Groundwater Impact Assessment for the Proposed Installation of an Underground Diesel Storage Tank – Herold's Bay Sewage Pump Station, Western Cape

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PROJECT TEAM

Report: DHS-24-263

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Author's Resume

Divan Stroebel is a SACNASP registered and active member of the Groundwater Division, the Geological Society of South Africa, hydrogeologist and professional geoscientist with more than 17 years of industry experience. He obtained his B.Sc. (Geology) degree in 2005 and his B.Sc. Honours (Geology) degree in 2006 from Stellenbosch University. From 2007, he worked throughout Africa as an exploration geologist in base metal, iron ore and gold exploration. In 2009 he joined a hydrogeological consultancy and completed additional groundwater modules at the Institute for Groundwater Studies (IGS), University of Free State. These modules included Aquifer Mechanics, Groundwater Chemistry, Groundwater Geophysics, Groundwater Modelling and Groundwater Management.

He was employed by mining giant, Rio Tinto in 2010 in Guinea as a Geologist, after which he was the Superintendent Geologist at Goldfields' Kloof mine from 2012. He joined AEON at the Nelson Mandela University (NMU) in 2014 as Associate Research Manager for the Karoo Shale Gas Research Programme- focused on Karoo hydrogeology.

Divan's technical experience includes all aspects of mineral exploration, extraction and reserve management as well as hydrogeological assessments, aquifer characterisation, groundwater supply development, groundwater and surface water characterisation and monitoring as well as water quality assessments.

Divan is very active in the hydrogeological community and has attended, presented at and co-organised numerous water-research workshops and conferences. In June 2016, he was appointed as a visiting researcher at Queen's University, Belfast. In China (2017), he successfully completed an international training programme on the Sustainable Development of Water Resources in Arid Regions for Developing Countries.

During his time at AEON, Divan researched the Groundwater Hydrochemistry and Aquifer Connectivity Baseline of the Eastern Cape Karoo. In anticipation of the controversial hydraulic fracturing planned for the Eastern Cape, he has obtained unique experience in the determination of salinity, aquifer yields and groundwater levels of the Karoo's scarce groundwater resources and has published an article in a special publication by the Geological Society of London on fractured aquifers on the topic. https://sp.lyellcollection.org/content/479/1/129

Divan is the founder and owner of DHS Groundwater Consulting Services and leads the team as principal hydrogeologist, overseeing all projects from inception to completion.

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- All the particulars furnished by me in this document are true and correct.

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Executive Summary

DHS Groundwater Consulting Services (Pty) Ltd. was appointed by Sharples Environmental Services cc to conduct a groundwater impact assessment prior to the proposed installation of an underground diesel storage tank (UST) at new Sewage Pump Station in Herold's Bay, Western Cape. The purpose of this geohydrological assessment is to determine any impact that the proposed installation may have on groundwater.

The site is underlain by the Maalgaten Granite which forms part of the George Pluton and the Cape Granite Suite. To the immediate south of the site, the Skaapkop Formation of the Kaaimans Group is observed.

According to DWAF, the site is underlain by a low-yielding, intergranular and fractured aquifer, which suggests groundwater presence in both the shallow, unconsolidated rock as well as in deeper, fractured rock. This is supported by the fact that groundwater was intersected in the two geotechnical boreholes, BH1 and BH2, at depths of 2.40- and 0.98 mbgl respectively. The boreholes intersected sandy colluvium followed by completely weathered colluvium consisting of granite schist which gradually grades into highly weathered schistose granite with both boreholes being terminated in moderately weathered schistose granite. BH1 was drilled to a depth of 8.67 mbgl, whilst BH was drilled to a depth of 8.20 mbgl.

No boreholes were identified during the hydrocensus or from various DWS databases within a reasonable distance of the site (1 km radius and maximum 3 km) or within the defined Groundwater Response Unit. It is thus assumed that groundwater use within the area is very limited to non-existent. Based on the national scale electrical conductivity map of South Africa, groundwater within the area typically exhibits a poor water quality ranging between 370- to 520 mS/m.

The aquifer vulnerability of the site is classified as "least" according to the DRASTIC method, which is consistent with the Aquifer System Management Index and Groundwater Quality Management index of "low". The lack of or absence of fractures present in the deeper bedrock may attribute to the low aquifer vulnerability. However, the intergranular aquifer which comprises the shallow, unconsolidated material, are likely to be more vulnerable and would require a higher degree of protection. This holds especially true for the investigated site.

Given the vulnerability rating of the aquifer, the "Source-Pathway-Receptor" principle is applied to determine the impact of the planned installation of the underground diesel storage tank. This is applied to both the construction and operational phase. Identified sources of contamination include spillages of toxic and harmful chemicals and leakages from the UST and associated pipework. The underlying aquifer, which includes the identified shallow aquifer as well as the deeper aquifer, represents both a pathway for contaminants as well as being a receptor. Evidence is seen of a fluctuation saturated level which may be an indication of groundwater-surface water interaction. Potential contaminants may enter the shallow aquifer and percolate into the adjacent stream. The aforementioned pathway is identified is the main area of concern.

The receptors of potential contaminants are thus mostly the shallow aquifer and to a lesser extent the deeper aquifer. No groundwater users were identified as receptors. Further potential receptors include the adjacent stream and surrounding environment. Potential contamination will be limited to the site proximity with the furthest extent being the coastal plain, situated approximately 150 m south-east of the site, should contaminants enter the stream. With this in mind, the risk assigned to the construction and operational phase of the proposed UST is classified as minor - negative. Special note should be taken of the identified shallow aquifer which may place the UST in close proximity or within the water table. The shallow water table will, however, enable early leak detection through installed piezometers. It is thus imperative that stringent mitigation measures are implemented to decrease the risk to the indicated negligible – negative. To prevent any contamination of the groundwater, regular monitoring thereof is strongly recommended.

The following recommendations are made:

- It is recommended that the monitoring network be installed prior to the installation of the UST and relevant mitigation, as described herein, is employed.
    - This will serve as monitoring of both the construction and operational phase.
- At least two monitoring boreholes are recommended to detect any potential contaminants.
    - Boreholes to be drilled to a depth of 20m.
    - Drilled at least 165mm in diameter.
    - Fitted with slotted, class 12, flush-fit, threaded ends, uPVC with an end cap (slots ideally from 2m down).
    - The inner diameter of the uPVC casing should not be less than 110 mm.
    - Gravel pack in borehole annulus (typically 3-5 mm in diameter).
    - Top 2m of annulus to be filled with bentonite seal.
    - Borehole to be fitted with lockable protection and to be clearly marked.
- Water levels and physical parameters should be recorded at least quarterly, with sampling and chemical analysis of major and trace anions and cations, inclusive of DOC, BTEX and VOC on a bi-annual basis.
    - Samples to be submitted to accredited SANAS laboratory and sample collection and transport as per laboratory standards.
- Shallow piezometers are to be installed in close proximity of the UST.
    - Minimum installation depth of 3.50 mbgl.
- A rapid response plan must be developed should any hydrocarbon spillages or leakages be detected.

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List of Abbreviations

Term	Definition
%	Percentage
CDT	Constant Discharge Test
CFU	Colony Forming Unit
DEA	Department of Environmental Affairs
DRO	Diesel Range Organics
DWAF	Department of Water Affairs & Forestry
DWS	Department of Water & Sanitation
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EWR	Ecological Water Requirement
GA	General Authorisation
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
GQM	Groundwater Quality Management
GRDM	Groundwater Resource Directed Measures
GRO	Gasoline Range Organics
GRU	Groundwater Resource Unit
Ha	Hectare
K	Hydraulic Conductivity
km	Kilometre
km^2	Square Kilometre
l/h	litres/hour
l/s	litres/second
LDPE	Low density polyethylene
M	meter
m/d	Meters per day
m^3	Cubic Meters

Term	Definition
m^3/a	Cubic Meters/annum
$m^3/ha/a$	Cubic Meters/hectare/annum
mamsl	meters above mean sea level
mbcl	meters below casing level
mbgl	meters below ground level
ML/d	Mega Litre/day
mm/a	Millimetres/annum
Mm^3/a	Million Cubic Meters/annum
mS/m	Millisiemens per meter
NEMA	National Environmental Management Act
NGA	National Groundwater Archive
nm	not measured
NTU	Nephelometric Turbidity Units
NWA	National Water Act
^oC	Degrees Centigrade
SABS	South African Bureau of Standards
SANAS	South African National Accreditation System
SANS	South African National Standards
SWL	Static water level
T	Transmissivity
TMG	Table Mountain Group
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
WARMS	Water Use Authorization & Registration Management System
WRC	Water Research Commission
WULA	Water Use Licence Application

1 Introduction

DHS Groundwater Consulting Services (Pty) Ltd. was appointed by Sharples Environmental Services cc to conduct a groundwater impact assessment prior to the proposed installation of an underground diesel storage tank (UST) at new Sewage Pump Station in Herold's Bay, Western Cape. The purpose of this geohydrological assessment is to determine any impact that the proposed installation may have on groundwater.

