GEOTECHNICAL DESK STUDY FOR THE HENDRINA GREEN HYDROGEN AND AMMONIA FACILITY

Hendrina, Mpumalanga

Prepared for: ENERTRAG SA

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REPORT SIGN OFF AND APPROVALS

Muhammad Osman
(Project Manager)

Trevor Pape
(Reviewer)

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National Environmental Management Act, 1998 (Act No. 107 Of 1998) And Environmental Impact Regulations, 2014 (As Amended) - Requirements for Specialist Reports (Appendix 6)

Regulation GNR 326 of 4 December 2014, as amended 7 April 2017, Appendix 6	Section of Report
1. (1) A specialist report prepared in terms of these Regulations must contain - a) details of - i. the specialist who prepared the report; and ii. the expertise of that specialist to compile a specialist report including a curriculum vitae;	Cover page, Page iv. Appendix B
b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	Appendix B
c) an indication of the scope of, and the purpose for which, the report was prepared;	1
(cA) an indication of the quality and age of base data used for the specialist report;	4, 5, 6, 11.
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	9
d) the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	N/A – Report based on desk study information.
e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	2
f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Appendix A 1, 2, 3, 4, 5.
g) an identification of any areas to be avoided, including buffers;	1, 2, 3, 4, 5.
h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	1, 2, 3, 4, 5.
i) a description of any assumptions made and any uncertainties or gaps in knowledge;	2.5

j) a description of the findings and potential implications of such findings on the impact of the proposed activity, (including identified alternatives on the environment) or activities;	3, 4, 5, 6, 7, 8.
k) any mitigation measures for inclusion in the EMPr;	Table 9.1 and 10.1
l) any conditions for inclusion in the environmental authorisation;	Table 9.1 and 10.1
m) any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Table 9.1
n) a reasoned opinion- I. (as to) whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and II. if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	9, 10. 9, 10. Table 9.1
o) a description of any consultation process that was undertaken during the course of preparing the specialist report;	Consultation undertaken by EAP as part of the EIA process.
p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Consultation undertaken by EAP as part of the EIA process.
q) any other information requested by the competent authority.	No other information relating to the geotechnical study has been requested at this time.
2) Where a government notice *gazetted* by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	No specific protocol for Geotechnical Assessments has been published.

environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

	(For official use only)
File Reference Number:	
NEAS Reference Number:	DEA/EIA/
Date Received:	

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

PROPOSED HENDRINA WIND FARMS:
HENDRINA NORTH AND SOUTH WINDFARMS, PROPOSED GRID CONNECTIONS VIA SUBSTATIONS AND POWERLINE AND ALL ASSOCIATED INFRASTRUCTURE.

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2. This form is current as of 01 September 2018. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.environment.gov.za/documents/forms.
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4. All documentation delivered to the physical address contained in this form must be delivered during the official Departmental Officer Hours which is visible on the Departmental gate.
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Email: EIAAdmin@environment.gov.za

SPECIALIST INFORMATION

Specialist Company Name:	SLR Consulting (South Africa) (Pty) Ltd			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	4	Percentage Procurement recognition	
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DECLARATION BY THE SPECIALIST

I, _____Muhammad Osman_________, declare that –

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

Signature of the Specialist

SLR Consulting (South Africa) (Pty) Ltd

Name of Company:

11/10/2022

Date

EXECUTIVE SUMMARY

This report presents the preliminary findings of a geotechnical desk study for the proposed Hendrina Green Hydrogen and Ammonia Facility, located in Mpumalanga. The facility will comprise production and storage facilities as well as associated infrastructure.

In accordance with the 1:250 000 Geological Map 2628 East Rand, published by the Council of Geoscience, the study area is underlain by stratigraphic units of the Ecca Group, Karoo Supergroup; Rooiberg Group of the Transvaal Supergroup and the Lebowa Granite Suite of the Bushveld Complex respectively. The study area is predominantly underlain by lithological units of the Ecca Group which is represented by sandstones, shales and coal seams of the Vryheid Formation.

Based on a preliminary hydrogeological assessment, the aquifers of the Karoo Supergroup display characteristics of intergranular and fractured rock. The borehole yielding potential of the aquifer is classified as D2, which implies an average borehole yield varying between 0.1 and 0.5 l/s.

The Seismic Hazard Map of South Africa (Kijko, 2008) indicates that the proposed study area comprises peak ground accelerations ranging between 0.12 g and 0.16 g, with a 10% probability of being exceeded in a 50 year period, which may potentially be due to the presence of mining activities in the area.

Further details relating to the presence and potential for undermined areas in close proximity to the green hydrogen and ammonia facility have been intentionally excluded from this report as such work is deemed necessary during a detailed geotechnical investigation subsequently forming part of the concept/preliminary design process.

One of the key elements of a geotechnical desk study report for environmental impact assessments is the geotechnical impact assessment matrix, which generally details the impact of the development on the natural geological environment. In accordance with the assessment criteria provided by WSP, the impact assessment matrix undertaken for this project, from a geotechnical perspective, was found to be "Negative with moderate to high impacts - The anticipated impacts will have considerable negative effects and will require the implementation of mitigation and monitoring measures".

It is recommended that a detailed geotechnical investigation be undertaken as part of the detailed design component of the project, to determine the prevailing subsurface conditions across the site and to optimise the positioning of the green hydrogen and ammonia facility.

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Geotechnical Desk Study for the Hendrina Green Hydrogen and Ammonia Facility

1. INTRODUCTION

SLR Consulting South Africa (Pty) Ltd has been appointed by ENERTRAG South Africa, hereafter referred to as "ENERTRAG", to undertake a geotechnical desk study assessment for the proposed construction of the Hendrina Green Hydrogen and Ammonia Facility located approximately 10 km west of the town of Hendrina, in the Mpumalanga Province of South Africa.

It is understood that the green hydrogen and ammonia facility will have a capacity generation of up to 150 MW and will encompass approximately 25 hectares of land with three possible alternative locations. The energy generated by the green hydrogen and ammonia facility will be utilised for private mining and industrial operations. Green hydrogen and ammonia production relies entirely on renewable energy resources with the only by-products being brine and oxygen. Hydrogen is mainly used commercially in hydrogen fuel cells, welding and production of other chemicals. Ammonia is primarily used in fertilizers, as refrigerant gas, and the manufacture of plastics, explosives and textiles.

The facility is being assessed as part of the Hendrina Renewable Energy Complex and involves the undertaking of Listed Activities identified in the Environmental Impact Assessment (EIA) Regulations, 2014 (as amended) and as such require an Environmental Authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) before being undertaken.

As part of this process, a geotechnical desk study assessment of all the proposed infrastructure is required in relation to the development area to assess the prevailing geological and geotechnical conditions and the geotechnical impacts the development will have on the natural environment.

1.1 COMPONENTS OF THE GREEN HYDROGEN AND AMMONIA FACILITY

As previously mentioned, ENERTRAG proposes to construct a green hydrogen and ammonia facility which will be located on approximately 25 ha of land within the Hendrina Renewable Energy Complex. The facility will function by using air and water to produce commercially usable green hydrogen and ammonia, a process that is more environmentally friendly than the traditional method of burning fossil fuels.

A simplified flow process diagram comparing the traditional production of ammonia relative to the current production of green ammonia is illustrated in Figure 1.1.

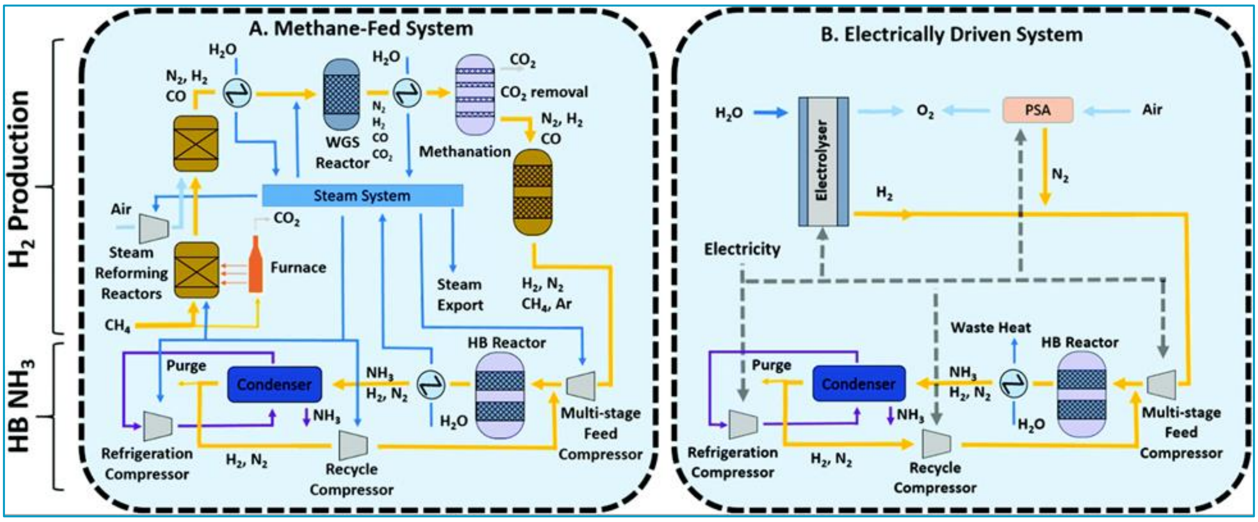

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Figure 1.1: Green Hydrogen and Ammonia Production – Traditional Vs Green Process.

The facility will comprise various component structures to ensure the efficient production of green hydrogen and ammonia. A summary of the components that will be required is itemised in Table 1.1 below as well as their respective footprints and storage capacities.

Table 1.1: Summary of Components Proposed for the Green Hydrogen and Ammonia Facility

Component	Footprint (Ha)	Storage Capacity (m^3/tons)
Water Reservoir	2	6 800/6 800
Water Treatment Unit	1.5	N/A
Electrolyser Unit	1	N/A
Air Separation Unit	0.5	N/A
Ammonia Processing Unit	2	N/A
Liquid Air Storage Unit (LAES)	1	3 983/3 505
Liquid Ammonia Storage Tank	2	2 273/1523
Hydrogen and Oxygen Storage Tank	12	59 566/800
Ancillary Infrastructure	3	N/A
Total Footprint	25	

1.1.1 Water Reservoir

Water will be stored in a reinforced concrete or steel reservoir with a footprint of up to 1.5 ha and a capacity of approximately 6 800 m^3. It is proposed that three water reservoirs will be located on site. Each reservoir will have a diameter of up to 25 m and a height of 6 m (maximum height up to 15m).

