GAUTENG: EMFULENI LOCAL MUNICIPALITY: UNITAS PARK EXTENSION 17 ON PORTION 224 OF THE FARM HOUTKOP 594-IQ, : DOLOMITE STABILITY FEASIBILITY INVESTIGATION

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GAUTENG: EMFULENI LOCAL MUNICIPALITY: UNITAS PARK EXTENSION 17 ON PORTION 224 OF HOUTKOP 594-IQ: FEASIBILITY LEVEL DOLOMITE STABILITY INVESTIGATION

SUMMARY

This report presents the results of a feasibility level dolomite hazard assessment on Portion 224 of the farm Houtkop 594-IQ, to be known as Unitas Park Extension 17, in the Emfuleni Local Municipality in compliance with SANS 1936 (2012). The site is earmarked for a commercial development.

The site is characterised by variable sub-surface conditions. The blanketing layer consists mainly of residual shale, carbonaceous residual shale and coal beds of the Karoo Supergroup and chert residuum of the Malmani Subgroup. Residual dolerite, highly weathered and hard rock dolerite of the Karoo Super group are intercepted in the southern portion of the site; and hard rock quartzite of the Black Reef Formation is intercepted directly north of the dolerite in one borehole. Dolomite bedrock is anticipated at a depth of more than 60m, as no dolomite bedrock was encountered in boreholes typically drilled to a depth of 60m. The groundwater level was recorded in ten boreholes on the site and the original groundwater level is taken as 20m (or 1445m AMSL) during the current investigation. This depth is considered as the regional groundwater level.

Based on the data gathered, the site is characterised in terms of two primary dolomite hazard zones, namely:

Dolomite Hazard Zone	Inherent Hazard Class	Description
1	1//1/4	Area largely reflecting a low susceptibility of all-size sinkhole and subsidence formation with respect to ingress of water and a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water changes as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

Dolomite Hazard Zone	Inherent Hazard Class	Description
2	1/4//1/4	Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water and groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water remains the same: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

In accordance with SANS 1936 (2012) Dolomite Hazard Zone 1 and Dolomite Hazard Zone 2present a tolerable hazard for the proposed commercial developments planned for Unitas Park Extension 17; provided dolomite stability footprint investigations are conducted and use is made of rationally designed reinforced concrete raft foundations catering for a 5m diameter loss of support for all structures in areas designated as D3.

The development should be subject to a stable groundwater rest level, monitored and controlled.

GAUTENG: EMFULENI LOCAL MUNICIPALITY: UNITAS PARK EXTENSION 17 ON PORTION 224 OF HOUTKOP 594-IQ: FEASIBILITY LEVEL DOLOMITE STABILITY INVESTIGATION

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2. TERMS OF REFERENCE AND SCOPE OF WORK

VGIconsult was appointed by Schulden Properties to conduct a feasibility level dolomite stability investigation on the site. VGIconsult presented budget and cost proposals to Schulden Properties on 5 October 2015.

The terms of reference and scope of the work to be undertaken were discussed with Mr Hans van Heerden of Schulden Properties and VGIconsult were instructed to proceed with the investigation accordingly on 21 October 2015.

3. AVAILABLE INFORMATION

Information sources include:

3.1. Topographic Data

- **Topographic Map, 1: 50 000 Scale Series**: issued by the Chief Directorate: Surveys and Mapping, Department of Land Affairs:

Sheet Name	Reference
Vereeniging	2627DB

3.2. Geological Information

- **Geological Map, 1: 250 000 Scale Series:** published by the Geological Survey of South Africa (Council for Geoscience):

Sheet Name	Reference
West Rand	2626

- **The Geology of South Africa**: by MR Johnson, CR Anhaeusser, RJ Thomas, 2006.

3.3. Reports

- Geo Buro, dated March 2008, entitled: “Dolomite Stability Investigation of Portions 156 and 203 of the farm Houtkop 594-IQ, Vereeniging” (Report No K16544-01).

3.4. Industry Standards and Publications

- **South African National Standard SANS 1936 Parts 1-4** (August 2012).

- “**A performance based approach to dolomite risk management**” by Buttrick, D., Trollip, N., Watermeyer, R., Pieterse, N, Gerber A., Environmental Earth Sciences, Springer-Verlag,**:** Volume 64, Issue 4 (2011), Page 1127-1138.

- **Department of Public Work’s Consultants Manual** entitled: “Department of Public Works: Appropriate development of infrastructure on dolomite: Manual for consultants: PW344”, dated September 2010.

- "Proposed **method for dolomite land hazard and risk assessment** in South Africa." by Buttrick, Van Schalkwyk, Kleywegt and Watermeyer, dated 2001, Journal of the South African Institution of Civil Engineering, Volume 43, Number 2.

3.5. Geohydrological Data and Reports

- Department of Water Affairs, National Office, Directorate Hydrological Services, Groundwater Information: HYDSTRA data (captured up to January 2013).

- Geohydrology Guideline Development: Implementation of Dolomite Guideline – Phase 1, Activities 19 & 28: Desktop development of a Dolomite Hydrogeological Compartment Map and explanation booklet (Report), dated November 2009, Project Number: 14/14/5/2, Authors: Martin Holland: Water Geosciences Consulting, Frans Wiegmans: Golder Associates.

- Department of Water Affairs, National Office, Directorate Hydrological Services, Groundwater Information: HYDSTRA data.

- Hobbs, P.J. 2004.Intermediate Groundwater Reserve Determination for Quaternary Catchments A21A & A21B. Project No. 2002-316[1] and Holland, M., 2007. Groundwater resource directed measures in Karst terrain with emphasis on aquifer characterization in the Cradle of Humankind near Krugersdorp, South Africa. Unpublished MSc thesis. University of Pretoria, Pretoria, South Africa.

4. DESCRIPTION OF THE STUDY AREA

4.1. Locality

The location of the site within the region is displayed in Figure 1.The site is located east of Houtkop Road and bordered by Unitas Park Extension 1 to the south-east.

Unitas Park Extension 17 is located on Portion 224 of the farm Houtkop 594-IQ in the Emfuleni Local Municipality. The investigation area covers a surface area of approximately 22,6ha.

4.2. Site Description

The site boundary, site layout with wet services and contour elevations are displayed in Figure 2. Emfuleni bulk services are located to the south-west of the site, as shown on Figure 2.The site is currently used for agricultural purposes. The site is proposed for commercial development on eighteen stands, including a filling station, builder's yard, shopping mall, service industries and mini storage facilities.

The topography of the site falls from 1467m AMSL in the north-east to 1463m AMSL in the south-west. Surface water runoff takes place as sheetwash along natural gradient towards Houtkop Road to the south-west of the site.

5. PROCEDURES USED IN THIS STUDY

5.1. Assimilation of Available Data

This investigation is initiated by gathering, assimilating and reviewing existing, available geological, geotechnical, geophysical and geohydrological data pertaining to the site.

[1]Refer to Section 5.7.2

5.2. Gravity Survey

The gravity method is the most widely used remote sensing technique applied on dolomite land. Variations in the earth's structure and composition give rise to variations in density. Indirectly the density variations are determined by measuring the gravity field which allows the determination of location, form, distribution of causative geological factors.

The gravity survey of a dolomitic terrain can be used to help determine dolomite bedrock configuration (bedrock topography). The gravity survey of the area under investigation was conducted on a 30m grid spacing by Engineering and Exploration Geophysical Services cc during the beginning of November 2015.

A relative Bouguer gravity anomaly contour map is produced from field surveys presenting anomalies of gravity high and low fields and gradients. Once depth of dolomite bedrock on the gravity high, low and gradients are confirmed by drilling, the relative Bouguer field is adjusted by subtracting a regional field so that the map becomes a better representation of depth to dolomite bedrock. Removal of the estimated regional field results in the creation of a residual data set. The residual gravity is displayed on Drawing VGI3925/1.

The gravity survey revealed a prominent west to east aligned gravity low field (deep dolomite bedrock, Karoo materials encountered to a depth of 60m in boreholes) in the central portion of the site extending also towards the north of the investigation area. The gravity low field is bordered by gravity high fields (presenting dolomite bedrock closer to surface, although not encountered in boreholes). A dolerite intrusion exists within the area of the gravity high field in the southern portion of the site.

5.3. Rotary Percussion Boreholes

5.3.1. Borehole Information

The positions of the twelve boreholes (3925/01 to 3925/12) drilled during the current investigation by VGIconsult, during 5 November 2015 to 11 November 2015, are displayed on Drawings VGI3925/1 and VGI3851/2. Two boreholes (1544/4 and 1544/5) drilled by Geo Buro are incorporated into this study to supplement the current investigation results.

The borehole logs are presented in Appendix 1 and summarised in Table 1.

5.3.2. Drilling Depths

a) Boreholes shall be drilled at least 6 metres into hard rock dolomite where such rock occurs at a shallower depth than 60 m;
b) Boreholes shall be drilled to at least 60 m if dolomite bedrock is not confirmed at shallower depth where dewatering is not occurring and the local authority has control of groundwater use;
c) In areas where the authorities do have a groundwater monitoring and control programme in place, boreholes intercepting intrusive rock need not be drilled into dolomite rock, provided at least 6 m of hard rock intrusive is confirmed.
d) In de-watered areas and areas where the authorities do not have a groundwater monitoring and control programme in place, a representative selection of boreholes should be drilled in excess of 60 m (typically to 100 m) or into dolomite bedrock to obtain a perspective of subsurface conditions below the OWL.

5.4. Investigation Type

As investigation type terms differ from document to document a comparison is provided:

SAICE SICP	SANS 1936	GFSH	Terminology used in this report
Pre-feasibility	-	-	Pre-feasibility-Stage
Feasibility	Feasibility-level-dolomite-stability	Phase 1	Feasibility-Stage
Tender design	-	-	Typically not applicable
Detailed design	Design-level	-	Design-Stage
Construction	Investigations-during-installation-of-services	Phase 2	Construction-Stage
Post construction	-	-	Typically not applicable
Remedial	-	-	Typically not applicable

According to SANS1936 Part 2 (2012) there are 3 stages of investigation, namely:

1. *Feasibility-level-dolomite-stability-investigations*
2. *Design-level-investigations*
3. *Investigations-during-installation-of-services*

The SAICE Site Investigation Code of Practice (SICP) identifies the following stages of investigation:

- ***Pre-feasibility*** *- desk study of available information and site walkover.*
- ***Feasibility*** *- comprehensive desk study and limited intrusive investigations (test pitting).*
- ***Tender design or Basic engineering*** *- geophysics, test pits, trial holes and limited boreholes with laboratory classification testing. A second round of investigations may be required to examine anomalies or uncertainties that emerge during the first round. This level is usually required for bankable feasibility studies.*
- ***Detailed design*** *- detailed intrusive investigations based on the development layout including boreholes, in-situ testing and advanced laboratory testing. Large scale trials may also be undertaken, e.g. test piles, pump tests, preload embankments etc.*
- ***Construction*** *- monitoring and additional testing during construction ensures that the geotechnical design criteria are being achieved. This phase of investigation also allows an appraisal of a much larger representation of the site geology often exposed during earthworks and foundation construction than is possible during earlier investigations. This is an often neglected part of the investigation process.*
- ***Post construction*** *- monitoring of the structure after construction provides valuable information in assessing the validity of the geotechnical model and the adequacy of the investigative methods. It also affords an opportunity to detect and remedy deficiencies, preferably before major damages are incurred.*
- ***Remedial*** *- forensic investigations attempt to identify the cause of failure or inadequate performance of structures and provide additional information to recommend appropriate remedial measures.*

5.5. Thickness and Depth Concepts

In the context of this report the concepts of thickness and depths are used as follows:

Depths		Thicknesses (Alluvium / Colluvium / Residuum)	
Range in m	**Appellation**	**Range in m**	**Appellation**
0-2/4	Near-surface	0-8/12	Thin
2/4-8/12	Shallow	8/12-16/24	Intermediate
8/12-16/24	Intermediate	16/24-36/44	Thick
16/24-36/44	Great Depth	36/44 and greater	Very Thick
More than 40	Very Great Depth	-	-

5.6. Coordinate System

The X- and Y-coordinates (values) for the boreholes, as reflected in Appendix 1, conform to the South African Coordinate System as set in the national control survey network maintained by the Chief Directorate: Surveys and Mapping of the Department of Land Affairs.

The X- and Y-values are given in metres latitude (7 digit value) and longitude (5 or 6 digit value). These coordinates are projected using the Gauss Conform Projection which is the Transverse aspect of the Mercator projection. The reference ellipsoid is the WGS84 (Hartebeeshoek 1994) ellipsoid.

The Central Meridian (longitude of origin or Lo) for this site is **27º.** In the South African coordinate system the X coordinates are measured **southwards from the equator** (where x = 0) towards the South Pole which is **positive.**

Y coordinates are measured from the Central Meridian (CM), increasing from the CM in a westerly direction so that Y is positive west of the CM and negative east of the CM.

5.7. Map Production (Projection, Co-ordinate System and Datum)

The projection information of the figures and drawings in this report are reflected on each individual figure and drawing and listed below:

Projection surface:	Mercator (cylinder)
Projection orientation:	Transverse aspect
Datum or reference ellipsoid:	World Geodetic System 84
Central Meridian:	In degrees (29 for this study)
False easting and northing:	Zero degrees
Scale factor:	1

A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth. A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid). Latitude and longitude values are traditionally measured either in decimal degrees or in degrees, minutes, and seconds (DMS). Latitude values are measured relative to the equator. Longitude values are measured relative to the prime meridian.
Data defined on a geographic coordinate system is displayed as if a degree is a linear unit of measure.

Although longitude and latitude can locate exact positions on the surface of the globe, it is not a uniform unit of measure. The drawings and figures are therefore presented (co-ordinated) in metres latitude (7 digit value) and longitude (5 or 6 digit value).

5.8. Hazard Characterisation Procedure

New national standards (SANS 1936, 2012) require use of internationally accepted terminology. The applicable terminology and its definition (with previous term used) are given below:

5.8.1. Terminology

5.8.1.1. Hazard

Source of potential harm. Hazard is the function of magnitude (of the events), area, and frequency.

5.8.1.2. Inherent Susceptibility (Inherent Risk)

A reflection of the geological susceptibility of a karst area to an event (sinkhole or subsidence). Inherent Susceptibility is expressed in terms of three broad categories, namely low, medium and high, typically, but not exclusively, denoting anticipated number of events per area over time.

5.8.1.3. Inherent Hazard Class (Inherent Risk Class)

A site is characterised in terms of **eight standard inherent hazard classes,** denoting the likelihood of an event (sinkhole or subsidence) occurring (susceptibility) as well as its likely size (diameter). The larger the Inherent Hazard Class (IHC) number, the greater the likelihood of the event occurring and the larger its potential size should it occur, for each respective inherent susceptibility category (low, medium, high).

5.8.1.4. Hazard Rating

The number of events per hectare that have occurred over a 20 year period due to human impact.

5.8.1.5. Tolerable Hazard Rating (Acceptable Development Risk)

The hazard rating is expressed as tolerable where the number of events experienced is less than and including 0.1 events per hectare per 20 years (preferably tending to 0 per hectare) that is exceeding the return period of 200 years and intolerable where the number of events experienced exceeds 0.1 events per hectare per 20 years (return period less than 200 years).

5.8.1.6. Return Period

Known as a recurrence interval and is an estimate of the interval of time between events of a certain size.

5.8.1.7. Subsidence (Doline)

Shallow, enclosed depression. In past South African literature subsidence, as defined above, is synonymous with doline. The term subsidence is substituted to prevent contradiction with international literature.

5.8.1.8. Sinkhole

A feature that occurs suddenly and manifests itself as a hole in the ground. In international literature the term sinkhole is often synonymous with doline.

5.8.1.9. Dolomite Land

Land underlain by dolomite or limestone rock directly or at a shallow depth, typically no more than:

a) 60m in areas where no de-watering has taken place and the local authority has jurisdiction and is monitoring and has control over the groundwater levels over the areas under consideration; or
b) 100m in areas where de-watering has taken place or where the local authority has no jurisdiction or control over groundwater levels.

5.8.1.10. Event

Occurrence [or change of a particular set of circumstances], in the context of this standard referring to a sinkhole or subsidence. An event can be one or more occurrences, and can have several causes. An event can consist of something not happening. An event can sometimes be referred to as an "incident" or "accident".

5.8.1.11. Potential Loss of Support

Refers to the removal of support below the foundation due to a nominal sinkhole or subsidence event. In proposing suitable foundation types in D3 areas, consideration should be given to the **potential loss of support** which could be anticipated for the designated Inherent Hazard Class based on the nascent[2] sinkhole size.

The philosophy to be applied to the design of the foundations is that in the event of catastrophic loss of support, there is sufficient time for occupants to safely escape after the occurrence of the sinkhole, and the level of expected damage associated with soil movements unrelated to sinkhole formation in near surface horizons is kept within reasonable limits.

5.8.2. Assessment Procedure

The hazard characterisation procedure (previously referred to as "risk" characterisation procedure in South African literature) is in accordance with the peer reviewed paper "A performance based approach to dolomite risk management":

The available information, geophysical data, borehole data and geohydrological information gathered during the investigation has been pooled and reviewed permitting the formulation of a perspective concerning the characterisation of the stability of the site.

The predominant mobilising agencies considered in this investigation are major groundwater level fluctuations (>6m), ingress of water, ground vibrations and gravity. Use is made of a generalised list of evaluation factors to evaluate the hazard. These factors are as follows:

- Receptacle development;
- Mobilising agencies, particularly ingress of water from leaking services;
- Potential sinkhole development space;
- Nature of the blanketing layer;
- Mobilisation potential of the blanketing layer;
- Bedrock morphology.

Receptacles or disseminated receptacles refer to any voids or cavities in the dolomite bedrock or in the overburden capable of receiving mobilised materials. *Receptacles are assumed to be present as no reliable geophysical tool exists to determine the location of these features. Consequently the information gathered from boreholes, including penetration times, air loss, hammer action, etc, combined with geophysical and geological information are used to formulate an impression of the degree of voids.*

The potential sinkhole development space, where used, refers to the expected maximum size sinkhole that conservatively may be anticipated to be generated if

[2]Adj. beginning to develop

sustained ingress of water were to occur. This factor is related to the depth of the receptacles or disseminated receptacles. The gravity survey, combined with borehole information strongly guides the appraisal of this factor.

The nature of the material covering the receptacles, be they above or in the bedrock, determines the susceptibility of the subsurface material to erosion by ingress of water. The presence of materials such as shales or intrusives, which can act as aquitards, serve to reduce the mobilisation potential and enhance the stability.

In the case of dramatic groundwater level fluctuations the susceptibility of the soil material to mobilisation (i.e. consolidation settlement - subsidence formation, or ravelling and arch failure - sinkhole formation, due to pore pressure changes in soils), is strongly influenced by the position of the original groundwater level in the subsurface profile. In assessing the susceptibility of a subsurface profile to sinkholes and subsidences due to groundwater level drawdown, attention is given to the nature and extent of the material below the groundwater level. For example in the case of compressible dolomite residuum, as the groundwater recedes, pore pressures in the residual dolomite soils, typically characterized by high void ratios, gradually dissipate and the effective stress on the soil increases causing consolidation of the compressible material.

A surface depression may occur gradually due to the load of the near-surface materials on the deeper lower density materials that settle into a denser state.

The general maximum magnitude of natural groundwater fluctuation in the Gauteng dolomites is in the order of 5m (Hobbs, 2004; Holland, 2007). Hence artificial groundwater level drawdown is generally defined as drawdown exceeding 6m.

Experience shows that groundwater level drawdown (beyond seasonal variations) has the greatest negative impact on dolomite stability in areas of shallow groundwater levels (30m or shallower) i.e. deeper (> 30m) groundwater levels, pose less of a negative impact on stability, in the event of groundwater level drawdown or dewatering. However, where groundwater drawdown occurs in areas of deeper groundwater, the size of instability is typically anticipated to be large to very large.

In view of the factors discussed above the following characteristics have been extracted from the gathered information during the assessment process:

- borehole position relative to the gravity data.
- collar elevation.
- depth to dolomite bedrock.
- depth to potential receptacles.
- depth to the present and original groundwater level.
- nature and thickness of blanketing layer i.e. material type, penetration times, etc.
- position of the bedrock with respect to the present and original groundwater level.
- thickness and nature of the soil materials above and below the present and original groundwater level.

Inherent susceptibility is a reflection of the geological susceptibility of a karst area to an event (sinkhole or subsidence formation) and is expressed in three broad categories, namely low, medium and high. The following reference to incidences, gives a perspective of the magnitude of problems encountered in each of the of hazard zones in research areas.

It is important to note that these figures are largely derived from developments not effectively and appropriately designed or maintained.

Inherent Susceptibility	Anticipated events per hectare over time (magnitude of problem)*
LOW	0 up to and including 0.1 events per hectare anticipated but occurrence of events cannot be excluded. Return Period is greater than 200 years.
MEDIUM	Greater than 0.1 and less than and equal to 1.0 events per hectare. Return period is between 200 and 20 years.
HIGH	Greater than 1.0 events anticipated per hectare. Return period is less than 20 years.
* that have occurred per hectare in a 20 year period in the "type" areas (statistics based on poor service design and maintenance)	

The study area is characterised in terms of eight standard Inherent Hazard Classes. These classes denote the chance of a sinkhole or subsidence occurring as well as its likely size (diameter).

The terminology used in terms of likely size of an event (sinkhole or subsidence) is defined as follows:

Maximum diameter of surface manifestation (in metres)	Terminology
< 2	Small-size
2-5	Medium-size
5-15	Large-size
> 15	Very large-size

The larger the Inherent Hazard Class number, the greater the chance of a sinkhole or subsidence occurring and the larger its potential size should it occur for each of the inherent susceptibility categories. The meaning/definition of each Inherent Hazard Class is as follows:

Inherent Hazard Class	Characterisation of Area
Class 1 Areas	Areas characterised as reflecting a **low** inherent susceptibility of **all sizes** of events occurring.
Class 2 Areas	Areas characterised as reflecting a **medium** inherent susceptibility of **small-size** events occurring.
Class 3 Areas	Areas characterised as reflecting a **medium** inherent susceptibility of **medium-size** events occurring.
Class 4 Areas	Areas characterised as reflecting a **medium** inherent susceptibility of **large-size** events occurring.
Class 5 Areas	Areas characterised as reflecting a **high** inherent susceptibility of **small-size** events occurring.
Class 6 Areas	Areas characterised as reflecting a **high** inherent susceptibility of **medium-size** events occurring.
Class 7 Areas	Areas characterised as reflecting a **high** inherent susceptibility of **large-size** events occurring.
Class 8 Areas	Areas characterised as reflecting a **high** inherent susceptibility of **very large-size** events occurring.

In this report Inherent Susceptibility is defined in terms of ingress of water and groundwater level drawdown reflected by two Inherent Hazard Class designations separated by a double forward slash, i.e.-

Inherent Hazard Class (ingress of water) // Inherent Hazard Class (groundwater level drawdown)

As an example, a designation of 1//8 indicates that the zone displays a low inherent susceptibility with respect to water ingress but a high inherent susceptibility with respect to groundwater level drawdown. As an example, a designation of Inherent Hazard Class 1//1/4/8 indicates that the zone displays a low inherent susceptibility with respect to water ingress but a low to high inherent susceptibility with respect to groundwater level drawdown. This definition may, for example, be necessary in cases where groundwater was not encountered or the original groundwater level is not known and dolomite bedrock could not be confirmed.

Often a zone is not characterised by a single Inherent Hazard Class. In some instances, the Inherent Hazard Classes are then indicated with the primary zone description given first followed by a suffix in brackets. The primary Inherent Hazard Class describes the predominant characterisation of the zone and the suffix describes the characterisation of anticipated pockets or small sub-areas within the zone. As an example, a designation of Inherent Hazard Class 8(4) indicates that the zone predominantly displays a high inherent susceptibility for up to very large-size sinkhole and subsidence formation with anticipated pockets or small sub-areas of Class 4 i.e. displaying a medium susceptibility for up to large-size sinkhole and subsidence formation.

