of, contaminated water.
- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cutoff drains.
- Water contaminated by contact with waste, as well as leachate, must be contained within the site. If it is to be permitted to enter the environment, it must conform or be treated so as to

conform to the Special or General Effluent Standards in terms of the Permit. [Ref. Government Gazette, No. 9225, 18 May 1984].

- The bases of trenches and cells must be so designed that water drains away from the deposited waste. Alternatively, cells must be so orientated as to facilitate drainage away from deposited waste. The resulting contaminated water, together with all other contaminated run-off arising from the landfill, must be stored in a sump or retention dam. It may be pumped from the dam and disposed of if it conforms to the Special, General or Specific Effluent Standards stipulated in the Permit.
- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.
- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.
- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

The following groundwater management options are recommended during operations:

- At B- sites, any sporadic leachate generated on account of unusual circumstances must be both reported to the Department and properly controlled. This could also include leachate recycling.
- Although no risk to groundwater users currently exists at the site, based on the sampling data, it is imperative that monitoring takes place and that lining of the landfill is considered to protect the aquifer, after implementation of the monitoring network and based on monitoring data and the risk profile of the site.

The following measures should be implemented during 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.

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.

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 are 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, ongoing basis during the landfill operations. This data will 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 $m^3/d \cdot m$.
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 NONDWENI 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 sub-contractor to conduct groundwater assessments for these unlicensed landfill sites. Nondweni landfill site is one of these 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 consulted to identify any boreholes.

2.1.1.1 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 Africa¹, which entails the following regional aquifer systems:

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

¹ Andiswa Matoti, Julian Conrad and Susan Jones, CSIR, 22 March 1999.

- 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 document². 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.

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 pollutant³. 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.

² Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

³ The South African Groundwater Decision Tool (SAGDT), Manual Ver. 1 (Department of Water Affairs and Forestry)

- 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 [3].

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 Nondweni landfill site is located approximately 0.5 km south of the town of Nondweni in KwaZulu-Natal (Figure 2). It is bordered on all sides by local streams, with the Amahlungulu village to its southeast.

3.2 Regional water Management Setting and Sensitivity

The site is situated in the Usutu to Mhlatuze sub-area of the Pongola-Umzimkulu Water Management Area (WMA), in quaternary catchment W21E (Figure 2). The Pongola-Umzimkulu WMA is located in KwaZulu-Natal and is one of the larger WMAs, as it is the result of the amalgamation of the Thukela, Mvoti-Mzimkulul and Mhlatze-half of the Usutu. The amalgamated WMA - Pongola-Umzimkulu is bounded by the Indian Ocean to the east, Mozambique, Swaziland and the Inkomati-Usuthu WMA to the north, Lesotho and the Vaal WMA to the west and the Mzimvubu-Tsitsikamma WMA to the south. The north of the WMA, formally the Usuthu to Mhlatuze WMA contains major rivers including the Pongola, Mhlatuze, Mkuze and Mfolozi. The Pongola River rises near Wakkerstroom in KwaZulu-Natal and flows eastdescending steeply west of the Lebombo Mountains. Its catchment is 7080 km², which is shared with Lesotho and Mozambique. The river is dammed at Jozini in KZN, and eventually joins the Maputu River in Mozambique. The Usuthu River starts in Mpumalanga, flows though Swaziland, re-enters South Africa and flows through Mozambique, finally emptying into Maputo Bay. Both these rivers have a number of tributaries and dams along the rivers. The Mhlatuze River is a tributary of the Usuthu and has a catchment area of 4209 km². This catchment area is in a high rainfall region, contains several freshwater lakes and contains a large dam called the Goedertrouw Dam, which is critical for the provision of water to the Richards Bay industrial complex. The area experiences water quality issues.

3.3 Climatic Conditions

Climatic data was obtained from the DWA weather station Klipfontein Dam (rainfall data and evaporation data) for the Nondweni area (Table 1)⁴. 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 31 years) is approximately 807 mm, with the high rainfall months between November and March.

⁴ Department of Water Affairs (DWA): www.dwa.gov.za

Table 1: Climatic Data

Month	Average monthly rainfall (mm)	Mean monthly evaporation
January	123,7	192,6
February	99,3	167,4
March	79,3	159,1
April	45	134,7
May	16,6	119,2
June	9,9	104,9
July	11,1	121
August	17,9	153,4
September	30,3	179
October	92,5	176
November	129,1	185,9
December	145,6	198,5
Annual	807,1	1944,4

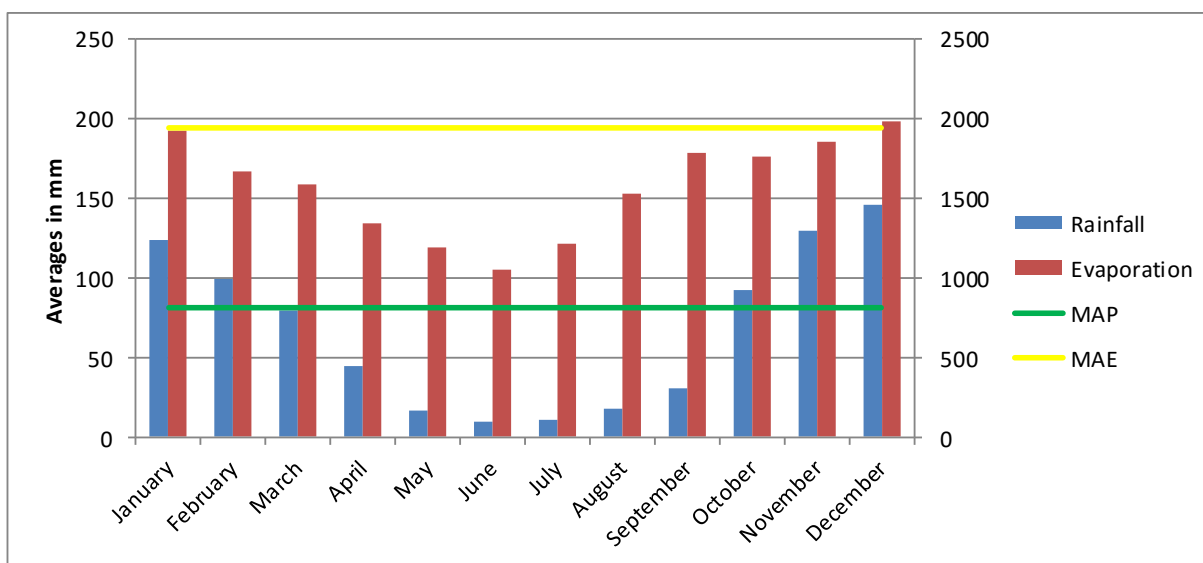


Figure 1: Climatic data representation

3.4 Regional Geology

The investigated area falls within the 2830 Dundee 1:250 000 geology series map and is situated approximately 0.5 km south of the town of Nondweni, KwaZulu-Natal. An extract of the map is shown in Figure 4.

The landfill site falls within quaternary sediments, which are underlain by the Dwyka formation, which consists of glacial sedimentary rocks. Below the Dwyka formation, the Nondweni formation is present, which consists predominantly of mafic rock, banded chert, calc-silicate rocks and micaceous schists. Jurassic dolerite can also be found in the area.

No geological structures (faults and dykes) could be identified on the geological map of the area.