A variety of possible water sources are being investigated for the broader development, which includes the following:

- Komati Power Station (technical preferred option): Bulk water infrastructure from the Usuthu Water Scheme currently feeding the surrounding coal mines and power stations (specifically Eskom Komati Power Station) may be utilised for construction and operational water. Initial water results indicate good quality supply in sufficient quantities is available. This option is the preferred water sourcing for the development due to excess water being available at the Power Station's water reservoirs.

- Groundwater: Various boreholes may be utilised across the project site for extraction of construction and operational water requirements. The volumes will be dependent on the available groundwater and the quality thereof, which has not yet been determined.

- Purified wastewater: Wastewater from nearby commercial or mining facilities could be sourced to provide the facility with water. This would depend on availability of suitable quality wastewater and agreements with the respective entities involved. It is possible that water may be sourced from existing surrounding mining operations that are experiencing or anticipating mine water decant from their operations. Using this water in the green hydrogen and ammonia facility is potentially beneficial.

An important aspect in water sourcing is the delivery mechanism to the plant. An above or below ground water pipeline will be constructed for the continuous or intermittent supply of water to the green hydrogen and ammonia facility. The pipeline will comprise a concrete pressure pipe, ductile iron pipe, galvanised iron or steel pipe, GRP/GRE pipe, Poly Vinyl Chloride Pipes, High Density Polyethylene pipes or other suitable material as required by the detailed design phase, situated (where buried) within a trench of up to 3 m wide and up to 2 m deep. Where required for the avoidance of obstacles, horizontal directional drilling may be utilised for installation. The pipe will carry raw water of 928 880 m^3 per annum at a throughput of up to 40 litres per second (usage requirements varying between the construction and operational phases). The pipeline inner diameter will be up to 300 mm.

1.1.2 Water Treatment

Water is required to produce hydrogen and for heating and cooling purposes. The water treatment facility will be housed in a warehouse with a footprint of 1 ha.

1.1.3 Electrolyser (Up to 150 MW)

The up to 150MW electrolyser will be housed in a warehouse building and will have a footprint of up to 1ha. The electrolyser will use direct electric current (obtained from the Renewable Energy Facilities) to drive an otherwise non-spontaneous chemical reaction, in this case the separation of $2H_2O$ (water molecule from the RO process) through a reduction-oxidation (redox) process into H_2 (Hydrogen on the cathode side) and O_2 (Oxygen on the anode side). Electrolysers are modular and currently range in size from 5 MW – 20 MW. It is proposed that the Green Hydrogen Facility will consist of 15 sets of 10 MW electrolysers. Each electrolyser unit will be powered through its own set of transformers and rectifiers.

1.1.4 Air Separator Unit

The air separation until will occupy a footprint of up to 0.5 ha and the intake tower will have a maximum height of up to 40 m (due to the height of the 'cold box' – the tallest vertical component of the air separation unit).

Air is obtained from the immediate surroundings and separated into nitrogen (N_2) and oxygen (O_2) with the impurities removed. The process involves air compression and temperature manipulation in a pressure-controlled environment to separate gasses from one another and produce gaseous N_2. The air separation unit will have a maximum capacity of up to 110,000 tpa.

1.1.5 Ammonia Processing Unit

Ammonia is produced through the Haber-Bosch process. This is where stoichiometric amounts of nitrogen and hydrogen are reacted to produce ammonia. The conversion is typically achieved at 100 barg and between 400 – 500 °C to favour the formation of ammonia at equilibrium. A catalyst is also used to favour the production of ammonia. The gas is then rapidly cooled to form anhydrous ammonia with the unreacted nitrogen and hydrogen recycled back to reactor.

Typical components of an ammonia production plant include compressors, filters, reactor chamber and beds, heat exchangers, water storage vessels, condensers, separators, circulators, absorbers and gas release valves.

1.1.6 LAES for Nitrogen Production

Liquid air energy will be used to liquefy nitrogen for storage, energy and feedstock requirements. Liquid air energy is the use of liquefied air, nitrogen, oxygen and even hydrogen to store Energy. LAES consists of three main stages:

- Cooling and separation of the air,
- Storage (usually in insulated vessels at low pressure) and
- Expanded for energy and/or production.

Components in the LAES include compressors, ambient and cryogenic heat exchangers, expansion valves, storage vessels, pumps, small turbines and generators.

1.1.7 Storage Tanks

Storage Tanks can be stored in pressurised as or gas in liquid form through the utilisation of a variety of specialised tanks. There are different kinds of storage tanks designs to store anhydrous ammonia, these include but are not limited to:

- Fixed roof tanks,
- Floating roof tanks,
- Low-temperature storage tanks, and
- Pressure tanks.

1.1.8 Storage Requirements

Nitrogen: Will be stored as a liquid in large cylindrical cryogenic storage tanks with a combined volume of approximately 4 100 tons. It is proposed that the facility will comprise two cylindrical cryogenic tanks which will each have a diameter of up to 14 m and a height of 15 m.

Ammonia: Green ammonia will be stored as anhydrous liquid ammonia, using similar storage equipment as that utilised for storing Liquid Natural Gas.

Hydrogen: Stored in vertical or horizontal storage bullets. The facility will house up to 20 horizontal pressure bullets, each having a diameter of up to 4 m and a length of up to 15 m.

Oxygen: Will be stored in vertical or horizontal storage bullets. The facility will house up to 16 vertical cryogenic storage bullets, each with a diameter of up to 4 m and length of up to 15 m.

Typical examples of the components mentioned above required for the green hydrogen and ammonia facility are included in Figure 1.2.

Figure 1.2: Typical Examples for the Green Hydrogen and Ammonia Facility Components.

Associated infrastructure required for the proposed facility includes, but are not limited to:

- Electrical infrastructure required for power supply to the facility.
- Temporary and permanent laydown areas required for temporary storage and assembly of components and materials.

- Access road/s to the site and internal roads between project components, with a width of up to up to 6 m wide respectively.
- A temporary concrete batching plant (if necessary).
- Temporary staff accommodation.
- Fencing and lighting.
- Lightning protection.
- Telecommunication infrastructure.
- Stormwater channels.
- Water pipelines.
- Offices.
- Operational control centre.
- Operation and Maintenance Area / Warehouse / workshop.
- Ablution facilities.
- A gate house.
- Control centre, offices, warehouses.
- Security building.

As part of the geotechnical desk study, three alternatives for the position of the facility have been assessed and will be discussed in following Sections. The preliminary layout for the above components is included in Figure 1.3.

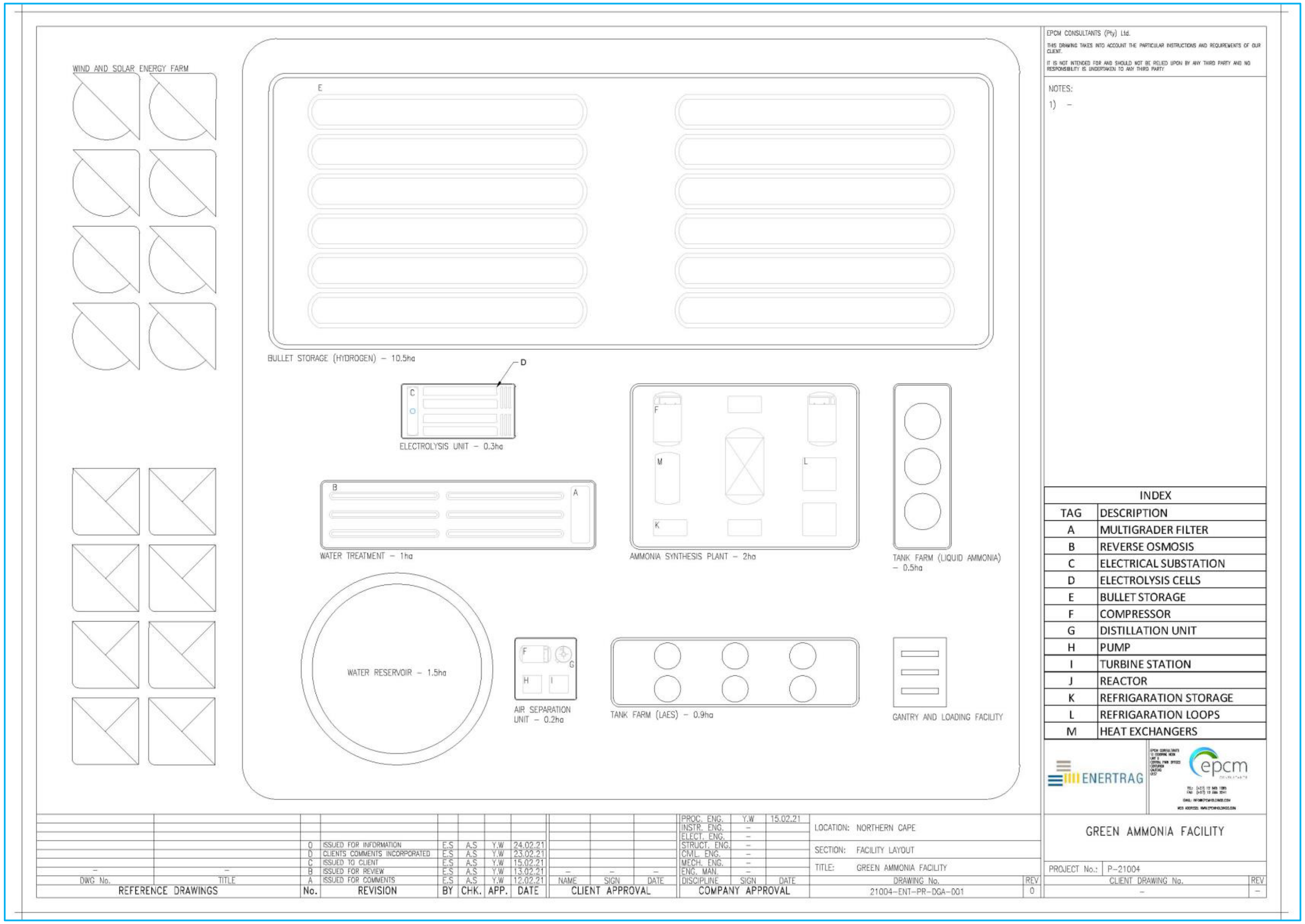

Figure 1.3: Preliminary Layout of Component Structures for the Green Hydrogen and Ammonia Facility.