Specific commentary is provided on the impact that a lowering of the ground water level or base level of erosion may have on the action of ingress water, i.e. does the susceptibility of the subsurface profile remain unchanged from an ingress of water perspective or not, as the the groundwater level is lowered and the previously "protected" profile is exposed. As an example, the lowering of the groundwater level and exposure of a poor subsurface profile in an area of previously shallow groundwater level designated as Inherent Hazard Class 3//7, results in a change in susceptibility from medium to high and the Inherent Hazard Class from 3 to 6 i.e. the Inherent Hazard Class 3//7 will change to Inherent Hazard Class 6//7 once groundwater level drawdown is factored in.

5.9. Dolomite Area Designation

Dolomite Area Designations must be identified on sites located on or near dolomite land (land where dolomite is located at or near [less than 100m] ground surface).The definitions of the Dolomite Area Designations as defined in SANS 1936 Part 1 (2012) is as follows:

D Designation	Description
D1	No precautionary measures are required.
D2	General precautionary measures, in accordance with the requirements of SANS 1936-3, that are intended to prevent the concentrated ingress of water into the ground, are required.
D3	Precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3, are required.

D Designation	Description
D4	Development may only be considered provided the following requirements are met: • Involvement of Competence Level 4 geo-practitioner in all the categories of the geotechnical engineering work, i.e. site characterization, analysis and design, supervision and review, supervision of execution and management (primary geo-practitioner). • Review and acceptance of all the categories of the geotechnical engineering work by a Competence Level 4 peer. This peer reviewer may not be a business associate of the primary geo-practitioner(s) and may not have a vested interest in the project. • All the categories of the geotechnical engineering work to be reviewed and accepted by the Authority who may request a further review by an Authority designated Competence Level 4 peer, if required. • The responsible Local Authority must indicate its commitment to maintain dolomite risk management principles in accordance with SANS 1936-4.

For new residential development it essential to consider the following:

The definitions (in particular that of D4) **have not as yet been** ratified by the NHBRC, nor has an updated Home Building Manual been published. Therefore in the case of residential housing the following definitions apply, as defined in Table 8, Section 2, Part 1 of the NHBRC Home Building Manual, Part 1 and 2, Revision 1, dated February 1999, in the interim:

D Designation	Description
D1	No precautionary measures are required to permit the construction of housing units due to the geological setting.
D2	The risk of *(susceptibility to)* sinkhole and doline *(subsidence)* formation is adjudged to be such that only general precautionary measures, which are intended to prevent the concentrated ingress of water into the ground, are required to permit the construction of housing units.
D3	The *risk of (susceptibility to*) sinkhole and doline *(subsidence)* formation is adjudged to be such that precautionary measures, in addition to those pertaining to the prevention of concentrated ingress of water into the ground, are required to permit the construction of housing units.
D4	The risk of *(susceptibility to)* sinkhole and doline *(subsidence)* formation is such that precautionary measures cannot adequately reduce the risk to acceptable limits *(render a tolerable hazard rating)* so as to permit the construction of housing units, or the precautionary measures which are required are impracticable to implement.

5.10. Monitoring Designations

According to SANS 1936 Part 4 (2012) Monitoring Designations must be identified and delineated according to the Inherent Susceptibility characterisation of the site and knowledge of problems which could impact on the infrastructure on site.

The generic Monitoring Activities considered appropriate for dolomite land are as follows:

Annotation	Activity*	Reaction	Purpose
A	**Visual inspections of ground, structures and above ground infrastructure**(e.g. buildings, taps, gardens, private and public open space etc.) and **dry services, sleeves, ducts, manholes and facility chambers for water ingress**: • Examine buildings for cracks. • Visual checks for outside dripping taps and pressure valves. • Visual checks for damp or moss grown areas. • Visual check for over-wetting of gardens. • Visual check for blocked drainage ports in garden walls. • Visual check for cracks in the ground.	Any evidence of cracking or ground settlement should immediately be reported and investigated. Any evidence of blockages should be reported and cleared immediately, or cracks repaired once settlement is halted. Any water ingress in dry services, sleeves, ducts, manholes and facility chambers shall be reported,, and point of entry repaired and investigated.	Monitor, control and prevention of concentrated ingress of water
B	**Visual inspection of stormwater systems**: • Visual checks for debris in open storm water channels at, for example, the start of the rainy season and after heavy storms. • Visual checks for water flowing out of stormwater manholes at the start of the rainy season and after heavy storms. • Search for ground cracks and cracks in lined and unlined channels.		
C	**Testing of wet-services for leaks**: • Regular air and water tests on wet-services. • In waste water and stormwater pipes with a diameter greater than 100 mm wet-services to be inspected by camera.	Any leaks to be reported and repaired immediately.	
D	**Monitoring of structures and ground levels:** In many instances visual inspections may not be sufficient: It may be necessary to undertake precision ground-surface levelling, particularly in areas that have been rehabilitated after a ground movement event. Such levelling must be undertaken by a surveyor, recorded and stored in the databank and appropriate actions taken when excessive settlement continues.	Any evidence of movement must be reported and investigated and appropriate repair work undertaken.	Monitor the effects of concentrated ingress of water or groundwater level drawdown

Annotation	Activity*	Reaction	Purpose
E	**Monitoring of the groundwater level:** This activity not only entails the measuring and recording of the groundwater level, but also the analysis and understanding of groundwater level trends over time and the control of excessive [beyond seasonal fluctuations] groundwater level drawdown: • Drill and equip strategic boreholes with the necessary equipment to measure the groundwater level. • Recorded groundwater level, monitoring well number, date and other relevant observations. • Analyse groundwater level trend over time on a regular basis. • Report artificial/excessive groundwater level drawdown to Municipality and the Department of Water Affairs. • Investigate cause of artificial/excessive groundwater level drawdown. • Arrest artificial/excessive groundwater level drawdown.	Evidence of lowering (exceeding 6 m) must be reported to Municipality and the Department of Water Affairs and appropriate action taken to ensure the groundwater level returns to within natural seasonal fluctuations.	Monitor, control and prevention of groundwater level drawdown
*If there is no evidence of a particular problem, this result should be recorded.			

Note that in SANS 1936 Part 4 (2012), pg 15, *the visual inspection of dry services, sleeves, ducts, manholes and facility chambers* is included as a separate monitoring activity (as Annotation D), with the Annotations D and E as listed above, annotated as E and F. for simplicity sake this activity has been included in Annotation A above.

The Frequency with which each Activity is to be performed is selected from the following categories:

Annotation	Frequency
$()^{DAILY}$	Activities to be undertaken daily.
$()^{WEEKLY}$	Activities to be undertaken weekly.
$()^{1}$	Activities to be undertaken once a month.
$()^{3}$	Activities to be undertaken quarterly.
$()^{6}$	Activities to be undertaken bi-annually.
$()^{12}$	Activities to be undertaken annually.
$()^{24}$	Activities to be undertaken once every two years.
$()^{NA}$	NO ACTION REQUIRED CURRENTLY
$()^{tbd}$	TO BE DETERMINED

Areas of **'no dolomite hazard'** require no monitoring from a dolomite risk management perspective. No action is required to lower the risk of dolomite-related instability, as these areas are not located on dolomite land. For example, portions of sites located on granite rock or Witwatersrand Supergroup rocks. Such areas may be designated as $(ABCDE)^{na}$.

Areas of **'low susceptibility',** for example Inherent Hazard Class 1 areas, are assigned a low priority and require **basic monitoring and maintenance activities at long intervals**, for example, where a site straddles very thick Karoo Supergroup rocks (in excess of 40 metres).

The site or portion thereof may, for example, be designated as $(ABC)^{24}D^{na}E^{12}$ indicating that all identified activities which control ingress of water need only be undertaken once every two years, precision structure- and ground levelling not being required and groundwater level monitoring being required at long intervals. However, where such rocks overlie dolomite residuum below the original groundwater level a designation of $\mathbf{E^3}$, as in $(ABC)^{24}D^{na}E^{3}$, may apply, indicating that groundwater level monitoring is critical and should be undertaken quarterly.

Areas of **'high susceptibility',** for example Inherent Hazard Class 5, 3(5), 3/6, should be areas of high priority in terms of monitoring and maintenance, and should receive attention more frequently. These areas require **stringent monitoring and maintenance activities at short intervals**. Such areas are typically characterised by:

- Metastable subsurface conditions or latent sinkhole formation.
- High Inherent Susceptibility conditions.
- Poor subsurface conditions e.g. cavities, cavernous conditions, sample or air loss.
- Previous sinkhole or subsidence formation.
- Palaeo-sinkhole or palaeo-subsidence structures.
- Geological contact areas.
- Fault zones.
- Shallow dolomite groundwater above dolomite bedrock.
- Anticipated ground settlement or
- Ponding of water, etc.

For example, an area in which various sinkholes have already occurred and is highly susceptible to sinkhole and subsidence formation from an ingress of water perspective a $\mathbf{(AB)^3}$ or even $\mathbf{(AB)^{daily}(D)^3}$ designation may apply, indicating the need to undertake activities controlling ingress of water quarterly, or even daily. A further example may be, an area in which various sinkholes have already been reported and is highly susceptible to sinkhole and subsidence formation from a groundwater level drawdown perspective. In such a case a $\mathbf{E^3}$ designation may apply, indicating the need to undertake activities to monitor groundwater fluctuations and drawdown quarterly.

Consideration should be given to the review of the frequencies of activities over time, for example, a site may be monitored visually on a seasonal basis for the first 2 years $(AB)^3$ after construction. Should no problems be recorded in that time, the frequency may be reviewed and changed to a longer interval, for example $(AB)^{12}$. The higher frequency in the intitial stages of a development allows for the setting of a good base line dataset having taken cognicance of seasonal influences on a site.

5.11. Permissible Land Use

According to SANS 1936- 1, Table 2 (2012), the development types suitable for the eight standard Inherent Hazard Classes are summarised as follows:

Inherent Hazard Class	Land Usage Type	Land Usage Permitted with Dolomite Area Designation and footprint investigation requirement in terms of Deemed-To-Satisfy
1	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D2 + FPI), C4 (D2 + FPI), C5 (D2 + DLI), C6 (D2 + DLI), C7 (D2), C8 (D2)
	High rise dwelling units	RH2 (D2 + FPI), RH3 (D2 + FPI)
	Low rise dwelling units	RL1 (D2 + FPI), RL2 (D2 + FPI)
	Dwelling houses	RN1 (D2), RN2 (D2), RN3 (D2)
2	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3 + FPI), C4(D3 + FPI), C5 (D3 + DLI), C6 (D3 + DLI), C7 (D3+ FPI), C8 (D3)

Inherent Hazard Class	Land Usage Type	Land Usage Permitted with Dolomite Area Designation and footprint investigation requirement in terms of Deemed-To-Satisfy
	High rise dwelling units	RH3 (D3 + FPI)
	Low rise dwelling units	RL1 (D2 + FPI), RL2 (D2 + FPI)
	Dwelling houses	RN1 (D3), RN2 (D3), RN3 (D3)
3	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3 + FPI), C5 (D3 + DLI), C6 (D3 + DLI), C7 (D3 + FPI), C8 (D3)
	High rise dwelling units	RH3 (D3 + FPI)
	Low rise dwelling units	RL2 (D3 + FPI)
	Dwelling houses	RN2 (D3), RN3 (D3)
4	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3 + FPI), C5 (D3 + DLI), C6 (D3 + DLI), C7 (D3 + FPI), C8 (D3)
	High rise dwelling units	RH3 (D3 + FPI)
	Low rise dwelling units	RL2 (D3 + FPI)
	Dwelling houses	RN2 (D3), RN3 (D3)
5	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3 + FPI), C5 (D3 + DLI), C6 (D3 + DLI), C7 (D3 + FPI), C8 (D3)
	High rise dwelling units	RH3 (D3 + FPI)
	Low rise dwelling units	RL2 (D3 + FPI)
	Dwelling houses	RN3 (D3 + FPI)
6	Commercial and miscellaneous non-residential usage	C2 (D3 + FPI), C3 (D3 + FPI), C6 (D3 + DLI) , C7 (D3 + FPI), C8 (D3)
	High rise dwelling units	NA
	Low rise dwelling units	NA
	Dwelling houses	NA
7	Commercial and miscellaneous non-residential usage	C6 (D3 + DLI)
	High rise dwelling units	NA
	Low rise dwelling units	NA
	Dwelling houses	NA
8	Commercial and miscellaneous non-residential usage	NA
	High rise dwelling units	NA
	Low rise dwelling units	NA
	Dwelling houses	NA

Land Use Class	Definitions
Commercial and miscellaneous non-residential usage	
C1	Places of detention, police stations, and institutional homes for the handicapped or aged
C2	Hospitals (including clinics), hostels, hotels
C3	Commercial developments ≤ 3 storeys, including railway stations, shops, wholesale stores, offices, places of worship, theatrical, indoor sports or public assembly venues, other institutional land uses, such as universities, schools, colleges, libraries, exhibition halls and museums, light (dry) industrial developments, dry manufacturing, commercial uses such as warehousing, packaging, electrical sub-stations, filling stations
C4	Commercial developments > 3 storeys, including railway stations, shops, wholesale stores, offices, places of worship, theatrical, indoor sports or public assembly venues, other institutional land uses, such as universities, schools, colleges, libraries, exhibition halls and museums, light (dry) industrial developments, dry manufacturing, commercial uses such as warehousing, packaging, electrical sub-stations
C5	Fuel depots, processing plants or any other areas for the storage of liquids, waste sites
C6	Outdoor storage facilities, stock yards, container depots
C7	Parking garages

Land Use Class	Definitions
C8	Parking areas
High rise dwelling units	
RH1	> 10 storeys
RH2	> 3 storeys, no higher than 10 storeys with a population of ≤ 1 500 people per hectare
RH3	> 3 storeys with a residential coverage ratio of ≤ 0,4, no higher than 10 storeys, and a population of ≤ 800 people per hectare
Low rise dwelling units	
RL1	≤ 3 storeys with 80 to 120 units per hectare and a population not exceeding 600 people per hectare
RL2	≤ 3 storeys with up to 80 units per hectare and a population not exceeding 400 people per hectare
Dwelling houses	
RN1	Up to 60 dwelling houses per hectare with stands larger than 150 m^2, and a population of ≤ 300 people per hectare
RN2	Up to 25 dwelling houses per hectare with stands no smaller than 300 m^2, and a population of ≤ 200 people per hectare
RN3	Up to 10 dwelling houses per hectare with 1 000 to 4 000 m^2 stands, and a population of ≤ 60 people per hectare

According to SANS 1936-1, Table 3 (2012), the infrastructure and social services suitable for the eight standard Inherent Hazard Classes are summarised as follows:

Infrastructure and social facilities		Inherent hazard class determined in accordance with the requirements of SANS 1936-2							
Designation	Description	1	2	3	4	5	6	7	8
		Dolomite area designation							
IN1	Trunk roads (national and regional roads which facilitate intercity travel) and primary distributor roads (major arterial roads forming the primary network for an urban area as a whole), railway lines, power lines, runways, bulk pipelines, including water, sewer, fuel and gas lines, pump stations	D2	D3					D4	
IN2	Reservoirs and public swimming pools, water care works, attenuation and retention ponds for stormwater management and artificial lakes	D2	D3				D4		
IN3	Cemeteries	D3				D4			
IN4	Dams, slimes dams	D3	D4						
IN5	Solid waste disposal facilities	D3						D4	

6. GEOLOGY AND GEOHYDROLOGY

6.1. Regional Geological Setting

According to the 1:250 000 scale geological map (refer to Figure 3), the site is located in an area underlain by dolomite and chert of the Malmani Sub-Group, Chuniespoort Group of the Transvaal Supergroup. The chert and dolomite is overlain by shale, siltstone, sandstone and coal beds of the Vryheid Formation, Ecca Group, Karoo Supergroup.

The various lithological units identified on the geological map near to the site are as follows:

Lithostratigraphic Unit	Lithology
Karoo Supergroup (Pv)	Shale, siltstone, sandstone, coal and soil derivatives.
Malmani Subgroup, Chuniespoort Group, Transvaal Supergroup (Vmd)	Dolomite, chert and associated soil derivatives

Unconsolidated materials deemed to be various recent deposits (most likely 24 Ma [Miocene Epoch] and younger)are anticipated to mantle the hard rock geology (and residual product thereof). The material varies in thickness, sedimentological- and geotechnical properties:

Post-Gondwana Deposits	
Colluvium: Hillwash	Soils of clayey, sandy and/or silty composition or gravels

6.2. Site Specific Geology

A total of twelve boreholes (3925/1 to 3925/12) were drilled by VGIconsult during the current investigation and two boreholes (1544/4 and 1544/5) by Geo Buro during a previous investigation on the site.

A summary of the material intercepted in the boreholes drilled on the site is reported here for ease of reference (explanations of letters, symbols and abbreviations are given in Table 1 at the back of the report):

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)							Dolomite Bedrock m and (m AMSL)	Quartzite Rock m and (m AMSL)
	Colluvium	Karoo Residual Shale (Carbona-ceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Dolomite Residuum	Karoo Soft rock Dolerite (Karoo) (m-m)	Karoo Dolerite Rock (Karoo) m and (m AMSL)		
3925-1 (1466)	0-1	1-4 16-23 25-34	-	4-16 23-25 34-60	-	-	-	>60 <1406	-
3925-2 (1463)	0-1	1-31 31-33* 33-42**	-	42-60	-	-	-	>60 <1403	-
3925-3 (1465)	0-1	1-31 31-37** 37-46*	-	46-60	-	-	-	>60 <1405	-
3925-4 (1465)	-	0-6 14-22 22-30*	-	6-14 30-60	-	-	-	>60 <1405	-
3925-5 (1464)	0-1	1-23 23-32*	-	32-60	-	-	-	>60 <1404	-
3925-6 (1463)	-	0-37 37-47* 47-60**	-	-	-	-	-	>60 <1403	-
3925-7 (1463)	-	0-23 28-33	-	33-60	-	-	-	>60 <1403	-
3925-8 (1465)	-	0-35 35-36* 36-50** 50-60*	-	-	-	-	-	>60 <1405	-
3925-9 (1463)	-	-	13-29	0-13*	-	29-30	30-36 (1433)	-	-

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)							Dolomite Bedrock m and (m AMSL)	Quartzite Rock m and (m AMSL)
	Colluvium	Karoo Residual Shale (Carbona-ceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Dolomite Residuum	Karoo Soft rock Dolerite (Karoo) (m-m)	Karoo Dolerite Rock (Karoo) m and (m AMSL)		
3925-10 (1465)	-	-	18-36	0-18*	-	36-37	37-43 (1428)	-	-
3925-11 (1466)	-	0-31	-	31-60	-	-	-	>60 <1406	-
3925-12 (1466)	-	0-34 34-40* 40-60**	-	-	-	-	-	>60 <1406	-
1544/4 (1464)	0-1	14-19	-	1-2 2-11* 11-14 19-21 21-24* 24-32	-	-	-	-	32-37 (1432)
1544/5 (1466)	0-1	5-18	-	1-5 18-60	-	-	-	>60 (<1406)	-

The boreholes intercepted the following horizons:

- **Colluvium** near surface. The horizons are of thin thickness or absent.
- **Residual Shale** near surface to intermediate depth. The horizons are of thin to very thick thickness. Thin to intermediate thick horizons of **carbonaceous residual shale** is typical intercepted from an intermediate to great depth below the residual shale in half of the boreholes drilled on site. Thin to intermediate thick horizons of **coal** is typical intercepted from a great to very great depth below the carbonaceous residual shale in five of the boreholes drilled on site.
- **Residual dolerite** at an intermediate depth intercepted in two of the boreholes drilled in the southern portion of the site. The horizons are of intermediate thickness.
- **Chert residuum** near surface to very great depths. The horizons are of thin to very thick thickness. Thin to intermediate thick horizons of **chert residuum interlayered with residual shale** is intercepted in 25% of the boreholes drilled on the site from near surface to intermediate depths.
- **Dolomite residuum is not intercepted in any of the boreholes drilled on the site.**
- **Highly weathered soft rock dolerite and hard rock dolerite** at a great depth. Encountered in the southern portion of the site.
- **Quartize rock of the Black Reef Formation** is intercepted from a great depth in one borehole.
- **Dolomite bedrock** is anticipated at a depth of more than 60m. Dolomite bedrock was not intercepted in any of the boreholes drilled to a typical depth of 60m on the site.

6.3. Regional and Site-specific Geohydrology

Refer to Figure 4 for pertinent groundwater information.

6.3.1. Quaternary Catchment Area

According to the country wide Quaternary Catchment data the site is located in Catchment C22F.

6.3.2. Groundwater Management Area

According to the Water Geosciences Consulting Dolomite Hydrogeological Compartment Map (2009) the site is located in a defined Dolomite Groundwater Compartment, namely the Kliprivier. The regional basin wide OWL is unknown.

To our knowledge the Kliprivier Dolomite Groundwater Compartment is currently not dewatered.

6.3.3. Groundwater Monitoring

This area is currently monitored by the Department of Water Affairs (DWA). A DWA groundwater monitoring borehole (C2N0870) is located approximately 2km west of the site.

6.4. Groundwater Depths (Site Specific and Current)

Groundwater was recorded in ten of the twelve boreholes at a depth of 11m to 25m (1440m AMSL to 1453m AMSL). The groundwater rest levels recorded during the current investigation is presumed to be the regional groundwater rest level (OWL).

A groundwater rest level of 20m (or 1445m AMSL) is considered for the dolomite hazard assessment of the site.

7. DOLOMITE STABILITY CHARACTERISATION

7.1. Investigation and Dolomite Hazard Assessment

The dolomite hazard assessment procedures are presented in Section 5.8. Summarised information concerning the hazard characterisation of the site is provided in Table 1 of this report and the dolomite hazard zonation is displayed on Drawing VGI3925/2.

7.2. Stability Characterisation

Based on the current boreholes (Boreholes 3925/1 to 3925/12, 1544/4 and 1544/5) drilled on the sitetwo dolomite hazard zones are defined, namely:

Dolomite Hazard Zone	Inherent Hazard Class	Description
1	1//1/4	Area largely reflecting a low susceptibility of all-size sinkhole and subsidence formation with respect to ingress of water and a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water changes as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

Dolomite Hazard Zone	Inherent Hazard Class	Description
2	1/4//1/4	Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water and groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water remains the same *i.e. Inherent Hazard Class 1/4.*

7.2.1. Dolomite Hazard Zone 1

The hazard characterisation of Zone 1 is summarised as follows:

a) Blanketing Layer

The blanketing layer consists of the following horizons (explanations of abbreviations are provided in Table 1):

- **Colluvium** near surface. The horizon is typically of thin (1m) thickness or absent.
- **Residual shale** near surface. The horizon is thick (23m to 37m). Thin (1m) to intermediate (10m) thick horizons of **carbonaceous shale** is typically intercepted from a great depth below the residual shale. Thin (6m) to intermediate (20m) thick horizons of **coal** is typically intercepted from a great to very great depth below the carbonaceous shale. These layers extend to a depth of more than 60m in Boreholes 3925-6, 3925-8 and 3925-12, representative of gravity low fields.
- **Residual dolerite** at an intermediate depth, intercepted in Boreholes 3925-9 and 3925-10. The horizon is of intermediate (16m to 18m) thickness.
- **Chert residuum** recorded at an intermediate to very great depth (typically below the OWL of 1445m AMSL (or 20m depth)). The horizon is thin (5m) to very thick (29m).Intermediate (13m to 18m) thick horizons of **chert residuum interlayered with residual shale** is intercepted near surface above the residual dolerite in Boreholes 3925-9 and 3925-10.
- **Dolomite residuum** is not intercepted in any of the boreholes drilled to a maximum depth of 60m.
- **No significant problematic conditions** (e.g. air loss, sample loss or voids) were recorded during the drilling process in any of the boreholes in this zone.