3.5 Regional Hydrogeology

According to the 1:500 000 General Hydrogeological Map⁵ the quaternary sediments in the area typically act as primary aquifers (intergranular aquifers). The aquifers in this area are mostly comprised of fine to medium grained material with localised coarser layers. Groundwater levels in these aquifers are generally shallower than 15m. Hydraulic conductivity⁶ in these aquifers ranges between 0.5 and 12 m/day with a mean value of 3 m/day and borehole yield between 0.5 and 2 L/s can be expected. However, in coarser sediments the hydraulic conductivity can reach up to 150 m/d. The main source of recharge into the shallow aquifers is rainfall that infiltrates through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. The water quality of these aquifer systems is typical of alkaline water in sandy aquifers. Groundwater quality within these aquifers is commonly below target water quality concentrations.

The underlying Dwyka formation is considered to be a fractured aquifer (secondary aquifer). This aquifer is comprised of glacial sedimentary rock and has a low average borehole yield of 0.1 L/s. This is mainly attributed to its massive, structureless nature, resulting in low hydraulic conductivities and storativities. Faults and contact zones with dolerite intrusions in this aquifer, exhibit higher yields with transmissivities ranging between 200 and 400 m²/day.

⁵ King, G.M., (2003). An explanation of the 1:500 000 General Hydrogeological Map. Vryheid 2730. DWAF.

⁶ 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).