2 Scope of Work

The objective of this assessment is to:

- Complete a geohydrological characterisation of the groundwater in the vicinity of the site;
- Complete an assessment of the groundwater use in the area by means of a hydrocensus, up to a maximum distance of 1 km from the site;
- Propose measures to mitigate identified negative impacts;
- Advise on a monitoring program as part of an environmental management plan;

This report is not intended to be an exhaustive description of the assessment, but rather serves as a specialist geohydrological assessment to evaluate the overall geohydrological character of the site, to inform the impact assessment, and propose mitigation measures where applicable.

3 Methodology

It must be stated that no intrusive groundwater investigations were done and reporting is thus based on and limited to observations made during the site visit, hydrocensus and the collation of available information. The work completed for the purposes of compiling a geohydrological report comprised the following:

3.1 Desktop Study

Undertake a desk study of existing information available from relevant literature, the National Groundwater Archive (NGA), the Water Use Authorization & Registration Management System (WARMS), the National Water Resources Monitoring (NWRM) Network, the Water Management System (WMS) and published geological and geohydrological maps and reports.

3.2 Site Visit & Hydrocensus

A site visit was conducted to evaluate the geology, geohydrology and potential receptors of possible groundwater impacts. A hydrocensus was carried out within maximum distance of a 1km radius to identify legitimate groundwater users, the groundwater potential and quality.

3.3 Aquifer Vulnerability Assessment

The national scale groundwater vulnerability map, which was developed according to the DRASTIC methodology (DWAF, 2005)[1] and recompiled in 2013 was used to assess the project area in terms of "Aquifer Vulnerability". Aquifer Vulnerability can be defined as *"the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer".*

3.4 Aquifer Characterisation

The aquifer(s) underlying the project area was classified in accordance with "A South African Aquifer System Management Classification"[2] developed by the Water Research Commission and DWAF.

3.5 Impact Assessment

The methodology used herein is broadly consistent to that described in the Environmental Impact Assessment Regulations[3] in terms of the NEMA[4].

The risk associated with the groundwater abstraction for the property pertains to both the construction and operational phases. Each impact was assessed individually and graded using a numerical system on the following factor.

- Intensity
- Duration
- Extent
- Probability

The values assigned to each factor were used to calculate the significance of each impact. Each individual impact was assessed and re-assessed after the appropriate mitigation was applied.

The "Impact Assessment Methodology" is presented in Chapter 8.

[1] DWAF, 2005. Groundwater Resources Assessment Project, Phase II (GRAII). Department of Water Affairs and Forestry, Pretoria.

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

[3] Environmental Impact Assessment Regulations, 2014 published under Government Notice No. 982 in Government Gazette No. 38282 of 4 December 2014

[4] National Environmental Management Act, 1998 (Act No. 107 of 1998) ("NEMA")

4 Setting

4.1 Site Location

The site is located within the Western Cape in the George Municipality in the town of Herold's Bay. The site is situated on erf number 116. (Figure 1).

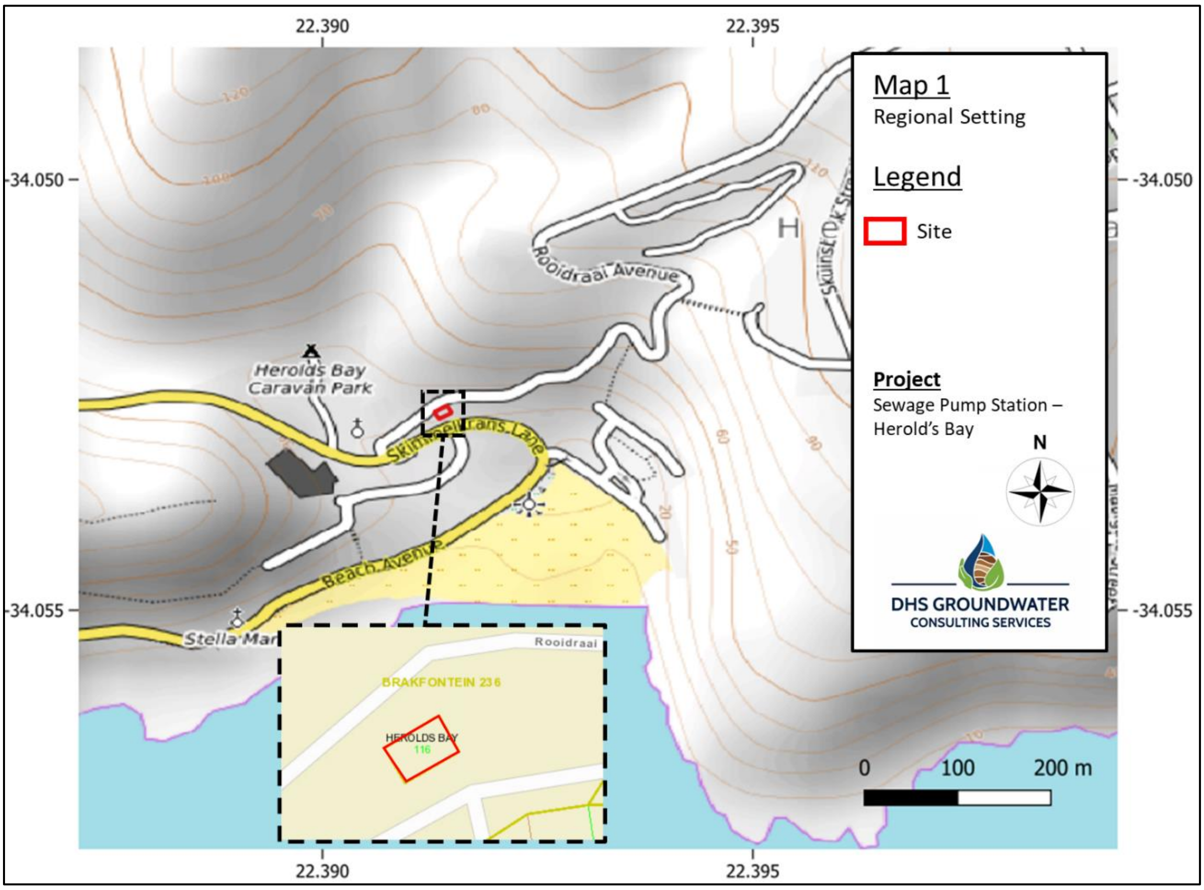


Figure 1. Site locality.

4.2 Topography and Surface Drainage

The site is located in quaternary catchment K30A within the Breede-Gouritz Water Management Area (WMA). The site is drained by a localised stream flowing in an easterly direction onto the Herold's Bay beach.