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)				
	Colluvium	Karoo Residual Shale (Carbonaceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Malmani Subgroup Dolomite Residuum
3925-2 (1463)	0-1	1-31 31-33* 33-42**	-	42-60	-

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)				
	Colluvium	Karoo Residual Shale (Carbonaceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Malmani Subgroup Dolomite Residuum
3925-3 (1465)	0-1	1-31 31-37** 37-46*	-	46-60	-
3925-5 (1464)	0-1	1-23 23-32*	-	32-60	-
3925-6 (1463)	-	0-37 37-47* 47-60**	-	-	-
3925-7 (1463)	-	0-23 28-33	-	23-28 33-60	-
3925-8 (1465)	-	0-35 35-36* 36-50** 50-60*	-	-	-
3925-9 (1463)	-	-	13-29	0-13*	-
3925-10 (1465)	-	-	18-36	0-18*	-
3925-11 (1466)	-	0-31	-	31-60	-
3925-12 (1466)	-	0-34 34-40* 40-60**	-	-	-

b) Dolomite Bedrock

Dolomite bedrock is anticipated at a depth of more than 60m. Dolomite bedrock is not intercepted to a maximum depth of 36m to 60m (or 1403m AMSL to 1406m AMSL) in any of the boreholes drilled on the site.

Highly weathered soft rock dolerite is intercepted from a great depth of 29m to 36m in Boreholes 3925-9 and 3925-10. Hard rock dolerite is intercepted from a great depth of 30m and 37m in Boreholes 3925-9 and 3925-10.

c) Hazard Characterisation

i. Blanketing Layer

The blanketing layer is of **very thick thickness**(29m to more than 60m).

The blanketing layer consists of:

- Karoo material, including residual shale, carbonaceous shale and coal; or
- Colluvium in sub-areas, Karoo material (i.e. residual shale, carbonaceous shale and coal) underlain by chert residuum; or.
- Interlayered chert residuum and shale, underlain by residual dolerite followed at depth by highly weathered soft rock dolerite and hard rock dolerite.

These various horizons are anticipated to be characterised by variable internal drainage characteristics. The residual shale, residual carbonaceous shale, residual dolerite and interlayered chert residuum with shale are characterised by **low internal drainage characteristics**, precluding or retarding ingress of water,

lowering the risk of sinkhole or subsidence formation. The chert residuum is anticipated to be characterised **by moderate internal drainage characteristics**.

Prolonged ingress of water is unlikely to lead to erosion and sinkhole or subsidence formation, taking into consideration the absence of dolomite residuum horizons and voids in the subsurface profile.

ii. Potential Development Space

In general the depth to dolomite bedrock (>60m), as well as the groundwater level (which acts as a base level for erosion) and the potential receptacles determine the Potential Development Space (PDS).

The groundwater level is anticipated at approximately 20m depth (1445 m AMSL). Therefore only a third of the blanketing layer is considered in determining the PDS. The PDS is characterised as**all-size**.

iii. Hazard Classification (with Ingress of Water as a Triggering Mechanism)

The typical subsurface profile consists of residual shale, carbonaceous residual shale, coal and chert residuum or interlayered chert residuum and shale underlain by residual dolerite, extending to a great to very great depth. No sample loss, air loss or voids was reported during the drilling phase. Highly compressible and erodible dolomite residuum horizons are absent in the subsurface profile. The groundwater level is anticipated at 20m depth typically located within residual shale.

Zone 1 is characterised as largely reflecting a low susceptibility of all-size sinkhole and subsidence formation with respect to ingress of water, i.e. Inherent Hazard Class 1.

iv. Hazard Classification (with Groundwater Drawdown as a Triggering Mechanism)

The groundwater level is anticipated at 20m depth above the dolomite bedrock (anticipated at a depth of more than 60m).

In areas where thick horizons of Karoo material is present a low susceptibility exists for sinkhole or subsidence formation in the event of major groundwater level drawdown. In areas where chert residuum is located below the groundwater level, the chert residuum will present a medium susceptibility for sinkhole or subsidence formation in the event of major groundwater level drawdown. Therefore Zone 1 is characterised as largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation in the event of major groundwater drawdown, i.e. Inherent Hazard Class //1/4.

v. Impact of Lowering of the Groundwater Level/Base Level of Erosion on the Action of Water Ingress

In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification changes as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

vi. Composite Hazard Classification

The composite hazard classification is **Inherent Hazard Class 1//1/4,** defined as an area largely reflecting a low susceptibility of all-size sinkhole and subsidence formation with respect to ingress of water and a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to groundwater level drawdown.

In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water changes as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

7.2.2. Dolomite Hazard Zone 2

The hazard characterisation of Zone 2 is summarised as follows:

a) Blanketing Layer

The blanketing layer consists of the following horizons (explanations of abbreviations are provided in Table 1):

- **Colluvium** near surface. The horizon is typically of thin thickness.
- **Residual shale** near surface to intermediate depth. The horizons are thin to intermediate thick. A thin horizon of **carbonaceous shale** is intercepted in Borehole 3925-4 from an intermediate depth below the residual shale.
- **Chert residuum** near surface to great depth. The horizons are thin to very thick. Thin to intermediate thick horizons of **chert residuum interlayered with residual shale** is intercepted in Borehole 1544/4 from near surface to intermediate depths.
- **Dolomite residuum** is not intercepted in any of the boreholes drilled to a maximum depth of 37m to 60m.
- **No significant problematic conditions** (e.g. major air loss, sample loss or voids) were recorded during the drilling process.

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)				
	Colluvium	Karoo Residual Shale (Carbonaceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Malmani Subgroup Dolomite Residuum
3925-1 (1466)	0-1	1-4 16-23 25-34	-	4-16 23-25 34-60	-
3925-4 (1465)	-	0-6 14-22 22-30*	-	6-14 30-60	-

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)				
	Colluvium	Karoo Residual Shale (Carbonaceous Shale*) Coal**	Karoo Residual Dolerite	Malmani Subgroup Chert Residuum (with Shale*)	Malmani Subgroup Dolomite Residuum
1544/4 (1464)	0-1	14-19	-	1-2 2-11* 11-14 19-21 21-24* 24-32	-
1544/5 (1466)	0-1	5-18	-	1-5 18-60	-

b) Dolomite Bedrock

Dolomite bedrock is anticipated at a depth of more than 60m. Dolomite bedrock is not intercepted to a maximum depth of 37m to 60m (or 1405m AMSL to 1432m AMSL) in boreholes drilled in this zone.

Hard rock quartzite of the Black Reef Formation was intercepted from a great depth of 32m in Borehole 1544/4.

c) Hazard Characterisation

i. Blanketing Layer

The blanketing layer is **thick to very thick**.

The blanketing layer typically consists of colluvium, residual shale, residual carbonaceous shale in sub-areas, chert residuum and interlayered chert residuum with shale in sub-areas.

The residual shale, carbonaceous shale and interlayered chert residuum with shale are characterised by **low internal drainage characteristics**, precluding or retarding ingress of water, lowering the risk of sinkhole or subsidence formation

The chert is anticipated to be characterised **by moderate internal drainage characteristics**.

Prolonged ingress of water is unlikely to lead to erosion and sinkhole or subsidence formation, taking into consideration the absence of dolomite residuum horizons and voids in the subsurface profile.

ii. Potential Development Space

In general the depth to dolomite bedrock, as well as the groundwater level (which acts as a base level for erosion) and the potential receptacles determine the Potential Development Space (PDS).

The groundwater level is anticipated at 20m depth or 1445m AMSL. The PDS is characterised as **large**.

iii. Hazard Classification (with Ingress of Water as a Triggering Mechanism)

The typical subsurface profile consists of colluvium, residual shale, and carbonaceous residual shale in sub-areas, chert residuum and interlayered chert residuum with shale in sub-areas, extending to a great to very great depth. Sample and air loss, as well as rapid penetration times were not reported during the drilling phase. The groundwater level is anticipated at 20m depth. Typically, chert residuum occurs above and below the groundwater level.

Zone2 is characterised as largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water, i.e. Inherent Hazard Class 1/4.

iv. Hazard Classification (with Groundwater Drawdown as a Triggering Mechanism)

The groundwater level is anticipated at 20m depth. The groundwater level is typically within the overburden above and below the chert residuum with a medium susceptibility for sinkhole or subsidence formation. In the event of major groundwater drawdown the susceptibility to sinkhole and subsidence formation is described as low to medium for large-size sinkhole or subsidence formation, i.e. Inherent Hazard Class //1/4.

v. Impact of Lowering of the Groundwater Level/Base Level of Erosion on the Action of Water Ingress

In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification remains the same: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

vi. Composite Hazard Classification

The composite hazard classification is **Inherent Hazard Class 1/4//1/4,** defined as an area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water and groundwater level drawdown.

In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification remains the same with respect to ingress of water as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*

8. CONCLUSIONS

8.1. Results

The site is characterised by variable sub-surface conditions. The blanketing layer consists mainly of colluvium (in sub-areas), Karoo Supergroup residual shale, carbonaceous residual shale, coal beds, Malmani Subgroup chert residuum and interlayered chert residuum with shale. Karoo Supergroup residual dolerite, highly weathered and unweathered dolerite rock is intercepted in the southern portion of the site and hard rock quartzite of the Black Reef Formation is intercepted directly north of the area where dolerite is encountered. Dolomite residuum is absent in the sub-surface profile on the site. Dolomite bedrock is anticipated at a depth of more than 60 as dolomite bedrock was not encountered

in any of the boreholes drilled on the site typically to a depth of 60m. The groundwater level was recorded at 20m or 1445m AMSL, and is taken as the regional groundwater level depth.

8.2. Dolomite Hazard Characterisation of the Site

The geotechnical data gathered during this investigation permits the dolomite hazard characterisation of the site in accordance with the method defined in SANS 1936, Part 2 (2012).

Based on the current data gathered, the site is characterised in terms of two primary dolomite hazard zones, namely:

Dolomite Hazard Zone	Inherent Hazard Class	Description
1	1//1/4	Area largely reflecting a low susceptibility of all-size sinkhole and subsidence formation with respect to ingress of water and a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water changes as follows: Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water *i.e. Inherent Hazard Class 1/4.*
2	1/4//1/4	Area largely reflecting a low to medium susceptibility of large-size sinkhole and subsidence formation with respect to ingress of water and groundwater level drawdown. In the event that the groundwater level is drawn down significantly (6 m or more), the hazard classification with respect to ingress of water remains the same *i.e. Inherent Hazard Class 1/4.*

9. RECOMMENDATIONS

9.1. Permissible Land Use (SANS 1936-1, 2012)

According to SANS 1936 Part 1 the site may be considered for the following land uses:

Dolomite Hazard Zone	Inherent Hazard Class	Design Hazard Class	Land Usage Type	Land Usage Permitted with Dolomite Area Designation and footprint investigation requirement in terms of Deemed-To-Satisfy
1	1//1/4	1* (D2)	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D2+ FPI), C4 (D2 + FPI), C5 (D2 + DLI), C6 (D2+ DLI), C7 (D2), C8 (D2)
			High rise dwelling units	NA
			Low rise dwelling units	NA
			Dwelling houses	NA
2	1/4//1/4	4 (D3)	Commercial and miscellaneous non-residential usage	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3+ FPI), C5 (D3 + DLI), C6 (D3+ DLI), C7 (D3 + FPI), C8 (D3)

Dolomite Hazard Zone	Inherent Hazard Class	Design Hazard Class	Land Usage Type	Land Usage Permitted with Dolomite Area Designation and footprint investigation requirement in terms of Deemed-To-Satisfy
			High rise dwelling units	NA
			Low rise dwelling units	NA
			Dwelling houses	NA
***Selected Design Hazard Class is dependent on groundwater level monitoring and control in perpetuity.**				

	Definitions
FPI	Footprint Investigations
DLI	Design (Stage) Investigations
C1	Places of detention, police stations, and institutional homes for the handicapped or aged
C2	Hospitals (including clinics), hostels, hotels
C3	Commercial developments ≤ 3 storeys, including railway stations, shops, wholesale stores, offices, places of worship, theatrical, indoor sports or public assembly venues, other institutional land uses, such as universities, schools, colleges, libraries, exhibition halls and museums, light (dry) industrial developments, dry manufacturing, commercial uses such as warehousing, packaging, electrical sub-stations, filling stations
C5	Fuel depots, processing plants or any other areas for the storage of liquids, waste sites
C6	Outdoor storage facilities, stock yards, container depots
C7	Parking garages
C8	Parking areas
RH1	> 10 storeys
RH2	> 3 storeys, no higher than 10 storeys with a population of ≤ 1 500 people per hectare
RH3	> 3 storeys with a residential coverage ratio of ≤ 0,4, no higher than 10 storeys, and a population of ≤ 800 people per hectare
RL1	≤ 3 storeys with 80 to 120 units per hectare and a population not exceeding 600 people per hectare
RL2	≤ 3 storeys with up to 80 units per hectare and a population not exceeding 400 people per hectare
RN1	Up to 60 dwelling houses per hectare with stands larger than 150 m^2, and a population of ≤ 300 people per hectare
RN2	Up to 25 dwelling houses per hectare with stands no smaller than 300 m^2, and a population of ≤ 200 people per hectare
RN3	Up to 10 dwelling houses per hectare with 1 000 to 4 000 m^2 stands, and a population of ≤ 60 people per hectare

According to SANS 1936 (2012), the commercial development proposed in Unitas Park Extension 17 is permitted in Dolomite Hazard Zone 1 and 2, provided:

1) Additional (Design Stage) dolomite stability footprint investigations are undertaken in terms of SANS 1936 Part 2 (2012) for any proposed new structure(s).
2) Foundations are designed in order to withstand a 5m diameter nominal loss of support in compliance with SANS1936 Part 3 (2012); applicable to areas designated as D3.
3) Precautionary measures are implemented;
4) All new wet services comply with SANS 1936 Part 3 (2012) and are designed taking the hazard classification into account;
5) Frequent monitoring and maintenance takes place.
6) Groundwater level monitoring andcontrol takes place and the groundwater level is

maintained within natural seasonal variations.

7) Dolomite risk management is implemented in compliance with SANS 1936 Part 4 (2012);

Development may result in a disturbance of the meta-stable conditions in the dolomite environment. Consequently, factors such as the basic design of the services, construction and service installation procedures, and ongoing infrastructure maintenance programmes are key elements in the overall strategy to reduce the probability of generating a sinkhole or subsidence. Risk management consists of key elements such as implementation of precautionary measures to prevent the concentrated ingress of water into the ground, monitoring actions to detect problems which could lead to formation of a sinkhole or subsidence and maintenance of infrastructure.

9.2. D Designation (SANS 1936-1, 2012)

Based on the information currently available the provisional (SANS 1936-2012) D Designation is as follows:

Dolomite Hazard Zone	Design Hazard Class	Provisional D Designation (in relation to permissible land uses)
1	1*	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D2+ FPI), C4 (D2 + FPI), C5 (D2 + DLI), C6 (D2+ DLI), C7 (D2), C8 (D2)
2	4	C1 (D3 + FPI), C2 (D3 + FPI), C3 (D3+ FPI), C5 (D3 + DLI), C6 (D3+ DLI), C7 (D3 + FPI), C8 (D3)
* Selected Design Hazard Class is dependent on groundwater level monitoring and control in perpetuity. Land Uses defined in Sections 9.1.		

SANS 1936-2 (2012) requires Design Stage investigations for some types of development. The final D designation is to be determined by a competent person prior to construction.

9.3. Design of Structures (SANS 1936-1, 2012)

9.3.1. Areas and Land Uses with D2 Designation

The foundation design of structures is subject to the geotechnical properties of surficial soils within proposed footprint areas.

9.3.2. Areas and Land Uses with D3 Designation

Based on the conditions outlined above it is recommended that structures are placed on a reinforced concrete raft foundation.

The foundation should have the following Performance Requirements:

- A sinkhole having a nominal diameter (typically no less than 5m) occurring anywhere beneath or adjacent to the building will not result in toppling or sliding failure of the building (or portion of the building) into such a sinkhole or subsidence.
- The design is such that, in the event of catastrophic loss of support, there is sufficient structural stability to allow occupants to safely escape from the building after the occurrence of the sinkhole.
- The foundation should, when subjected to a loss of support due to sinkhole formation, carry the proposed loads within that section of the structure and have deflection limits permitting safe evacuation of people. It must be noted

that these deflection limits selected may result in severe structural damage. From a financial risk control and structural insurance perspective the Code of Practise requirements on acceptable Level of Damage should be followed.

- It should be understood that sinkholes are typically surrounded by an outer peripheral zone of less catastrophic ground subsidence.

9.4. Precautionary Measures (SANS 1936-3, 2012)

- The minimum standards applicable to any design work, services, future upgrading, repair or maintenance work as contained in **SANS 1936, Part 3 (2012): Design and construction of buildings, structures and infrastructure**" must be complied with as a point of departure, as this standard now forms part of the National Building Regulations.

- New wet services should be designed to minimize the potential for leaks etc, and comply with SANS 1936 Part 3 (2012), and the Department of Public Works Consultants Manual, where applicable.

9.5. Stormwater Management (SANS 1936-4, 2012)

a) **Absolutely no ponding of water should be permitted on the site**. An essential component of risk management is ensuring that stormwater is efficiently and effectively removed from the proximity of infrastructure and safely distributed or deposited into either municipal stormwater systems or natural river courses.

b) Where stormwater canals cross the site and carry large quantities of water, the **canals** should be lined.

9.6. Monitoring Programme (SANS 1936-4, 2012)

The procedure in the designation of monitoring activities and frequencies on site is described in Section 5.9:

Inherent Hazard Class Area	**Monitoring Designation**
Entire site	$(ABC)^{12}D^{na}E^{3}$
Explanation	
A	Visual inspections of ground, structures and infrastructure (e.g. roads, storm water canals, ditches) and dry services, sleeves, ducts, manholes and facility chambers for water ingress immediately after construction and thereafter annually.
B	Visual inspection of stormwater systems crossing the site for blockages at inception and thereafter annually.
C	Testing of wet services at inception. In the event of a crack or problem being identified during visual inspection, the wet services should be tested immediately. If no problems arise, test wet services annually.
D	No precision monitoring of the ground level is required.
E	Groundwater levels should be monitored by the Emfuleni Local Municipality in terms of a regional dolomite risk management programme. The groundwater level is typically recorded within the overburden. The groundwater level (of the dolomite aquifer) should be maintained within natural seasonal fluctuation limits. Any substantial lowering of the groundwater level may induce ground subsidence events on the site.

Monitoring designations assigned during this investigation are deemed provisional and should be finalised as part of the Dolomite Risk Management Plan.

9.7. Dolomite Risk Management (SANS 1936-4, 2012)

According to Part 4 of the South African National Standard Number 1936 every Local Authority in whose jurisdiction a proposed development is located must establish, document, implement and maintain a Dolomite Risk Management System.

In order to implement such a system, a regional dolomite stability assessment must be undertaken. This assessment should underpin all the planning decisions of the Municipality.

9.8. Dolomite Risk Management Principles

A Dolomite Risk Management Plan should be drawn up for the property. Dolomite Risk Management should incorporate steps to mitigate risk before, during and after construction.

Ongoing water precautionary measures and the monitoring and maintenance of buildings and infrastructure form an integral part of any dolomite risk management programme aimed at the mitigation of the negative impacts of urban development on the metastable conditions prevalent in dolomite land.

The mitigation measures include:

- placing restrictions on land use and development densities;
- establishing requirements for the management of surface drainage;
- establishing requirements for the management and monitoring of groundwater levels;
- establishing requirements for the maintenance of water bearing structures and services;
- identifying all the risks that are to be managed for the life time of the development; and
- establishing suitable risk management controls, processes, procedures and measures to manage the identified risks.

9.9. Maintenance Strategy

The subsurface conditions noted during these investigations, necessitates the introduction of a pro-active maintenance strategy for water bearing infrastructure.

This maintenance strategy and precautionary measures provided above in this report should be adhered to in order to reduce the probability of the occurrence of ground movement events.

It should be emphasised that the formation of sinkholes and subsidences can only be prevented in this area, by the implementation of a strict maintenance system.

Although the primary objective of such a maintenance strategy is to reduce the probability of ground movement there are other important benefits, inter alia:

- a reduction in bulk water wastage by timeous maintenance;
- avoiding crises expenditure;
- reducing pollution of the aquifer;
- involving the community in order to enhance the exchange of information;
- developing and evaluating performance criteria in conjunction with the potential hazard characterisation, permitting the identification of sub-areas in the development which should be prioritised for service maintenance or replacement.

9.10. Database of Sinkholes, Subsidences and Structural Damage

It is strongly recommended that any sinkholes, subsidences and/or structural damage that may occur in future should be recorded on a Dolomite Risk Management System.

Detailed historical records of this nature are most useful in developing a clearer perspective on the stability situation in the development and the installation and management of a pro-active maintenance strategy.

9.11. Potentially Problematic Near-surface Soils

Potentially problematic soils mantle the bedrock over the site area. A near-surface soils investigation should be undertaken as part of the Design Level investigations.

10. GENERAL

10.1. Verification Process

The findings in this report are based upon our interpretation of the data recovered during these investigations. While every effort has been made, within the limits of the project budget, time and present-day insight, to determine overall ground conditions on this site, poorer sub-areas may have been missed. For this reason, it is recommended that a competent specialist is always invited to inspect open works on this site in order to further confirm the findings described in this report.

10.2. Third Party Reviews

If this report is reviewed by third parties, it should be noted that dolomite hazard assessment and management is an empirical science and consequently such parties may formulate opinions concerning the findings, conclusions and recommendations of this investigation at variance with those contained in this report. This fact should be borne in mind when costs are incurred on this project prior to receipt of the comments of these parties. VGIconsult Projects and its personnel cannot be held responsible for these divergent views or consequential damages.

