GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600
PO Box 12412, Die Boord,
7613, South Africa
Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Project no: 2023_03-5074
Phase B
Drilling Supervision at Akkerendam Nature Reserve, Calvinia
07 December 2023

Llewellyn Reesberg
JVZ Construction
Calvinia Bulk Water Supply
Tel: +27 21 862 1973
Email: llewellyn@jvzconstruction.co.za

Dear Llewellyn,

Drilling of Managed Aquifer Recharge (MAR) boreholes for the Calvinia Bulk Water Supply, Calvinia, Northern Cape.

Five managed aquifer recharge (MAR) boreholes were drilled in the Akkerendam Nature Reserve, north of Calvinia, between the 8th and 22nd of November 2023 (**Map 1**). All areas were investigated by means of on-site structural and geological mapping and a geophysical survey (GEOSS, 2023). These boreholes are to be used as infiltration boreholes to facilitate the process of rainwater infiltration, storage and transfer. This would in turn, facilitate a local rise in the groundwater level, and optimise local recharge to the aquifer. The town of Calvinia is reliant on this aquifer for municipal groundwater and the proposed MAR system would enhance the sustainability of this critical water resource.

The borehole depths varied between 84 – 119 m. The drill sites were chosen, based on drilling results of production boreholes Cal Nat6 and Cal DV1, with the aim to be in close proximity to successful production boreholes. This is to increase the percentage of recharge proximal to the abstraction point. Details pertaining to the MAR boreholes drilled are summarised in **Table 1** and **Table 2**, and detailed borehole logs are included in **Appendix A**. A conceptual geological cross section of the region is presented in **Figure 1**, superimposed on **Map 2**. Upon completion of the drilling, the boreholes were surveyed using a high-accuracy Trimble DA2 Catalyst GPS.

The boreholes were all drilled by H&A Drilling (Andries Volgraaff) using 304.8 mm air percussion drilling to a depth of 6 m, installing 273 mm OD/264 mm ID solid, mild steel casing to a depth of 6 m (4.5 mm wall thickness, SABS approved). This was followed by 203 mm air percussion drilling to the final depth of the borehole. The boreholes were developed with compressed air for at least one hour upon completion of the drilling. The boreholes were closed at surface with a solid mild-steel flange, which require a size 24 spanner to be opened.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