2. ASSESSMENT METHODOLOGY

2.1 SCOPE OF WORKS

The objectives of this desk study were to assess the geological and geotechnical conditions prevailing across the study area.

This involved a literature review and a review of topographic and geological maps of the region. Consideration was given to, but not limited to the following from a desktop level:

- The influence of topography on site suitability.
- The envisaged geological and geotechnical influences on the competency of foundations for the construction of structures.
- Tectonic influences and mine related seismicity on overall stability, namely the presence of faulting, lineaments, preferred discontinuity orientations and underground coal mines.
- Potential implications for the geotechnical design and engineering of the respective sites.
- Recommendations regarding requirements for subsequent detailed geotechnical investigations to inform the engineering design process.

2.2 TERMS OF REFERENCE

The geotechnical desk study assessment is based upon SLR's proposal entitled, "*720.05085.P0004 Hendrina Green Hydrogen and Ammonia Facility VO*," dated the 15 September 2022.

2.3 SPECIALIST CREDENTIALS

Mr. Osman is a qualified engineering geologist, having attained a Bachelor of Science Honours Degree in Engineering and Environmental Geology, from the University of Kwa-Zulu Natal. He is registered as a Professional Natural Scientist (Registration No. 115552). Mr. Osman holds the position of Senior Engineering Geologist at SLR's Hilton branch. He has experience in the various fields of earth science and ground engineering, namely: engineering geology, geotechnical engineering and materials investigations. At present Mr. Osman specializes in conducting foundation investigations and material investigations for dams, roads and renewable energy projects.

This report was reviewed by Mr. Trevor Pape. Mr Pape is a senior engineering geologist with more than 35 years' experience in the engineering geology of infrastructure. He has been involved in all phases of site investigations for projects, from reconnaissance and feasibility level through to detailed design and construction involvement. He has carried out projects in South Africa, Swaziland, Botswana, Mozambique, Namibia, New Zealand, Liberia, Zambia, Zimbabwe, Tanzania, Guinea, and Thailand.

His primary focus is on site investigations and making recommendations for special foundations in the civil engineering, building and mining industries, including hotels and office buildings; railways, roads and bridges; housing developments; industrial and mining infrastructure developments; power stations and power lines; and pipelines and water reservoirs. His expertise also includes the evaluation of materials for use in roads and earthworks construction, dolomite stability investigations, aerial photographic interpretation, and land facet classification.

The detailed Curriculum Vitaes' of the key personnel are included in **Appendix A** of this report.

2.4 APPROACH

The geotechnical desk study assessment for the Green Hydrogen and Ammonia Facility entailed a review of available geotechnical reports as well as a review of topographic and geological maps. Consideration was given to the terrain, geology, hydrogeology and envisaged geotechnical constraints.

The assessment involved a review of the following information:

- 1:250 000 scale Geological Map 2628 East Rand (Council for Geoscience, 1991).
- Aerial photography (Google Earth imagery, current and historical) and project component shape files provided by Enertrag SA.
- Technical report entitled, "Geological Assessment of the Meerlus Region between Komati and Hendrina, Mpumalanga", produced by WSP Environmental (Pty) Ltd, dated 14 June 2019.
- Technical report entitled, "Geotechnical Desk Study: Proposed Construction of the 132 Kv Boschmanskop – Hendrina/Aberdeen Powerline and Substation", produced by M.J van der Walt Engineering Geologist CC, dated November 2017.
- Project Description and Impact Assessment Methodology for Hendrina Renewable Energy Complex supplied by WSP via ENERTRAG, September 2022.
- Seismicity data from the Department of Mineral Resources and Energy's website.

2.5 ASSUMPTIONS AND LIMITATIONS

The interpretation of the overall geotechnical conditions across the site is based on a review of available information on the project area. Subsurface and geotechnical conditions have been inferred at a desktop level from the available information, past experience in the project area and professional judgement. The information and interpretations are given as a guideline only and there is no guarantee that the information given is totally representative of the entire area in every respect. No responsibility will be accepted for consequences arising out of the fact that actual conditions vary from those inferred. The information must be verified by the undertaking of a detailed geotechnical site investigation.

3. SITE DESCRIPTION

3.1 LOCALITY

The Project is located 17km west of Hendrina, in the Steve Tshwete Local Municipality, of the Nkangala District Municipality, Mpumalanga Province. Three alternative Project locations are being investigated for the development of the proposed Project:

Site Alternative 1 is located on Portion 3 of the Farm Dunbar 189IS, at the site of an old, abandoned farmyard and has three powerline options from the associated Hendrina North and South Wind Energy Facilities ("WEF") as follows:

- Powerline option 1 is up to 2 km in length, to the Hendrina North WEF substation Option 1 on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 7 km in length, to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 1.5 km in length, to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

Water supply to the site will be via a new pipeline up to 16 km in length from the Komati Power Station.

Site Alternative 2 is located on Portion 3 of the Farm Dunbar 189IS and Portion 18 of the Farm Weltevreden 193IS, adjacent to the proposed Hendrina South WEF substation and has three powerline options from the associated wind farms as follows:

- Powerline option 1 is up to 3 km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 8 km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 0.5 km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS;

Water supply to the site will be via a new pipeline up to 16 km in length from the Komati Power Station.

Site Alternative 3 is located on Portions 14 and 15 of the Farm Weltevreden 193IS and has three powerline options from the associated wind farms as follows:

- Powerline option 1 is up to 5 km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 5 km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 7 km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

Water supply to the site will be via a new pipeline up to 16 km in length from the Komati Power Station.

The proposed three alternatives are indicated in Figure 3.1.

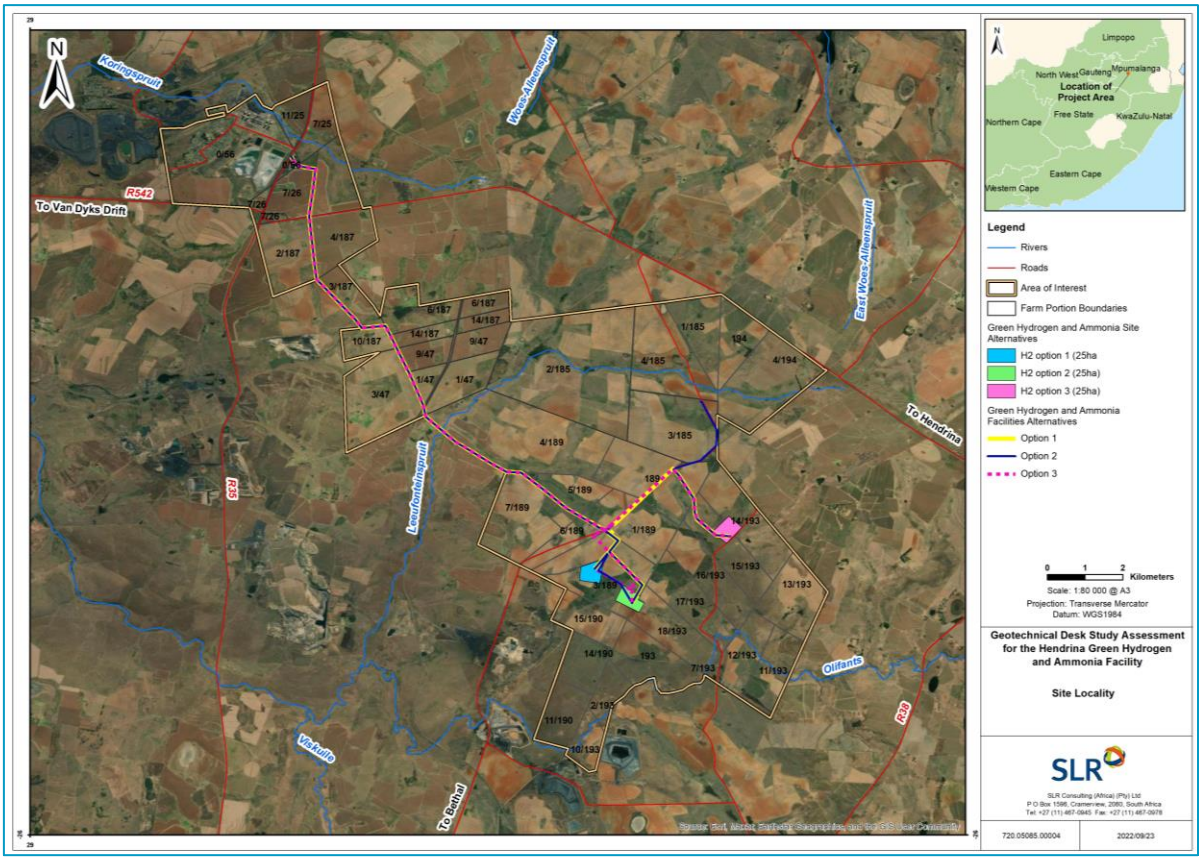

Figure 3.1: Positions of the Three Proposed Site Alternatives

3.2 LAND USE AND VEGETATION

The proposed green hydrogen and ammonia facility within the renewable energy complex is bounded predominantly by agricultural farmlands

According to Mucina et al (2005), the regional biome within which the study site is located is classed as the Grassland Biome, comprising sweet and sour grass plants.

3.3 CLIMATE

The study area is characterized by a warm and temperate climate with a “Cwb” classification according to the Köppen-Geiger climate classification. Hendrina receives a relatively low mean annual precipitation of 482 mm. The average lowest rainfall is received in July (2 mm) and the highest in December (93 mm), which is a seasonal variation of 91 mm.

The average maximum midday temperatures for Hendrina ranges from 30°C in January to 21°C in July. The minimum temperatures for Hendrina ranges from 13°C in December to 3°C in July. Figure 3.2 summarizes the climatic conditions for Hendrina, Mpumalanga.