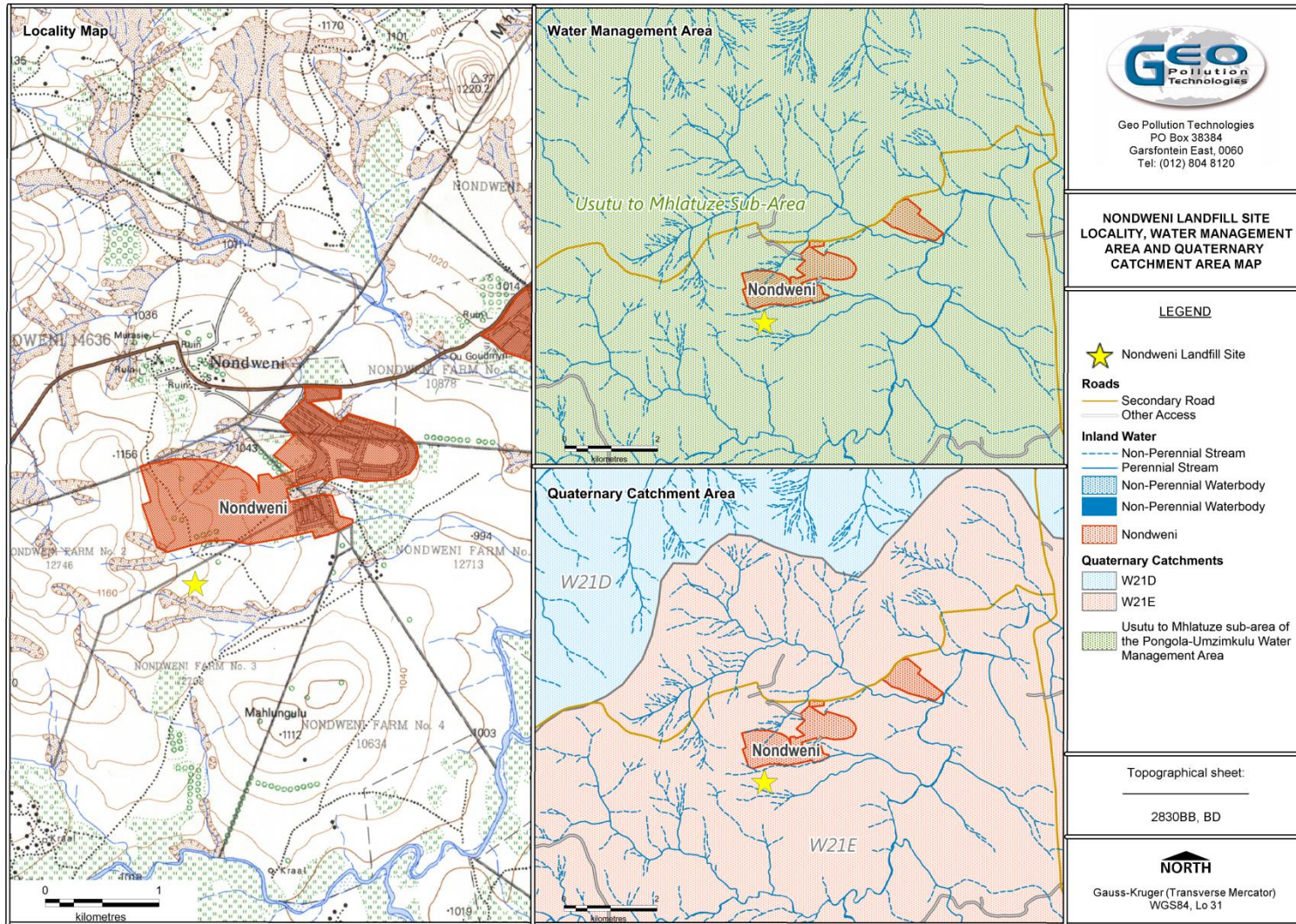


Figure 2: Site Location and Quaternary Catchment Boundaries

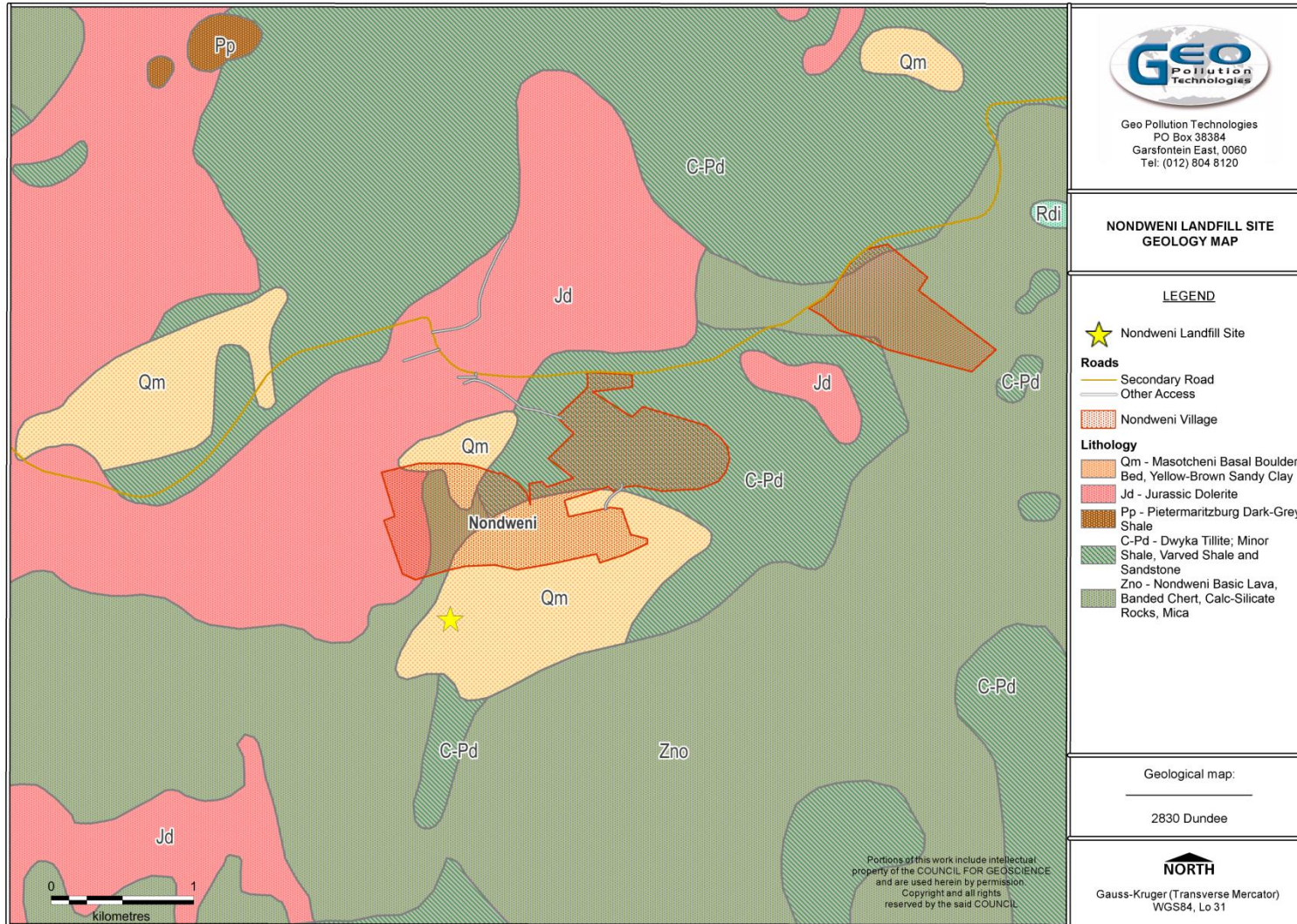


Figure 3: Regional Geology Map (1:250 000 geology series map)

4. GROUNDWATER ASSESSMENT

The hydrogeological setting is described under the headings below.

4.1 Site Topography and Drainage

The topography (shown in Figure 4) 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.

The area is characterised by a sharp undulating topography and in the area of the landfill site the slope is more or less in the order of 4:100 (0.04).

Locally, drainage on site is towards the east. Two non-perennial streams border the site to the north and south, where drainage is routed to.

4.2 Hydrocensus

A hydrocensus was conducted as a site familiarisation exercise and collection of essential groundwater related data from the study area and surrounding environments. The hydrocensus was conducted on 9 October 2015. However, no boreholes were encountered in the area.

4.2.1 Boreholes

No boreholes were encountered during the hydrocensus.

4.2.2 Surface water

Two surface water features were found during the hydrocensus. However, both were dry at the time of the hydrocensus.

4.2.3 Access restrictions and other issues

The following access restrictions were encountered during the hydrocensus:

- No access restrictions were encountered during the hydrocensus.

4.3 Water Levels

No water levels could be measured during the hydrocensus as no boreholes were encountered.

4.4 Water quality

No groundwater samples could be collected during the hydrocensus as no boreholes were encountered.

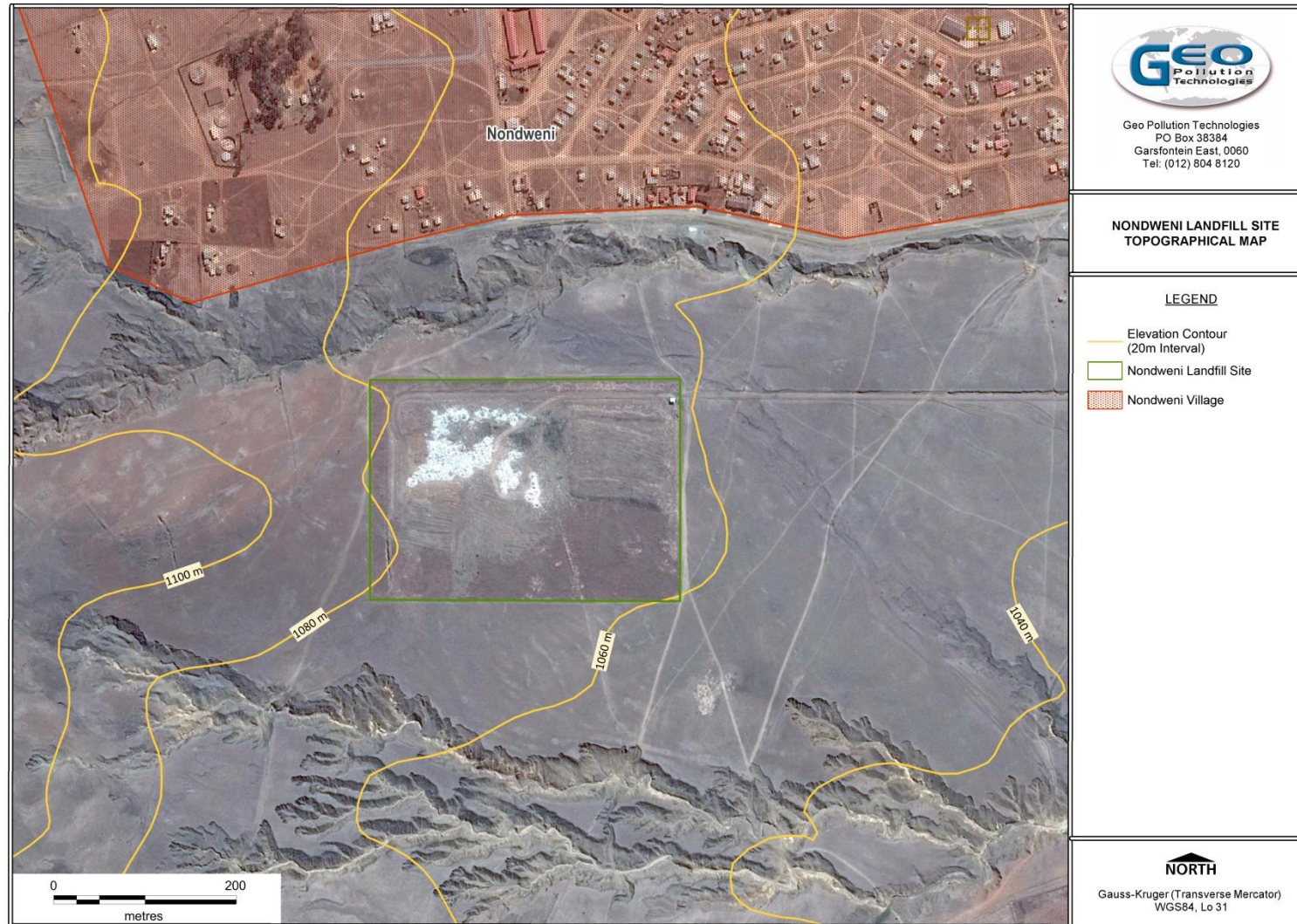


Figure 4: Site Topography

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 document⁷. The aquifer classification map of South Africa is shown in Figure 5. 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.

Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a "Minor Aquifer System", based on the fact that the underlying Karoo aquifer is likely to be fractured but unlikely to produce significant volumes of water.

In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 2 and Table 3.

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

Table 2: 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	
Minor Aquifer System:	2	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 3: Ratings - Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	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 4.