4.3 Climate

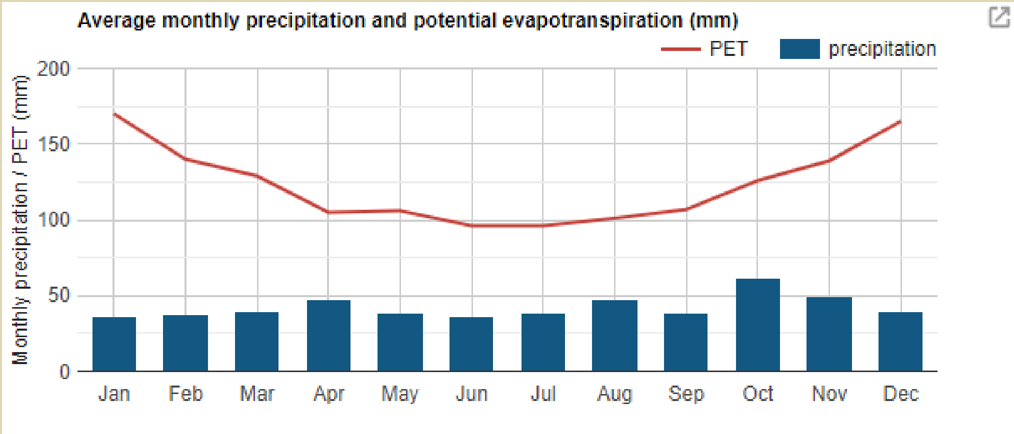
The weather is mild without extreme conditions with an average summer temperature of 19.55°C and a winter temperature of 13.10°C. The winter months of June, July and August receive the lowest average windspeed of 11.55 km/h while the summer months of December, January and February receive the highest average windspeed of 14.11 km/h.

Meteorological data obtained from SamSam Water Climate Tool[5] is presented in Figure 2. Figures of 515 mm for the mean annual precipitation (MAP) and 1487 mm for the potential evapotranspiration (PET) is reported. The PET exceeds the MAP by an order of magnitude, resulting in a negative moisture index. Rainfall within the study area is bimodal where both summer and winter rainfall occurs, a feature typical of the south-east coastal region of the country.

SamSamWater Climate Tool

Latitude, longitude: -34.0528, 22.3913

The average annual rainfall (1970-2000) for this location is 515 mm per year.
Average monthly rainfall and potential evapotranspiration (PET) values are displayed in the chart and table below.



description	PET	precipitation
01 - January	170	36
02 - February	140	38
03 - March	129	40
04 - April	105	48
05 - May	106	39
06 - June	96	36
07 - July	96	39
08 - August	101	48
09 - September	107	39
10 - October	126	62
11 - November	139	50
12 - December	165	40
Total	1,487	515

To copy the data for use in other software: click on the icon in the top-right corner of the table to open in a new tab. There you can select and copy the values.

Close

The data in this tool is sourced from WorldClim v2 and Global Aridity Index and Potential Evapotranspiration (ET0)

Figure 2. Precipitation and evapotranspiration within the project area.

[5] https://www.worldclim.org/ & Global Aridity Index and Potential Evapotranspiration Climate Database v2

4.4 Geology

The site is underlain with the Maalgaten Granite and forms part of the George Pluton and is part of the Cape Granite Suite of rocks. To the immediate south of the site is the Skaapkop Formation which forms part of the Kaaimans Group. This is present as a thin band of metasediments in the form of gritty quartzites, phyllite and schist.

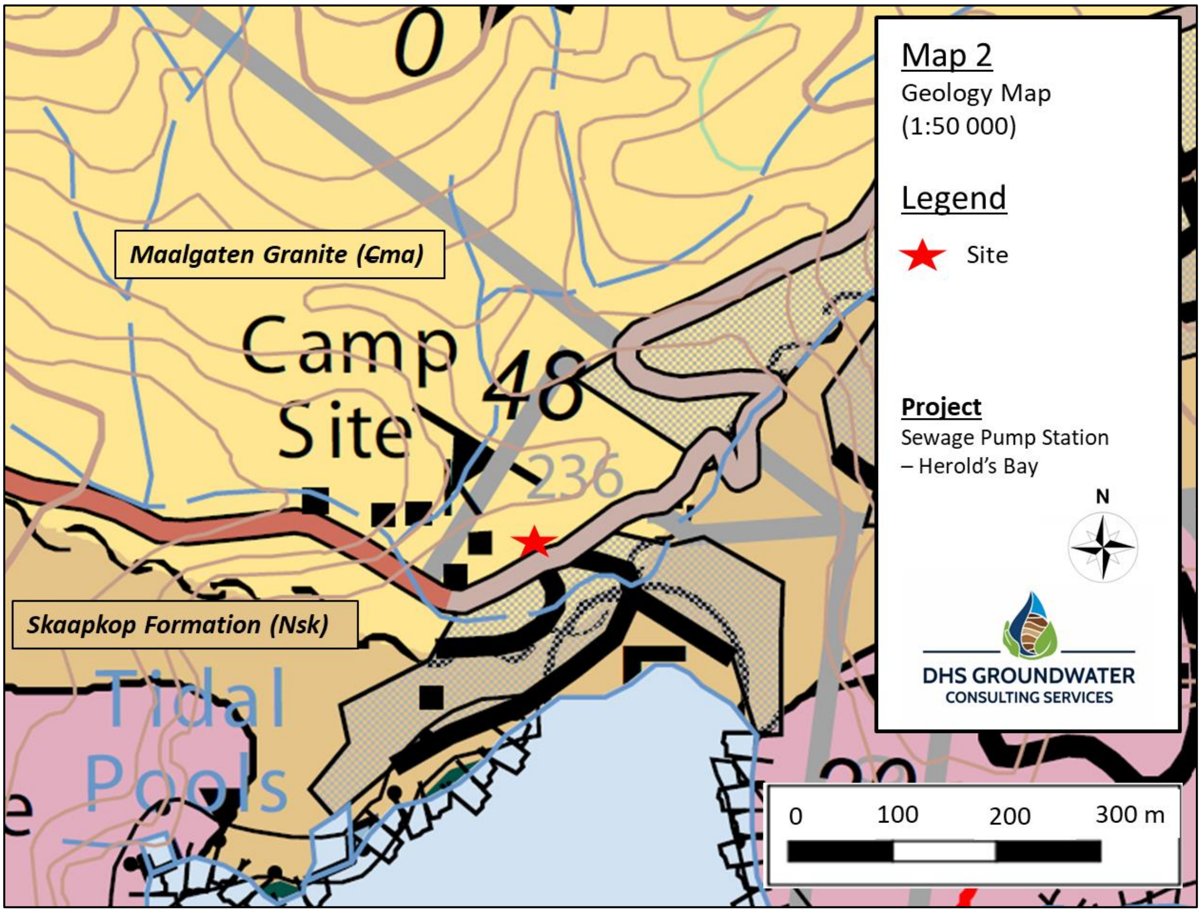


Figure 3. 1:50 000 Geological map.

The Maalgaten Granite is a leucocratic, mostly porphyritic, biotite-muscovite granite with variable degrees of deformation. The Cape Granite Suite was emplaced during several distinct cycles of magmatism during the late Ediacaran to Early Cambrian. These granites were probably derived from melting of the Neoproterozoic Kaaimans Group of the Pan-African Saldania Belt, which they intrude.

The lithostratigraphy is shown in Table 1.

Table 1. Lithostratigraphy of underlying geology.

Supergroup	Group	Formation	Lithology
Cape Granite Suite	~	Maalgaten Granite (Ꞓma)	Leucocratic, mostly porphyritic, biotite-muscovite granite
~ ~	Kaaimans	Skaapkop (Nsk)	Gritty quartzite, Phyllite and Schist

4.5 Geohydrology

Aquifers within the Cape Granites are mostly associated with erosion processes and other secondary deformation processes. Older granites have better water potential, due to a more developed and higher erosion structure. If the erosion is deeper than the water table, the likelihood of water is very high.

The metasediments of the Kaaimans Group are typically not classified as a potential aquifer system and holds a low potential for groundwater development due to its impermeable argillaceous and clayey nature. Furthermore, although it has undergone several deformational episodes, little fracturing occurs due to the incompetent nature of the rocks. Well-developed foliation and lineation patterns caused by the intrusion of the cape granite suite are indicated as areas favourable for groundwater exploitation, however limited.

Unless otherwise stated, the published 1:500 000 General Hydrogeological Map[6] and associated explanatory booklet[7] were used as basis to describe the geohydrological conditions.