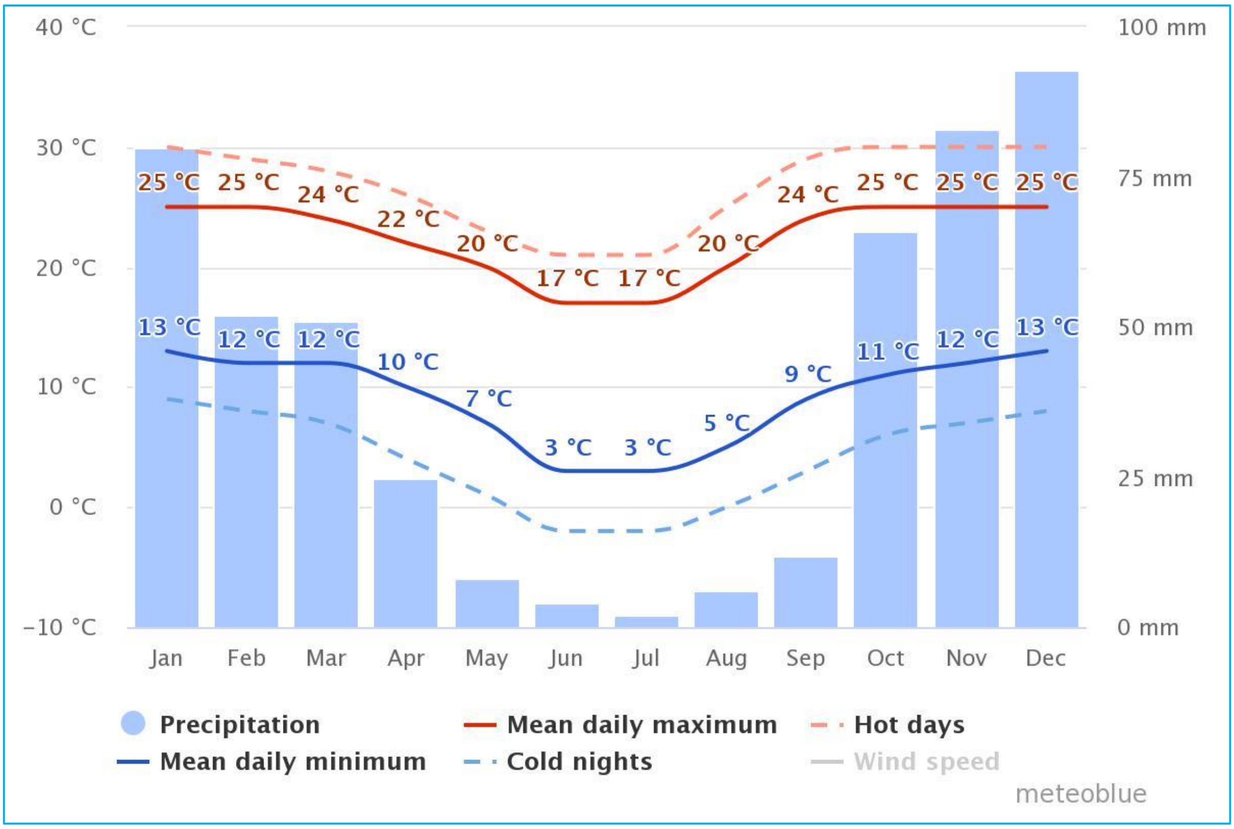

Figure 3.2: Summary of Climatic Conditions *(Source: Meteoblue)*.

3.4 DRAINAGE AND TOPOGRAPHY

Based on a desk study assessment, the project area consists of the non-perennial Leeufonteinspruit River traversing further North and the perennial Olifants River further South. There are various non-perennial tributaries situated across the proposed footprint which are observed to drain into agricultural farm dams.

Slope variation analysis undertaken for the proposed area in its entirety indicates that the topography is characterised by flat to gentle terrain, comprising slope angles ranging between 0° and 14°. Spot heights indicate that the elevation across the site ranges between 1572 m and 1691 m above mean sea level, with a difference in elevation of approximately 119 m.

The general drainage features observed and the topographic variation occurring across the proposed development area is included in Figure 3.3 and Figure 3.4.

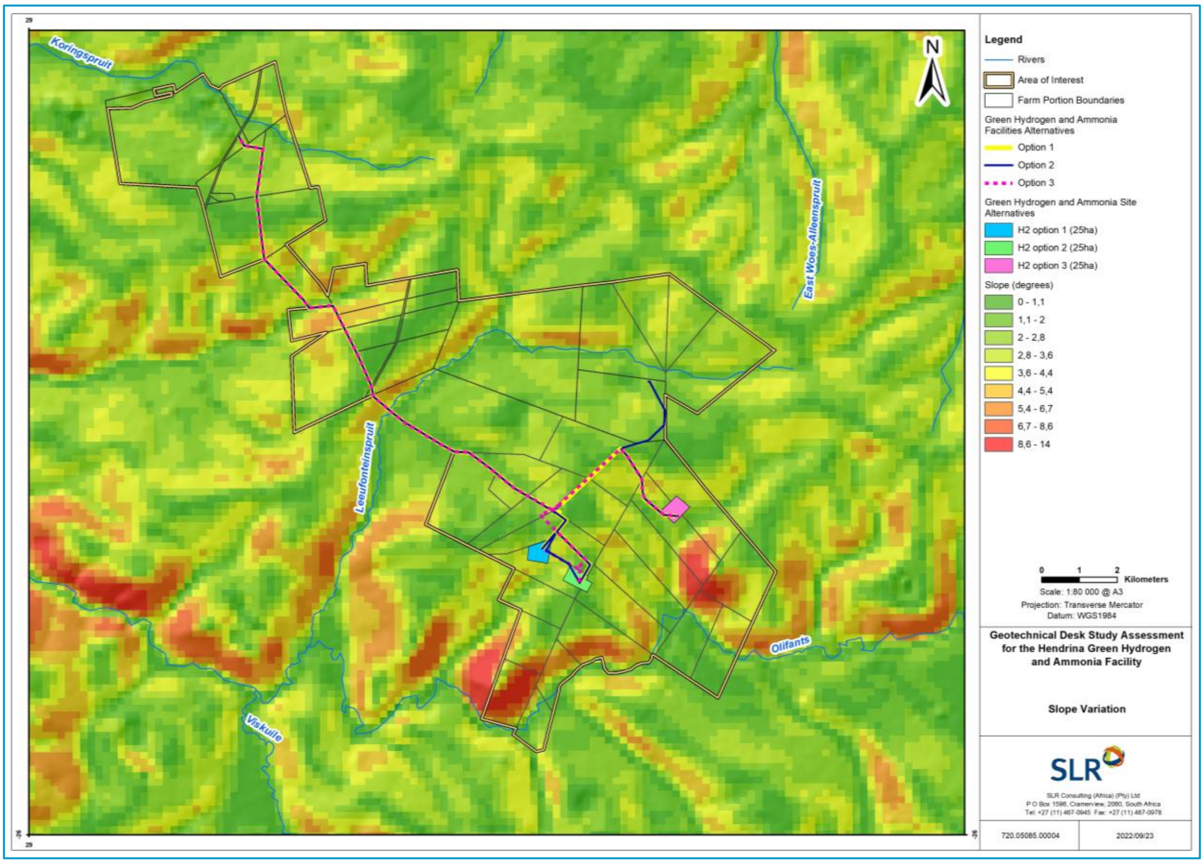

Figure 3.3: Slope Variation in Degrees and Drainage Features.

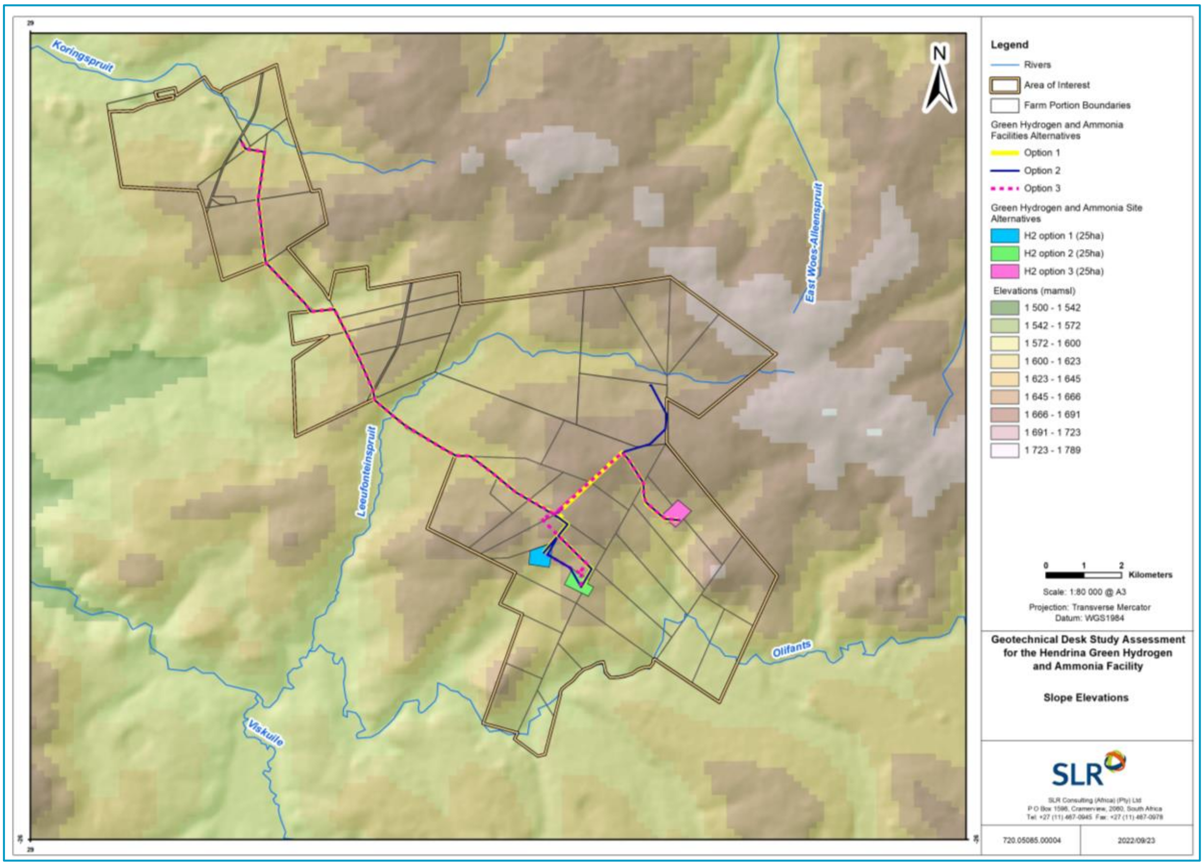

Figure 3.4: Elevation (mamsl) and Drainage Features.