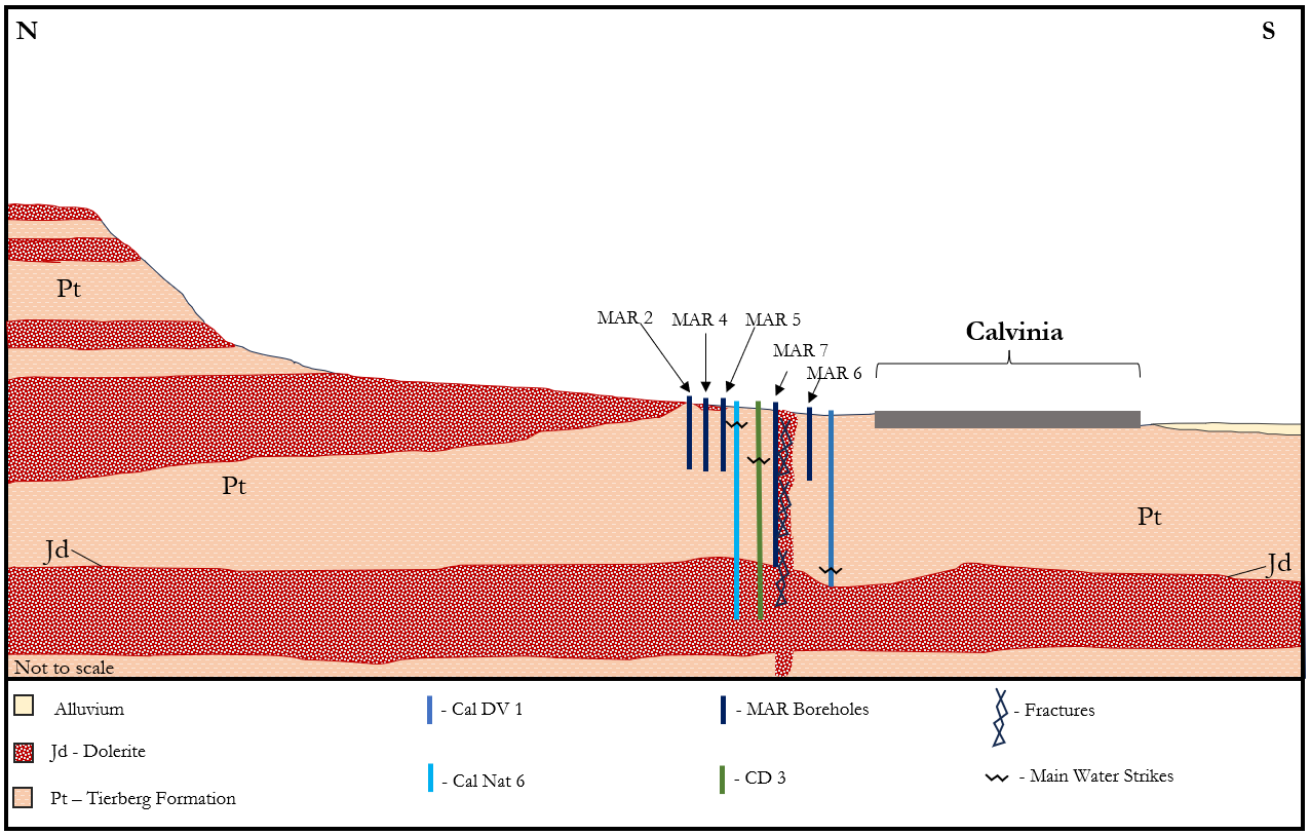


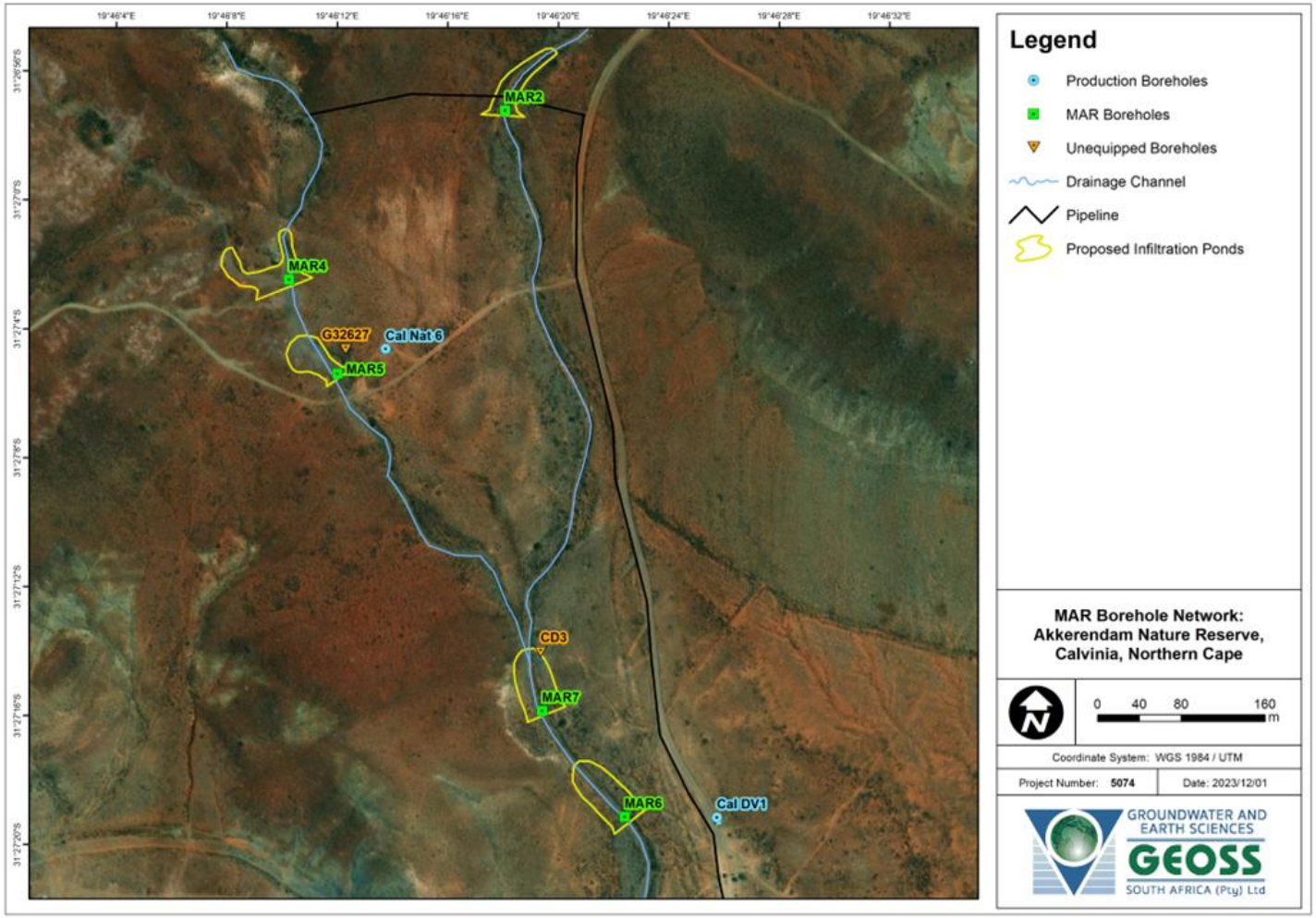
Figure 1: Conceptual geological cross section of the Akkerendam Nature Reserve, Calvinia