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

= 2 x 2 = 4

Table 4: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	
3 - 6	Medium Level	4
6 - 10	High Level	
>10	Strictly Non-Degradation	

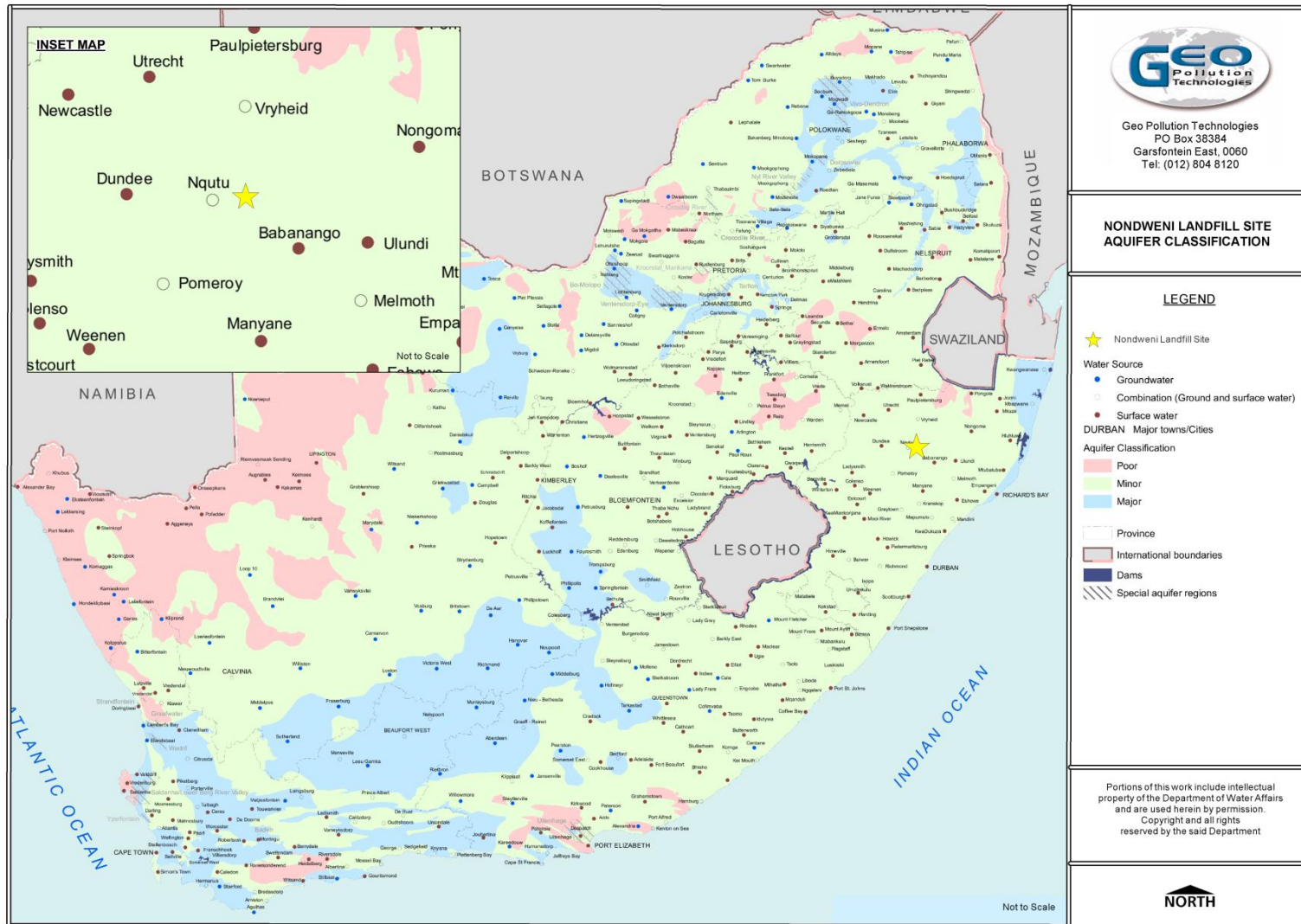


Figure 5: Nondweni Landfill Site Aquifer Classification

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 6) was used to quantify the vulnerability of the aquifer underlying the site using the below assumptions.

- Depth to groundwater level below the site was estimated from the 1:500 000 General Hydrogeological Map⁸ to be at mean of ~10 mbgl.
- Groundwater recharge of 65mm/a,
- Sandy soil vadose zone
- Gradient of 1% was 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.

⁸ King, G.M., (2003). An explanation of the 1:500 000 General Hydrogeological Map. Vryheid 2730. DWAF.

- 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 54%, which is medium.

5.3 Aquifer Protection Classification

A Groundwater Quality Management Index of 4 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a **medium to low 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 bordering streams to the north and south of the site