4. GEOLOGY

According to the 1:250 000 Geological Map 2628 East Rand published by the Council of Geoscience, the study area is underlain by stratigraphic units of the Ecca Group, Karoo Supergroup; Rooiberg Group of the Transvaal Supergroup and the Lebowa Granite Suite of the Bushveld Complex respectively.

4.1 VRYHEID FORMATION, ECCA GROUP

The proposed development area is predominantly underlain by lithological units of the Ecca Group which is represented by sandstones, shales and coal seams of the Vryheid Formation, all deposited in a shallow marine environment. The Vryheid Formation has been extensively intruded by Jurassic aged dolerite, becoming relatively more prevalent further south of the proposed study area.

Sandstones comprise a larger portion of the Karoo sediments and are generally closely intercalated with mudrocks, resulting in alternating bands of arenaceous and argillaceous sediments. The Vryheid Formation sandstones may typically occur as arkosic to greywacke, ranging from a generally coarse grained, poorly sorted material to a fine grained, well sorted material, with an abrupt upward transition.

Of significant economic importance is the presence of coal seams located stratigraphically between the sandstone and mudrock bedding partings, at the base of the Vryheid Formation. The lower coal seams attain thicknesses of approximately 18 m which progressively diminishes upwards through the formation, due to various depositional and post-depositional factors (Brink, 1983).

4.2 ROOIBERG GROUP, TRANSVAAL SUPERGROUP

The Rooiberg Group is represented at the southern extremity of the site by the Selons River Formation which consists essentially of red porphyritic rhyolite, a very fine grained or cryptocrystalline volcanic rock of granitic composition containing phenocrysts of alkali-feldspar. In some exposures, the rhyolites are clearly flow banded while in others they are massive. Pyroclastic materials, often in the form of soft tuffs and minor layers of sandstone and shale, are commonly intercalated with the rhyolite (Brink, 1979).

4.3 LEBOWA GRANITE SUITE, BUSHVELD COMPLEX

The Lebowa Granite Suite of the Bushveld Complex underlies the southernmost portion of the proposed development area, and predominantly comprises medium to coarse grained porphyritic or biotite granites. The climatic N-value for the area within the Bushveld granites occur is between 3 and 4 (Weinert, 1980). The predominant mode of weathering is a combination of both chemical and physical resulting in the development of residual soils consisting of angular grains of quartz and feldspar with a small percentage of kaolinitic clay (Brink, 1981).

4.4 RECENT DEPOSITS

Transported soils, referred to as recent deposits, are generally un-lithified sediments that have been derived from the slow disintegration of the parent bedrock material, which have been disbursed from their original locations and deposited by geomorphic processes. The transported soils anticipated to occur across the study area are:

- **Colluvium:** A term that includes all soils on hill slopes that have been displaced under the influence of gravity. In certain cases, the geotechnical characteristics of the colluvial soils may lead to an approximation of the parent bedrock material.
- **Alluvium:** Deposits that result from the transportation and deposition of sediments by rivers or similar water courses. These deposits are generally present along rivers and floodplains and may contain fine to coarse grain sizes which is dependent on the origin of the sediment as well as through the processes of eluviation and illuviation.
- **Pedocretes:** Superficial deposits that have formed either as weathering residues or by cementation of pre-existing soils by various authigenic minerals precipitated from the soil water or ground water. The pedocretes likely to be encountered across the study area are mainly ferricrete with sub-ordinate calcrete which may occur as nodular or hardpan.
- **Pebble Marker:** The base of the transported soil which is characterised by the presence of a gravel horizon, representing the most recent major geological unconformity in the soil profile. The pebble marker is generally a zone of high permeability due to the abundance of angular, sub-angular and rounded gravel fragments of mixed origin.

A detailed Geological Map of the underlying lithologies occurring across the study area is presented in Figure 4.1 below.

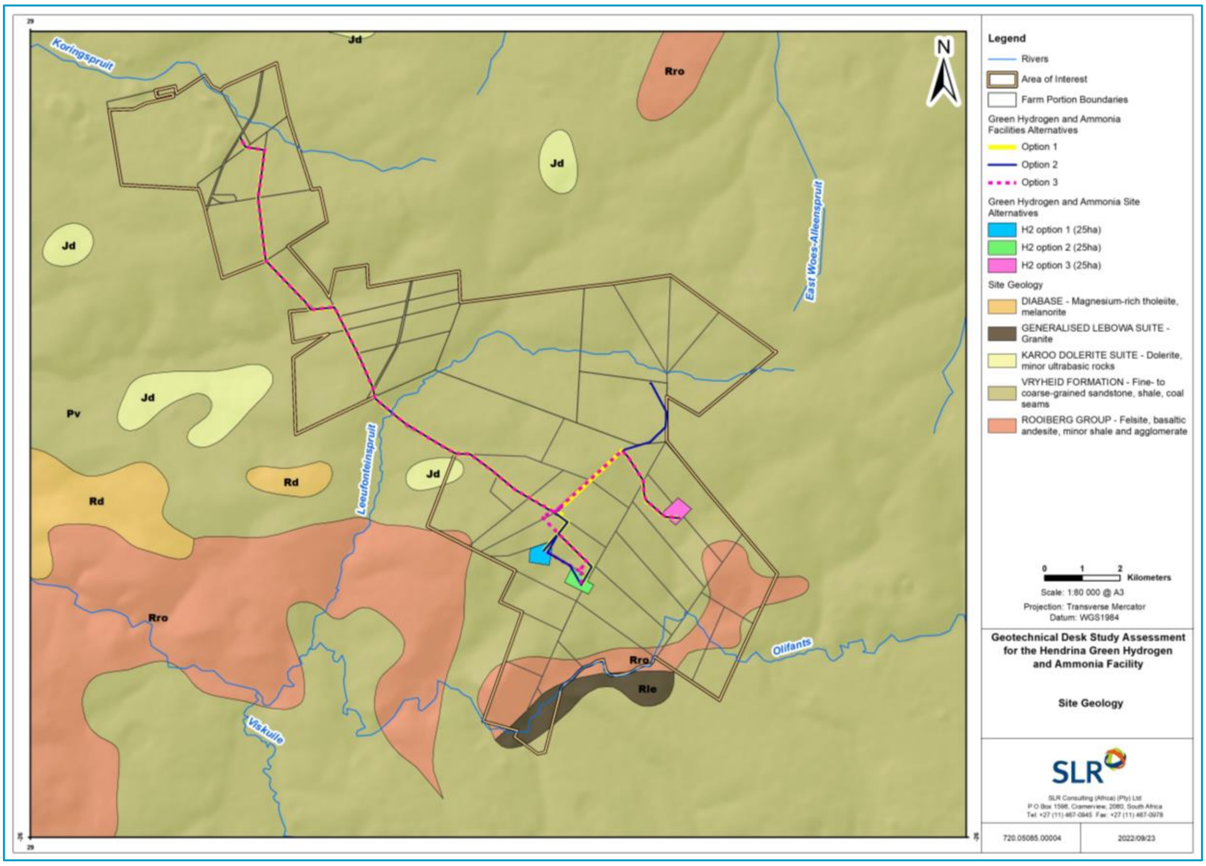

Figure 4.1: Geological Map of the Proposed Development Area.

5. HYDROGEOLOGY

The green hydrogen and ammonia facility within the Hendrina Renewable Energy Complex is underlain by Karoo sedimentary rocks and dolerite intrusions, as mentioned in Section 4, and the hydrogeological characteristics of the study area is a function of the geological formations. The aquifers of the Karoo Supergroup display characteristics of intergranular and fractured rock. The borehole yielding potential of the aquifer is classified as D2, which implies an average borehole yield varying between 0.1 and 0.5 l/s.

According to Barnard (2000), there are typically six different modes of groundwater occurrence associated with these formations:

- Weathered and fractured sedimentary rocks not associated with dolerite intrusions.
- Indurated and jointed sedimentary rocks alongside dykes.
- Narrow weathered and fractured dolerite dykes.
- Basins of weathering in dolerite sills and highly jointed sedimentary rocks enclosed by dolerite.
- Weathered and fractured upper contact zones of dolerite sills.
- Weathered and fractured lower contact zones of dolerite sills.

Numerous springs occur at lithological contacts such as where sandstone overlies an impervious shale horizon, along fault zones or along impermeable dolerite dykes. Groundwater seepage in lower lying areas contributes substantially to sustaining the dry season flow in the stream systems that drain these landscapes.

A detailed Hydrogeological Map illustrating the aquifer types and borehole yielding potential across the study area is presented in Figure 5.1.