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za



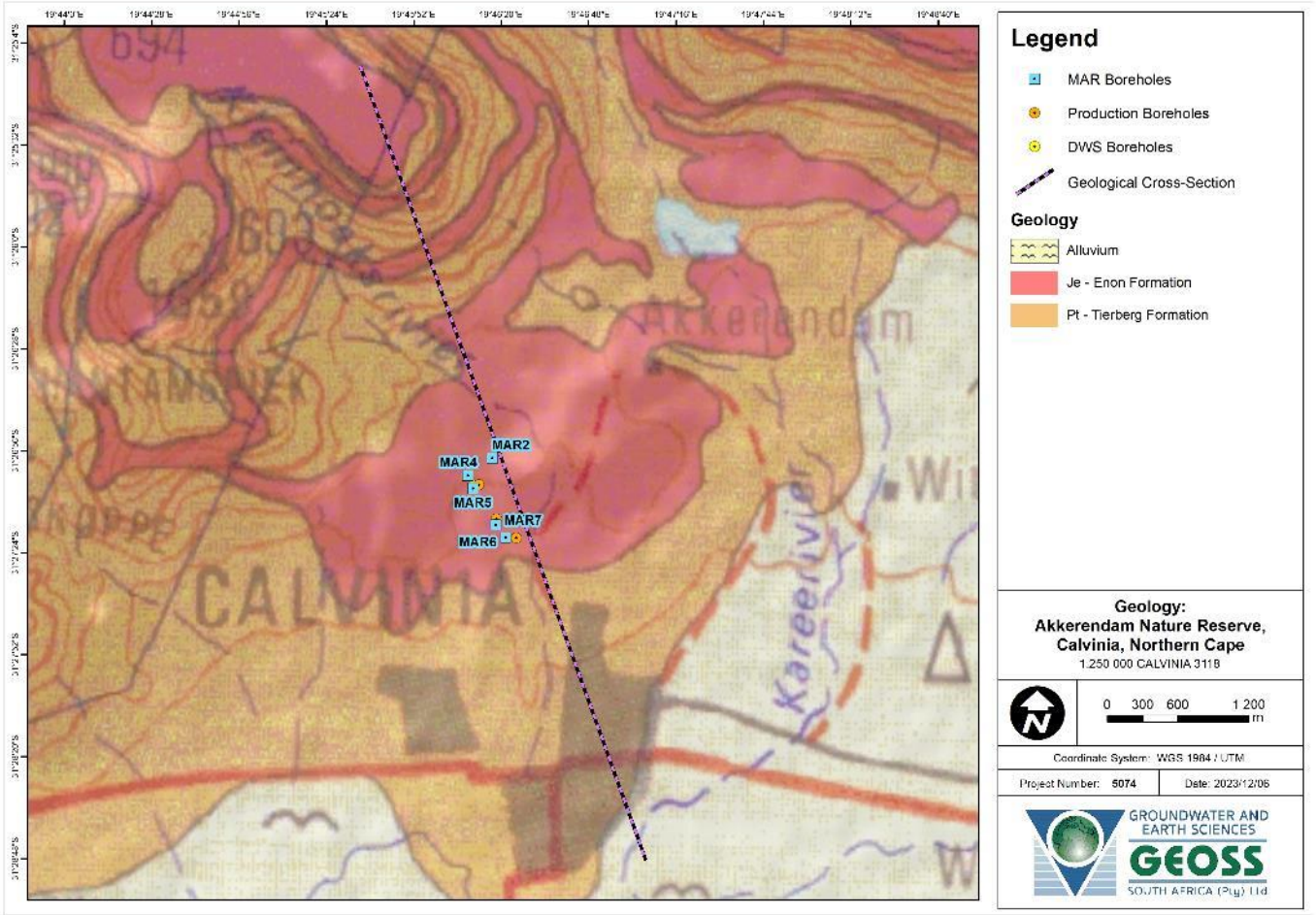
Map 1: Locality map of the Akkerendam Nature Reserve, showing MAR and production boreholes.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za



Map 2: 1:250 000 geological map series (3118, Calvinia).

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600
PO Box 12412, Die Boord,
7613, South Africa
Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Drilling Results of MAR Borehole 2:

The drilling of MAR borehole 2 (-31.4492022; 19.7716799) commenced on 20th of November 2023. Several fractures were intersected at depths of 6 m, 9 m and 58 m, resulting in a total airlift yield of 500 L/h (0.14 L/s). The lithology intersected at MAR 2 was green-brown baked shale, underlain by grey-black shale of the Tierberg Formation. The borehole was drilled to a final depth of 84 m. The groundwater seems to be of good quality in terms of salinity and pH, with the field chemistry measuring: EC (electrical conductivity) of 58 mS/m, TDS (Total Dissolved Solids) of 290 mg/L and pH of 7.2.