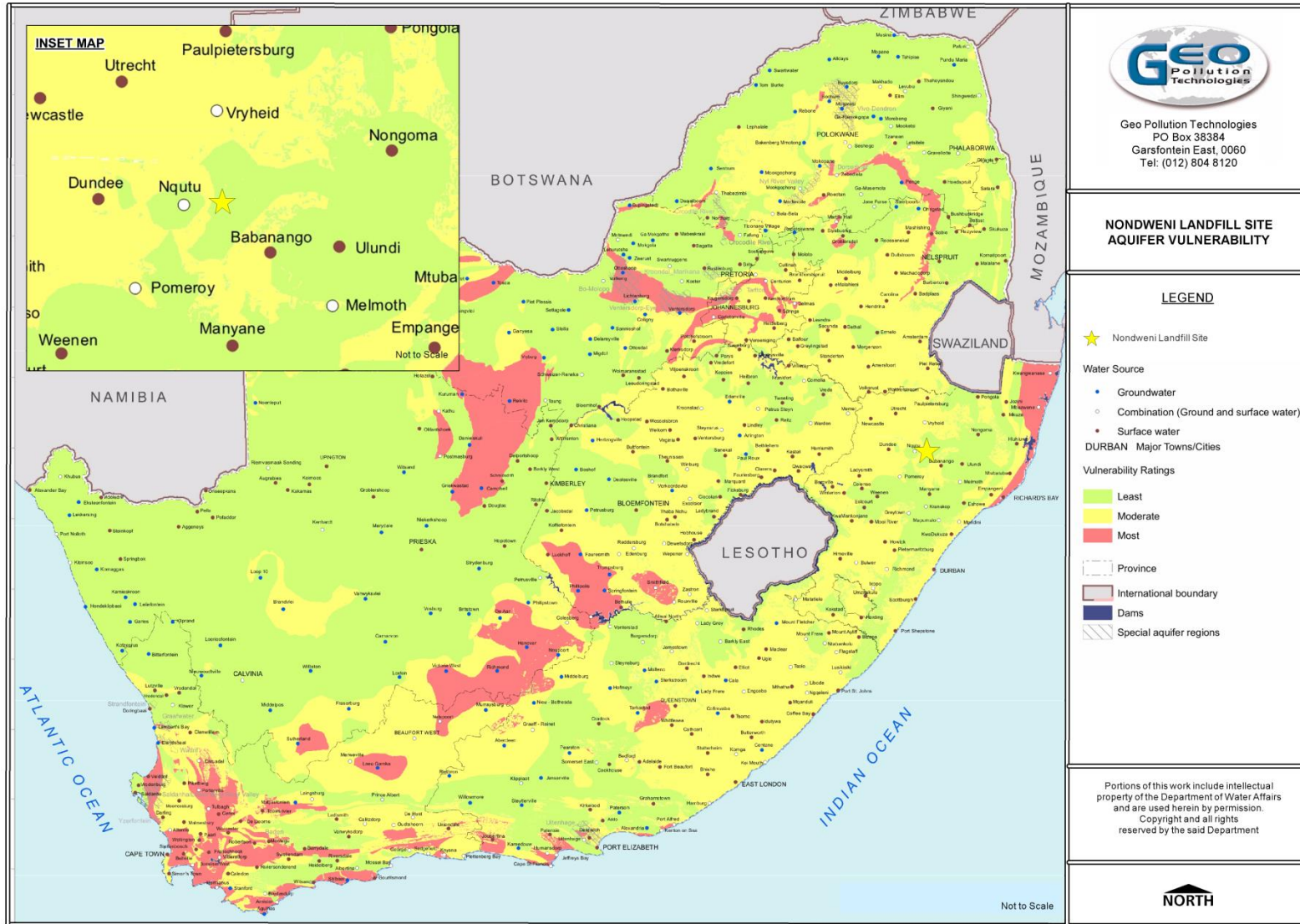


Figure 6: Nondweni Landfill Site Aquifer Vulnerability

6. SOURCE-PATHWAY-RECEPTOR MODEL

The sources, pathways and receptors identified can be described as follows:

- Sources - Landfill Site -Unlined and a potential source of leachate. No berms or trenches to capture leachate.
- Pathways - Possible exposure through surface water runoff. No berms or trenches to capture or route runoff. No lining to capture leachate to groundwater.
- Receptors - Potential surface water users in the local village.

Based on the site visit, the groundwater pathway is currently not complete, as no boreholes were encountered, which can be used for groundwater abstraction. However, should contaminants from the landfill (source) travel through the vadose zone to the aquifer (pathway) it is likely that groundwater may be affected, as the uppermost geology on site is highly permeable. Additionally, any surface water body (receptor) which is connected to groundwater in the vicinity of the site is likely to be affected. Therefore, storm water trenches and leachate capture systems should be considered for the site.



Figure 7: Unlined Landfill Site; No Berms or Trenches Present

7. IMPACT ASSESSMENT AND GROUNDWATER MANAGEMENT PROGRAMME

7.1 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 NEMA⁹.

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. The criteria used for the assessment of the potential impacts of the project are described in Table 5. Cumulative impacts will be included as part of the impact assessment process.

Table 5: 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.
Confidence	This is the level of knowledge/information that the environmental impact practitioner or a specialist had in his/her judgement.

⁹ Guideline document EIA regulations (April 1998): Implementation of sections 21, 22 and 26 of the environment conservation act.

Criteria	Description
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.

7.2 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.

7.3 Extent

The physical and spatial scale of the impact is classified in Table 6 below.

7.4 Duration

The lifetime of the impact is measured in relation to the lifetime of the proposed project, as per Table 7.

7.5 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 8.

7.6 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 9.

7.7 Level of confidence

The level of knowledge the EAP or a specialist had in their judgement.

7.8 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:

$$\text{Significance value} = (\text{Extent} + \text{Duration} + \text{Intensity}) \times \text{Probability}$$

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 10. 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.

7.9 Identifying the Potential Impacts without Mitigation Measures (WOM)

Significance without mitigation is rated on the following scale as contemplated in Table 10:

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.

7.10 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 10 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.

7.11 Impacts Assessment and Management Options

Based on the impact assessment criteria as detailed in the preceding paragraph an impact rating is given in Table 10. The table also summarises all the groundwater related EMP's and should be implemented during the operation of the landfill.

Table 6: Impact Extent

Criteria	Description	Scoring	Nondweni 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	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	

Table 7: Impact Duration

Criteria	Description	Scoring	Nondweni 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 8: Impact Intensity

Criteria	Description	Scoring	Nondweni 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	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	

Table 9: Impact Probability

Description	Scoring	Nondweni Landfill Site (Degradation of Groundwater Quality)
Without Mitigation (WOM)		
The possibility of the impact occurring is none, due either to the circumstances, design or experience (less than 24% chance of occurring).	1	4
The possibility of the impact occurring is very low, either due to the circumstances, design or experience (25 - 49%).	2	
There is a possibility that the impact will occur to the extent that provisions must therefore be made (50 - 69%).	3	
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	
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)		
The possibility of the impact occurring is none, due either to the circumstances, design or experience (less than 24% chance of occurring).	1	3
The possibility of the impact occurring is very low, either due to the circumstances, design or experience (25 - 49%).	2	
There is a possibility that the impact will occur to the extent that provisions must therefore be made (50 - 69%).	3	
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	
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 10: Impact Significance

Criteria	Description	Scoring	Nondweni 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	39
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 11: Water Management Options (Operation)

Nondweni Landfill Site (Degradation of Groundwater Quality)			
Significance Rating (WOM)	Impact	Management Options	Significance Rating (WM)
52	Leaching/Seeping of contaminants into sub-surface	Surface hydrology design should include surface drainage and storm water diversion drains, to meet the requirements of the Water Act. This includes the separation of unpolluted from polluted surface water and the containment of polluted water on site in impoundments. Also, where leachate is generated, it must be contained separately from water which is only slightly polluted through contact with the waste.	39
		In the case of hazardous waste disposal sites, the design must make provision for containment of hazardous waste. This implies the complete separation of the waste body and any associated leachate from the surrounding soil or rock strata, by means of a liner and a leachate collection system.	
		Leachate management is necessary in the case of B+ and hazardous waste disposal sites, where significant leachate is generated. The design includes a liner underlying the site, as well as leachate collection and treatment measures. It must make provision for the control of significant seasonal or continuous leachate generation, predicted by means of the Climatic Water Balance, or the Site Water Balance.	
		Leachate management is not necessary at Blandfill sites, provided that they are properly designed and operated. However, if this is not the case, and significant leachate is generated as a result of poor drainage or the disposal of high moisture wastes, it must be detected as soon as possible.	
		Monitoring systems for surface and ground water pollution should be indicated. This will include the positions of both surface water sampling points and monitoring boreholes.	
		The Progressive Rehabilitation Plan should indicate when areas should reach their final level and how they will be progressively restored, by means of final cover or capping, topsoiling and vegetating. The type of vegetation envisaged should also be described.	
		Drains must divert or contain the peak design storm of 50 year return period for the particular catchment area. The system must effect ively separate unpolluted water, that has not come into contact with waste, from polluted water. The upslope cut-off drains must divert clean storm water around the site and into the natural drainage system	
		Polluted water, on the other hand, must be collected in toe drains, retained on the site and managed in accordance with the Department's directives. This may include controlled release, recycling and evaporation or treating with any leachate that has been collected.	