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TABLES

Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)					Soft rockDolerite (Karoo) (m-m)	Dolerite rock (Karoo) m and (m AMSL)	Dolomite Bedrock m and (m AMSL)	Quartzite rock m and (m AMSL)	Ground-water rest level in m and (m AMSL)	Air & Sample Losses (m-m)	Susceptibility Characterisation			
												Ingress of water		Groundwater Drawdown	
	Colluvium	Residual Shale (Carbonaceous shale*) Coal**	Residual Dolerite	Chert Residuum (with Shale*)	Dolomite Residuum							Subsidence Formation	Sinkhole Formation	Subsidence Formation	Sinkhole Formation
3925-1 (1466)	0-1	1-4 16-23 25-34	-	4-16 23-25 34-60	-	-	-	>60 <1406	-	Strike @ 34 24 (1442)	-	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM
3925-2 (1463)	0-1	1-31 31-33* 33-42**	-	42-60	-	-	-	>60 <1403	-	Strike @ 11 11 (1452)	-	LOW	LOW	LOW to MEDIUM	LOW to MEDIUM
3925-3 (1465)	0-1	1-31 31-37** 37-46*	-	46-60	-	-	-	>60 <1405	-	Strike @ 46 20 (1445)	-	LOW	LOW	LOW to MEDIUM	LOW to MEDIUM
3925-4 (1465)	-	0-6 14-22 22-30*	-	6-14 30-60	-	-	-	>60 <1405	-	Strike @ 31 25 (1440)	-	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM
3925-5 (1464)	0-1	1-23 23-32*	-	32-60	-	-	-	>60 <1404	-	Strike @ 37 11 (1453)	-	LOW	LOW	LOW to MEDIUM	LOW to MEDIUM
3925-6 (1463)	-	0-37 37-47* 47-60**	-	-	-	-	-	>60 <1403	-	No Strike 21 (1442)	-	LOW	LOW	LOW	LOW
3925-7 (1463)	-	0-23 28-33	-	23-28 33-60	-	-	-	>60 <1403	-	Strike @ 46 19 (1444)	-	LOW	LOW	LOW to MEDIUM	LOW to MEDIUM
3925-8 (1465)	-	0-35 35-36* 36-50** 50-60*	-	-	-	-	-	>60 <1405	-	No Strike 19 (1446)	-	LOW	LOW	LOW	LOW
3925-9 (1463)	-	-	13-29	0-13*	-	29-30	30-36 (1433)	-	-	No Strike Dry	-	LOW	LOW	LOW	LOW
3925-10 (1465)	-	-	18-36	0-18*	-	36-37	37-43 (1428)	-	-	No Strike 21 (1444)	-	LOW	LOW	LOW	LOW
3925-11 (1466)	-	0-31	-	31-60	-	-	-	>60 <1406	-	Strike @ 56 Dry	-	LOW	LOW	LOW to MEDIUM	LOW to MEDIUM

Table 1: Summarised Borehole Information and Inherent Susceptibility Characterisation

{} Hazard classification with respect to ingress of water (lowering of the base level of erosion) in the event that the groundwater level is drawn down significant (6 m or more)

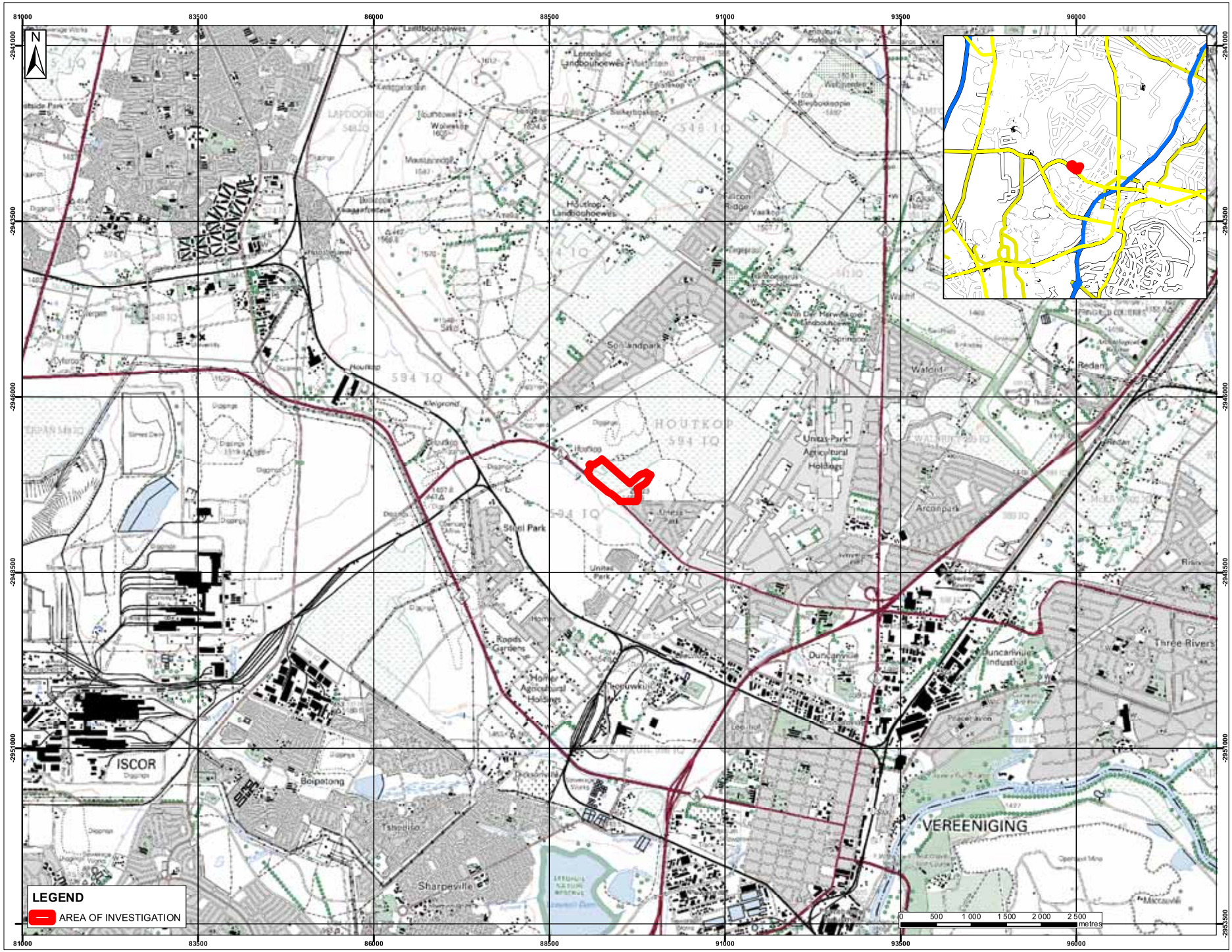
Borehole Number with collar elevation in m AMSL	Blanketing Layer (m) – (m)					Soft rockDolerite (Karoo) (m-m)	Dolerite rock (Karoo) m and (m AMSL)	Dolomite Bedrock m and (m AMSL)	Quartzite rock m and (m AMSL)	Ground-water rest level in m and (m AMSL)	Air & Sample Losses (m-m)	Susceptibility Characterisation			
												Ingress of water		Groundwater Drawdown	
	Colluvium	Residual Shale (Carbonaceous shale*) Coal**	Residual Dolerite	Chert Residuum (with Shale*)	Dolomite Residuum							Subsidence Formation	Sinkhole Formation	Subsidence Formation	Sinkhole Formation
3925-12 (1466)	-	0-34 34-40* 40-60**	-	-	-	-	-	>60 <1406	-	Strike @ 51 23 (1443)	-	LOW	LOW	LOW	LOW
1544/4 (1464)	0-1	14-19	-	1-2 2-11* 11-14 19-21 21-24* 24-32	-	-	-	-	32-37 (1432)	Strike @ 36 ?	-	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM
1544/5 (1466)	0-1	5-18	-	1-5 18-60	-	-	-	>60 (<1406)	-	Strike @ 33 ?	-	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM	LOW to MEDIUM

Table 1: Summarised Borehole Information and Inherent Hazard Characterisation

* The site is located in the KliprivierDolomite Groundwater Compartment

** The dolomite groundwater level used in the hazard assessment is at (an average of) 20 m depth below ground or 1445 m AMSL

FIGURES



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system
Transverse Mercator — False Northing = 0°
Central Meridian = 27° — Scale Factor = 1
False Easting = 0° — Datum = WGS 84

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

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discipline
GEOTECHNICAL

service
VGI3925:
UNITAS PARK EXTENTION 17

Project Number
VGI3925

drawing title
LOCALITY PLAN
(REF.: MAP 2627 DB VEREENIGING 1:25 000)

ref.no. VGI3925 — designed I.K.
scale 1:50 000 — drawn AR.G.
date NOVEMBER 2015 — checked I.K.

Drawing number
FIGURE 1

TOPOGRAPHICAL SHEET LEGEND

National freeway

National route

Arterial route

Main road

Secondary road

Railway (showing a station)

River: Perennial (has water all year)

Non perennial

Dam

Pan: Perennial

Non perennial

Dry

Canal

Powerline (major lines only)

Contour

Spot height (elevation at a point)

Trigonometrical Beacon (with beacon number)

Built up area (High and Low density)

(Residential, commercial and industrial) Building (of significance or isolated)

Bridge

Cultivated Land

Row of trees (where of significance)

Wind pump

Communication tower

Eroded area

Sandy area

Boundary: International

Provincial

Cadastral farm (original farm)

Protected Areas

No.	DATE	AMENDMENT	D.P.W.

co-ordinate system

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

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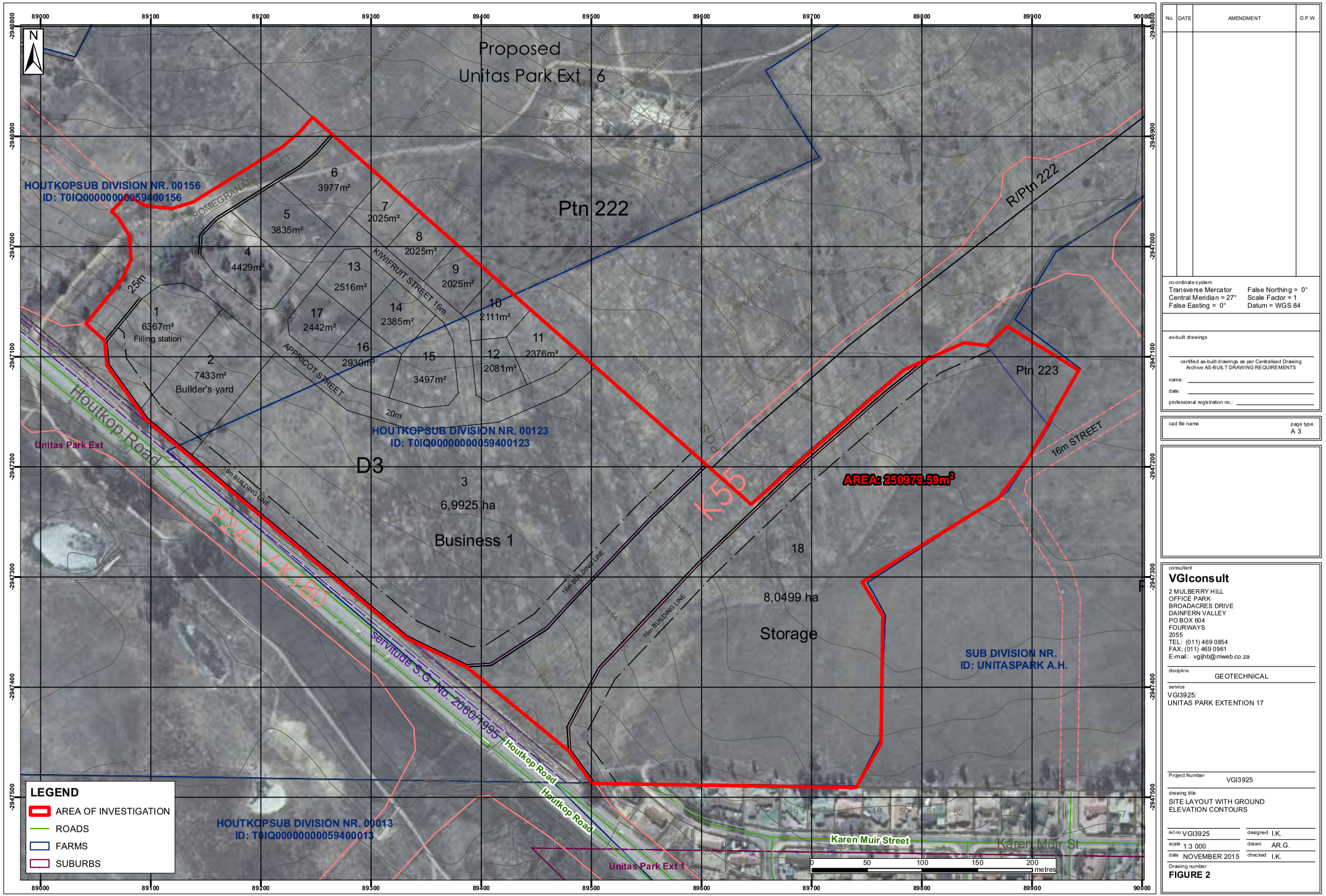
UNITAS PARK EXTENTION 17

Project Number
VGI3925

drawing title
TOPOGRAPHICAL SHEET LEGEND
(REF.: MAP 2627 DB VEREENIGING 1:25 000)

ref.no. VGI3925
designed I.K.
scale
drawn AR.G.
date NOVEMBER 2015
checked I.K.

Drawing number
FIGURE 1A



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system
Transverse Mercator — False Northing = 0°
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False Easting = 0° — Datum = WGS 84

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

name:

date:

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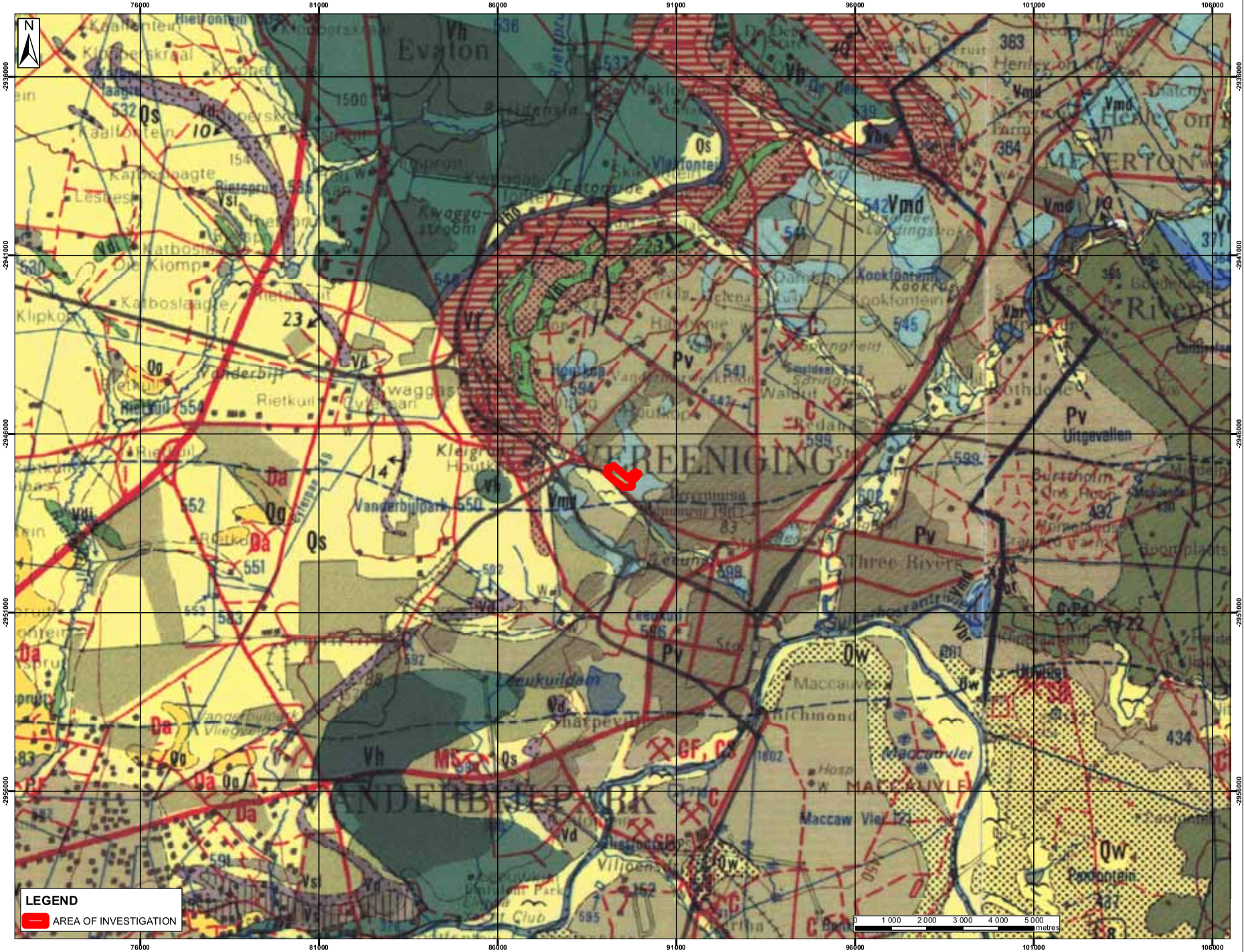
VGI3925:
UNITAS PARK EXTENTION 17

Project Number
VGI3925

drawing title
SITE LAYOUT WITH GROUND ELEVATION CONTOURS

ref.no. VGI3925 — designed I.K.
scale 1:3 000 — drawn AR.G.
date NOVEMBER 2015 — checked I.K.

Drawing number
FIGURE 2



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system
Transverse Mercator — False Northing = 0°
Central Meridian = 27° — Scale Factor = 1
False Easting = 0° — Datum = WGS 84

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FAX: (011) 469 0961
E-mail: vgijhb@mweb.co.za

discipline
GEOTECHNICAL

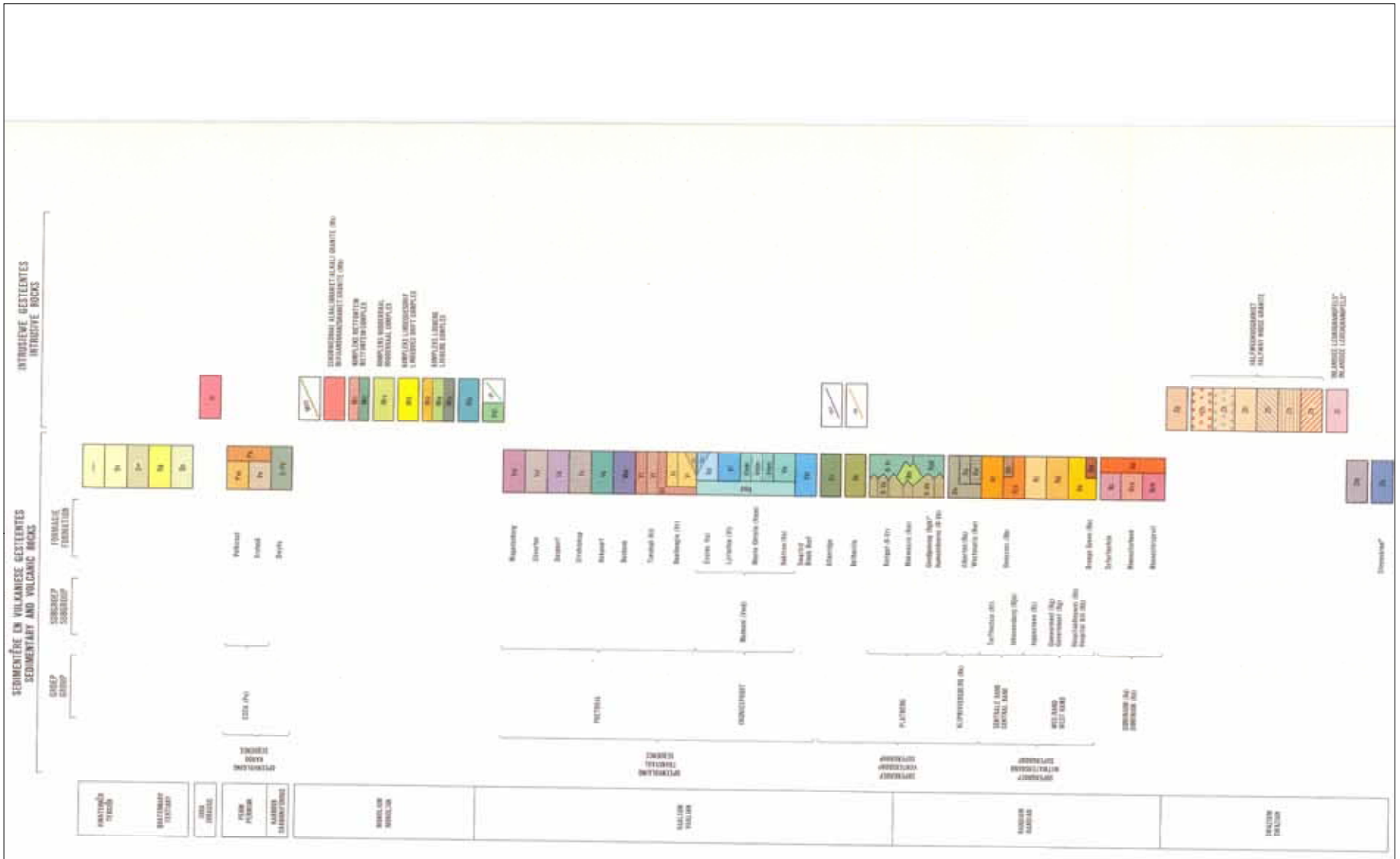
service
VGI3925:
UNITAS PARK EXTENTION 17

Project Number
VGI3925

drawing title
REGIONAL GEOLOGY
(REF.: MAP 2626 WEST RAND
1:250 000 GEOLOGICAL SERIES)

ref.no. VGI3925 — designed I.K.
scale 1:100 000 — drawn AR.G.
date NOVEMBER 2015 — checked I.K.

Drawing number
FIGURE 3



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

name:

date:

professional registration no.:

cad file name

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Project Number
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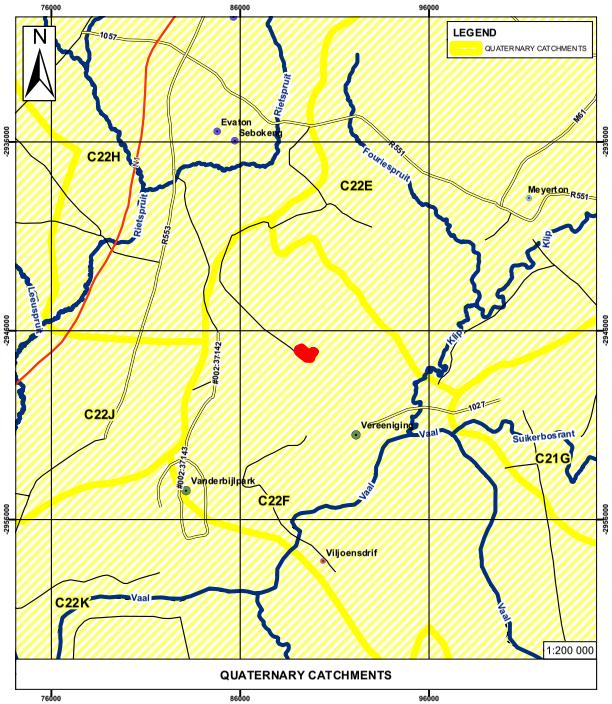
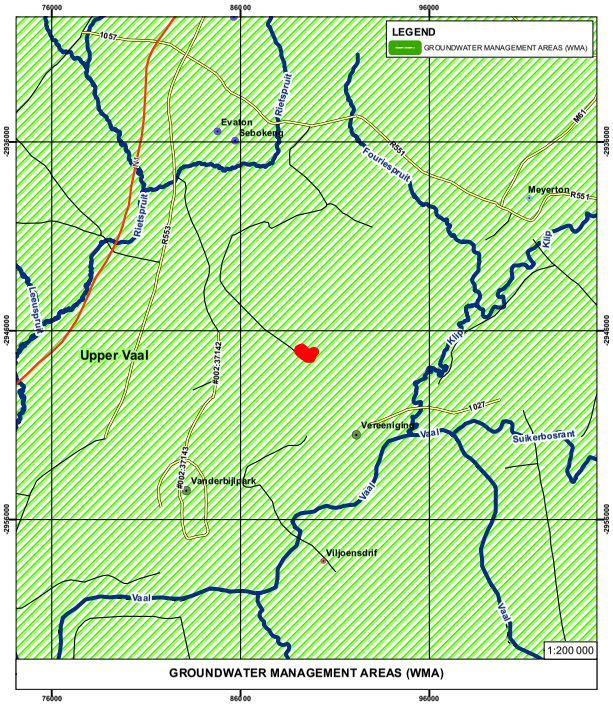
drawing title
GEOLOGY LEGEND
(REF.: MAP 2626 WEST RAND
1:250 000 GEOLOGICAL SERIES)

ref.no. VGI3925
designed I.K.
scale
drawn AR.G.
date NOVEMBER 2015
checked I.K.