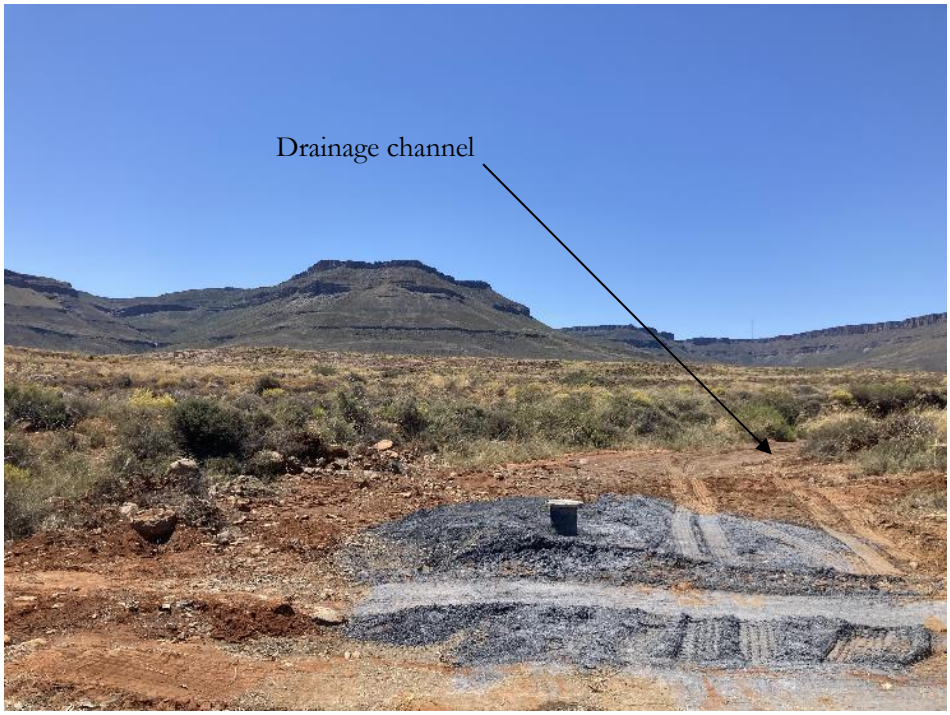


Figure 2: Infiltration borehole MAR 2.

Drilling Results of MAR Borehole 4:

The drilling of MAR borehole 4 (-31.4506722; 19.7695179) commenced on 21st of November 2023. Several fractures were intersected at depths of 4 m, 9 m, 12 m, 43 m, 53 m, and 68 m, resulting in a total airlift yield of 500 L/h (0.14 L/s). The borehole was drilled through a dolerite sill, into shale of the Tierberg Formation. The lithology intersected at MAR 4 was weathered to competent dolerite, underlain by green-brown baked shale and grey-black shale of the Tierberg Formation. The borehole

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600
PO Box 12412, Die Boord,
7613, South Africa
Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

was drilled to a final depth of 85 m. The groundwater seems to be of good quality in terms of salinity and pH, with the field chemistry measuring: EC (electrical conductivity) of 53 mS/m, TDS (Total Dissolved Solids) of 270 mg/L and pH of 8.2.

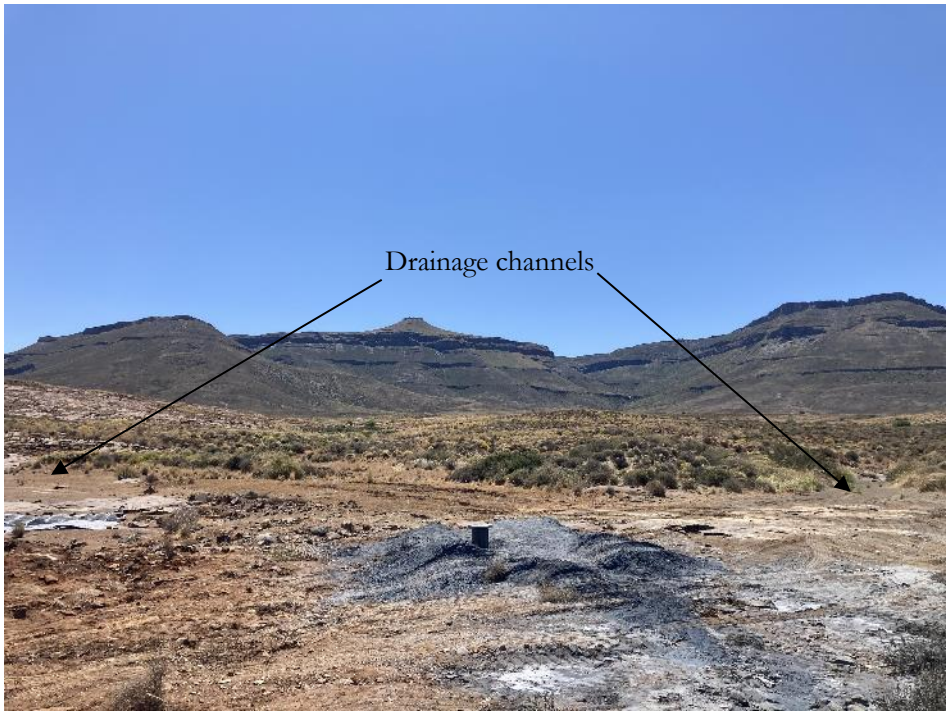


Figure 3: Infiltration borehole MAR 4.

Drilling Results of MAR Borehole 5:

The drilling of MAR borehole 5 (-31.4514812; 19.7700134) commenced on 08th of November 2023. Several fractures were intersected at depths of 8 m, 11 m, 18 m, 61 m and 71 m, resulting in a total airlift yield of 1 800 L/h (0.5 L/s). The borehole was drilled through a dolerite sill, into shale of the Tierberg Formation. The lithology intersected at MAR 5 was competent dolerite, underlain by green-brown baked shale and grey-black shale of the Tierberg Formation. The borehole was drilled to a final depth of 85 m. The groundwater seems to be of good quality in terms of salinity and pH, with the field chemistry measuring: EC (electrical conductivity) of 59 mS/m, TDS (Total Dissolved Solids) of 300 mg/L and pH of 7.7.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Figure 4: Infiltration borehole MAR 5.