Nondweni Landfill Site (Degradation of Groundwater Quality)			
Significance Rating (WOM)	Impact	Management Options	Significance Rating (WM)
		The liner design for a contaminated water pond at a general waste disposal site must correspond with those for a G:B+ site of the same size, minus the leachate collection layer (see Appendix 8.2). The liner design for a contaminated water pond at a hazardous waste disposal site must correspond with the liner design for the landfill itself, minus the top leachate collection layer.	
		It is a Minimum Requirement that there always be an acceptable physical separation between the proposed waste body and the wet season high elevation of the ground water. This applies whether cover excavations take place on site or not. The minimum permissible separation is 2m.	
		Leachate management which involves the construction of liners. Similarly, adopting the Precautionary Principle, the Minimum Requirements require minimal liners at B- landfills. This is, however, not to manage, but to detect the presence of leachate. In the case of all hazardous waste sites and lagoons, however, the Minimum Requirements require a substantial liner and leachate management system to be provided, regardless of the Climatic Water Balance.	
		Leachate collection is usually achieved using a graded underliner and drains which lead to a collection point or sump. Depending on soil quality, the underliner may be an engineered low permeability natural soil or clay liner, a geomembrane liner, or both.	
		All landfills have the potential to generate sporadic leachate. In all landfills, therefore, the base must be so sloped that any leachate formed, even sporadic leachate, is directed to a control point.	
		The leachate treatment system will depend on the leachate composition and on the most appropriate method of treatment. This could be on-site chemical, physical or biological treatment, and/or off-site treatment where leachate is passed into a sewer or pipeline for treatment elsewhere.	
		All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.	
		Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions. All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.	
		The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement.	
The Department requires a Water Quality Monitoring Plan as part of the permitting requirements. This involves background analyses, detection monitoring, investigative monitoring and post-closure monitoring. The Water Quality Monitoring Plan ensures that the water quality in the vicinity of a landfill is regularly monitored and reported upon throughout its life, so that, where necessary, remedial action can be taken.			

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 Nondweni 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 and long term impacts as well as 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 through 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.

8.1 During Operations

The water management/mitigation options during operations are discussed below.

8.1.1 Surface Water Management

The following surface water management options are recommended during operations:

- In Class G:C and G:S landfills, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation.
- Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a Minimum Requirement, as spoil from the excavation makes this possible.
- The basic landfill unit is a cell of compacted waste which, when completed at the end of each day, is entirely contained by cover material. The sides are usually formed by 1,5m to 2,0m high berms, constructed from soil, rubble, or sloped waste covered by daily cover.
- Regardless of the co-disposal ratio used or the amount of leachate generated, it is a Minimum Requirement that there are no free liquid surfaces on the landfill and that the fill is trafficable.
- Upslope run-off water must be diverted away from the waste, to prevent water contamination and to minimise leachate generation.
- Where contaminated water or leachate does arise on a site, it must be managed. This means that it must be kept out of the environment. This also applies to the drainage from wash bays and spills at hazardous waste landfills.
- Clean, uncontaminated run-off water must not be permitted to mix with, and increase the volume of, contaminated water.
- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cutoff drains.

- Water contaminated by contact with waste, as well as leachate, must be contained within the site (see example in Figure 8 below). If it is to be permitted to enter the environment, it must conform or be treated so as to conform to the Special or General Effluent Standards in terms of the Permit. [Ref. Government Gazette, No. 9225, 18 May 1984].

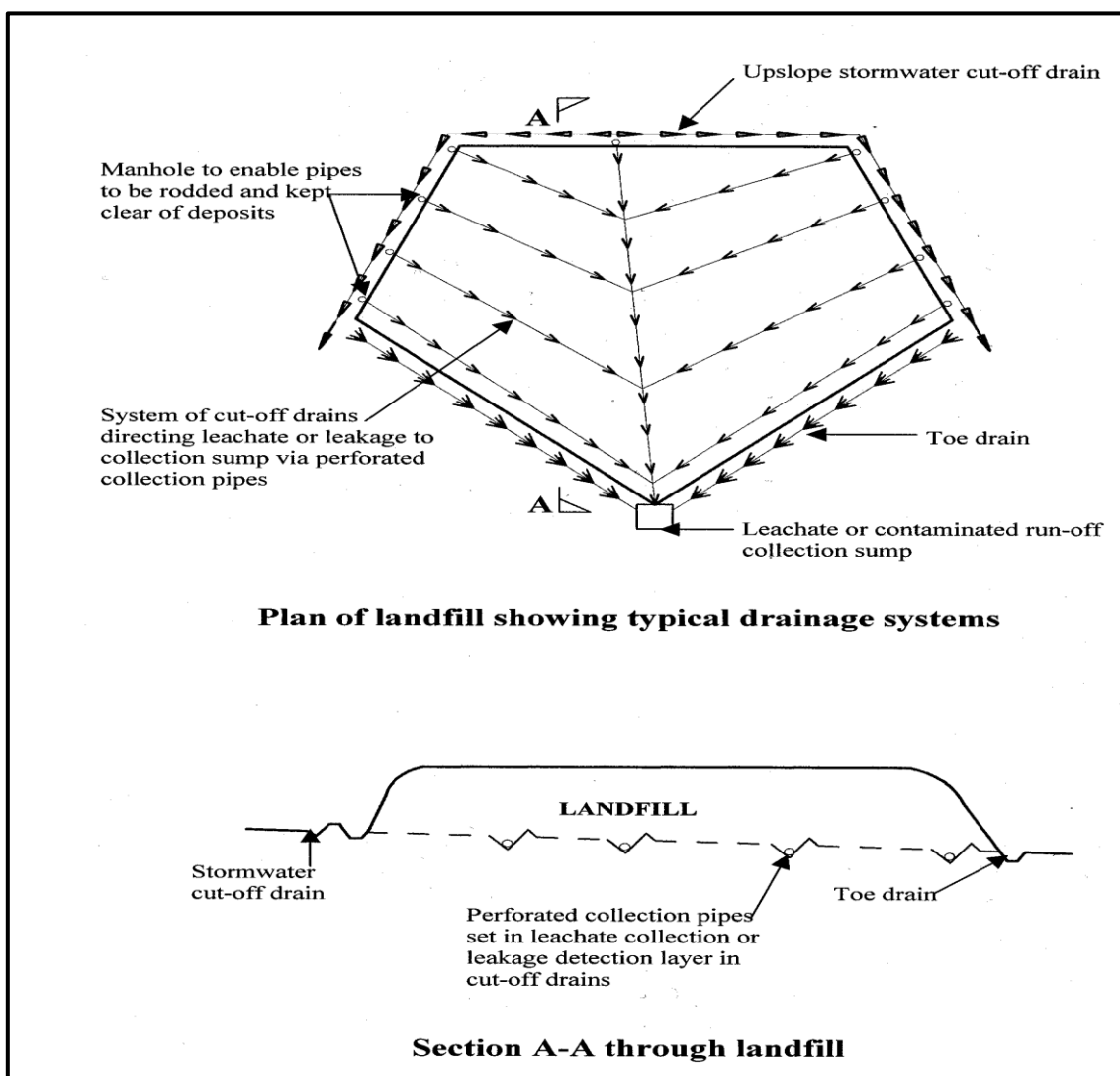


Figure 8: Example of a Leachate collection system (taken from Minimum Requirements, DWAF 1998)

- The bases of trenches and cells must be so designed that water drains away from the deposited waste. Alternatively, cells must be so orientated as to facilitate drainage away from deposited waste. The resulting contaminated water, together with all other contaminated run-off arising from the landfill, must be stored in a sump or retention dam. It may be pumped from the dam and disposed of if it conforms to the Special, General or Specific Effluent Standards stipulated in the Permit.
- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.
- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.
- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

8.1.2 Groundwater Management

The following groundwater management options are recommended during operations:

- At B- sites, any sporadic leachate generated on account of unusual circumstances must be both reported to the Department and properly controlled. This could also include leachate recycling.