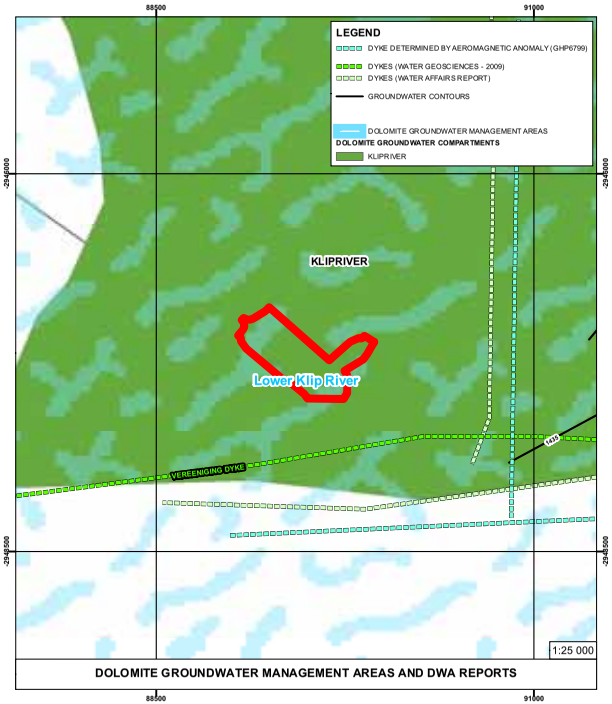
Drawing number
FIGURE 3A



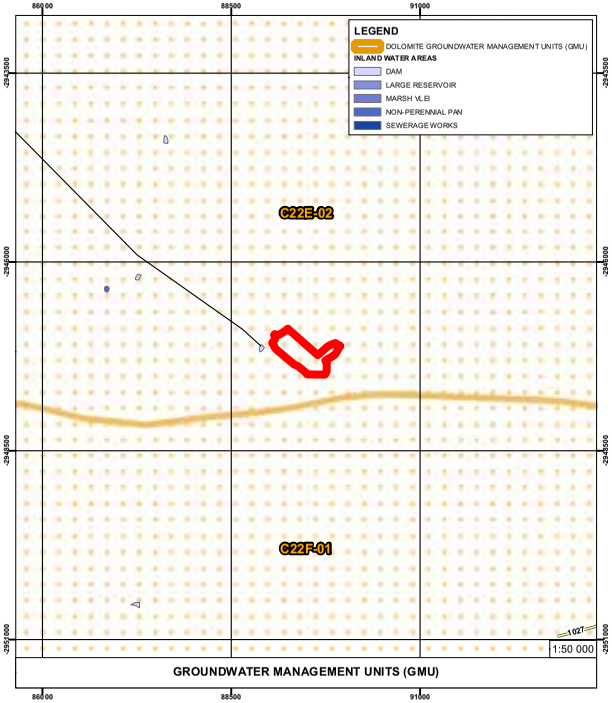
QUATERNARY CATCHMENTS



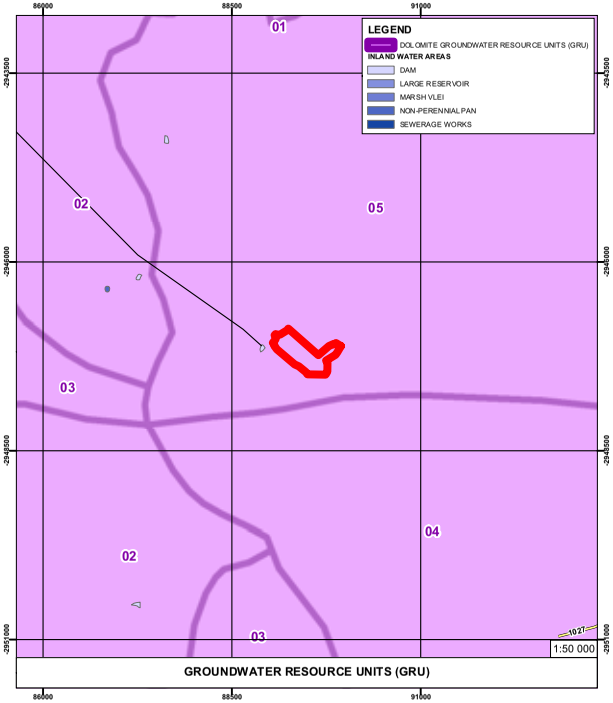
GROUNDWATER MANAGEMENT AREAS (WMA)



DOLOMITE GROUNDWATER MANAGEMENT AREAS AND DWA REPORTS



GROUNDWATER MANAGEMENT UNITS (GMU)



GROUNDWATER RESOURCE UNITS (GRU)

NATIONAL GROUNDWATER INFORMATION SYSTEM

No.	DATE	AMENDMENT	D.P.W.

GENERAL LEGEND

- AREA OF INVESTIGATION
- RSA TOWNS
- CAPITAL / CITY
- CHIEF ADMINISTRATIVE TOWN
- MAJOR TOWN
- OTHER TOWN
- SECONDARY TOWN
- SETTLEMENT
- FREEWAY ROADS
- MAIN ROADS
- NATIONAL ROADS
- SECONDARY ROADS
- RIVERS

co-ordinate system
Transverse Mercator — False Northing = 0°
Central Meridian = 27° — Scale Factor = 1
False Easting = 0° — Datum = WGS 84

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discipline
GEOTECHNICAL

service
VGI3925:
UNITAS PARK EXTENTION 17

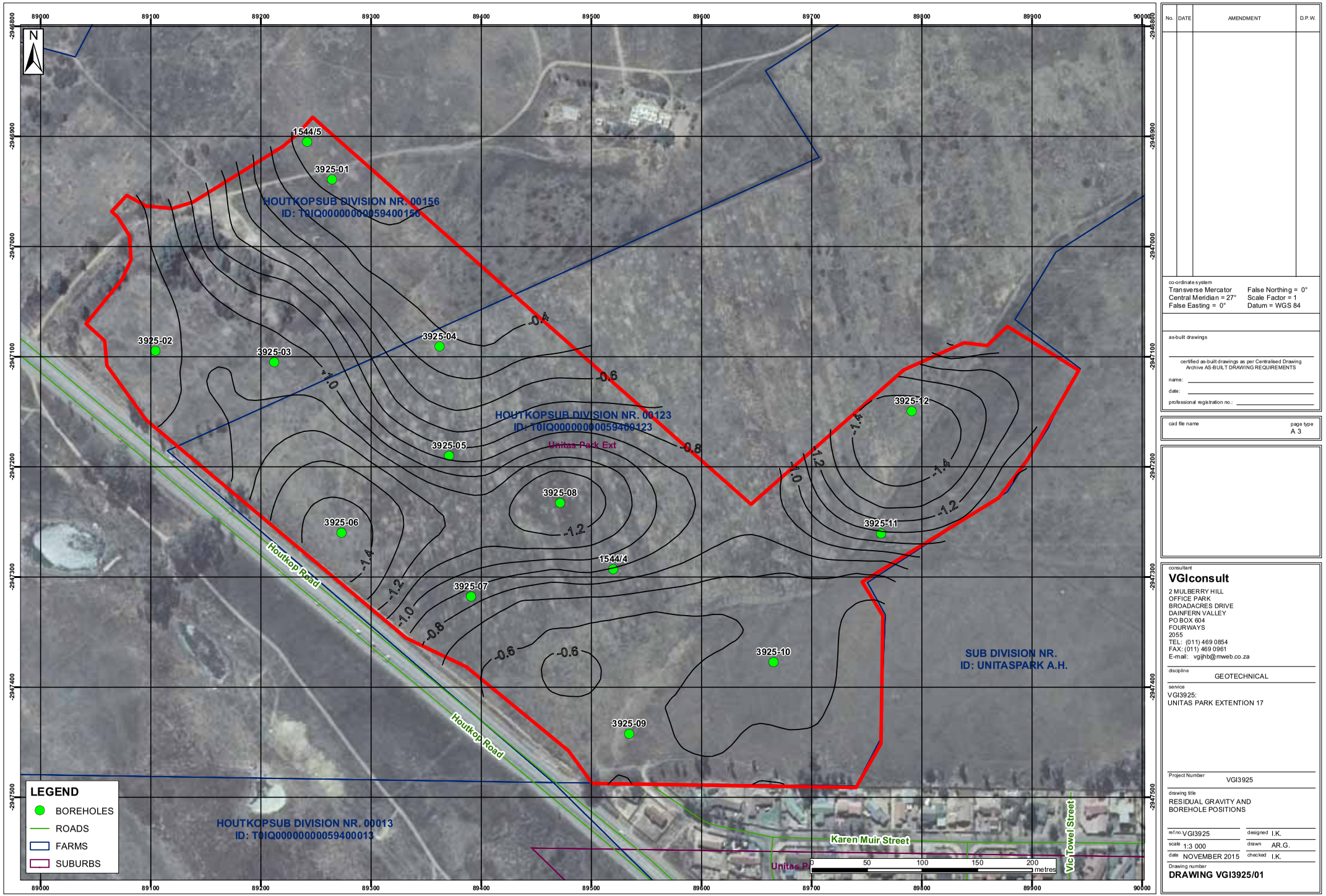
Project Number
VGI3925

drawing title
REGIONAL GEOHYDROLOGY
(REF.: MAP 2627 DB VEREENIGING 1:25 000)

ref.no. VGI3925 — designed I.K.
scale — drawn AR.G.
date NOVEMBER 2015 — checked I.K.

Drawing number
FIGURE 4

DRAWINGS



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system
Transverse Mercator — False Northing = 0°
Central Meridian = 27° — Scale Factor = 1
False Easting = 0° — Datum = WGS 84

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

name:

date:

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cad file name

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discipline
GEOTECHNICAL

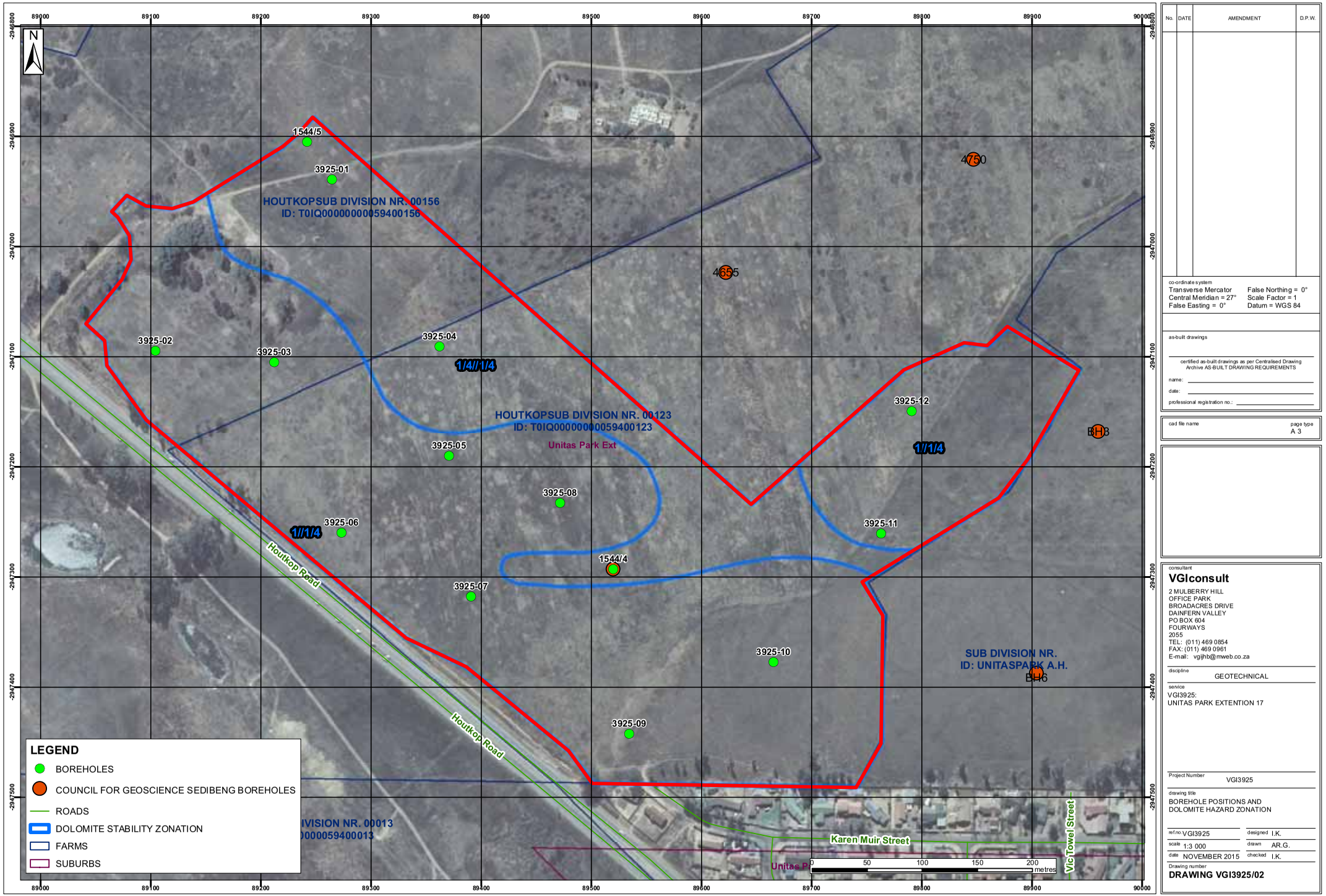
service
VGI3925:
UNITAS PARK EXTENTION 17

Project Number
VGI3925

drawing title
RESIDUAL GRAVITY AND
BOREHOLE POSITIONS

ref.no. VGI3925	designed I.K.
scale 1:3 000	drawn AR.G.
date NOVEMBER 2015	checked I.K.

Drawing number
DRAWING VGI3925/01



No.	DATE	AMENDMENT	D.P.W.

co-ordinate system
Transverse Mercator — False Northing = 0°
Central Meridian = 27° — Scale Factor = 1
False Easting = 0° — Datum = WGS 84

as-built drawings

certified as-built drawings as per Centralised Drawing Archive AS-BUILT DRAWING REQUIREMENTS

name:

date:

professional registration no.:

cad file name

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discipline: GEOTECHNICAL

service
VGI3925:
UNITAS PARK EXTENTION 17

Project Number: VGI3925

drawing title
BOREHOLE POSITIONS AND
DOLOMITE HAZARD ZONATION

ref.no. VGI3925 — designed I.K.
scale 1:3 000 — drawn AR.G.
date NOVEMBER 2015 — checked I.K.

Drawing number
DRAWING VGI3925/02

APPENDICES

BOREHOLE PROFILES APPENDIX 1

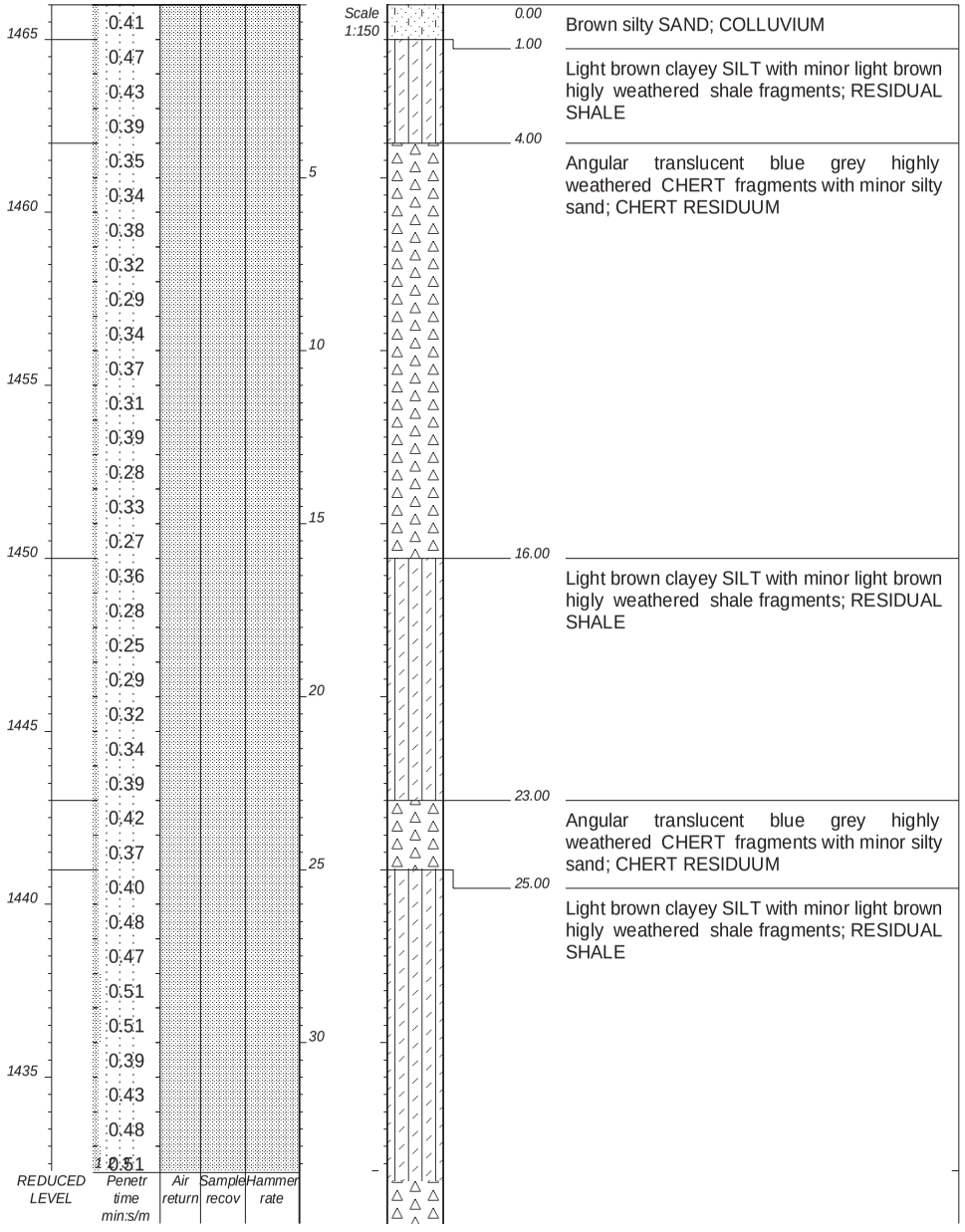
APPENDIX 1

BOREHOLE PROFILES

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/01
Sheet 1 of 2

JOB NUMBER: VGI3925



0.00 – 1.00 Brown silty SAND; COLLUVIUM

1.00 – 4.00 Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

4.00 – 16.00 Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

16.00 – 23.00 Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

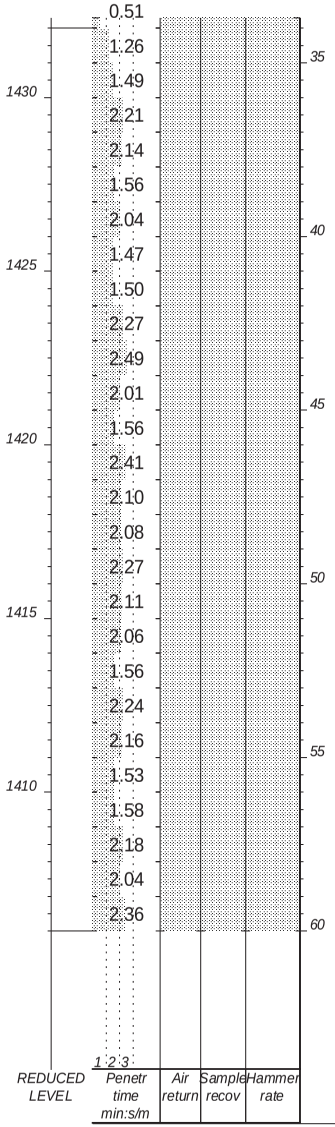
23.00 – 25.00 Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

25.00 – Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/01
Sheet 2 of 2

JOB NUMBER: VGI3925



34.00 Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

60.00

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 34 m.

3) Groundwater rest level recorded at 24 m on 2015/11/06.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/05
DATE : 2015/11/09

ELEVATION : 1466 m AMSL
X-COORD : 2946941
Y-COORD : -89265

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/01

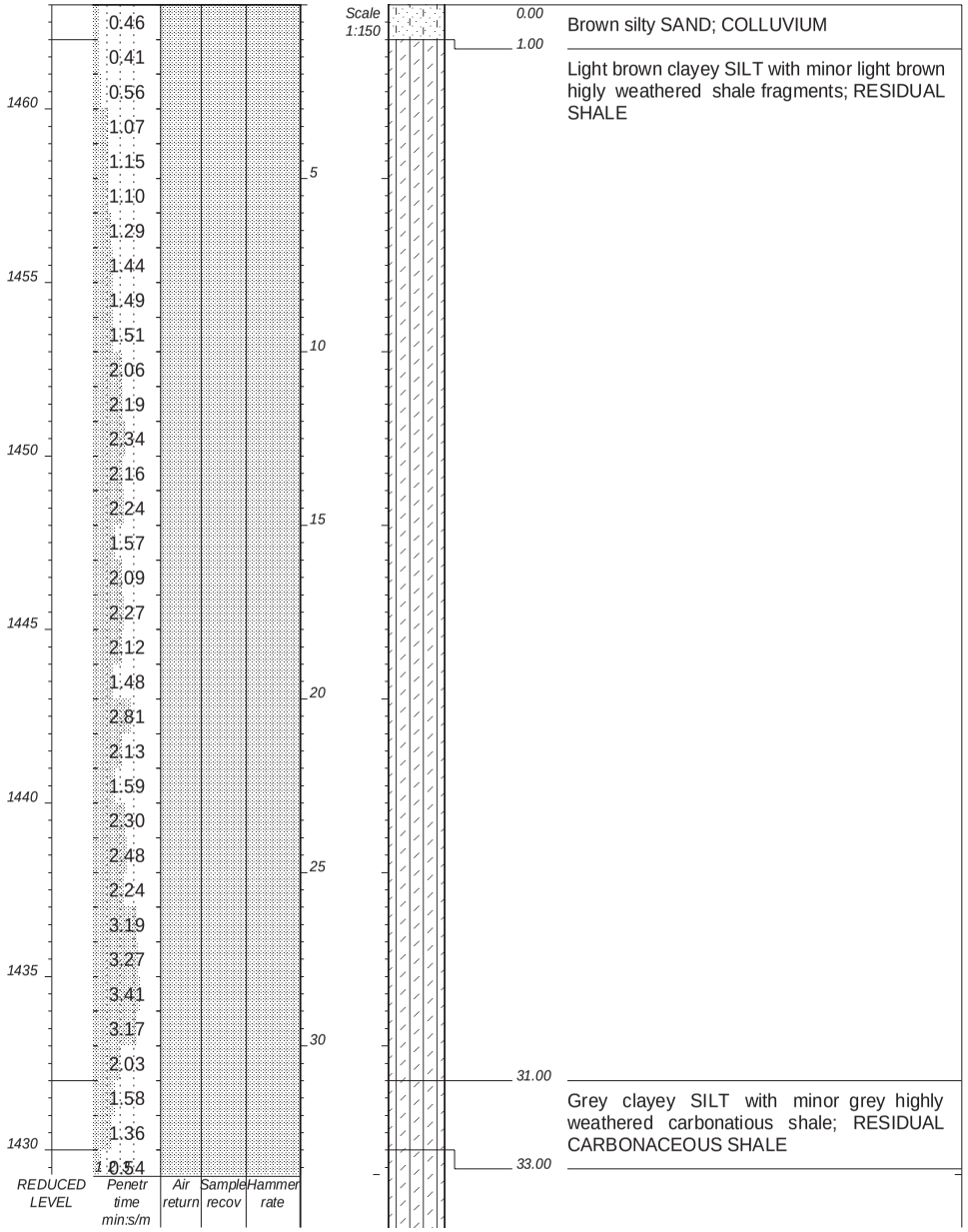
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/02
Sheet 1 of 2

JOB NUMBER: VGI3925



Brown silty SAND; COLLUVIUM

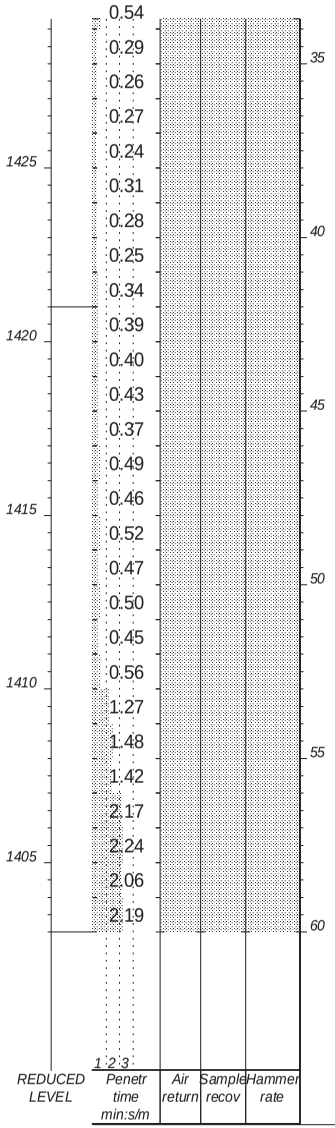
Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/02
Sheet 2 of 2

JOB NUMBER: VGI3925



Black clayey SILT with minor coal fragements; COAL

42.00

Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

60.00

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 11 m.