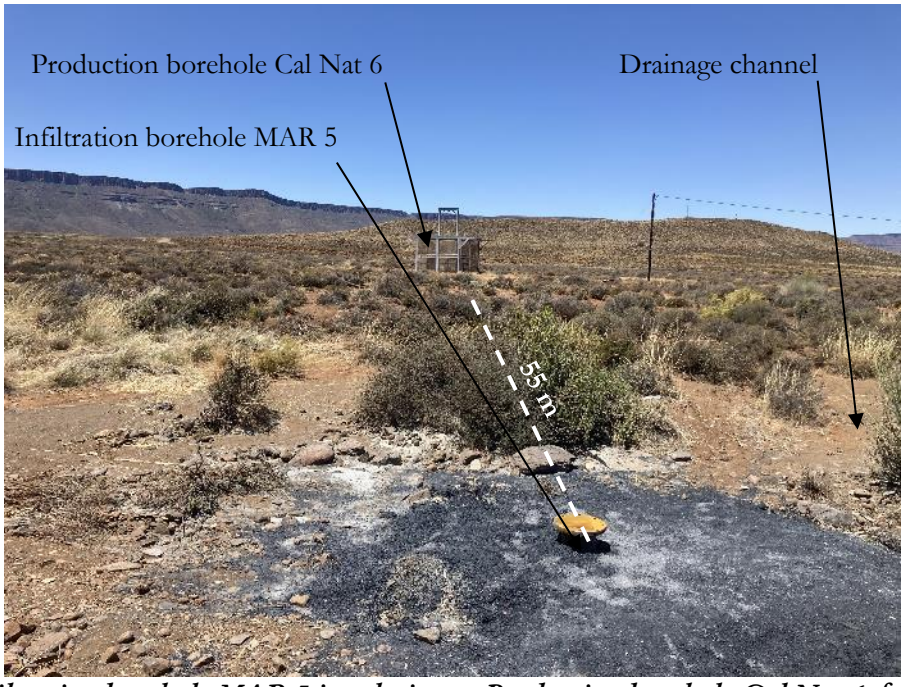


Figure 5: Infiltration borehole MAR 5 in relation to Production borehole Cal Nat 6, from the north.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600
PO Box 12412, Die Boord,
7613, South Africa
Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Drilling Results of MAR Borehole 6:

The drilling of MAR borehole 6 (-31.4552828; 19.7729331) commenced on 13th of November 2023. Several fractures were intersected at depths of 15 m, 27 m, 53 m and 74 m, resulting in a total airlift yield of 720 L/h (0.2 L/s). The lithology intersected at MAR 6 was light-brown baked shale, underlain by grey-black shale of the Tierberg Formation. The borehole was drilled to a final depth of 84 m. The groundwater seems to be of good quality in terms of salinity and pH, with the field chemistry measuring: EC (electrical conductivity) of 43 mS/m, TDS (Total Dissolved Solids) of 210 mg/L and pH of 8.4.

Figure 6: Infiltration borehole MAR 6.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Drilling Results of MAR Borehole 7:

The drilling of MAR borehole 7 (-31.4543752; 19.7720941) commenced on 14th of November 2023. Several fractures were intersected at depths of 4 m, 16 m, 25 m, 32 m and 77 m, resulting in a total airlift yield of 11 000 L/h (3.06 L/s). The initial airlift yield during drilling was 40 000 L/h (11.11 L/s), however, during borehole development, the airlift yield decreased to 11 000 L/h (3.06 L/s), indicating low storage. The borehole was drilled on the upstream side of a ~0.5 m wide dyke. The lithology intersected at MAR 7 was green-brown baked shale, underlain by grey-black shale of the Tierberg Formation, underlain by a competent dolerite sill. The borehole was drilled to a final depth of 119 m. The groundwater seems to be of good quality in terms of salinity and pH, with the field chemistry measuring: EC (electrical conductivity) of 50 mS/m, TDS (Total Dissolved Solids) of 250 mg/L and pH of 7.0.