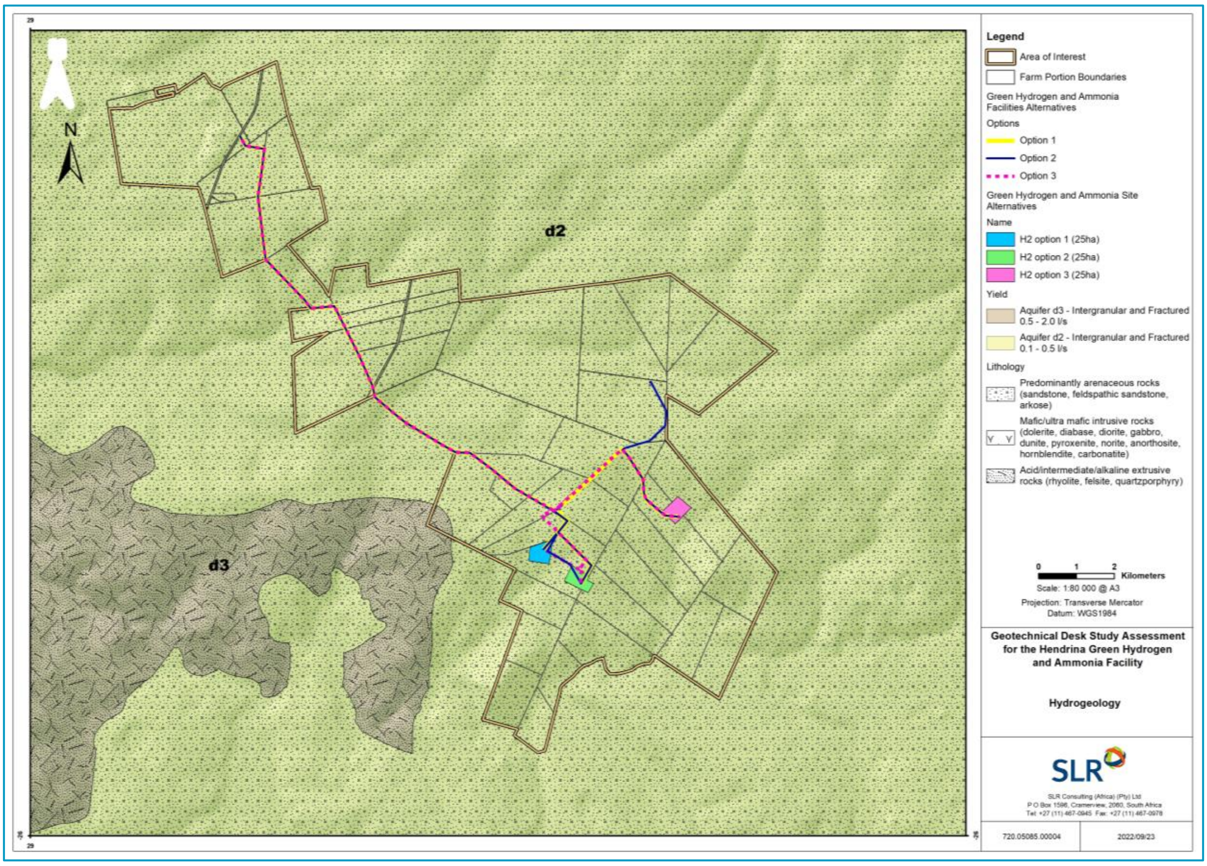

Figure 5.1: Hydrogeological Map of the Proposed Development Area.

6. ENGINEERING GEOLOGY

Engineering geology refers to the engineering characteristics of the natural earth materials for founding of structures and identifies the suitability of in-situ soils for use as construction materials.

Hendrina is characterized by a Weinert Climatic N-value of approximately 3, indicating that the predominant mode of weathering will be by chemical decomposition, forming deep residual subsurface horizons (Brink, 1983).

The majority of the study area is dominated by the Vryheid Formation with minor occurrences of Jurassic aged dolerite intrusions. The southern boundary of the proposed development area is underlain by rock units of the Rooiberg Group and Lebowa Granite Suite, as mentioned in Section 4 of this report. Colluvial deposits can be anticipated along hillslopes with alluvial deposits anticipated near drainage features, especially adjacent to the rivers crossing the site.

6.1 VRYHEID FORMATION

The Vryheid Formation is predominantly arenaceous, coarse grained, and consists predominantly of sandstones, grits, arkoses, with subordinate mudrocks and coal seams. The sandstones of the Vryheid formation, while consisting predominantly of quartz, may contain significant quantities of rock fragments consisting of micaceous fragments (mica / clay minerals / chlorite) and felsite (fine grained quartz / feldspar mixture). The quartz-rich sandstones disintegrate to form sandy residual soils, whereas the feldspathic sandstones generally decompose to form clayey sands or sandy clays of low to medium plasticity (Brink, 1983). Based on previous investigations undertaken in near proximity to the study area, the sandstone bedrock was observed to weather to sandy and clayey residual soils.

The abovementioned rock types may be closely intercalated, resulting in highly variable geotechnical conditions, both vertically and horizontally. It is not unusual for a weak lens of mudrock to occur within a competent layer of sandstone, or for a band of rock to disappear horizontally over a short distance. The occurrence of weaker strata within or below competent rock strata may be problematic for the founding of heavy structures. The assumption that the founding conditions will improve with depth does not necessarily apply in the case of the Vryheid Formation.

In respect of sourcing construction materials for roads and laydown areas consideration could be given to natural gravely or crushed sandstone bedrock. Selective usage must be exercised to avoid using sandstone containing excessive pyrite and muscovite, which can cause distress when used as basecourse (Brink, 1983). In addition, where chemical stabilization is required the clay matrix of sandstones make them suitable for stabilization with lime (Brink, 1983). The occurrence, nature, material quality and quantity of sandstone and other potential construction materials will have to be assessed during the detailed geotechnical investigation. It is recommended that provision be made to procure aggregates for use in upper pavement layerworks construction and the manufacture of concrete from commercial sources.

On the contrary, mudrocks such as siltstone, mudstone and “mud-shales” are not considered suitable for use as construction materials, due to their swelling characteristics, excessive absorption of water and poor engineering performance. Slope stability issues can arise in areas where closely intercalated sandstones and mudrock co-exist. When mudrocks slake or disintegrate the exposed sandstone layers are undercut, which can result in rockfalls (Brink, 1983).

6.2 ROOIBERG GROUP

Due to the presence of a large amount of free silica in the rock, coupled with a very fine-grained texture, rhyolite is extremely resistant to chemical decomposition resulting in relatively thin residual soils, seldomly exceeding 1.5 m to 2.0 m in thickness.

Apart from its hardness and resistance to decomposition, rhyolite comprises a high degree of jointing, with predominantly vertical or steeply inclined joint sets. The joint planes are predominantly observed to be very smooth, planar and continuous, presenting stability hazards in deep cuts, which is further exacerbated by the presence of clay coatings between the joint planes.

6.3 LEBOWA GRANITE SUITE

Granitic and granophyric rocks have essentially the same mineralogical and chemical compositions and therefore have similar engineering properties. The weathering profile of the Bushveld granites results in jointing or minor compositional differences giving rise to alternating sequences of decomposed and unweathered rock (Brink, 1981). The gradation from unweathered granite bedrock to residual soils commences with widely spaced joints, sealed with chlorite progressing to the gradual alteration of the feldspars to a soft brown clay, and finally to a yellowish-brown kaolinitic clay with a low to moderate plasticity. The mode of weathering is thus a combination of chemical and physical disintegration, resulting in the development of residual soils comprising angular grains of quartz and feldspar with a small percentage of kaolinitic clay. The development of relatively more clayey soils is possible, which will give rise to stiff, silty clays or clayey silts generally containing sands and fine gravels of both quartz and feldspar.

The unweathered granitic bedrock is considered suitable for use as crushed rock for concrete aggregate, riprap and basecourse materials.

7. SEISMICITY

In accordance with research undertaken by Andrzej Kijko, in particular, studies entitled, “Data Driven Probabilistic Seismic Hazard Assessment Procedure for Regions with Uncertain Seismogenic Zones” and “The South African National Seismograph Network”, it is observed that moderate to high expected peak ground accelerations (PGA) can be correlated with the presence of mining activities occurring in an area. The Seismic Hazard Map of South Africa (Kijko, 2008) included as Figure 7.1, indicates that the proposed study area comprises peak ground accelerations ranging between 0.12 g and 0.16 g, with a 10% probability of being exceeded in a 50 year period, which may potentially be due to the presence of mining activities in the area.

Further details relating to the presence and potential for undermined areas in close proximity to the green hydrogen and ammonia facility has been intentionally excluded from this report as such work is deemed necessary during a detailed geotechnical investigation subsequently forming part of the concept/preliminary design process.

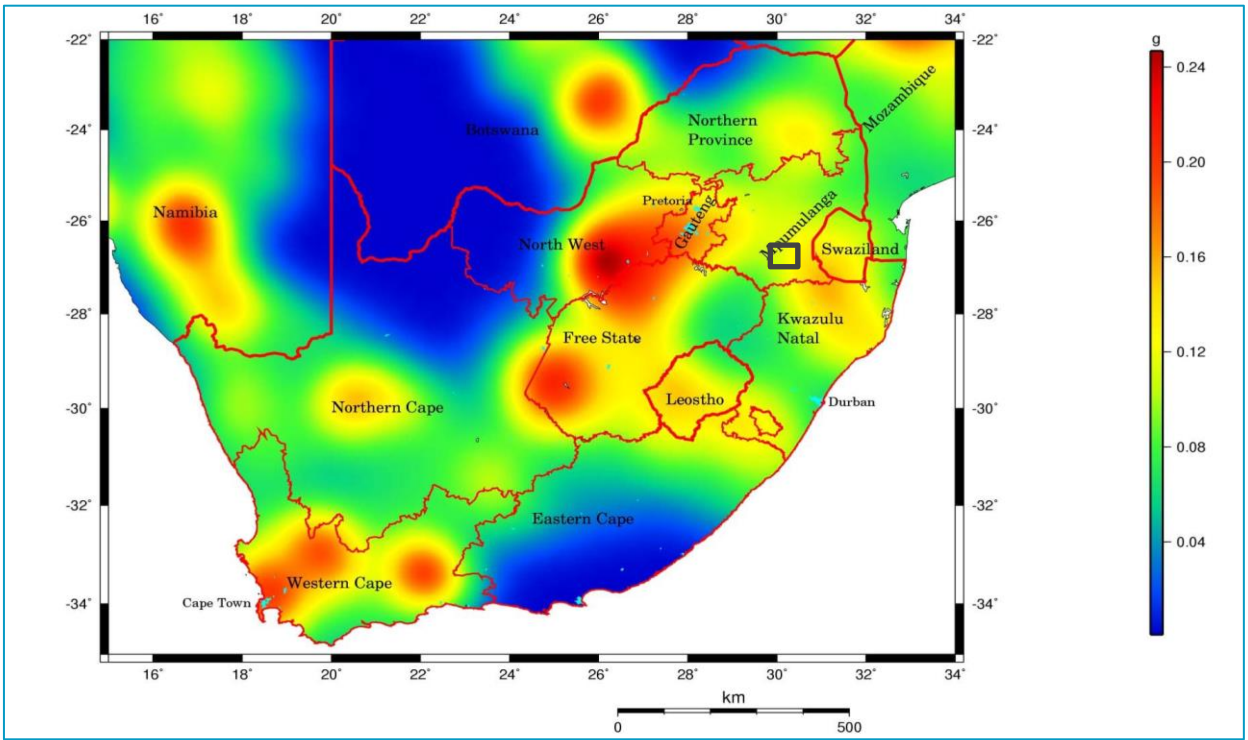

Figure 7.1: Seismic Hazard Map of South Africa (Kijko, 2008).