8.2 Rehabilitation and Closure

8.2.1 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.

8.2.2 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 positions which can assess the groundwater status at certain areas. The boreholes can be grouped classification 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.”¹⁰

Currently a monitoring network does not exist for the site. The recommended boreholes are listed in Table 12 and Table 13 and the areas to site these monitoring boreholes are shown in Figure 9. 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 hydrogeological 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 12 below. The geological data required includes stratigraphy, lithology, structure and permeability. The hydrogeological 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 9) is based on the experience and assisted by available geological and hydrogeological data. However the final positions should be based on geophysics.

¹⁰ 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 it is required to prove the underlying geology, this depth is sufficient if no groundwater 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 12: 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 (NH ₃ - N), Chemical Oxygen Demand (COD), Chlorides (Cl), Electrical Conductivity (EC), Nitrate (NO ₃ - 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		
Communal (<25 t/d)	0 to 1	20 m downstream		Annually for: Calcium (Ca), Fluoride (F), Magnesium (Mg), Sodium (Na), Sulphate (SO ₄)
Private boreholes	2 to 3	Within 1-5 km from waste		

Table 13: 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									
NONM W1	-28.20247	30.805804	Nondweni Landfill Site	Nondweni Landfill Site	25	Risk Assessment and Monitoring	Monitoring	Bi-Annually	New
NONM W2	-28.203366	30.808922	Nondweni Landfill Site	Nondweni Landfill Site	25	Risk Assessment and Monitoring	Monitoring	Bi-Annually	New

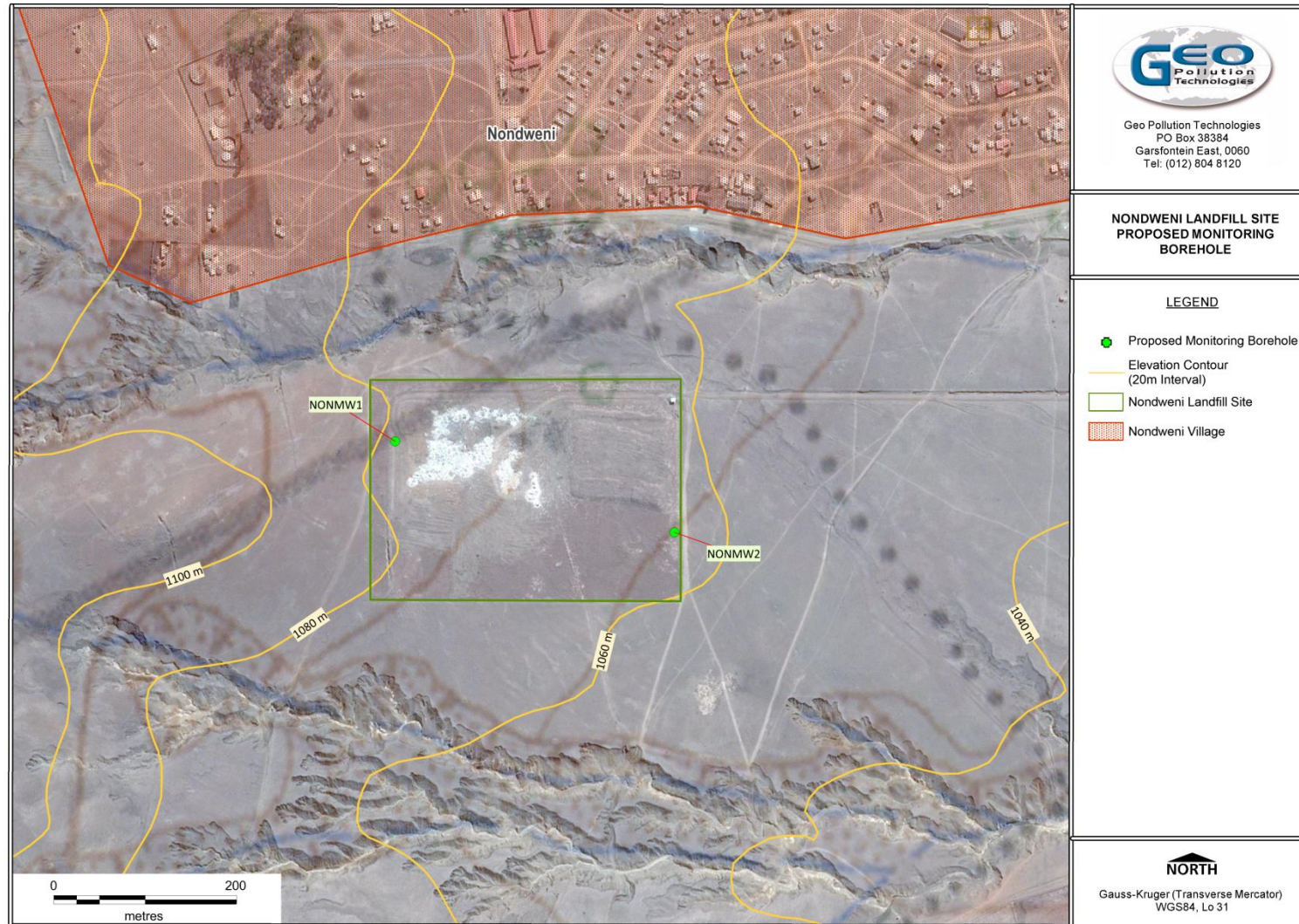


Figure 9: Proposed monitoring positions (new boreholes to be sited by geophysics)

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 10) 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.