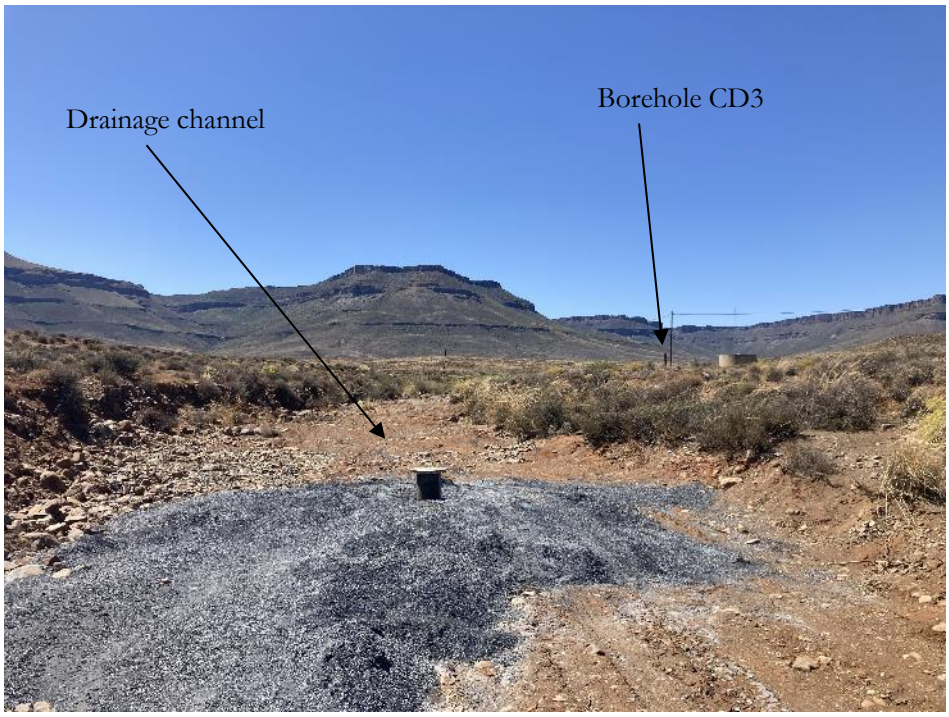


Figure 7: Infiltration borehole MAR 7 in relation to borehole CD3, located to the north.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600
PO Box 12412, Die Boord,
7613, South Africa
Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Table 1: Summary of MAR boreholes drilled.

ID	Latitude (DD, WGS 84)	Longitude (DD, WGS 84)	Elevation (mamsl)	Depth (m)	Fracture depths (mbgl)	Main water strike (mbgl)	Yield (L/h)	Yield (L/s)	EC (mS/m)	TDS (mg/L)	pH	Drilling order
MAR_2	-31.4492022	19.7716799	1025.1	84	6, 9, 58	9	500	0.14	58	290	7.2	4
MAR_4	-31.4506722	19.7695179	1024.4	85	4, 9, 12, 43, 53, 68	68	500	0.14	53	270	8.2	5
MAR_5	-31.4514812	19.7700134	1019.8	85	8, 11, 18, 61, 71	18	1 800	0.5	59	300	7.7	1
MAR_6	-31.4552828	19.7729331	1008.7	84	15, 27, 53, 74	27, 74	720	0.2	43	210	8.4	2
MAR_7	-31.4543752	19.7720941	1010.3	119	4, 16, 25, 32, 77	32	11 000	3.06	50	250	7.0	3

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Table 2: Summary of pictures taken during the drilling process.

	Weathered dolerite fracture		Competent dolerite
	Green-brown baked shale of the Tierberg Formation		Fracture in green-brown baked shale.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

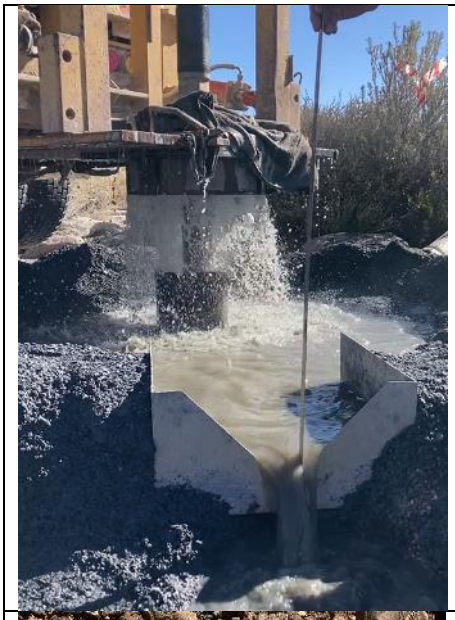
	Fracture in grey-black shale of the Tierberg Formation		Grey-black shale of the Tierberg Formation
	Large fracture in grey-black shale of the Tierberg Formation at MAR 7.		Example of open borehole with flange.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

	Airlift yield of 1800 L/h (0.5 L/s) at borehole MAR 5.		Borehole development at MAR 5.
	Dolerite dyke at MAR 7.		Example of drill chip garden at MAR 5.

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

	Borehole development at MAR 7.		Airlift yield of 1800 L/h (0.5 L/s) at borehole MAR 5.
	273 mm OD/ 264 mm ID Solid Mild Steel casing		Picture of the drilling process

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Unit 12, Technostell
9 Quantum Street, Technopark,
Stellenbosch, 7600

PO Box 12412, Die Boord,
7613, South Africa

Tel: +27 (0)21 880 1079
info@geoss.co.za
www.geoss.co.za

Results and Recommendations:

In general, the five MAR boreholes that were drilled are deemed to be successful with multiple fractures at various depths intersected at each borehole. Therefore, the following is recommended for each borehole:

- Installation of an electronic water level data logger to 1 meter above the end of the borehole.
- A falling head test, to collect data on the aquifer matrix acceptance capacity. Production boreholes in proximity to the MAR boreholes should be monitored during these tests.
- Continuous monitoring of water levels of infiltration into the MAR boreholes as well as water level monitoring on the production boreholes to monitor reaction and recharge to the local aquifer.