4.6 Aquifer Types and Borehole Yields

Groundwater within the project area occurs predominantly within intergranular and fractured rock aquifers with reported yields of 0.1 – 0.5 L/s.

4.7 Depth to Groundwater

The static groundwater level generally occurs at approximately 21m below surface. It must be stated that this is low resolution interpolation and is an average. It is not intended to define water level depths on small scale.

4.8 Groundwater Recharge and Baseflow

The study area falls within quaternary catchment K30A. The mean annual precipitation and annual recharge figures for the study area is presented in Table 2. Vegter's (1995)[8] recharge and baseflow maps were used to obtain a first estimate of regional recharge and groundwater contribution to rivers and streams (baseflow).

Table 2. Regional Rainfall, Recharge and Baseflow.

Mean Annual Precipitation (mm):	515
Annual Recharge (mm):	50 - 75
Percentage Recharge of MAP:	9.71% - 14.56%
Annual Baseflow (mm):	> 100
Percentage Baseflow of MAP:	> 19.42%

[6] 1:500 000 General Hydrogeological Map, Oudtshoorn 3320 (1998)

[7] MEYER, P S (1999). An explanation of the 1:500 000 General Hydrogeological Map Oudtshoorn 3320. Department of Water Affairs and Forestry, Pretoria.

[8] Vegter, J.R. (1995). An explanation of a set of national groundwater maps; WRC Report No. TT 74/95. Water Research Commission, Pretoria.

4.9 Groundwater Quality

Electrical Conductivity (EC) of groundwater in the area is generally between 370 and 520 mS/m[9]. This is considered as a "poor" water quality with respect to drinking water standards.

4.10 Aquifer Vulnerability

The national scale Groundwater Vulnerability Map, which was developed according to the DRASTIC methodology (DWAF, 2005) and recompiled in 2013 was used to assess the aquifers underlying the site in terms of "Aquifer Vulnerability". Aquifer Vulnerability can be defined as *"the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer"*.

The DRASTIC method takes into account the following factors:

- D = depth to groundwater (5)
- R = recharge (4)
- A = aquifer media (3)
- S = soil type (2)
- T = topography (1)
- I = impact of the vadose zone (5)
- C = conductivity (hydraulic) (3)

The number indicated in parenthesis at the end of each factor description is the weighting or relative importance of that factor.

Aquifer Vulnerability is rated as follows:

Green represents the least vulnerable region that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached
Yellow represents the moderately vulnerable region, which is vulnerable to some pollutants, but only when continuously discharged or leached.
Red represents the most vulnerable aquifer region, which is vulnerable to many pollutants except those strongly absorbed or readily transformed in many pollution scenarios.

[9] Murray R, Beker K, Ravenscroft P, Musekiwa, C AND Dennis, R. (2012). A Groundwater Planning Toolkit for the Main Karoo Basin: Identifying and quantifying groundwater development options incorporating the concept of wellfield yields and aquifer firm yields. WRC Report No. 1763/1/11, Pretoria, South Africa.

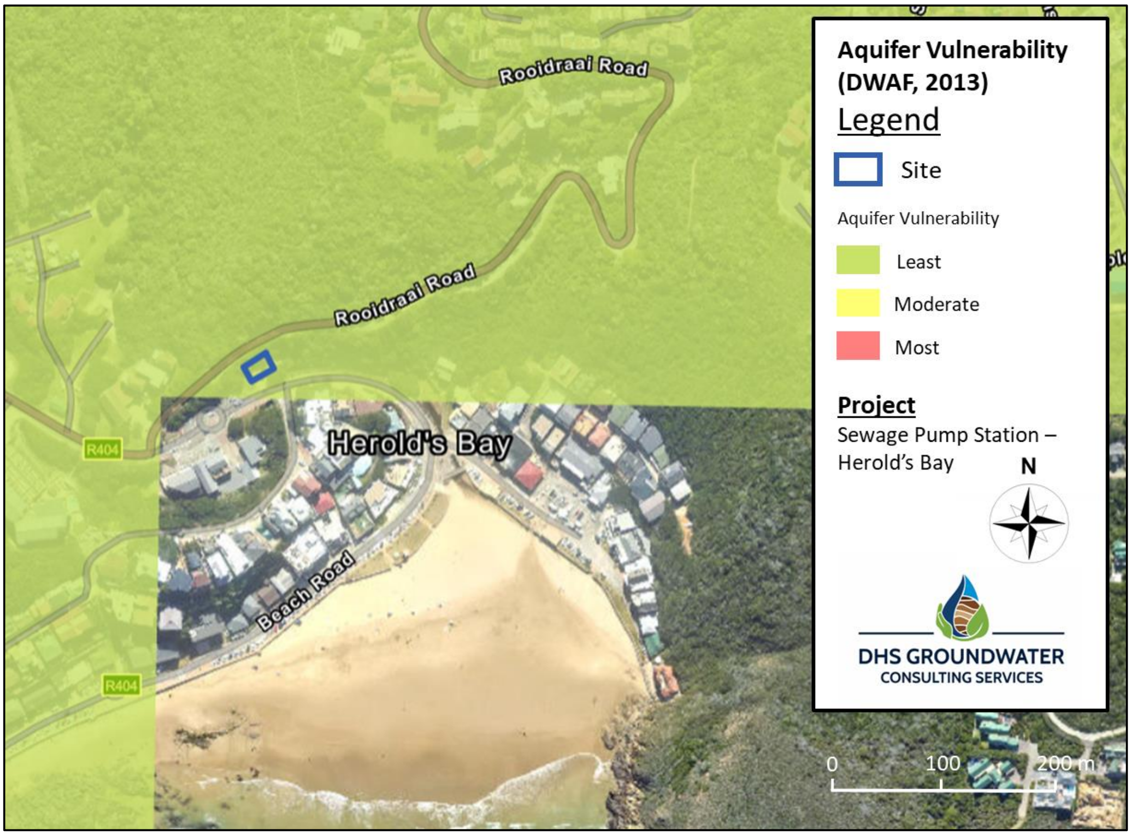


Figure 4. Regional groundwater vulnerability for the study area (DWAF, 2013).

The vulnerability of the aquifers within the project area is rated as "least" vulnerable to pollutants.

5 Site Specific Assessment

5.1 Review of Geotechnical Report – Report no.: 23060G-01(0311-RP-Rev0) by PeraGage

Two boreholes were drilled on-site to respective depths of 8.67- (BH1) and 8.20 mbgl (BH2) (Figure 5) [10].

Figure 5. Geotechnical borehole locations.

The site is underlain by a sandy colluvium to a depth of 1.60 mbgl, which gradually becomes a completely weathered granite schist to a depth of 2.30 mbgl. This is underlain by highly weathered, soft to medium hard granite schist to a depth of 4.00 mbgl. The boreholes were terminated in moderately weathered granite shist.

Groundwater was recorded at a depth of 2.40 mbgl in BH01 and at depth of 0.98 mbgl within BH02. It must be noted that upon the site investigation, which was conducted nine months since drill completion, it was found that the boreholes were destroyed by on-going construction, however, excavation pits part of the construction were open to a depth of 2.80 mbgl. The exposed subsurface strata were noted as described above, however, importantly, the excavation pits were dry with no groundwater present (Figure 6).

[10] PeraGage South Africa (Pty) Ltd. (2023). Report on the Geotechnical Investigation for the Upgrading of Herold's Bay Pump Station, George. Report no.: 23060G-01(0311-RP-Rev0).

Figure 6. On-site excavation pit showing the absence of shallow groundwater.

5.2 Existing Groundwater Information

The boreholes as identified from the various databases along with the boreholes identified during the hydrocensus are shown in the below (Figure7).