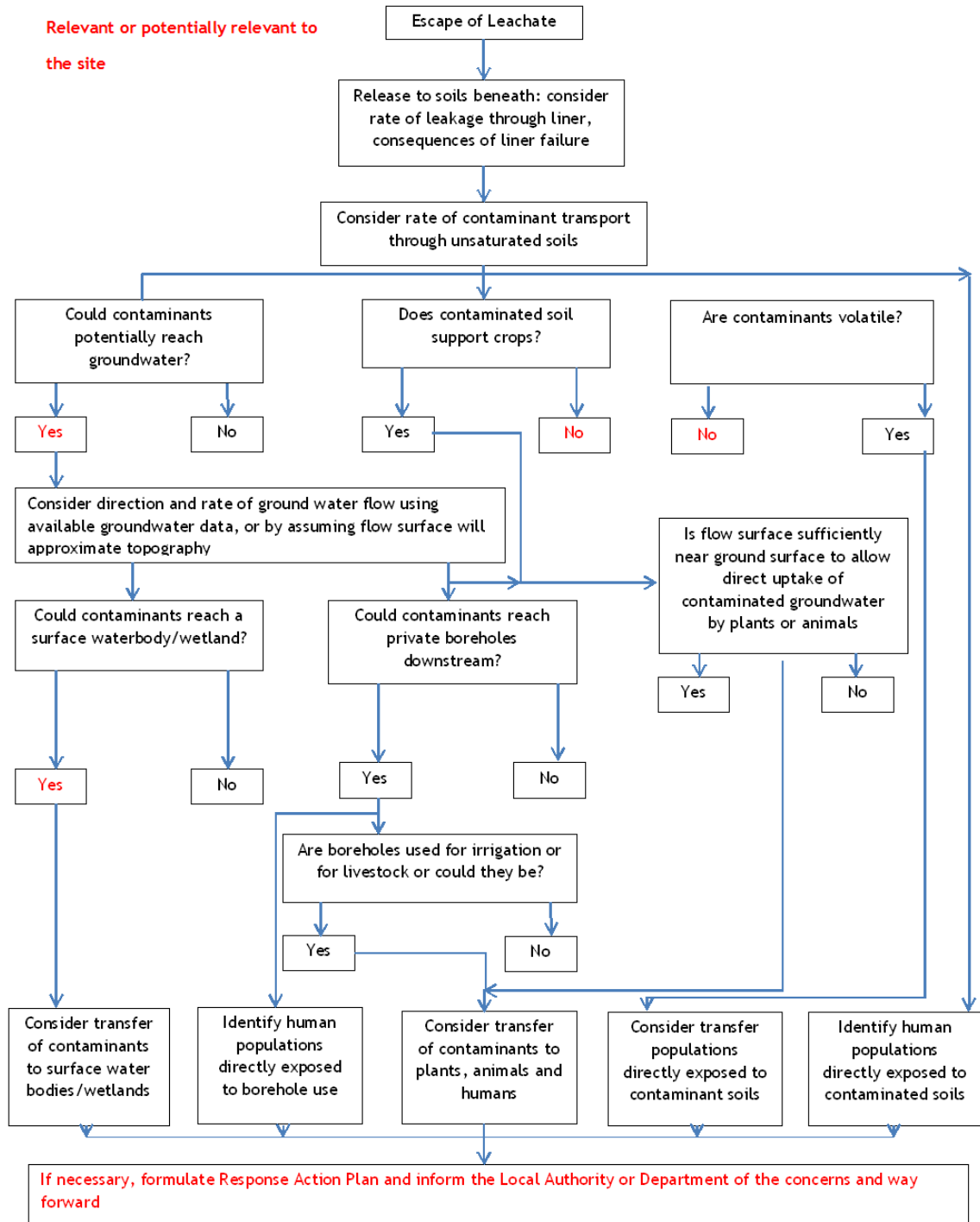


Figure 10: Environmental Consequences of Failure for Groundwater

11. CONCLUSIONS AND RECOMMENDATIONS

This section will briefly summarise the current groundwater conditions in the area of the landfill and the recommendations to minimise the effect of the landfill on the groundwater.

11.1 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

11.2 Desk Study

A description of the regional area information is given below:

- The Nondweni landfill site is located approximately 0.5 km south of the town of Nondweni in KwaZulu-Natal. It is bordered on all sides by local streams, with the Amahlungulu village to its southeast.
- The site is situated in the Usutu to Mhlatuze sub-area of the Pongola-Umzimkulu Water Management Area (WMA), in quaternary catchment W21E.
- 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 31 years) is approximately 807 mm, with the high rainfall months between November and March.
- The landfill site falls within quaternary sediments, which are underlain by the Dwyka formation, which consists of glacial sedimentary rocks. Below the Dwyka formation, the Nondweni formation is present, which consists predominantly of mafic rock, banded chert, calc-silicate rocks and micaceous schists. Jurassic dolerite can also be found in the area.

11.3 Hydrogeological Setting

11.3.1 Topography and drainage

- The area is characterised by a sharp undulating topography and in the area of the landfill site the slope is more or less in the order of 4:100 (0.04).
- Locally, drainage on site is towards the east. Two non-perennial streams border the site to the north and south, where drainage is routed to.

11.3.2 Hydrocensus

A hydrocensus was conducted as a site familiarisation exercise and collection of essential groundwater related data from the study area and surrounding environments. The hydrocensus was conducted on 9 October 2015. However, no boreholes were encountered in the area.

11.3.3 Water levels

No boreholes were encountered during the hydrocensus.

11.3.4 Water quality

No boreholes were encountered during the hydrocensus.

11.4 Source-Pathway-Receptor

The sources, pathways and receptors identified can be described as follows:

- Sources - Landfill Site -Unlined and a potential source of leachate. No berms or trenches to capture leachate.
- Pathways - Possible exposure through surface water runoff. No berms or trenches to capture or route runoff. No lining to capture leachate to groundwater.
- Receptors - Potential surface water users in the local village.

Based on the site visit, the groundwater pathway is currently not complete, as no boreholes were encountered, which can be used for groundwater abstraction. However, should contaminants from the landfill (source) travel through the vadose zone to the aquifer (pathway) it is likely that groundwater may be affected, as the uppermost geology on site is highly permeable. Additionally, any surface water body (receptor) which is connected to groundwater in the vicinity of the site is likely to be affected. Therefore, storm water trenches and leachate capture systems must be considered for the site.

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 Minor Aquifer System
- The aquifer vulnerability can be regarded as Medium
- The aquifer protection classification is Medium to Low

11.6 Water Management Options

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.

11.6.1 During Operations

The following surface water management options are recommended during operations:

- In Class G:C and G:S landfills, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation.
- Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a Minimum Requirement, as spoil from the excavation makes this possible.
- The basic landfill unit is a cell of compacted waste which, when completed at the end of each day, is entirely contained by cover material. The sides are usually formed by 1,5m to 2,0m high berms, constructed from soil, rubble, or sloped waste covered by daily cover.
- Regardless of the co-disposal ratio used or the amount of leachate generated, it is a Minimum Requirement that there are no free liquid surfaces on the landfill and that the fill is trafficable.
- Upslope run-off water must be diverted away from the waste, to prevent water contamination and to minimise leachate generation.
- Where contaminated water or leachate does arise on a site, it must be managed. This means that it must be kept out of the environment. This also applies to the drainage from wash bays and spills at hazardous waste landfills.
- Clean, uncontaminated run-off water must not be permitted to mix with, and increase the volume of, contaminated water.
- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cutoff drains.
- Water contaminated by contact with waste, as well as leachate, must be contained within the site. If it is to be permitted to enter the environment, it must conform or be treated so as to conform to the Special or General Effluent Standards in terms of the Permit. [Ref. Government Gazette, No. 9225, 18 May 1984].
- The bases of trenches and cells must be so designed that water drains away from the deposited waste. Alternatively, cells must be so orientated as to facilitate drainage away from deposited waste. The resulting contaminated water, together with all other contaminated run-off arising from the landfill, must be stored in a sump or retention dam. It may be pumped from the dam and disposed of if it conforms to the Special, General or Specific Effluent Standards stipulated in the Permit.
- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.
- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.
- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

The following groundwater management options are recommended during operations:

- At B- sites, any sporadic leachate generated on account of unusual circumstances must be both reported to the Department and properly controlled. This could also include leachate recycling.

- Although no risk to groundwater users currently exists at the site, based on the sampling data, it is imperative that monitoring takes place and that lining of the landfill is considered to protect the aquifer, after implementation of the monitoring network and based on monitoring data and the risk profile of the site.

11.6.2 Rehabilitation and closure

The following measures should be implemented during 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.

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.

11.7 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. The monitoring as recommended in the report should be established as soon as the monitoring boreholes are drilled.
- Monitoring of groundwater upstream and downstream of the landfill site are 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, ongoing basis during the landfill operations. This data will 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