8. GEOTECHNICAL APPRAISAL

Based on previous investigations carried out in near proximity to study area as well as Weinert's climatic N-Value of 3, deeply weathered residual soils of a clayey and sandy nature may prevail across the proposed development area.

Competent, founding conditions can be anticipated at depths beyond 3 m from natural ground level and will need to be assessed and verified during the detailed geotechnical investigation. It must be noted that no details pertaining to the foundation design were provided during compilation of this report.

It is assumed that the green hydrogen and ammonia facility will comprise various structures such as water pipelines, water reservoirs, compressed hydrogen storage and air separation units, and as such, multiple foundation solutions may be required to satisfy the loading requirements of each structure. Consideration can be given to the following foundation types:

- Due to the dynamic loading of the water reservoirs, a ring beam foundation would be ideal to support the structure and distribute the loads into the residual soils or weathered bedrock.

- Pad footings, comprising columns and reinforced bases can be considered for founding of the compressed hydrogen tanks and associated buildings relating to the green hydrogen and ammonia facility. The pad footings are required to be keyed into a competent horizon, either weathered bedrock or a pre-treated subgrade comprising good quality material.

- Ancillary structures proposed across the development area, are recommended to be founded on an engineered raft foundation solution and depends upon the size and loads of the proposed structures. As it is assumed that these structures will be lightly loaded, subgrade pre-treatment accompanied by addition of water can be implemented to break the bonds between the soil particles. This will entail over-excavating the material to beyond the optimal founding depth, followed by backfilling of the same material in layers compacted to at least 95% of Modified AASHTO maximum dry density at or near to the optimum moisture content. This will result in densification of the subsurface materials and reducing collapse settlement to within acceptable limits. It is also recommended that an impermeable concrete apron be constructed around the perimeter of these structures following construction and that management of surface water be properly implemented. Alternatively, lightly reinforced strip footings can be considered for the proposed associated buildings.

It must be noted that a detailed geotechnical investigation will inform and finalise the recommendations of the most effective foundation solution for all structures and will play a pivotal role in determining the actual founding conditions prevailing across the proposed development area.

8.1 EXCAVATION CONDITIONS

Of specific importance to the development is the excavation conditions prevailing across the site, which will generally impact the preparation and construction of foundations, trenches for buried services and access roads. Based on the geology of the area and the subsequent engineering geological implications mentioned in Sections 4 and 6, the following excavation conditions can be anticipated but will need to be confirmed during a detailed site investigation:

- Topsoil and Colluvium – generally soft excavation.
- Residual and pedocretes – soft to generally intermediate excavation. Can possibly occur as hard excavation if hardpan pedocretes are encountered.
- Weathered bedrock – generally intermediate to hard excavation.

The above excavation conditions have been referenced from SANS 1200 (1986), which is further summarised in Table 8.1.

Table 8.1: Summary of Excavation Conditions (SANS 1200, 1986).

Class of Excavation	Definition
Soft	Material that can be efficiently excavated, without prior ripping by the following equipment: Bulldozer with a mass of at least 22 tons and an engine developing approximately 145 kW at the flywheel. A tractor-scraper unit with a mass of at least 28 tons and an engine developing approximately 245 kW at the flywheel, pushed by a bulldozer during loading (35 tons, 220 kW). Track-type front end loader with a mass of at least 22 tons and an engine developing approximately 140 kW at the flywheel.
Intermediate	Material that can be efficiently ripped by a bulldozer with a mass of at least 35 tons when fitted with a single tine ripper and an engine developing approximately 220 kW at the flywheel.
Hard	Material that cannot be efficiently ripped by a bulldozer equivalent to that described for Intermediate Excavation and requires blasting.
Boulder Class A	Material containing in excess of 40% by volume of boulders between 0.03 m^3 and 20 m^3 in size, in a matrix of softer material or smaller boulders.
Boulder Class B	Materials containing 40% or less by volume of boulders ranging from 0.03 m^3 to 20 m^3 in size, in a matrix of soft material or smaller boulders

9. GEOTECHNICAL IMPACT ASSESSMENT MATRIX

From a geological/geotechnical perspective, no fatal flaws have been identified in the desk study assessment that would prevent the construction of the proposed development at any of the aforementioned alternative sites. This will need to be followed on by a detailed geotechnical investigation to confirm the presence and potential of fatal flaws throughout the preferred site. It must be noted that the extent or presence of any undermined areas cannot be determined at a desk study level and will require further investigation.

The impact of the project alternatives on the geological environment will predominantly relate to the removal and displacement of soil, boulders and bedrock referred to in this report as “subsoils”. The levelling of areas to create building platforms will also result in the displacement and exposure of subsoils. These impacts will have a negative visual impact on the environment, which in some cases can be remediated. The risk of soil erosion is also increased during construction activities, by the removal of vegetation and by possible disturbance to the natural drainage environment, subsequently leading to the prevention of infiltration of rainwater and increased surface run-off. Areas of concentrated surface flow can be anticipated at the energy facilities, resulting in gradual erosion of unconsolidated soil during the operational life of the facilities. This can result in the creation of preferential drainage features, unless remediated through proper engineering design (i.e., stormwater drainage).

Based on the impact assessment matrix undertaken for this project, from a geotechnical perspective, the impact of the Hendrina Green Hydrogen and Ammonia Facility was found to be “Negative with Medium to High impacts - The anticipated impacts will have considerable negative effects and will require the implementation of mitigation and monitoring measures”. The geotechnical impact assessment matrix is detailed in Table 9.1 and was formulated based on a matrix provided by WSP.

The site is considered suitable for the proposed development provided that the recommendations presented in this report are adhered to, which needs to be verified by more detailed geotechnical investigations during the detailed design stage.

Table 9.1: Geotechnical Impact Assessment Matrix with Mitigation

Impact Activity	Aspect	Impact / Risk Description	Nature of Impact	Probability		Sensitivity of the Aspect		Severity of the Impact (Magnitude)		Duration		Scale / Extent		Significance (without Mitigation)	
Vegetation clearance & Soil Erosion	Terrestrial Biodiversity	Vegetation clearance in preparation for construction activity will definitely occur on at least the development footprint, where protected ecosystems are present. This will result in the permanent loss of the affected portions of the system if not mitigated. The risk of soil erosion is increased resulting in the prevention of infiltration of rainwater thereby increasing surface run-off.	Negative	5	Definite	3	Sensitive	5	High	5	Permanent	2	Site	75	High

Management Actions	Probability		Sensitivity of the Aspect		Severity of the Impact		Duration		Scale / Extent		Significance (with Mitigation)	
Prevent impacts / vegetation clearance beyond the minimum required development footprint, to reduce the impact severity and scale. Rehabilitate and re-vegetate affected areas after construction is concluded and at the end of the life of the facility to reduce impact duration.	5	Definite	3	Sensitive	3	Moderate	4	Long Term	1	Isolated	55	Medium

10.COMPARATIVE ASSESSMENT OF ALTERNATIVES

A comparative assessment has been undertaken, from a desk study perspective, of the most preferred site from the three alternatives provided by the Client and is listed in Table 10.1 below.

KEY:

PREFERRED	The alternative will result in a low impact/reduce the impact
FAVOURABLE	The impact will be relatively insignificant
LEAST PREFERRED	The alternative will result in a high impact/increase the impact
NO PREFERENCE	The alternative will result in equal impacts

Table 10.1: Green Hydrogen and Ammonia Facility Alternative Sites

Facilities	Preference	Reasons
Green Hydrogen & Ammonia Facility 1 (H2 Option 1) (25ha)	Preferred	Preferred as this alternative consists of shorter routes relating to the construction of the water pipeline and powerline. The geology at all the alternative sites consists of the same lithologies, however may comprise varying geotechnical conditions relating to the thicknesses of the underlying geological horizons.
Water Pipeline 1 (Option 1a) (16 km)	Preferred	
Powerline Option 1 (2 km)	Preferred	
Powerline Option 2 (7 km)	Preferred	
Powerline Option 3 (1.5 km)	Preferred	
Green Hydrogen & Ammonia Facility 2 (H2 Option 2) (25ha)	No Preference	Longer routes. The geology at all the alternative sites consists of the same lithologies, however may comprise varying geotechnical conditions relating to the thicknesses of the underlying geological horizons. From a geotechnical perspective, there is no preference amongst the alternative sites.
Water Pipeline 2 (Option 2a) (17 km)	No Preference	
Powerline Option 1 (3 km)	No Preference	
Powerline Option 2 (8 km)	No Preference	
Powerline Option 3 (0.5 km)	No Preference	
Green Hydrogen & Ammonia Facility 2 (H2 Option 3) (25ha)	No Preference	The geology at all the alternative sites consists of the same lithologies, however may comprise varying geotechnical conditions relating to the thicknesses of the underlying geological horizons. From a geotechnical perspective, there is no preference amongst the alternative sites.
Water Pipeline 3 (Option 3a) (19 km)	No Preference	
Powerline Option 1 (5 km)	No Preference	
Powerline Option 2 (5 km)	No Preference	
Powerline Option 3 (7 km)	No Preference	

Based on Table 10.1 above , the Green Hydrogen and Ammonia Facility 1 (H2 Option 1) along with the associated infrastructure, has been selected as the preferred alternative as the proposed routes for the water pipeline and powerline are relatively shorter, which will result in less trench excavations and visual impacts. All the alternative sites are all underlain by lithologies of the Vryheid Formation, hence have no geotechnical preferences. It must be noted that there is a possibility of varying geotechnical conditions relating to the thicknesses, weathering and engineering properties of the underlying geological horizons, which can only be determined by site specific detailed investigations.

11. CONCLUSIONS AND RECOMMENDATIONS

The foregoing report presents the findings concluded from a geotechnical desk study undertaken for the proposed Hendrina Green Hydrogen and Ammonia Facility. As part of the geotechnical desk study, three alternative sites for the green hydrogen and ammonia facility, inclusive of three route alternatives for the associated infrastructure, were assessed.