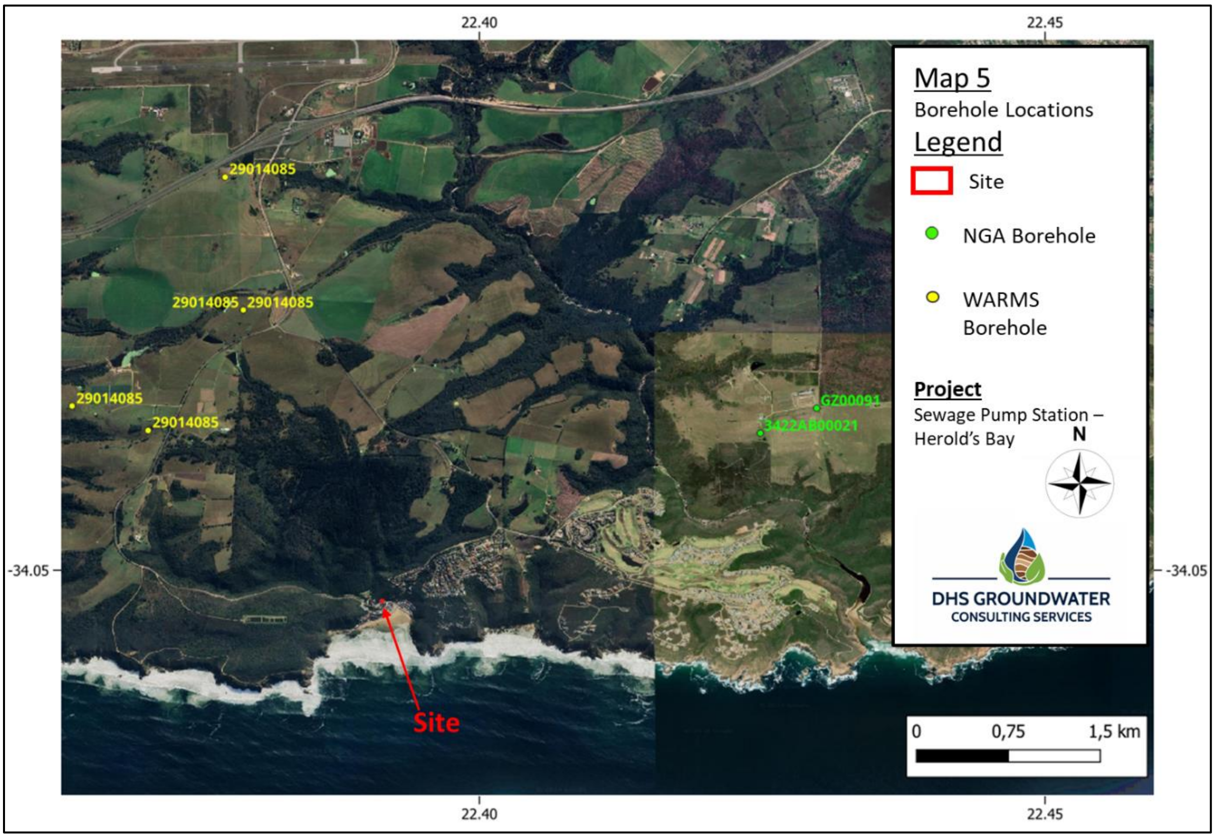


Figure 7. Borehole locations.

5.2.1 National Groundwater Archive

A desktop hydrocensus was carried out within a one-kilometre search radius around the site boundaries. This was done to determine groundwater use in the area. A search of the National Groundwater Archive (NGA), which provides data on borehole positions, groundwater chemistry and yield, when available, was carried out to identify proximal boreholes. These sites are then typically verified in the field and provide background information on the area, should they exist.

A search of the NGA produced zero boreholes within a 1 km radius from the site. The search radius was extended to 5 km and two boreholes were identified. A summary of the borehole data contained in the database is presented in Table 3.

Table 3. Summary of data contained in the NGA.

BH Id	Latitude (°)	Longitude (°)	Water Use	BH Depth (m)	SWL (mbgl)	Yield (L/s)
3422AB00021	-34.0379	22.42483	-	100		-
GZ00091	-34.03569	22.42981	Irrigation	-	14.88	5.00

5.2.2 Water Use Authorization & Registration Management System (WARMS)

The WARMS database (updated 13 February 2024) provides (but is not limited to) data on borehole positions, groundwater use and registered abstraction volume. The WARMS indicated there are zero boreholes within the 1 km search area of the site. The search was extended to a 5 km radius which identified five boreholes. The identified WARMS sites are summarised in Table 4.

Table 4. Summary of data contained in the WARMS.

Register No.	Latitude (°)	Longitude (°)	Water Use	Registered Volume m^3/a
29014085	-34.027028	22.379111	Irrigation	22043
29014085	-34.015306	22.377528	Irrigation	23703
29014085	-34.037667	22.370722	Irrigation	6680
29014085	-34.0355	22.364	Irrigation	140090
29014085	-34.027028	22.379139	Irrigation	581457

5.3 Hydrocensus

A hydrocensus was conducted on 28 February 2024 to establish groundwater use within the larger project area. The hydrocensus extended to a minimum distance of ~1km from the site boundaries, except where a river or a surface water body exist. The hydrocensus did not extend past such a feature as surface water bodies are usually hydraulically connected to an aquifer, act as a constant-head boundary and a groundwater pollution plume or cone of depression would theoretically not extend past a constant head boundary. Any information pertaining to the abstraction, yield and quality of groundwater was sought.

No groundwater users were identified. It was noted that water users opted for rainwater harvesting which is deemed sufficient as a reserve supply of water for the majority of the inhabitants within the hydrocensus area.

5.4 Groundwater Flow Direction

Generally, groundwater elevations mimic surface topography, and groundwater flows from higher lying ground towards lower lying springs or valleys (drainage lines). The five-meter contours for the area are given in Figure 8 and indicates the inferred groundwater flow directions. The site generally slopes to the east in the direction of the local stream. The general groundwater flow direction will thus be in an easterly direction towards and along the stream.

Figure 8. Map with 5m contours showing the inferred groundwater flow direction.

5.5 Groundwater Response Unit

In order to define a more localised area within which groundwater and groundwater users may be affected by potential pollutants, a "Geohydrological Response Unit" (GRU), is delineated. It is defined as a groundwater system that has been delineated or grouped into a single significant water resource based on one or more characteristics that are similar across that unit. Criteria to map a GRU would include:

1. Areas of similar geology;
2. Groundwater elevations generally mimic surface topography, and groundwater flows from higher lying ground towards lower lying springs or valleys (drainage lines), therefore surface water catchment boundaries may be used as surrogate for groundwater divides;
3. Rivers/Streams acting as a constant head boundary;
4. Impermeable dykes/lineaments acting as no-flow boundaries; and lastly
5. Expert judgement and interpretation.

For this study area there are drainage features that enable the definition of a more localised aquifer (i.e., a GRU).

The GRU has been defined as follow:

- The western, northern and eastern boundaries were defined by topographic highs;
- The southern boundary was defined by the coastal plain.

The mapped GRU covers a total area of 258 ha and is indicated in Figure 9.