3) Groundwater rest level recorded at 11 m on 2015/11/06.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/05
DATE : 2015/11/09

ELEVATION : 1463 m AMSL
X-COORD : 2947100
Y-COORD : -89103

HOLE No: 3925/02

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

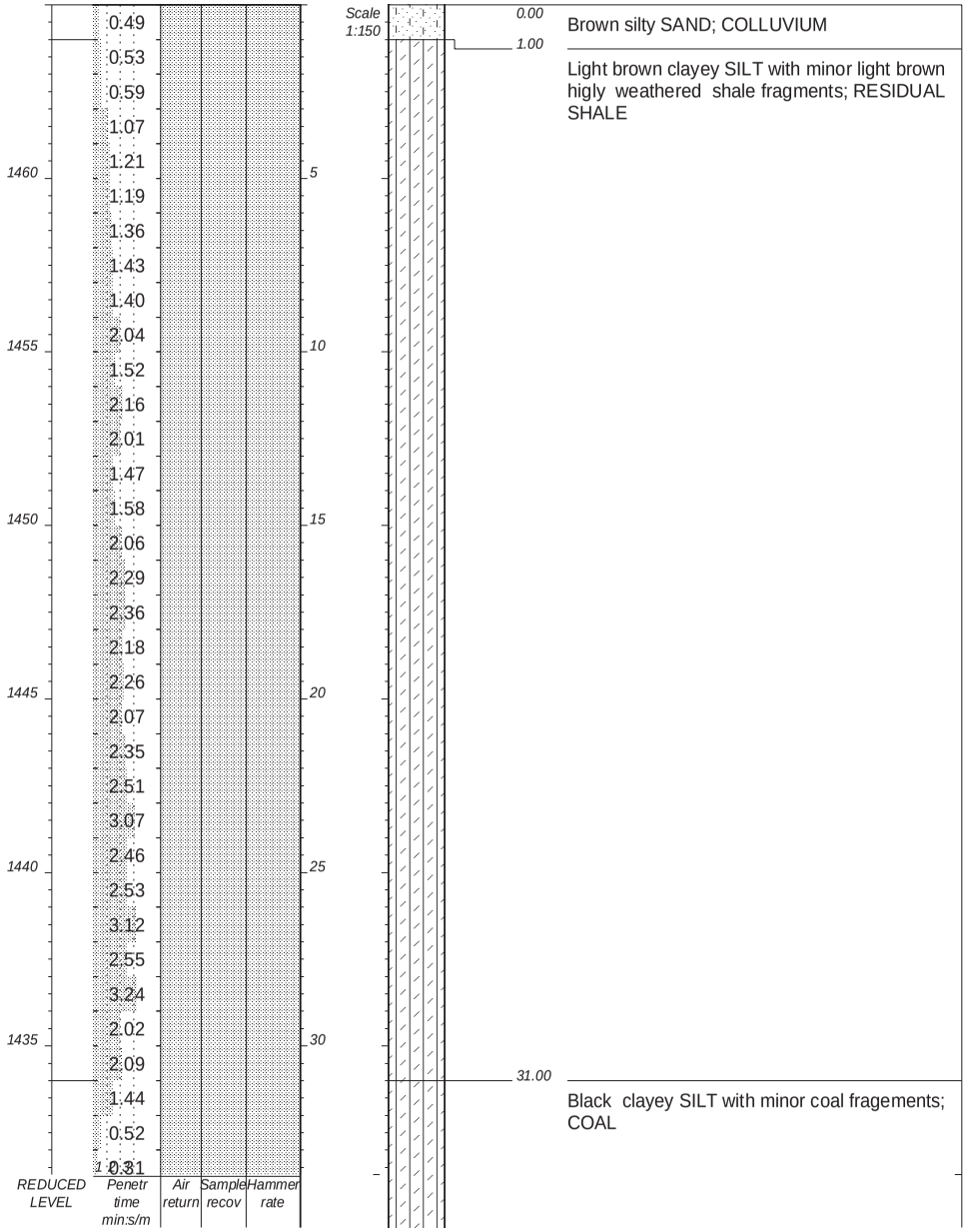
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/03
Sheet 1 of 2

JOB NUMBER: VGI3925



Brown silty SAND; COLLUVIUM

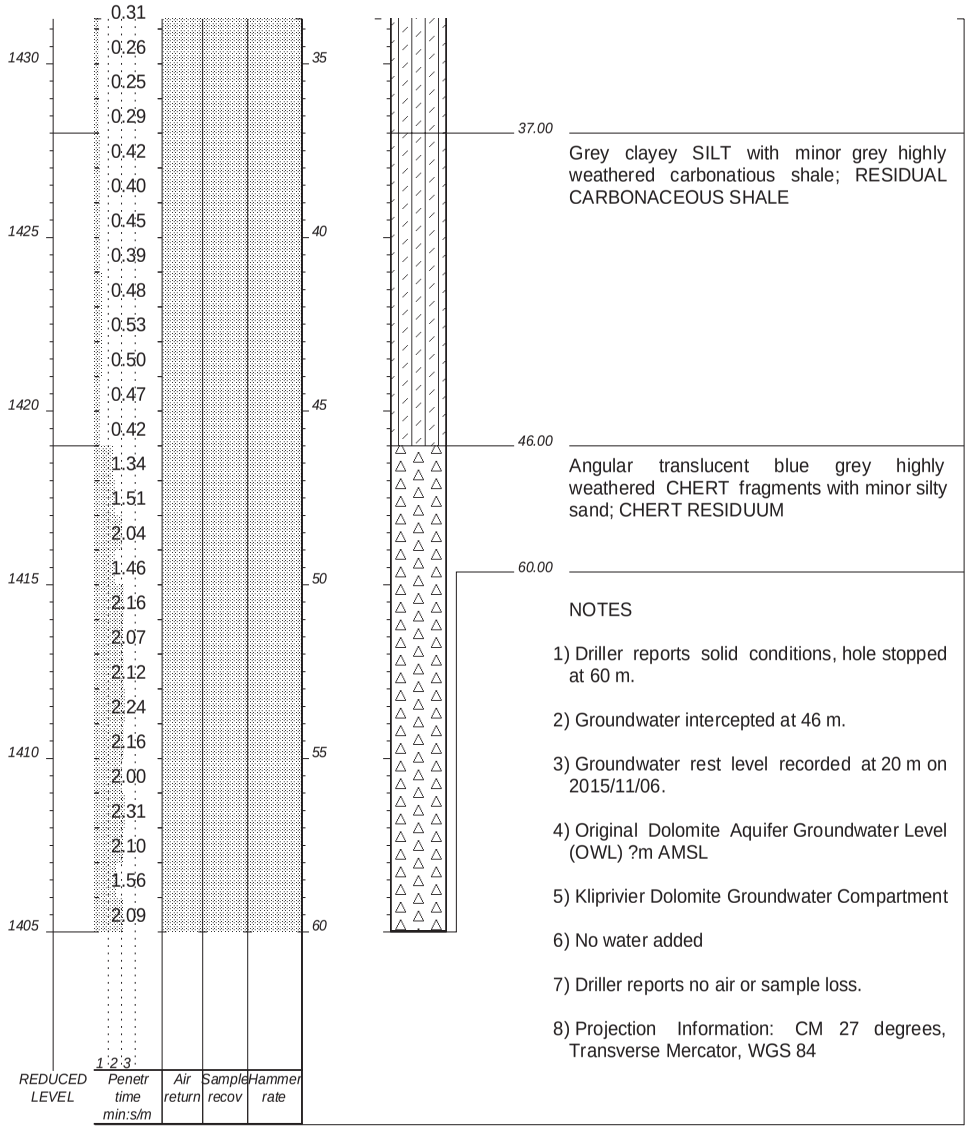
Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

Black clayey SILT with minor coal fragements; COAL

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/03
Sheet 2 of 2

JOB NUMBER: VGI3925



Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 46 m.

3) Groundwater rest level recorded at 20 m on 2015/11/06.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/05
DATE : 2015/11/06

ELEVATION : 1465 m AMSL
X-COORD : 2947106
Y-COORD : -89215

HOLE No: 3925/03

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
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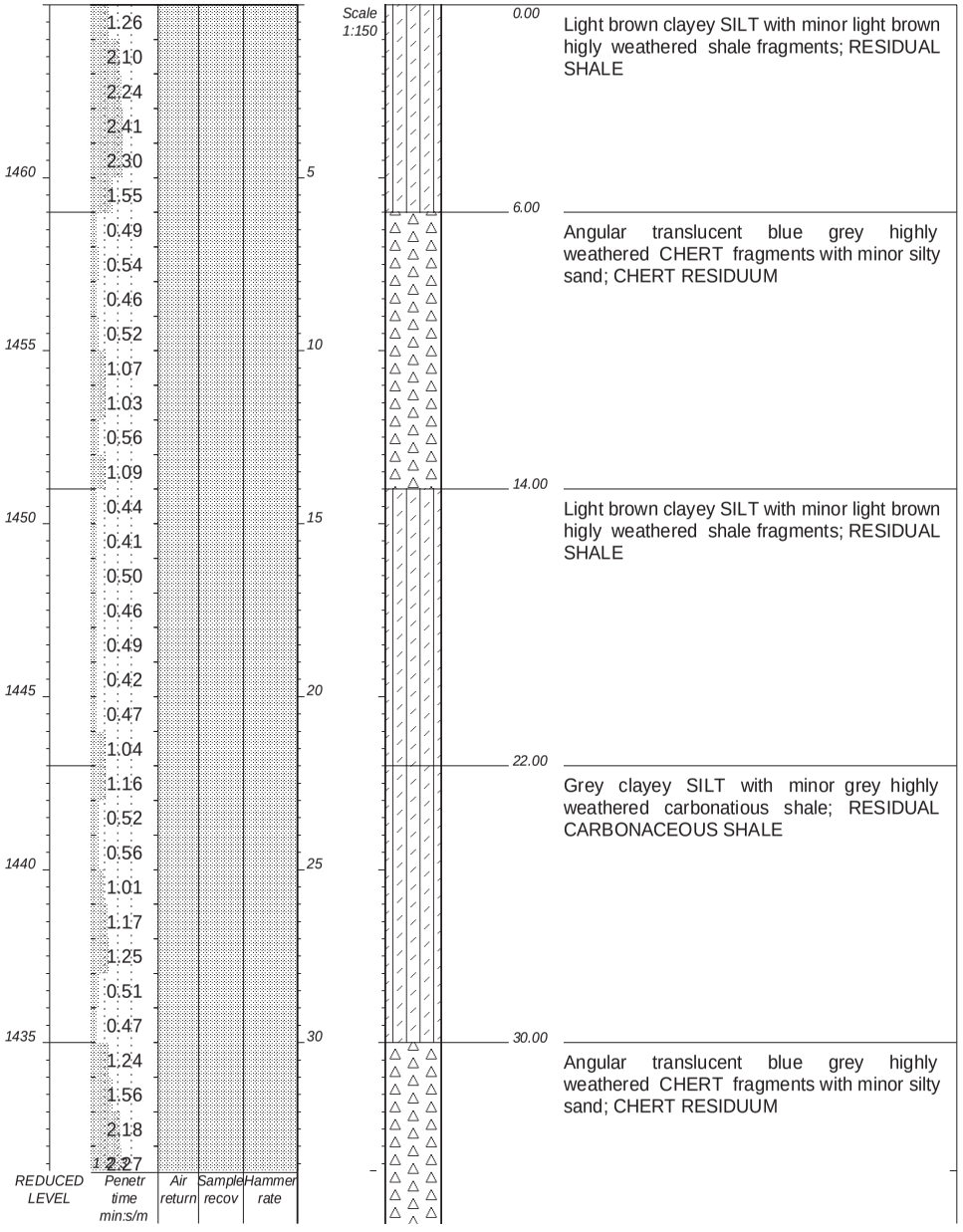
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/04
Sheet 1 of 2

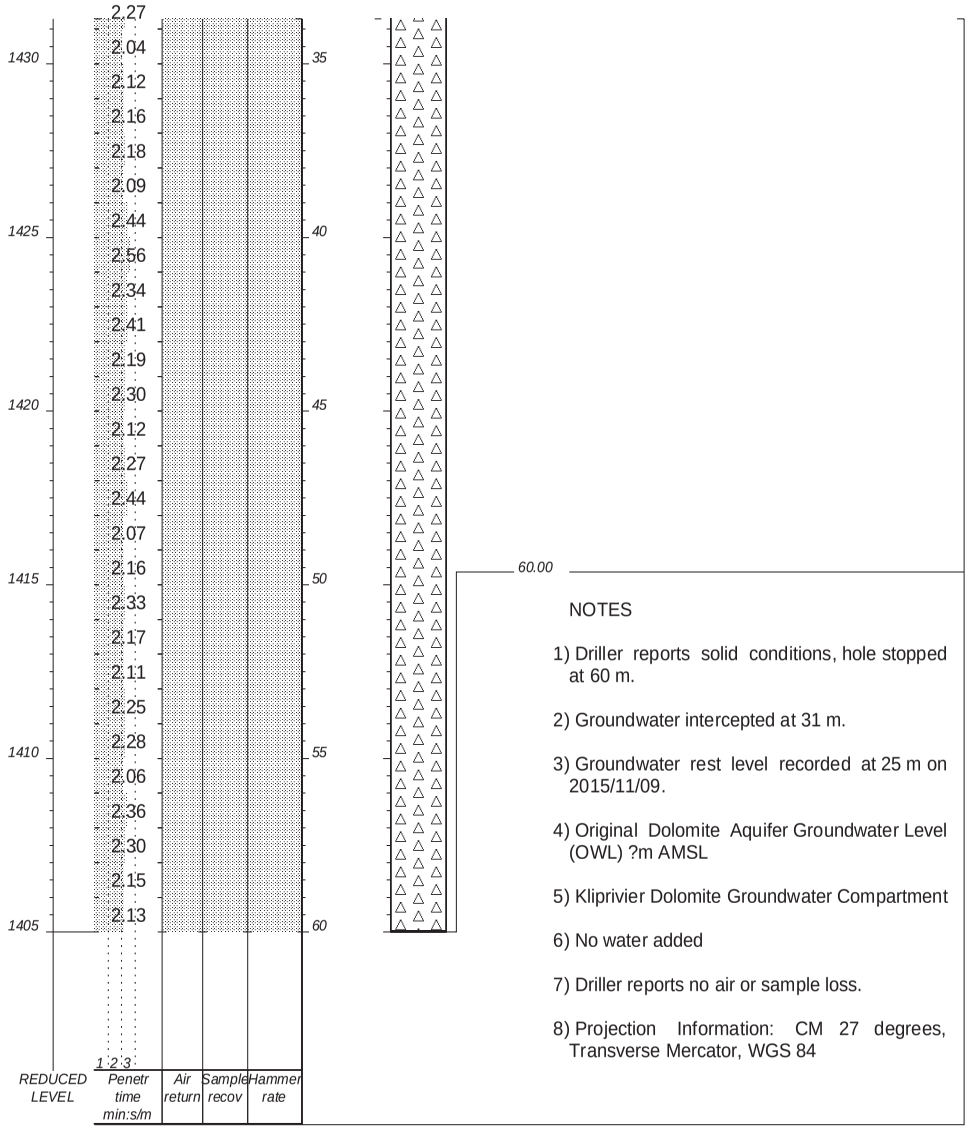
JOB NUMBER: VGI3925



SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/04
Sheet 2 of 2

JOB NUMBER: VGI3925



NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 31 m.

3) Groundwater rest level recorded at 25 m on 2015/11/09.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/05
DATE : 2015/11/06

ELEVATION : 1465 m AMSL
X-COORD : 2947094
Y-COORD : -89362

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/04

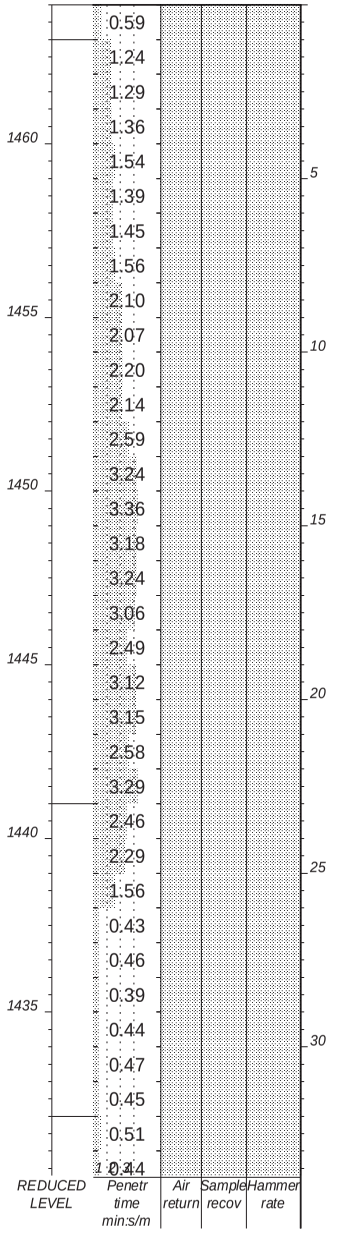
D055 DBB

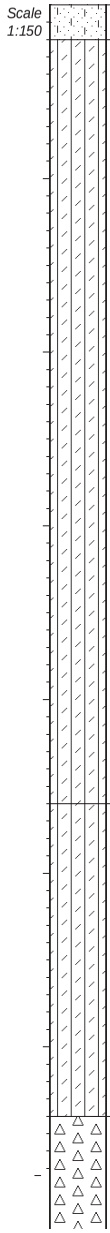
dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/05
Sheet 1 of 2

JOB NUMBER: VGI3925





Brown silty SAND; COLLUVIUM

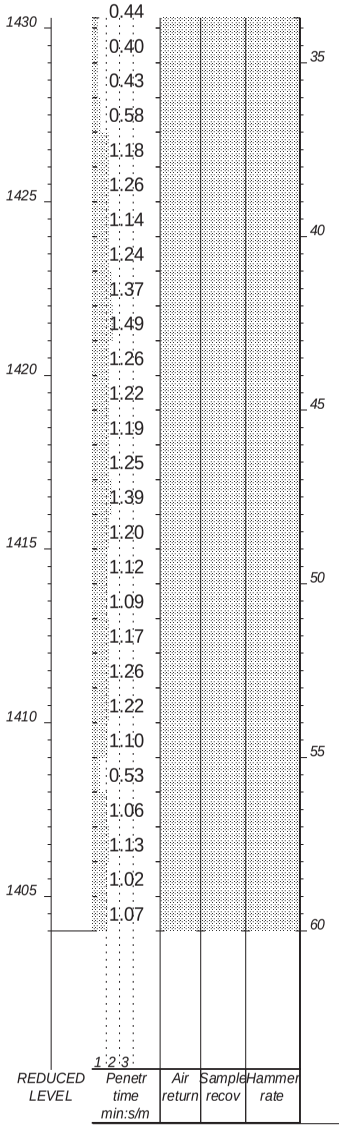
Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

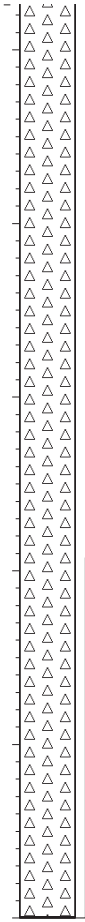
Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/05
Sheet 2 of 2

JOB NUMBER: VGI3925





Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

60.00

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 37 m.

3) Groundwater rest level recorded at 11 m on 2015/11/09.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/05
DATE : 2015/11/06

ELEVATION : 1464 m AMSL
X-COORD : 2947191
Y-COORD : -89371

HOLE No: 3925/05

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
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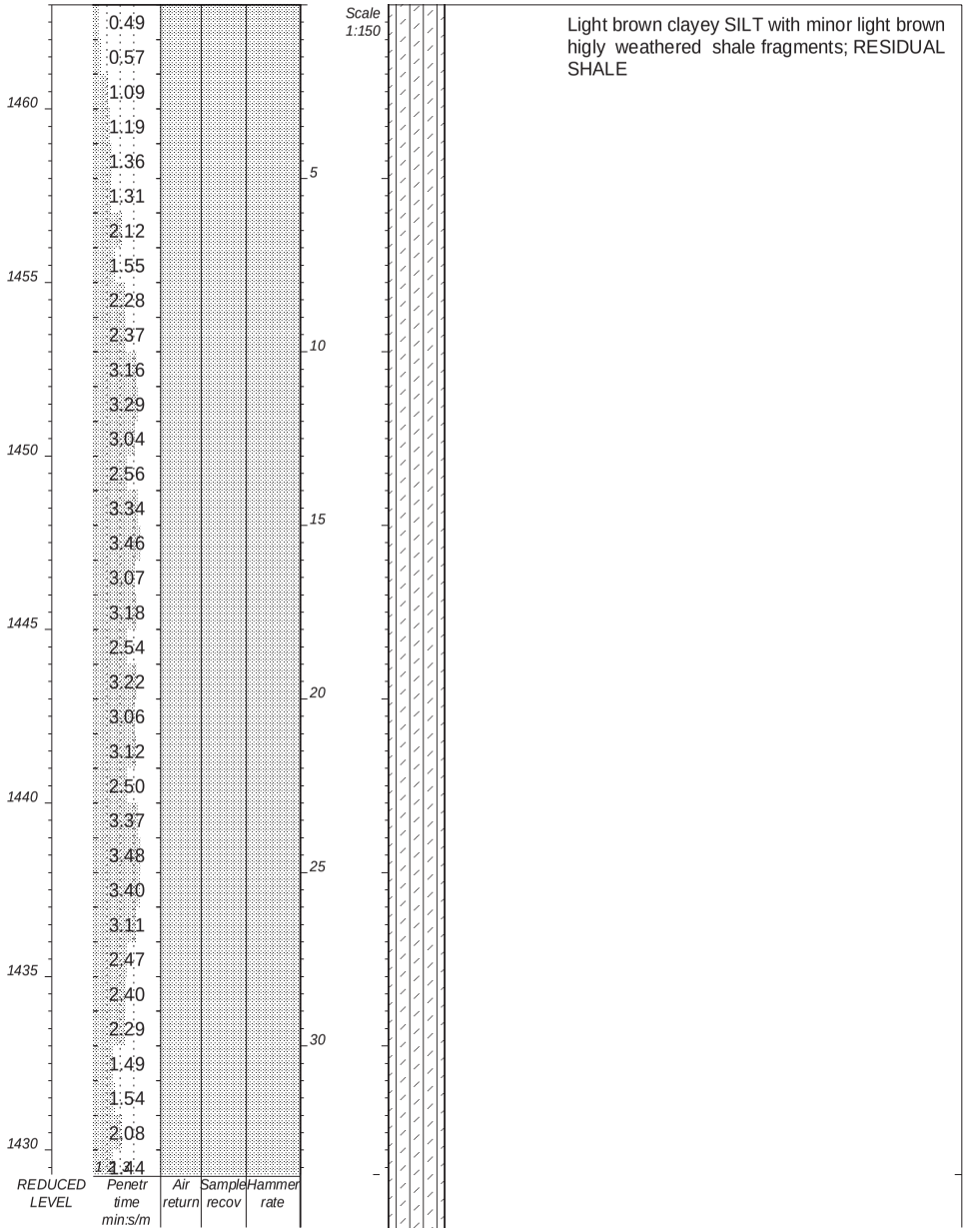
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/06
Sheet 1 of 2