The next step for the infiltration boreholes will be blasting of the competent rock around the borehole in an area of 4 m x 4 m x 2.3 m. This, to excavate rock for the construction of an infiltration pit, which will allow for water infiltration into the borehole. Following the blasting, the solid mild-steel casing currently installed at the borehole will be cut off, and replaced with a perforated casing to allow for maximum infiltration into the borehole. The infiltration pit should be filled with upward, coarsening material to allow for optimal groundwater flow into the borehole. It is recommended to use a well-rounded, silica based, gravel pack as the upper most infiltration material in the infiltration pit to allow for an optimal infiltration rate and quick settlement.

Feel free to contact me if there are any questions related to the topics discussed.

Yours sincerely,

Jandré de Beer
Project Hydrogeologist

APPENDIX A : BOREHOLE LOGS

Log of Borehole No.: MAR 2

Location:	Calvinia	**Latitude:**	-31.4492022
Date:	20-Nov-23	**Longitude:**	19.7716799
Client:	JVZ Construction	**Ground Elevation:**	1025.1 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Green-brown baked shale (0 - 6 m)	0, 10, 20, 30, 40, 50, 60, 70, 80		304 mm Normal air percussion drilling (0 - 6 m)
			273 mm OD/264 mm ID Solid mild steel casing (0 - 6 m)
			Fractures at 6 and 9 m.
			203 mm Air Percussion Drilling, Open Borehole Construction (6 - 84 m)
Grey-black shale (6 - 84 m)			Water strike at 58 m
			End of borehole at 84 m

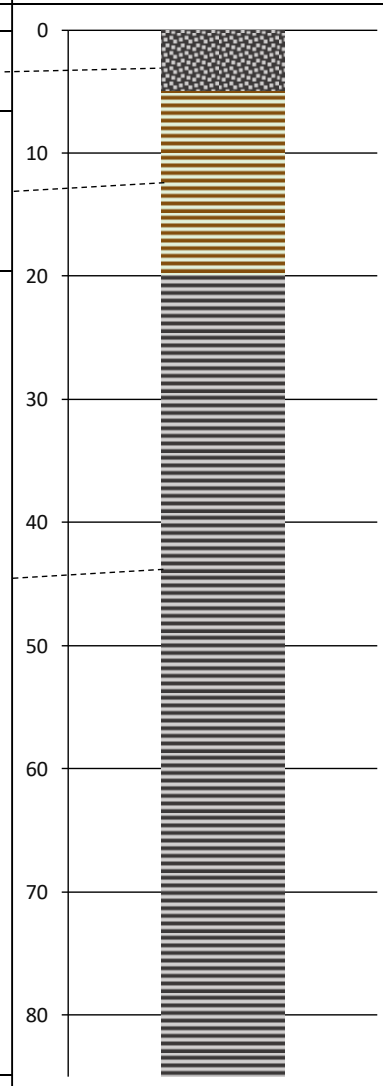
Drilled By:	H&A Drilling	**Remarks:**	Airlift yield = 500 L/h
Drill Method:	Air percussion		
Logged By:	GEOSS South Africa		

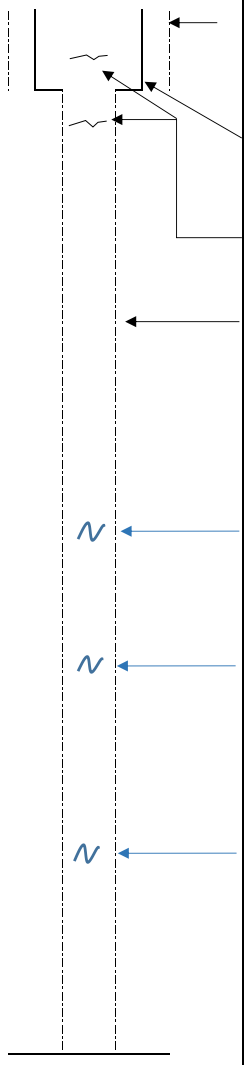
GEOSS SOUTH AFRICA (Pty) Ltd

Log of Borehole No.: MAR 4

Location:	Calvinia	**Latitude:**	-31.4506722
Date:	21-Nov-23	**Longitude:**	19.7695179
Client:	JVZ Construction	**Ground Elevation:**	1024.4 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Dolerite (0 - 6 m)			304 mm Normal air percussion drilling (0 - 6 m)
Green - brown baked shale (5 - 20 m)			273 mm OD/264 mm ID Solid mild steel casing (0 - 6 m)
			Fractures at 4 and 9 m.
			203 mm Air Percussion Drilling, Open Borehole Construction (6 - 85 m)
Grey-black shale (20 - 85 m)			Water strike at 43 m
			Water strike at 53 m
			Water strike at 68 m
			End of borehole at 85 m