In accordance with the 1:250 000 Geological Map 2628 East Rand, published by the Council of Geoscience, the study area is underlain by stratigraphic units of the Ecca Group, Karoo Supergroup; Rooiberg Group of the Transvaal Supergroup and the Lebowa Granite Suite of the Bushveld Complex respectively. The site is anticipated to be underlain by deep residual soils.

Further details relating to the presence and potential for undermined areas in close proximity to the green hydrogen and ammonia facility have been intentionally excluded from this report as such work is deemed necessary during a detailed geotechnical investigation subsequently forming part of the concept/preliminary design process.

The impact of the development was found to be "Negative with moderate to high impacts - The anticipated impacts will have considerable negative effects and will require the implementation of mitigation and monitoring measures." Based on a preliminary geotechnical assessment, the site is considered suitable for the proposed development, provided the recommendations provided in this report are adhered to.

Conclusions presented in this report will have to be more accurately confirmed during the detailed geotechnical investigation, which is recommended to be undertaken during the detailed design phase of the project. The detailed geotechnical investigation must entail the following:

- Profiling and sampling exploratory test pits to determine founding and subgrade conditions for the green hydrogen and ammonia facility as well as the associated infrastructure.
- Geotechnical materials investigation for construction sources – gravel and rock.
- Thermal resistivity and electrical resistivity geophysical testing for electrical design and ground earthing requirements.
- Groundwater sampling of existing boreholes to establish a baseline of the groundwater quality for construction purposes.
- Disturbed and undisturbed sampling to be carried out across the proposed development area for laboratory analysis.

APPENDIX A: CV'S OF KEY PERSONNEL

CURRICULUM VITAE

MUHAMMAD OSMAN

SENIOR ENGINEERING GEOLOGIST

Geotechnical Engineering, Kwa-Zulu Natal.

QUALIFICATIONS

Pr Sci Nat	2021	Professional Natural Scientist with SACNASP
BSc Hons	2014	BSc Honours in Engineering and Environmental Geology, University of Kwa-Zulu Natal
BSc Geol	2013	BSc Degree in Geological Sciences, University of Kwa-Zulu Natal

EXPERTISE

- Project Management
- Subcontractor Supervision
- Infrastructure Development
- Renewable Energy
- Housing/Township Investigations
- Centre-line Investigations and Road Reserve Upgrades
- Borrow Pit and Materials Investigations
- Dam Investigations (Water & Waste)
- Pipeline and Reservoir Construction
- Heavily and Lightly Loaded Structures
- Foundation Assessments
- Slope Stability Analysis

Mr Muhammad Osman is a qualified engineering geologist with a BSc Honours degree in Engineering and Environmental Geology attained from the University of Kwa-Zulu Natal. He has 8 years of experience in the fields of engineering geology, geotechnical and materials investigations across South Africa and in Mozambique, for renewable energy projects, dams, roads, pipelines, single and multiple storey structures, as well as the co-ordination and supervision of geotechnical drilling operations.

As part of a geotechnical team, his responsibilities include preparation of detailed proposals and tender procurement documents, coordinating and undertaking field investigations and in-situ testing, analysis and interpretation of laboratory test results, detailed report compilation, supervision as well as management of projects and their budgets.

Muhammad is registered as a Professional Natural Scientist (Pr.Sci.Nat) with the South African Council for Natural Scientific Professions in the geological sciences (Reg No.115558).

PROJECTS

Hendrina, Camden I & Camden II Renewable Energy Facilities (2022)	Desktop geotechnical assessments for the Hendrina, Camden I and Camden II Renewable Energy Complexes. The studies focused on associated structures such as grid connections and substations.
Sibanye-Stillwater WPL TD6 Tailings Dam (2022)	Geotechnical Project Lead for the CPTu Campaign at the Western Platinum TD6 Tailings Storage Facility. The project also included a test pit investigation and installation of vibrating wire piezometers.

Sibanye-Stillwater Karee TD1/TD4 Tailings Dams (2022)	Geotechnical Project Lead for the CPTu Campaign at the Karee TD1 and TD4 Tailings Storage Facilities. The project also included a test pit investigation and installation of vibrating wire piezometers.
Tarkwa LoM Study (2022)	Geotechnical Project Lead for the Tarkwa Gold Mine Expansion Study, Ghana
Akyem LoM Study (2022)	Geotechnical Project Lead for the Akyem Gold Mine Expansion Study, Ghana
Ludeke Dam Remediation (2021)	Detailed geotechnical investigation to determine the cause of seepage on the right flank and settlement of the gravity retaining walls on the left flank of the Category 3 dam. Carried out drilling supervision, core logging and CPT testing.
Heineken Solar PV Plant (2021)	Project Leader and Field Engineering Geologist for the proposed Heineken Solar PV Plant underlain by Dolomite terrain in Sedibeng, Johannesburg. Field work comprised off trial pitting and DPL testing on a grid and surface mapping.
Kenhardt Solar PV Plant (2021)	Assistant project leader for the geotechnical investigation for the proposed Kenhardt Solar PV Plant in Upington. The investigation entailed the undertaking of trial pitting and percussion drilling in predominantly calcrete materials.
Brandvlei Wind Energy Facility (2021)	Desktop geotechnical study for the proposed Brandvlei Wind Energy Facility located in the Northern Cape. The study also focused on associated structures such as powerlines and substations.
Rietkloof Wind Energy Facility (2021)	Desktop geotechnical study for the proposed Rietkloof Wind Energy Facility located in the Northern Cape. The study also focused on associated structures such as powerlines and substations.
Karreebosch Wind Energy Facility (2021)	Desktop geotechnical study for the proposed Karrebosch Wind Energy Facility located in the Northern Cape. The study also focused on associated structures such as powerlines and substations.
Bevenson Dam (2020)	Detailed geotechnical investigation to determine the cause of seepage along the downstream shoulder of Bevenson Dam. The investigation entailed the drilling of rotary boreholes at various elevations of the downstream shoulder and analysis of the clay core material.
N2 Ballito to Tinley Manor (2020)	Assisting in the compilation of an interpretative geotechnical report for the proposed National Route 2 (N2) upgrade from Ballito to Tinley Manor, approximately 27km of road alignment.
Gluckstadt Water Supply Scheme (2020)	Project Leader and Field Engineering Geologist for the construction and installation of approximately 100Km of bulk and reticulation pipelines, 8 concrete reservoirs, a water treatment works and associated pump stations. The field investigation comprised the undertaking of trial pits, in-situ testing and representative disturbed/undisturbed sampling.
Eskom Eastern Cape Radio Towers (2020)	Geotechnical investigation for the proposed Eskom Radio Tower project comprising the erection of radio masts across the Eastern Cape. The investigation entailed the excavation of trial pits and DPL testing.

Piesang River Wetland Rehabilitation (2020)	Project Leader and Field Engineering Geologist undertaking a geotechnical materials investigation to determine the suitability and utilisation of in-situ materials for construction purposes.
National Route 3 (N3) Upgrade (2019)	Compilation of an interpretative geotechnical report for the proposed National Route 3 (N3) upgrade from Ashburton to Townhill. The project comprised the upgrading and construction of new carriageways, interchanges and drainage infrastructure.
Usuthu RWSS Off Channel Storage Dam (2019)	Detailed geotechnical investigation for the proposed construction of Usuthu RWSS Off Channel Storage Category 3 dam. The investigation entailed the drilling of rotary core boreholes along the proposed centre line, right and left flanks. A detailed materials investigation was also conducted, comprising drilling and trial pitting, for use during construction.
Ntuzuma to Ogunjini Water Supply Scheme (2019)	Geotechnical investigation for the proposed construction of a 20Km pipeline and 20Ml reservoir. The investigation entailed trial pitting along the proposed pipeline alignment and drilling supervision at the reservoir site.
Darvill Wastewater Treatment Works Sludge Dam (2019)	Geotechnical investigation for the proposed Darvill WWTW Sludge Dam and materials investigation for construction purposes. The field investigation consisted of trial pitting and in-situ testing.
Namas and Zonnequa Wind Farms (2018)	Pre-feasibility geotechnical investigation for the proposed Namas and Zonnequa Windfarms comprising a total of 100 wind turbine generators and associated substations. The investigation comprised trial pitting through aeolian and pedocrete materials.
Mzingazi Canal Bridge (2018)	Pre-feasibility geotechnical investigation for the proposed upgrade of the Mzingazi Canal Bridge crossing the Tuzi Gazi Waterfront in Richards Bay.
Military Veterans Residential Units (2018)	Detailed geotechnical investigation for proposed Military Veterans Housing Project in and around Pietermaritzburg. The investigation comprised trial pitting and in-situ testing for single and multiple storey units.
Bellair Clusters 1 & 2 Housing Development (2017)	Project Leader and Field Engineering Geologist for the proposed low to medium income housing as part of DOHS Serviced Sites Programme.
Department of Public Works Offices (2017)	Geotechnical and foundation investigation for the proposed upgrade to the Department of Public Works offices in Pietermaritzburg, in order to determine the cause of settlement and cracking. The investigation comprised the excavation and exposure of foundations, undisturbed sampling and in-situ testing.
Ethekwini Municipality Housing Developments (2017)	Geotechnical investigations for various housing developments in and around Durban. The investigations comprised trial pitting and in-situ testing for single and multiple storey residential units.

South 32 Mozal Desalination Plant (2017)	Geotechnical investigation for the proposed desalination plant to be constructed at the Mozambique Aluminium (Mozal) smelter in Matola, Mozambique. The investigation also included the pipeline alignment from the harbour.
Pietermaritzburg Airport Expansion (2016)	Detailed geotechnical investigation for the proposed upgrade to Pietermaritzburg Airport which included the construction of new access roads and additional buildings across the airport compound. The investigation entailed the excavation of trial pits, undisturbed sampling and in-situ testing.
Various Small to Medium Scale Projects (2015-2016)	Geotechnical investigation for various small to medium scale projects, including but not limited to housing developments, pipeline investigations and sanitation projects across Kwa-Zulu Natal.

MEMBERSHIPS

SACNASP (Pr Sci Nat)	Professional Natural Scientist with the South African Natural Scientific Professions

RECORD OF REPORT DISTRIBUTION

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