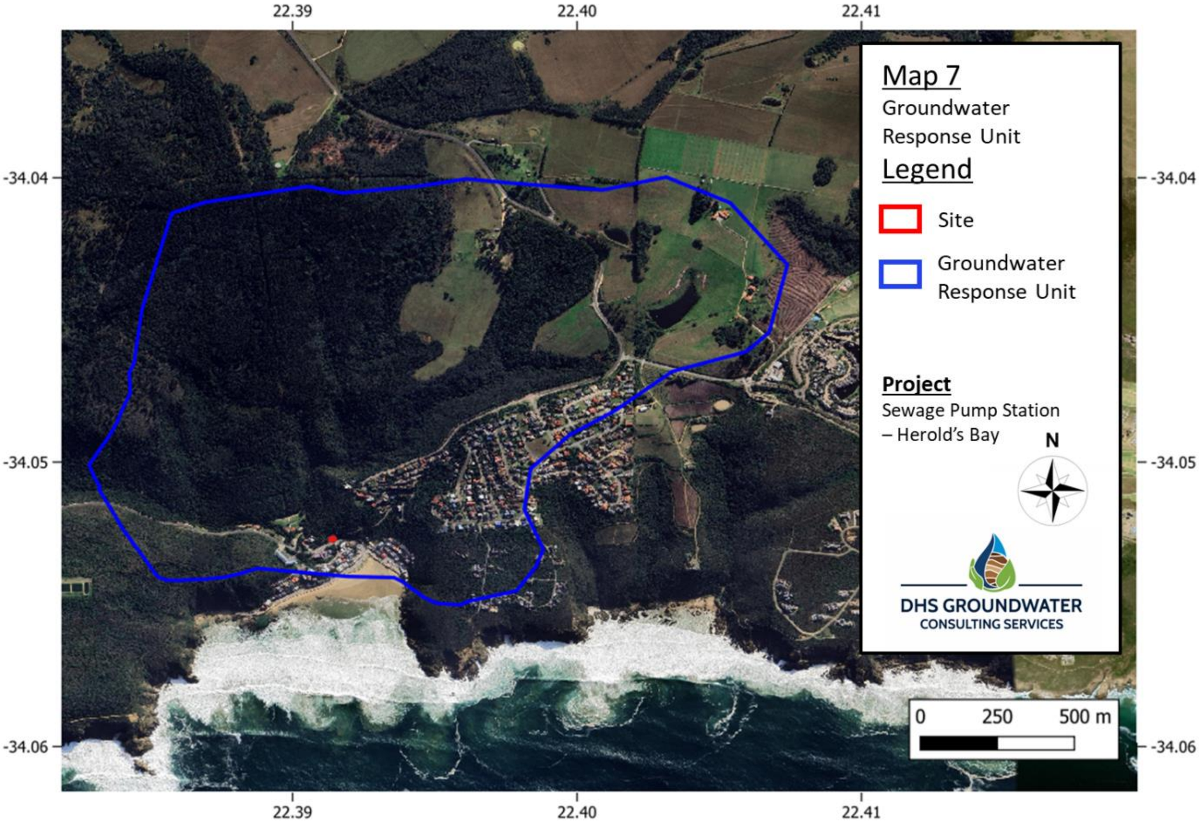


Figure 9. Mapped GRU.

<u>It is important to note that no groundwater users were identified within the GRU from both the DWS databases and during the hydrocensus.</u>

6 Aquifer Classification

The aquifer(s) underlying the project area were classified in accordance with "A South African Aquifer System Management Classification, December 1995" by Parsons. Classification has been done in accordance with the following definitions for Aquifer System Management Classes:

- 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 the available information it can be concluded that aquifer system in the study area can be classified as a "Minor Aquifer System". The aquifers are mostly important to maintain baseflow to the ecosystem and seldom produce large quantities of groundwater.

In order to achieve an Aquifer System Management Index and a Groundwater Quality Management Index a point scoring system, as presented in Table 5 and Table 7 below, was used.

Table 5. Ratings for the Aquifer System Management and Second Variable Classifications.

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

The values in Table 5 are naturally subjective, but is based on the aquifer descriptions given previously. The importance of each aquifer should provide guidance on the protection to be assigned to each area.

The level of protection required of a groundwater system depend, amongst other, on the aquifer system classification class and the fractured extent and connectivity of the aquifers. The assumption is that a higher fracture presence results in a higher aquifer connectivity. An aquifer system management index can be derived with the following equation:

Aquifer System Management Index = Aquifer System Management Class x Fracturing

= 2 x 1 = 2

Table 6. Ratings for the Aquifer System Management Index.

Aquifer System Management Index	**Level of Protection**	**Study Area**
<1 1 - 3 3 - 6 6 - 10 >10	Limited Low Level Medium Level High Level Strictly Non-Degradation	2

The ratings for the Aquifer System Management Classification and Second Variable Classification (Fracturing) yield an Aquifer System Management Index of 2 for the study area, indicating that a "low" level of groundwater protection is required in terms of prevailing groundwater flow regime management.

Table 7. Ratings for the Groundwater Quality Management (GQM) Classification System.

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

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 1 = 2

Table 8. GQM index for the study area.

GQM Index	Level of Protection	Study Area
<1 1 - 3 3 - 6 6 - 10 >10	Limited Low Level Medium Level High Level Strictly Non-Degradation	2

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 2 for the study area, indicating that a "low" level of groundwater protection is required in terms of groundwater quality management.

In terms of DWS's overarching water quality management objectives which is (1) protection of human health and (2) the protection of the environment, the significance of this aquifer classification is that if any potential risk exists, measures must be triggered to limit the risk to the environment. In this instance it would be the (1) protection of the "Minor Aquifer", (2) the external groundwater users in the area, and (3) maintain baseflow to the Kat River which drains the subject area.

7 Preliminary Risk Assessment

In order to assess the risks associated with the proposed development at the site specifically with reference to the UST, the "Source-Pathway-Receptor" principle was applied as outlined in the G4 Impact Prediction Best Practice Guideline for the Mining Industry (DWA, 2007)[11] . The following preliminary risk assessment is based on the information collected during the desktop study, literature review and fieldwork assessment.

7.1 Identified Sources

The sources of groundwater contamination for the development can be grouped into those associated with the construction phase as well as the operational phase.

7.1.1 Construction Phase

Sources of pollution from construction sites usually include hydrocarbons, paint, solvents, cleaners and other harmful chemicals. This also includes miscellaneous construction debris and dirt.

Soil contamination, with subsequent groundwater contamination, is a possibility during the construction phase as a result of improper management, use, disposal or spillage of hazardous materials and substances not limited to hydrocarbons, solvents and cement. Should solid waste material generated during the construction phase not be stored correctly prior to disposal, soil contamination is likely to occur.

Groundwater contamination can also occur if contaminants are spilled on hard surfaces and are then washed by rainwater into stormwater systems where they are then discharged into the surrounding environment or directly into the local stream.

7.1.2 Operation Phase

There are several potential groundwater pollutants that may potentially emanate from an operational underground hydrocarbon storage tank.

- The potential for spillages and seepages is amongst the highest of concerns that exists with the underground storage of fuel;
- Parking areas where oil and grease may leak from vehicles and subsequently wash into the nearby stream;
- General industrial and workshop related spillages.

7.2 Pathways

The potential risk pathways pertaining to the site are typically as follows:

- The weathered soil/vadose zone and the saturated water level (shallow aquifer);
    - Should contaminants leach into the soil to percolate into the groundwater system, there is a high possibility that they could be transported into the proximal stream;
- The deeper fractured aquifer;
    - Although the aquifer underlying the site is classified as minor with low permeability, the presence of secondary fractures within the underlying aquifer may well serve as hydraulic pathways for any potential contaminants percolating through the shallow aquifer and into the deeper aquifer.

[11]. 2007. Best Practice Guidelines: Impact Prediction (G4).

7.3 Receptor

The receptor of potential contaminants will be the following:

- Shallow and Deeper Aquifer;
- Adjacent stream;
- Surrounding environment.

It is evident from the above that the risk of potential contaminants entering the groundwater (and the nearby stream and environment) is high should no mitigation plans be in place.

7.4 Recommended Mitigation Plans

In order to mitigate the risk, monitoring boreholes should be drilled and pump tested to assess the aquifer, both shallow and deep, characteristics. From the geological logs of the underlying lithology and hydraulic properties of the aquifer, methods to mitigate the risk can be established based on the level of risk.

8 Impact Assessment

The assessment of the predicted significance of impacts for a proposed development is by its nature, inherently uncertain – environmental assessment is thus an imprecise science. To deal with such uncertainty in a comparable manner, a standardised and internationally recognised methodology has been developed. This methodology will be applied in this study to assess the significance of the potential environmental impacts of the proposed development.

For each predicted impact, certain criteria are applied to establish the likely **significance** of the impact, firstly in the case of no mitigation being applied and then with the most effective mitigation measure(s) in place.

These criteria include the **intensity** (size or degree scale), which also includes the **type** of impact, being either a positive or negative impact; the **duration** (temporal scale); and the **extent** (spatial scale). For each predicted impact, the specialist applies professional judgement in ascribing a numerical rating for each of these criteria respectively as per Table 9, Table 10 and Table 11 below. These numerical ratings are used in an equation whereby the **consequence** of the impact can be calculated. Consequence is calculated as follows:

Consequence = type x (intensity + duration + extent)

Depending on the numerical result, the impact's consequence would be defined as either extremely, highly, moderately or slightly detrimental; or neutral; or slightly, moderately, highly or extremely beneficial. These categories are provided in Table 13.