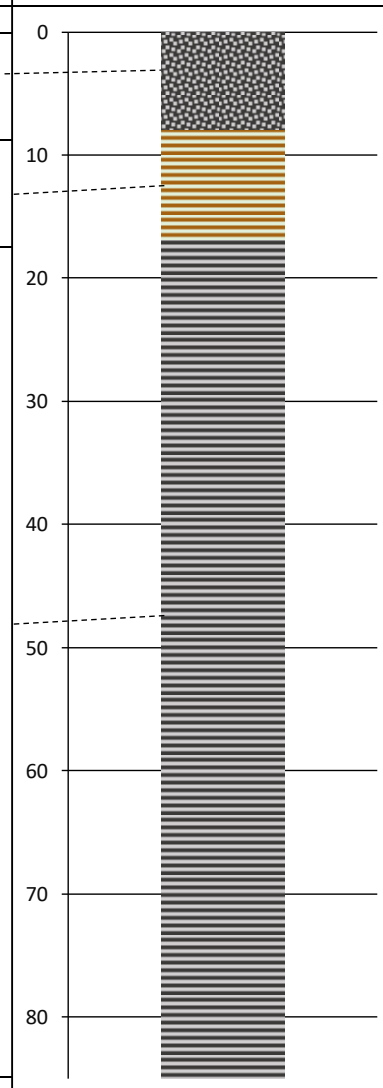
Drilled By:	H&A Drilling	**Remarks:**	Airlift yield = 500 L/h
Drill Method:	Air percussion		
Logged By:	GEOSS South Africa		

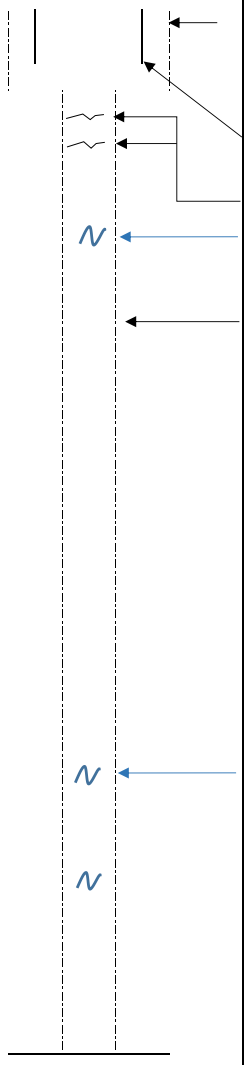
GEOSS SOUTH AFRICA (Pty) Ltd

Log of Borehole No.: MAR 5

Location:	Calvinia	**Latitude:**	-31.4514812
Date:	08-Nov-23	**Longitude:**	19.7700134
Client:	JVZ Construction	**Ground Elevation:**	1019.8 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Dolerite (0 - 8 m)			304 mm Normal air percussion drilling (0 - 6 m)
Green-brown baked shale (8 - 17 m)			273 mm OD/264 mm ID Solid mild steel casing (0 - 4.5 m)
			Fracture at 8 m and 11 m
			Water strike at 18 m
			203 mm Air Percussion Drilling, Open Borehole Construction (6 - 85 m)
Gre-black shale (17 - 85 m)			
			Water strike at 61 m
			Water strike at 71 m
			End of borehole at 85 m





Drilled By:	H&A Drilling	**Remarks:**	Airlift yield = 1 800 L/h
Drill Method:	Air percussion		
Logged By:	GEOSS South Africa		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Borehole No.: MAR 6

Location:	Calvinia	**Latitude:**	-31.4552828
Date:	13-Nov-23	**Longitude:**	19.7729331
Client:	JVZ Construction	**Ground Elevation:**	1008.7 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Green-brown baked shale (0 - 15 m)	0, 10, 20, 30, 40, 50, 60, 70, 80	304 mm Normal air percussion drilling (0 - 6 m) 273 mm OD/264 mm ID Solid mild steel casing (0 - 6 m) Fracture at 15 m Water strike at 27 m 203 mm Air Percussion Drilling, Open Borehole Construction (6 - 84 m) Water strike at 53 m Water strike at 74 m End of borehole at 84 m
Grey - black shale (15 - 84 m)			

Drilled By:	H&A Drilling	**Remarks:**	Airlift yield = 720 L/h
Drill Method:	Air percussion		
Logged By:	GEOSS South Africa		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Borehole No.: MAR 7

Location:	Calvinia	**Latitude:**	-31.4543752
Date:	14-Nov-23	**Longitude:**	19.7720941
Client:	JVZ Construction	**Ground Elevation:**	1010.3 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Green-brown baked shale (0 - 77 m)	0, 10, 20, 30, 40, 50, 60, 70	304 mm Normal air percussion drilling (0 - 6 m) 273 mm OD/264 mm ID Solid mild steel casing (0 - 6 m) Fractures at 4 m and 16 m Water strike at 25 m Water strike at 32 m 203 mm Air Percussion Drilling, Open Borehole Construction (6 - 84 m)	
Grey - black shale (77 - 110 m)	80, 90, 100, 110	Water strike at 77 m	
Green - brown baked shale (110 - 117 m)			
Dolerite (117 - 119 m)	120		End of borehole at 119 m

Drilled By:	H&A Drilling	**Remarks:**	Airlift yield = 11 000L/h
Drill Method:	Air percussion		
Logged By:	GEOSS South Africa		

GEOSS SOUTH AFRICA (Pty) Ltd