JOB NUMBER: VGI3925

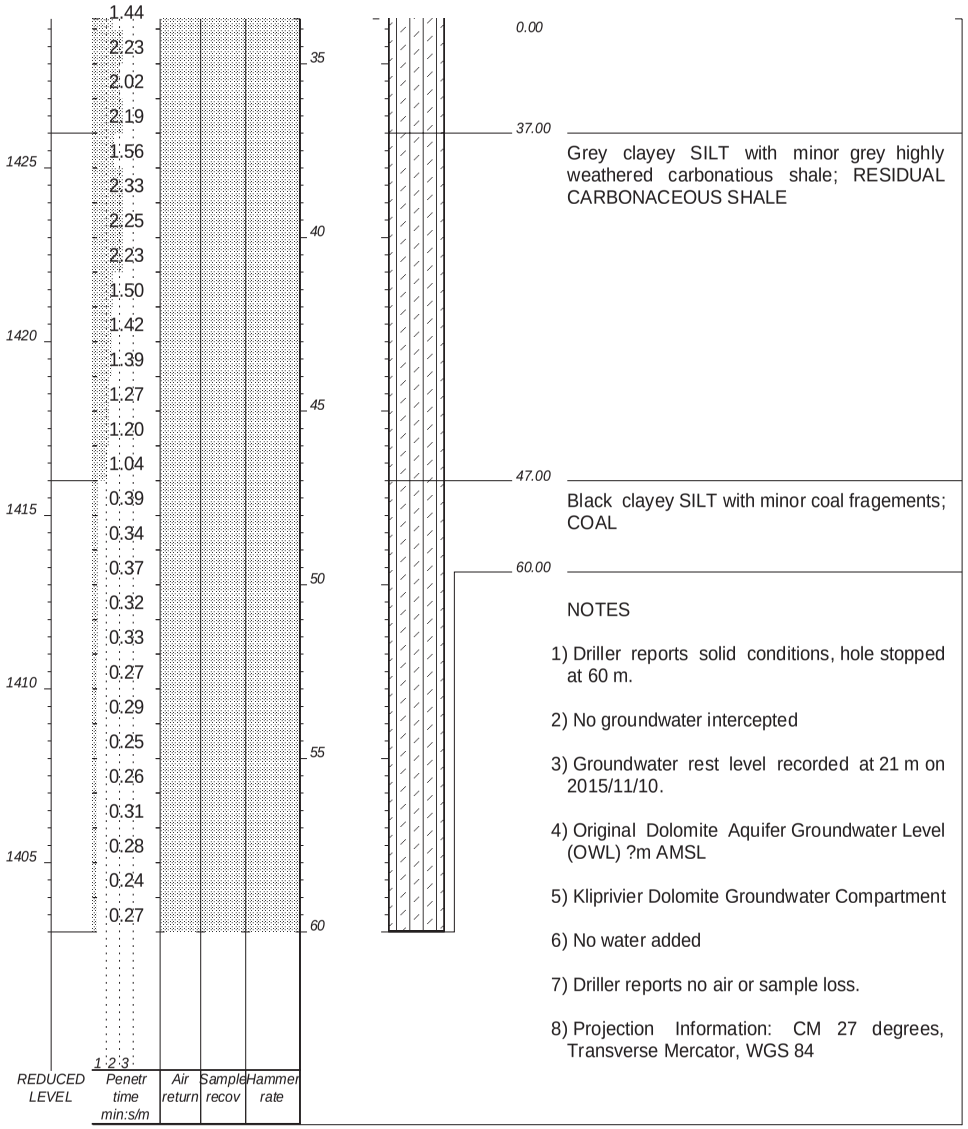


Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/06
Sheet 2 of 2

JOB NUMBER: VGI3925



Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

Black clayey SILT with minor coal fragements; COAL

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) No groundwater intercepted

3) Groundwater rest level recorded at 21 m on 2015/11/10.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/09
DATE : 2015/11/11

ELEVATION : 1463 m AMSL
X-COORD : 2947262
Y-COORD : -89274

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/06

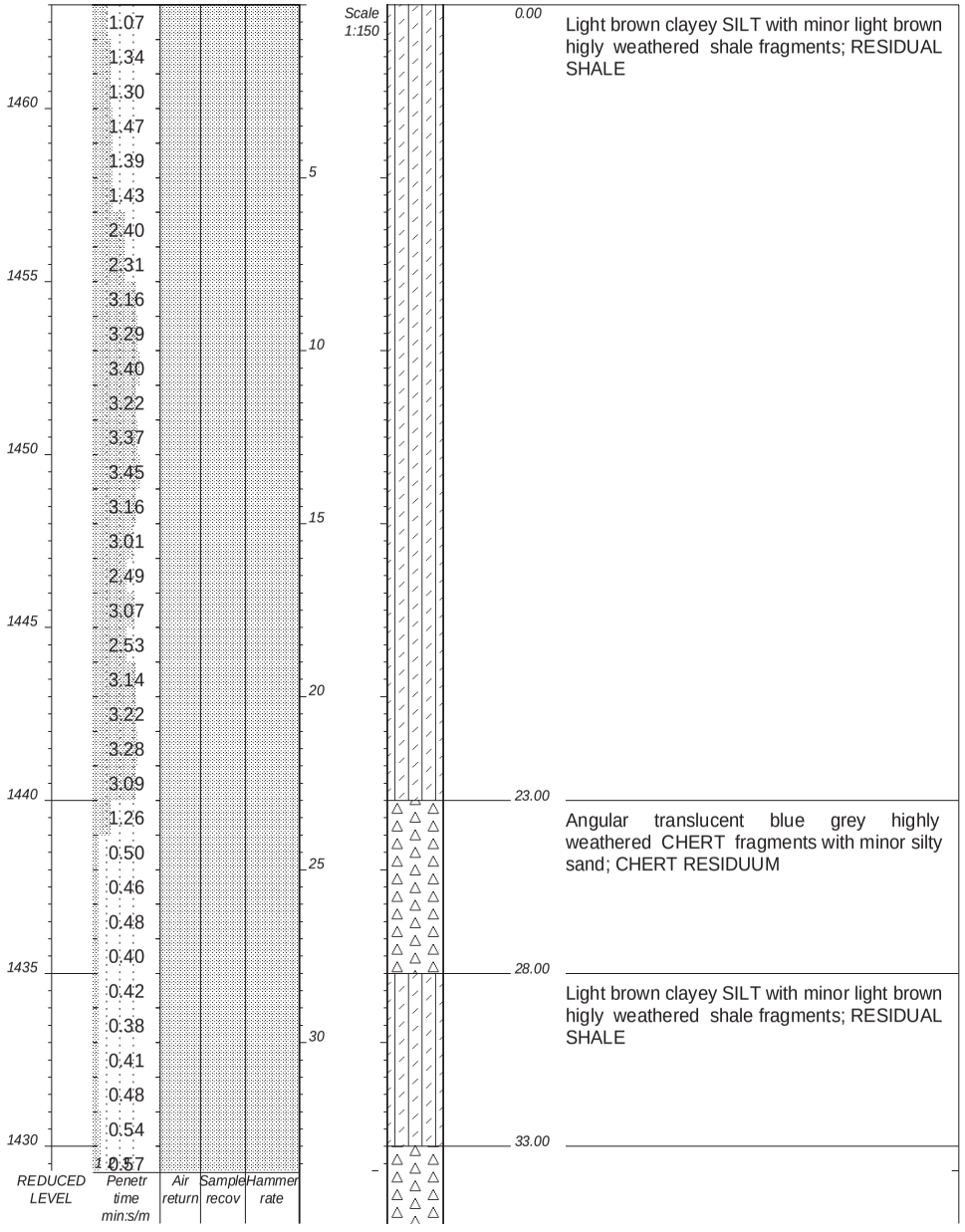
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/07
Sheet 1 of 2

JOB NUMBER: VGI3925



Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

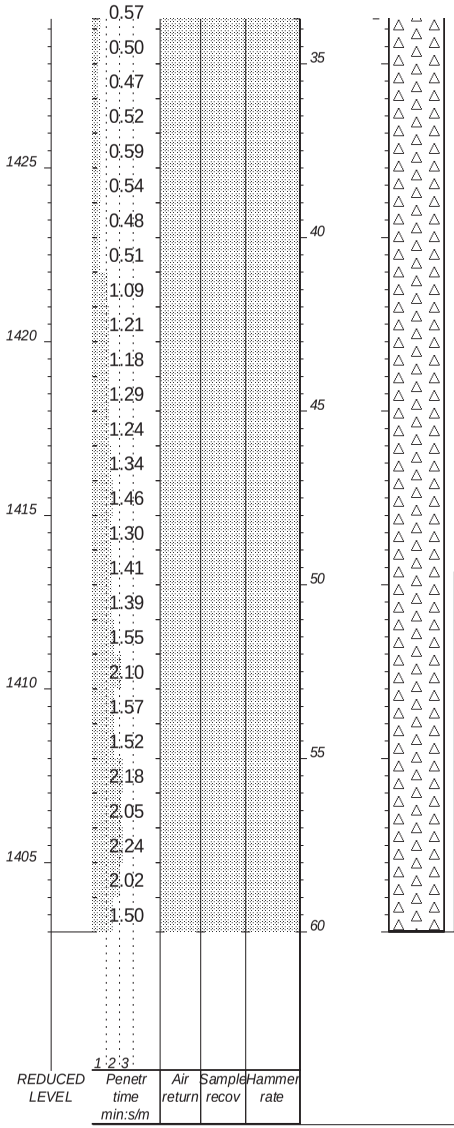
Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/07
Sheet 2 of 2

JOB NUMBER: VGI3925



Angular translucent blue grey highly weathered CHERT fragments with minor silty sand; CHERT RESIDUUM

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 46 m.

3) Groundwater rest level recorded at 19 m on 2015/11/10.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/09
DATE : 2015/11/11

ELEVATION : 1463 m AMSL
X-COORD : 2947318
Y-COORD : -89391

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/07

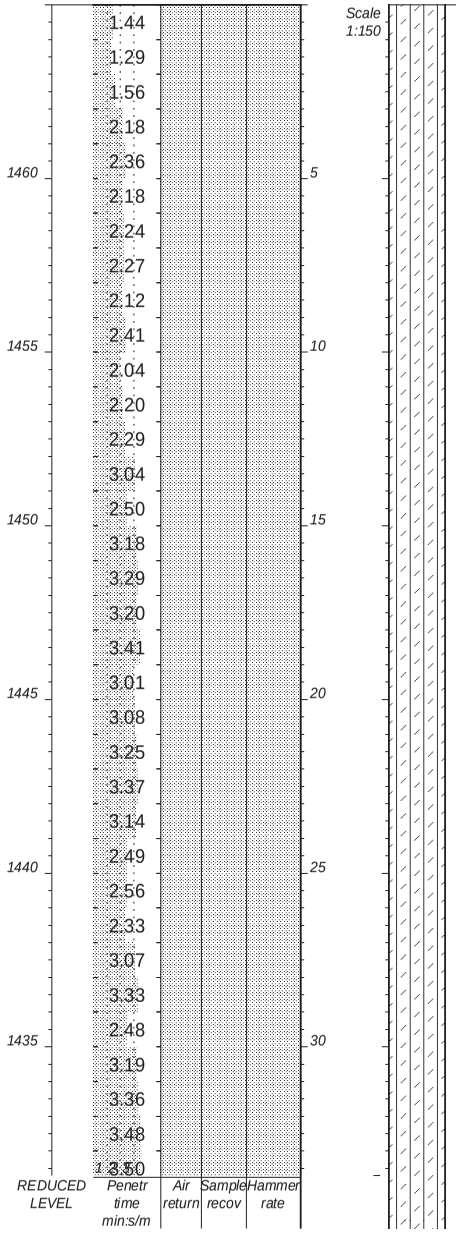
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/08
Sheet 1 of 2

JOB NUMBER: VGI3925

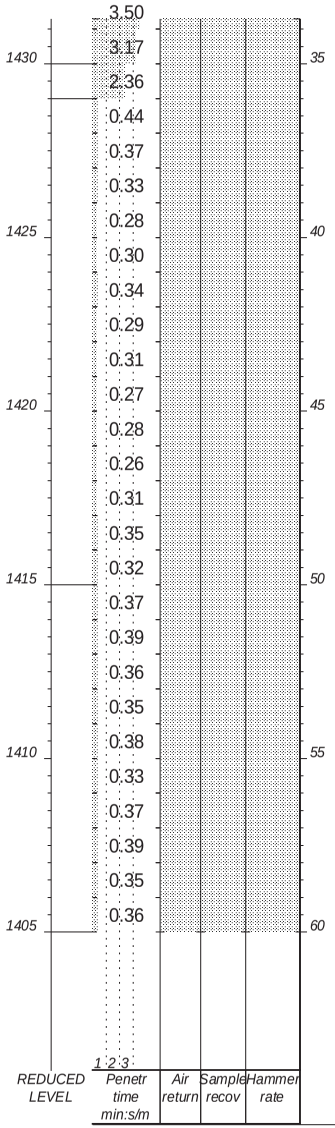


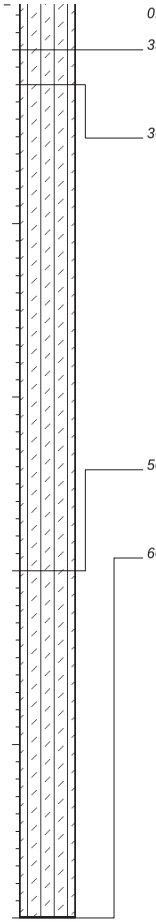
Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/08
Sheet 2 of 2

JOB NUMBER: VGI3925





Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

Black clayey SILT with minor coal fragements; COAL

Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) No groundwater intercepted

3) Groundwater rest level recorded at 19 m on 2015/11/11.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/10
DATE : 2015/11/11

DATE : 01/12/15 12:43
TEXT : ..C:\DOTFILES\201512~1.TXT

ELEVATION : 1465 m AMSL
X-COORD : 2947235
Y-COORD : -89471

HOLE No: 3925/08

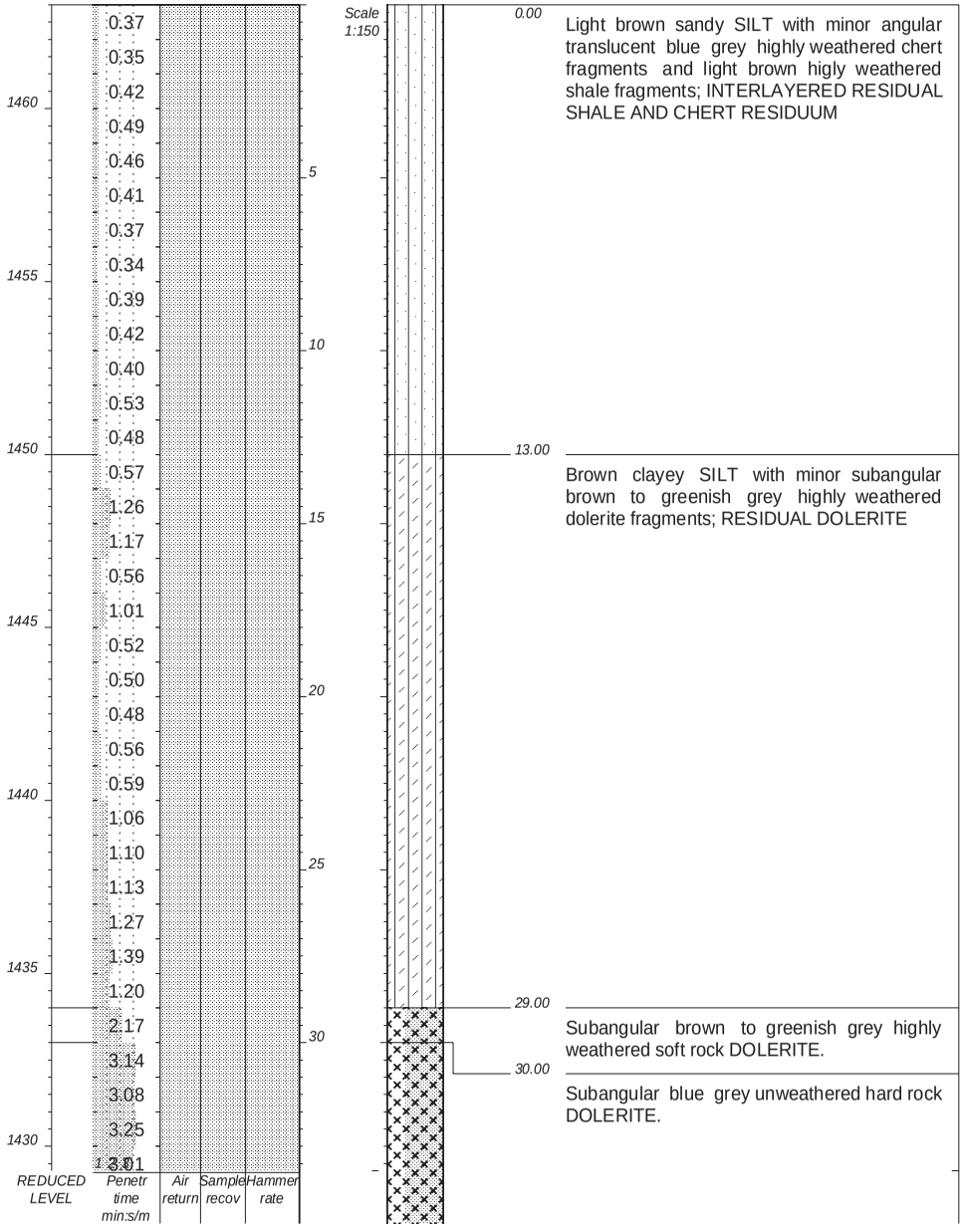
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/09
Sheet 1 of 2

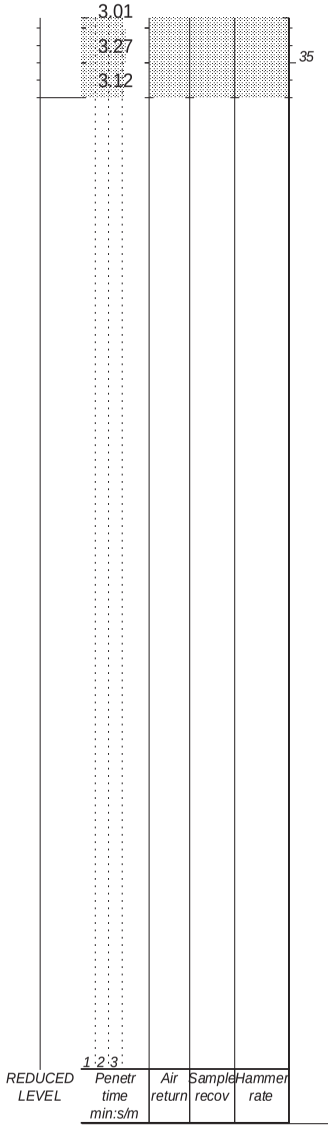
JOB NUMBER: VGI3925



SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/09
Sheet 2 of 2

JOB NUMBER: VGI3925



NOTES

1) Driller reports solid conditions between 30 m to 36 m.

2) No groundwater intercepted

3) Groundwater rest level recorded as Dry on 2015/11/11.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/10
DATE : 2015/11/11

ELEVATION : 1463 m AMSL
X-COORD : 2947444
Y-COORD : -89532

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:44
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/09

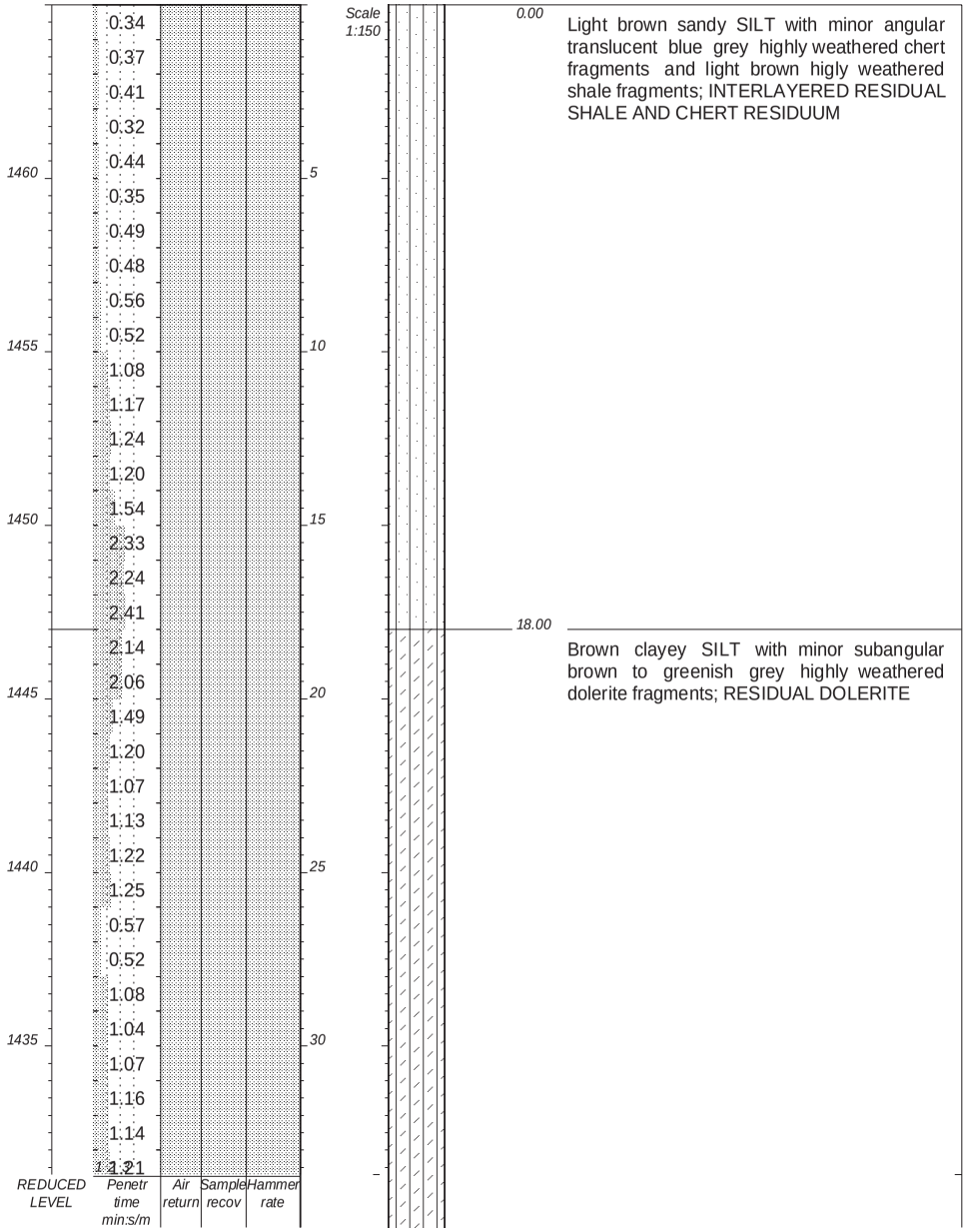
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/10
Sheet 1 of 2

JOB NUMBER: VGI3925



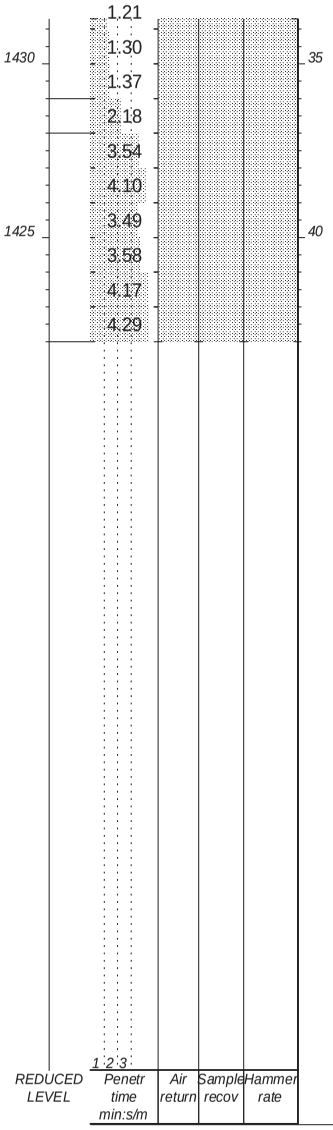
0.00 Light brown sandy SILT with minor angular translucent blue grey highly weathered chert fragments and light brown higly weathered shale fragments; INTERLAYERED RESIDUAL SHALE AND CHERT RESIDUUM

18.00 Brown clayey SILT with minor subangular brown to greenish grey highly weathered dolerite fragments; RESIDUAL DOLERITE

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/10
Sheet 2 of 2

JOB NUMBER: VGI3925



36.00 Subangular brown to greenish grey highly weathered soft rock DOLERITE.

37.00 Subangular blue grey unweathered hard rock DOLERITE.

43.00

NOTES

1) Driller reports solid conditions between 37 m to 43 m.