To calculate the significance of an impact, the **probability** (or likelihood) of that impact occurring is also taken into account. The most suitable numerical rating for probability is selected from Table 12 below and applied with the consequence as per the equation below:

Significance = consequence x probability

Depending on the numerical result, the impact would fall into a significance category as negligible, minor, moderate or major, and the type would be either positive or negative. These categories are provided in Table 14.

Once the significance of an impact occurring without mitigation has been calculated, the specialist must also apply their professional judgement to assign ratings for the same impact after the proposed mitigation has been implemented.

The tables on the following pages show the scales used to classify the above variables, and define each of the rating categories.

Table 9. Definition of Intensity ratings.

Rating	Criteria	
	Negative impacts (Type of impact = -1)	**Positive impacts** (Type of impact = +1)
7	Irreparable damage to biophysical and / or social systems. Irreplaceable loss of species.	Noticeable, on-going benefits to which have improved the quality and extent of biophysical and / or social systems, including formal protection.
6	Irreparable damage to biophysical and / or social systems and the contravention of legislated standards.	Great improvement to ecosystem processes and services.
5	Very serious impacts and irreparable damage to components of biophysical and / or social systems.	On-going and widespread positive benefits to biophysical and / or social systems.
4	On-going damage to biophysical and / or social system components and species.	Average to intense positive benefits for biophysical and / or social systems.
3	Damage to biophysical and / or social system components and species.	Average, on-going positive benefits for biophysical and / or social systems.
2	Minor damage to biophysical and / or social system components and species. Likely to recover over time. Ecosystem processes not affected.	Low positive impacts on biophysical and / or social systems.
1	Negligible damage to individual components of biophysical and / or social systems.	Some low-level benefits to degraded biophysical and / or social systems.

NOTE: Where applicable, the intensity of the impact is related to a relevant standard or threshold, or is based on specialist knowledge and understanding of that particular field.

Table 10. Definition of Duration ratings.

Rating	Criteria
7	**Permanent:** The impact will remain long after the life of the project
6	**Beyond project life**: The impact will remain for some time after the life of the project
5	**Project Life:** The impact will cease after the operational life span of the project
4	**Long term**: 6-15 years
3	**Medium term:** 1-5 years
2	**Short term:** Less than 1 year
1	**Immediate**: Less than 1 month

Table 11. Definition of Extent ratings.

Rating	Criteria
7	**International:** The effect will occur across international borders
6	**National:** Will affect the entire country
5	**Province/ Region:** Will affect the entire province or region
4	**Municipal Area:** Will affect the whole municipal area
3	**Local:** Extending across the site and to nearby settlements
2	**Limited:** Limited to the site and its immediate surroundings
1	**Very limited:** Limited to specific isolated parts of the site

Table 12. Definition of Probability ratings.

Rating	Criteria
7	**Certain/ Definite:** There are sound scientific reasons to expect that the impact will definitely occur
6	**Almost certain/Highly probable:** It is most likely that the impact will occur
5	**Likely:** The impact may occur
4	**Probable:** Has occurred here or elsewhere and could therefore occur
3	**Unlikely:** Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
2	**Rare/ improbable:** Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the project but has happened elsewhere. The possibility of the impact manifesting is very low as a result of design, historic experience or implementation of adequate mitigation measures
1	**Highly unlikely/None:** Expected never to happen.

Table 13. Application of Consequence ratings.

Range		Significance rating
-21	-18	Extremely detrimental
-17	-14	Highly detrimental
-13	-10	Moderately detrimental
-9	-6	Slightly detrimental
-5	5	Negligible
6	9	Slightly beneficial
10	13	Moderately beneficial
14	17	Highly beneficial
18	21	Extremely beneficial

Table 14. Application of Significance ratings.

Range		Significance rating
-147	-109	Major - negative
-108	-73	Moderate - negative
-72	-36	Minor - negative
-35	-1	Negligible - negative
0	0	Neutral
1	35	Negligible - positive
36	72	Minor - positive
73	108	Moderate - positive
109	147	Major - positive

Despite attempts at providing a completely objective and impartial assessment of the environmental implications of development activities, environmental assessment processes can never escape the subjectivity inherent in attempting to define significance. The determination of the significance of an impact depends on both the context (spatial scale and temporal duration) and intensity of that impact. Since the rationalisation of context and intensity will ultimately be prejudiced by the observer, there can be no wholly objective measure by which to judge the components of significance, let alone how they are integrated into a single comparable measure.

Table 15. Impact and risk ratings for the construction phase.

Project Phase	Construction			
Impact	Spillages of diesel, petrol, oil, paints, clears and other harmful chemicals. These substances may potentially percolate into the groundwater and enter the surrounding environment.			
Mitigatability	High		Mitigation exists and will considerably reduce significance of impacts.	
Potential Mitigation	i) Install the UST according to applicable national SANS standards. ii) Site to be monitored regularly for contaminant spillages and if detected, contact spillage remediation companies. iiI) Separate, tightly cover and monitor toxic substances to prevent spills and possible site contamination. iv) Cover stockpiles of building materials like cement, sand and other powders. v) Regularly inspect stockpiles for spillages and store away from waterways or drainage areas. vi) Collect any wastewater generated from site activities during construction insettlement tanks then screen, discharge the clean water,and dispose of remaining sludge according to environmental regulations.			
Assessment	**Without mitigation**		**With mitigation**	
Intensity	2	Minor damage to biophysical and / or social system components and species. Likely to recover over time. Ecosystem processes not affected.	2	Minor damage to biophysical and / or social system components and species. Likely to recover over time. Ecosystem processes not affected.
Duration	3	Medium term: 1-5 years	2	Short term: Less than 1 year
Extent	3	Local Area: Extending across the site and to nearby settlements	2	Limited: Limited to the site and its immediate surroundings
Type	-1	Negative	-1	Negative
Consequence	-8	Slightly detrimental	-6	Negligible
Probability	4	Probable: Has occurred here or elsewhere and could therefore occur	4	
Significance	-32	Minor - negative	-24	Negligible - negative
Comment on Consequence and Significance	After the implementation of mitigation measures, the consequence becomes neglible and the significance, negligible - negative.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Table 16. Impact and risk ratings for the operational phase.

Project Phase	Operational			
Impact	Spillages of diesel, oil and other harmful chemicals. Leakage from underground diesel storage tank (UST) and associated pipework. These substances may potentially percolate into the groundwater and enter the surrounding environment.			
Mitigatability	High		Mitigation exists and will considerably reduce significance of impacts.	
Potential Mitigation	i) All areas where potential spillages may occur are to be paved and cemented. ii) Maintain operation of the fuelling station as per national standards. iii) Set up a comprehensive monitoring system, such as observation boreholes, to detect any leakages/groundwater chemistry changes on-site. iv) Install shallow aquifer piezometers in close proximity to the UST to be monitored regularly for any leakages. v) Should a leak be detected or the monitoring boreholes be contaminated, a baseline Phase 1 Contamination Assessment should be undertaken and the site remediated in consultation with a contamination remediation consultant and the Authorities.			
Assessment	**Without mitigation**		**With mitigation**	
Intensity	3	Damage to biophysical and / or social system components and species.	1	Negligible damage to individual components of biophysical and / or social systems.
Duration	3	Medium term: 1-5 years	2	Short term: Less than 1 year
Extent	3	Local Area: Extending across the site and to nearby settlements	2	Limited: Limited to the site and its immediate surroundings
Type	-1	Negative	-1	Negative
Consequence	-9	Slightly detrimental	-5	Negligible
Probability	4	Probable: Has occurred here or elsewhere and could therefore occur	4	
Significance	-36	Minor - negative	-20	Negligible - negative
Comment on Consequence and Significance	After the implementation of mitigation measures, the consequence becomes neglible and the significance, negligible - negative.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

As stated, this risk assessment is based on available data as gathered during the desktop study and the field assessment.