2) No groundwater intercepted

3) Groundwater rest level recorded at 21 m on 2015/11/11.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/10
DATE : 2015/11/11

ELEVATION : 1465 m AMSL
X-COORD : 2947379
Y-COORD : -89662

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:44
TEXT : ..C:\DOTFILES\201512~1.TXT

HOLE No: 3925/10

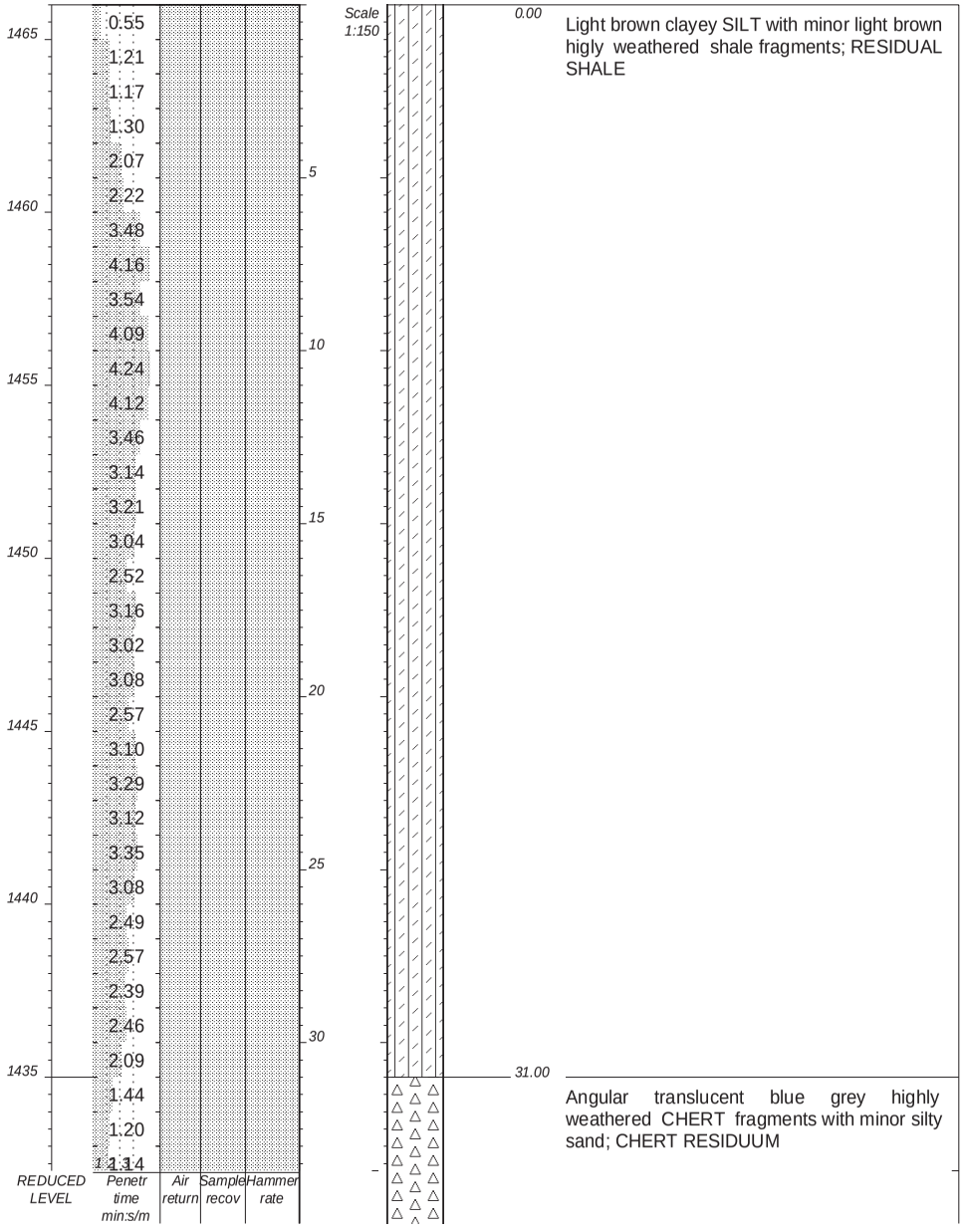
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/11
Sheet 1 of 2

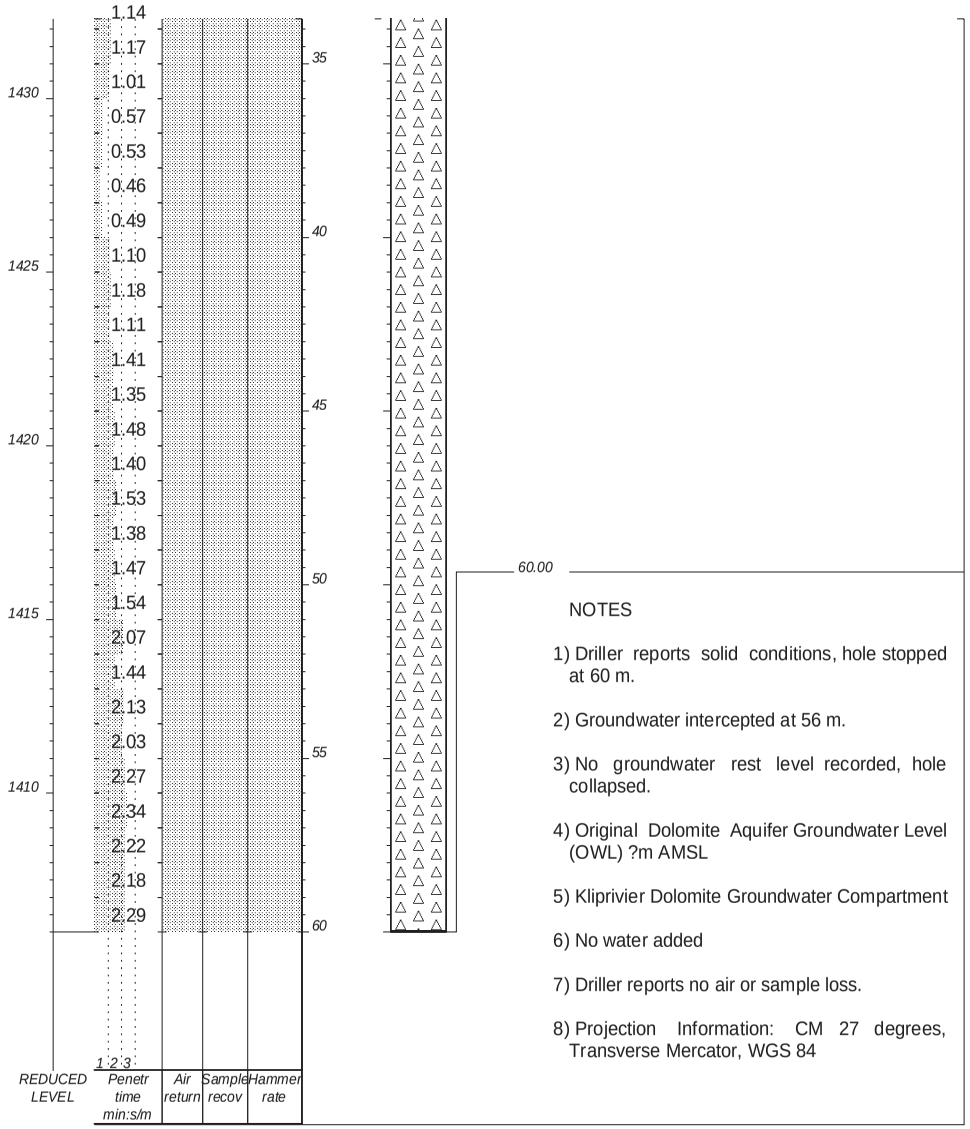
JOB NUMBER: VGI3925



SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/11
Sheet 2 of 2

JOB NUMBER: VGI3925



NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 56 m.

3) No groundwater rest level recorded, hole collapsed.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/10
DATE : 2015/11/11

ELEVATION : 1466 m AMSL
X-COORD : 2947262
Y-COORD : -89762

HOLE No: 3925/11

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:44
TEXT : ..C:\DOTFILES\201512~1.TXT

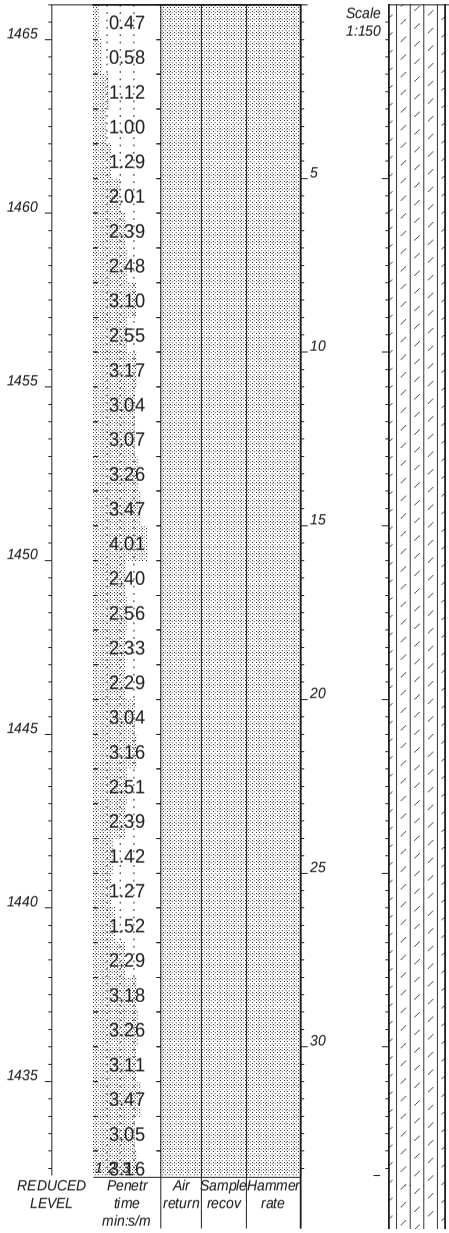
D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/12
Sheet 1 of 2

JOB NUMBER: VGI3925

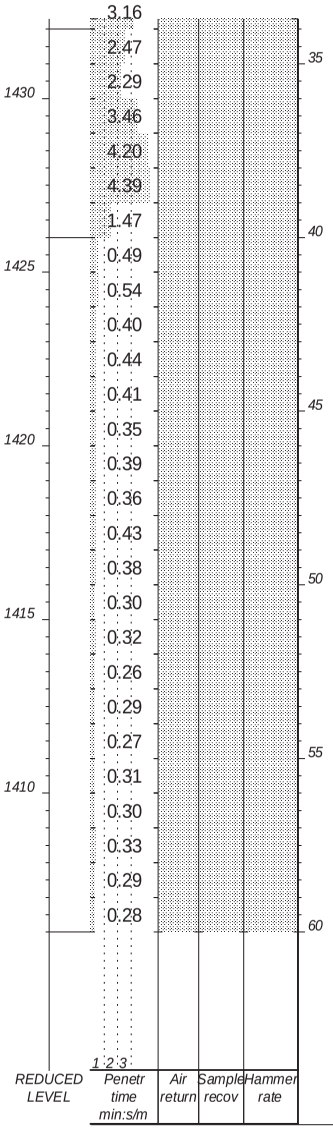


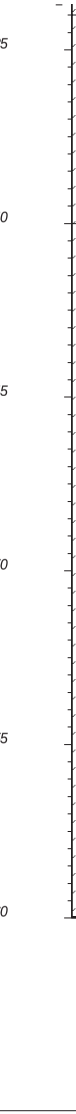
Light brown clayey SILT with minor light brown higly weathered shale fragments; RESIDUAL SHALE

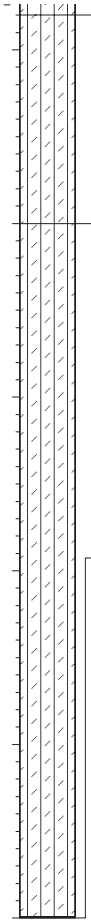
SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

HOLE No: 3925/12
Sheet 2 of 2

JOB NUMBER: VGI3925







0.00

Grey clayey SILT with minor grey highly weathered carbonatious shale; RESIDUAL CARBONACEOUS SHALE

40.00

Black clayey SILT with minor coal fragements; COAL

60.00

NOTES

1) Driller reports solid conditions, hole stopped at 60 m.

2) Groundwater intercepted at 51 m.

3) Groundwater rest level recorded at 23 m on 2015/11/12.

4) Original Dolomite Aquifer Groundwater Level (OWL) ?m AMSL

5) Kliprivier Dolomite Groundwater Compartment

6) No water added

7) Driller reports no air or sample loss.

8) Projection Information: CM 27 degrees, Transverse Mercator, WGS 84

CONTRACTOR : RUBICON BORE
MACHINE : ROCK GIANT
DRILLED BY : S. MORELE
PROFILED BY : J.MEINTJES

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

INCLINATION : 90 DEGREES
DIAM : 165mm
DATE : 2015/11/11
DATE : 2015/11/11

DATE : 01/12/15 12:44
TEXT : ..C:\DOTFILES\201512~1.TXT

ELEVATION : 1466 m AMSL
X-COORD : 2947153
Y-COORD : -89788

HOLE No: 3925/12

D055 DBB

dot.PLOT 5006 J&W

SCHULDEN PROPERTIES
UNITAS PARK EXTENSION 17

LEGEND
Sheet 1 of 1

JOB NUMBER: VGI3925

	SAND	{SA04}
	SANDY	{SA05}
	SILT	{SA06}
	SILTY	{SA07}
	CLAYEY	{SA09}
	DOLERITE	{SA18}{SA42}
	CHERT	{SA21}

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

INCLINATION :
DIAM :
DATE :
DATE :

ELEVATION :
X-COORD :
Y-COORD :

TYPE SET BY : J.MEINTJES
SETUP FILE : SETUP.SET

DATE : 01/12/15 12:44
TEXT : ..C:\DOTFILES\201512~1.TXT

LEGEND
SUMMARY OF SYMBOLS

D055 DBB

dot.PLOT 5006 J&W

DOLOMITE TECHNOLOGY

PERCUSSION BOREHOLE LOG

2015/08/14
02:40 PM
1
Profiel

X= 0.00 Y= 0.00 Z= 0.00 masl

Project no:	1544-DT	Client	**Hans van Heerden**
Project name:	Ged. 156&203 van Plaas Houtkop	Drill contractor:	JK Development
Date drilled:	20080117	Driller:	France
Date profiled:	20080122	**BH NO:**	**BH 1544/4**

Penetr rate	Penetration rate min:s/m	CAV	V SFT	SFT	FAIR H	SOLID	Air loss	DEPTH m	Symbol	Chip size mm	Depth m	DESCRIPTION
0.38			1.0				NONE	1		<5		Brown sandy clay with yellow white to brown, moderately weathered sub-angular to rounded chert. Transported / Topsoil. 80% Sandy clay, 20% Chert.
0.45			1.0				NONE	2			1.5	
0.56			1.0				NONE	3				
1.05			0.1	0.9			NONE	4				
0.57			1.0				NONE	5				
0.51			1.0				NONE	6				
0.52			1.0				NONE	7		<5		Light pinkish grey silty clay with translucent white grey, slightly weatherd sub-angular chert and light grey to white, moderately weathered sub-rounded mudrock. 10% Chert and 10% Mudrock. 80% Silty clay, 20% Chert/Mudrock.
1.04			0.3	0.7			NONE	8				
1.02				1.0			NONE	9				
0.52			0.9	0.1			NONE	10				
0.57			1.0				NONE	11			11	
1.25			0.1	0.9			NONE	12				
1.02				1.0			NONE	13		<5		Brown sandy clay with minor translucent yellow brown to white, slightly weathered angular chert. Residual chert. 90% Sandy clay, 10% Chert.
1.37				1.0			NONE	14			14	
2.25				1.0			NONE	15				
2.53				1.0			NONE	16				
2.18				1.0			NONE	17				
2.35				1.0			NONE	18				Yellow brown sandy clay. 100% Clay (Mudrock).
1.05				1.0			NONE	19			18.5	
1.18				1.0			NONE	20		<5	20	Yellow brown to grey, unweathered angular chert. 100% Chert layer.
1.56				1.0			NONE	21		<5	21	Light brown sandy clay with grey, unweathered angular chert. Residual chert. 80% Sandy clay, 20% Chert.
1.27				1.0			NONE	22				
2.08				0.3	0.7		NONE	23		<5		Light grey sandy clay with light grey, moderately weathered sub-rounded mudrock and light grey to grey, unweathered angular chert. 20% Mudrock and 10% Chert. 70% Sandy clay, 30% Mudrock/Chert.
1.37				1.0			NONE	24			24	
1.14				1.0			NONE	25				
1.55				1.0			NONE	26				
1.41				1.0			NONE	27		<10		Translucent light grey to grey, unweathered angular chert. 100% Residual chert.
1.44				1.0			NONE	28				
2.36				0.1	0.9		NONE	29				
1.40				1.0			NONE	30			30	

Notes:

1. No water encountered. Moist between 0-1m, 13-20m and 22-30m. Dry between 0-14m and 20-23m.
2. Good sample recovery, no sample loss and no air loss.
3. No water used during drilling.
4. Hammer rate generally regular, except between 3-4m, 7-8m, 9-10m, 11-12m, 14-15m, 22-23m and 28-29m, where it was irregular.

Logged by A. Michel

DOLOMITE TECHNOLOGY

PERCUSSION BOREHOLE LOG

2015/08/14
02:40 PM
1
Profiel

X= 0.00 Y= 0.00 Z= 0.00 masl

Project no:	1544-DT	Client	**Hans van Heerden**
Project name:	Ged. 156 & 203 Plaas Houtkop	Drill contractor:	JK Development
Date drilled:	20080117	Driller:	France
Date profiled:	20080122	**BH NO:**	**BH 1544/4cont.**

Penetr rate	Penetration rate min:s/m	CAV	V SFT	SFT	FAIR H	SOLID	Air loss	DEPTH m	Symbol	Chip size mm	Depth m	DESCRIPTION
2.06					1.0		NONE	31		<10		Translucent light grey to grey, unweathered angular chert. 100% Residual chert.
2.15					0.1	0.9	NONE	32			31.5	
3.28						1.0	NONE	33		<5		Translucent white to dark grey, unweathered angular quartzite. 100% Quartzite Hardrock.
3.19						1.0	NONE	34				
3.38						1.0	NONE	35				
3.21						1.0	NONE	36	▼			
3.19						1.0	NONE	37			37	
0.00							0.00	38				
0.00							0.00	39				
0.00							0.00	40				
0.00							0.00	41				
0.00							0.00	42				
0.00							0.00	43				
0.00							0.00	44				
0.00							0.00	45				
0.00							0.00	46				
0.00							0.00	47				
0.00							0.00	48				
0.00							0.00	49				
0.00							0.00	50				
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0.00							0.00	55				
0.00							0.00	56				
0.00							0.00	57				
0.00							0.00	58				
0.00							0.00	59				
0.00							0.00	60				

Notes:

1. Water encountered between 35-36m. Wet between 33-37m. Moist between 30-31m and 33-34m. Dry between 30-33m.
2. No air loss and no sample loss, good sample recovery.
3. Water applied during drilling between 34-35m.
4. Hammer rate generally regular, except between 31-32m, where it was irregular.

Logged by A. Michel
Copyright DOLOMITE TECHNOLOGY

DOLOMITE TECHNOLOGY

PERCUSSION BOREHOLE LOG

2015/08/14
02:39 PM
1
Profiel

X= 0.00 Y= 0.00 Z= 0.00 masl

Project no:	1544-DT	Client	**Hans van Heerden**
Project name:	Ged. 156&203 van Plaas Houtkop	Drill contractor:	JK Development
Date drilled:	20080117	Driller:	France
Date profiled:	20080122	**BH NO:**	**BH 1544/5**

Penetr rate	Penetration rate min:s/m	CAV	V SFT	SFT	FAIR H	SOLID	Air loss	DEPTH m	Symbol	Chip size mm	Depth m	DESCRIPTION
0.22			1.0				NONE	1		<5	1	Brown sandy clay with traces of yellow white to brown, moderately weathered sub-angular to rounded chert. Transported / Topsoil. 95% Sandy clay, 5% Chert.
1.17			0.1	0.9			NONE	2		<10		Yellow brown sandy clay with translucent white grey, slightly weathered sub-angular chert. Residual chert. 70% Sandy clay, 30% Chert.
1.21				1.0			NONE	3			3	
1.52				1.0			NONE	4		<5		Greyish brown silty clay with translucent white grey, slightly weathered angular chert. Residual chert. 80% Silty clay, 20% Chert.
1.14				1.0			NONE	5			5	
0.42			0.9	0.1			NONE	6				Light pinkish grey silty clay with minor grey, highly weathered sub-rounded mudrock. Mudrock. 90% Silty clay, 10% Mudrock.
0.49			1.0				NONE	7				
0.35			1.0				NONE	8		<5		
0.41			1.0				NONE	9				
0.45			1.0				NONE	10			10	
0.37			1.0				NONE	11				Light grey to grey, slightly weathered sub-angular to sub rounded mudrock. 100% Mudrock/Siltstone.
0.46			1.0				NONE	12				
1.24			0.1	0.9			NONE	13				
0.41			1.0				NONE	14		<15		
0.53			1.0				NONE	15				
1.24			0.9	0.1			NONE	16				
0.47			1.0				NONE	17				
0.53			1.0				NONE	18			18	
0.40			1.0				NONE	19				Orange brown sandy clay with minor translucent yellow brown to grey, slightly weathered sub-angular chert. Mudrock. 90% Sandy clay, 10% Chert.
0.45			1.0				NONE	20		<5	20	
2.02			0.1	0.9			NONE	21		<10	21	Translucent light grey, unweathered angular chert. 100% Residual chert.
1.21				1.0			NONE	22				Light brown sandy clay with translucent yellow white to grey, unweathered angular chert. Residual chert. 30% Sandy clay, 70% Chert.
1.24				1.0			NONE	23		<5		
0.47			0.9	0.1			NONE	24				
0.48			1.0				NONE	25			25	
0.59			1.0				NONE	26				Translucent yellow white to grey, unweathered angular chert. 100% Residual chert.
1.29			0.1	0.9			NONE	27				
1.04				1.0			NONE	28		<5		
1.18				1.0			NONE	29				
1.00				1.0			NONE	30			30	

Notes:

1. No water encountered. Moist between 21-30m. Dry between 0-22m and 24-30m.
2. Good sample recovery, no sample loss and no air loss.
3. No water used during drilling.
4. Hammer rate generally regular, except between 1-2m, 5-6m, 12-13m, 15-16m, 20-21m, 23-24m and 26-27m, where it was irregular.

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DOLOMITE TECHNOLOGY

PERCUSSION BOREHOLE LOG

2015/08/14
02:39 PM
1
Profiel

X= 0.00 Y= 0.00 Z= 0.00 masl

Project no:	1544-DT	Client	**Hans van Heerden**
Project name:	Ged. 156 & 203 Plaas Houtkop	Drill contractor:	JK Development
Date drilled:	20080117	Driller:	France
Date profiled:	20080122	**BH NO:**	**BH 1544/5cont.**

Penetr rate	Penetration rate min:s/m	CAV	V SFT	SFT	FAIR H	SOLID	Air loss	DEPTH m	Symbol	Chip size mm	Depth m	DESCRIPTION
1.05				1.0			NONE	31				
2.16					0.3	0.7	NONE	32				
2.03					1.0		NONE	33	▼	<5		Light grey sandy clay with translucent light grey to grey, unweathered angular chert. Residual chert. 30% Sandy clay, 70% Chert.
1.54				0.9	0.1		NONE	34				
1.47				1.0			NONE	35				
3.31					0.1	0.9	NONE	36			36	
1.19				0.9	0.1		NONE	37				
1.24				1.0			NONE	38				
1.54				1.0			NONE	39				
1.22				1.0			NONE	40				
1.28				1.0			NONE	41				
1.30				1.0			NONE	42				
1.36				1.0			NONE	43				
2.19					0.5	0.5	NONE	44				
1.24				1.0			NONE	45				
1.16				1.0			NONE	46				
1.26				1.0			NONE	47				
1.19				1.0			NONE	48		<5		Translucent light grey to grey, unweathered angular chert. 100% Residual chert.
1.23				1.0			NONE	49				
1.29				1.0			NONE	50				
1.33				1.0			NONE	51				
1.26				1.0			NONE	52				
1.29				1.0			NONE	53				
1.53				1.0			NONE	54				
1.32				1.0			NONE	55				
1.36				1.0			NONE	56				
1.51				1.0			NONE	57				
1.49				1.0			NONE	58				
1.40				1.0			NONE	59				
1.52				1.0			NONE	60			60	

Notes:

1. Water encountered between 32-33m. Wet between 32-60m. Moist between 30-32m.
2. No air loss and no sample loss, good sample recovery.
3. No water applied during drilling.
4. Hammer rate generally regular, except between 31-32m, 33-34m, 35-36m and 43-44m, where it was irregular.

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