Limitations were found in the following:

- The hydrocensus;
  - There is a potential that groundwater users are located within the one kilometre radius of the site;
    - Not all groundwater users display the relevant signage to indicate groundwater use;
    - It is thus safe to assume that the amount of groundwater users is in fact greater than are currently represented in this report, although being unlikely due to the geographical setting of Herold's Bay and unfavourable geological conditions for groundwater development.
- No deep geology logs below the geotechnical borehole depths;
- No aquifer parameters.

It is recommended that these limitations be addressed once the monitoring boreholes are drilled. The acquired information will be used to accurately mitigate the risk.

The impacts, as listed above, of the underground diesel storage tank on groundwater is dependent on mostly the shallow geology and to a lesser extent the deeper geology. A shallow water table of between 0.98- to 2.40 mbgl was recorded within the geotechnical boreholes, however, during the site visit conducted nine months since drill completion, no groundwater was observed to a depth of 2.80 mbgl within an excavated pit. <u>This does indicate a fluctuating water table/saturated water level and would place the UST in close proximity or within the water table. The shallow water table would, however, allow for early leak detection. It is thus imperative that stringent mitigation protocols, as outlined herein, are implemented and maintained.</u>

The deeper aquifer is assumed to consist of impermeable granite and schistose granite with limited fractures present. The low permeability of the deeper aquifer would place it at a lower risk as compared to the shallow aquifer/saturated groundwater level, however, this needs to be confirmed during the drilling of monitoring boreholes.

With the above taken into consideration, the risk involved with an UST is classified as minor – negative, however, with mitigation strategies put in place the impact significance can be further reduced to negligible - negative.

9 Discussion

According to DWAF, the site is underlain by a low-yielding, intergranular and fractured aquifer, which suggests groundwater presence in both the shallow, unconsolidated rock as well as in deeper, fractured rock. This is supported by the fact that groundwater was intersected in the two geotechnical boreholes, BH1 and BH2, at depths of 2.40- and 0.98 mbgl respectively. The boreholes intersected sandy colluvium followed by completely weathered colluvium consisting of granite schist which gradually grades into highly weathered schistose granite with both boreholes being terminated in moderately weathered schistose granite. BH1 was drilled to a depth of 8.67 mbgl, whilst BH was drilled to a depth of 8.20 mbgl.

No boreholes were identified during the hydrocensus or from various DWS databases within a reasonable distance of the site (1 km radius and maximum 3 km) or within the defined Groundwater Response Unit. It is thus assumed that groundwater use within the area is very limited to non-existent. Based on the national scale electrical conductivity map of South Africa, groundwater within the area typically exhibits a poor water quality ranging between 370- to 520 mS/m.

The aquifer vulnerability of the site is classified as "least" according to the DRASTIC method, which is consistent with the Aquifer System Management Index and Groundwater Quality Management index of "low". The lack of or absence of fractures present in the deeper bedrock may attribute to the low aquifer vulnerability. However, the intergranular aquifer which comprises the shallow, unconsolidated material, are likely to be more vulnerable and would require a higher degree of protection. This holds especially true for the investigated site.

Given the vulnerability rating of the aquifer, the "Source-Pathway-Receptor" principle is applied to determine the impact of the planned installation of the underground diesel storage tank. This is applied to both the construction and operational phase. Identified sources of contamination include spillages of toxic and harmful chemicals and leakages from the UST and associated pipework. The underlying aquifer, which includes the identified shallow aquifer as well as the deeper aquifer, represents both a pathway for contaminants as well as being a receptor. Evidence is seen of a fluctuation saturated level which may be an indication of groundwater-surface water interaction. Potential contaminants may enter the shallow aquifer and percolate into the adjacent stream. The aforementioned pathway is identified is the main area of concern.

The receptors of potential contaminants are thus mostly the shallow aquifer and to a lesser extent the deeper aquifer. No groundwater users were identified as receptors. Further potential receptors include the adjacent stream and surrounding environment. Potential contamination will be limited to the site proximity with the furthest extent being the coastal plain, situated approximately 150 m south-east of the site, should contaminants enter the stream. With this in mind, the risk assigned to the construction and operational phase of the proposed UST is classified as minor - negative. <u>Special note should be taken of the identified shallow aquifer which may place the UST in close proximity or within the water table. The shallow water table will, however, enable early leak detection through installed piezometers. It is thus imperative that stringent mitigation measures are implemented to decrease the risk to the indicated negligible – negative.</u> To prevent any contamination of the groundwater, regular monitoring thereof is strongly recommended.

10 Environmental Management & Groundwater Monitoring Program

The main objective of the proposed and discussed mitigation measures, pertaining to the identified impacts, is to maintain and monitor the local groundwater quality to:

- Ensure that Schedule 1 water users within the area have groundwater supply with an adequate and uncontaminated water quality.
- Ensure that registered groundwater use within the catchment have groundwater supply with an adequate and uncontaminated water quality.
- Ensure that groundwater with an adequate and uncontaminated water quality is available to maintain groundwater dependent ecosystems (baseflow feeding the rivers/streams draining the subject area and wetlands).

It is recommended that two monitoring boreholes should be drilled, one up-gradient of the proposed UST and one down-gradient. This will allow for groundwater quality and monitoring across the site. These boreholes should be drilled prior to the construction of the UST in order to determine any possible contamination of groundwater during this phase. The holes will serve for monitoring post-construction and during the operational phase.

The boreholes should be appropriately designed and constructed. It is recommended a geohydrologist be appointed to manage and supervise the drilling and should be responsible for the design and construction. No drilling should be undertaken without, at the very least, the consultation of a geohydrologist.

Furthermore, the installation of shallow piezometers in close proximity of the UST must form part of the monitoring network. This is especially important due to the presence of the shallow aquifer. A minimum installation depth of 3.50 mbgl is recommended.

Table 21 below presents the parameters and frequency that should form part of the groundwater monitoring program. It is proposed that the data should be captured into an appropriate electronic database for easy retrieval and submission to the relevant authority as required, and reviewed by a geohydrologist on a bi-annual basis to ensure no contamination of the groundwater occurs. Groundwater samples should be taken in accordance to the relevant SANS 5667-11:2015 standard.

Table 17. Proposed Monitoring Requirements.

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Quarterly	Temporal variation
	EC, ORP, pH, Do	Quarterly	Changes in chemical and microbial composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. Temporal variation
Chemical	Major ions and trace elements including DOC, BTEX and VOC	Bi-annually	Changes in chemical and microbial composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions.

Furthermore, the installation of shallow piezometers in close proximity of the UST must form part of the monitoring network. This is especially important due to the presence of the shallow aquifer. The piezometers need to be inspected regularly for the potential presence of hydrocarbons which may indicate a UST leak.

11 Conclusion & recommendations

The following recommendations are made:

- It is recommended that the monitoring network be installed prior to the installation of the UST and relevant mitigation, as described herein, is employed.
    - This will serve as monitoring of both the construction and operational phase.
- At least two monitoring boreholes are recommended to detect any potential contaminants.
    - Boreholes to be drilled to a depth of 20m.
    - Drilled at least 165mm in diameter.
    - Fitted with slotted, class 12, flush-fit, threaded ends, uPVC with an end cap (slots ideally from 2m down).
    - The inner diameter of the uPVC casing should not be less than 110 mm.
    - Gravel pack in borehole annulus (typically 3-5 mm in diameter).
    - Top 2m of annulus to be filled with bentonite seal.
    - Borehole to be fitted with lockable protection and to be clearly marked.
- Water levels and physical parameters should be recorded at least quarterly, with sampling and chemical analysis of major and trace anions and cations, inclusive of DOC, BTEX and VOC on a bi-annual basis.
    - Samples to be submitted to accredited SANAS laboratory and sample collection and transport as per laboratory standards.
- Shallow piezometers are to be installed in close proximity of the UST.
    - Minimum installation depth of 3.50 mbgl.
- A rapid response plan must be developed should any hydrocarbon spillages or leakages be detected.

Should the above monitoring network be in place and mitigation measures be considered, as outlined herein, the risk assigned to potential impacts of contamination during both the construction and operational phase is negligible - negative.

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