Dolomite Stability Investigation

Waterloo Solar Plant, Waterloo Farm, Near Vryburg, North West Province

January 2015 REF: JG0002/02/1/2015/2536

SMEC REPORT
QUALITY ASSURANCE ISSUE DATA

Report Title:	Dolomite Stability Report - Waterloo Solar Plant
Client:	Sunedison LLC
Project Name:	Sunedison Solar PV Geotechnical Investigations
Report Number:	JG0002/02/01/2015/2536
Revision Number	Final Report **(Incorporating CGS Comments)**

Revision History:

Date	Report Status	Written by	Reviewed/Approved by	Issued to	
				Name	Institution
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2015/01/05	**Final Report (incorporating CGS comments)**				

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1. INTRODUCTION AND TERMS OF REFERENCE

1.1 Scope

This report presents the findings of a dolomite stability investigation for the proposed Waterloo Solar Park. The site is located near Vryburg in the North West province and covers an approximately 150ha portion of Waterloo Farm. The development will comprise ground-mounted single axis tracker solar photovoltaic (PV) panels, with a substation, office, warehouse and associated infrastructure.

1.2 Terms of Appointment

The work was carried out for Sunedison LLC, in accordance with our quote (Quote no. Q775) dated June 2014. Appointment was confirmed by a letter of acceptance received from Kabu Kaseu on the 10th of July 2014.

1.3 Aims and Methodology

The objective of the study is to evaluate the dolomite conditions on the site (with particular reference to the south-eastern corner where the electricity substation, office, workshop and store will be located).

The following methodology was adopted to realise the aims of the study:

- Review of available geological records and site plans.
- Review of aeromagnetic survey data sourced from the Council for Geoscience (CGS).
- Carry out a gravity survey of a 3ha portion of the site (located in the south-eastern corner of the site).
- Carry out percussion drilling on the site, as follows:
    - Positioned according to the Bouguer Anomalies measured over the 3ha portion of the site.
    - Located randomly over the remainder of the site.
- Analysing and interpreting the finding of the gravity and drilling investigations.
- To classify the inherent risk class of the 3ha portion and the remainder of the site.
- To recommend precautionary measures to be taken during design and construction in order to minimise sinkhole formation.

1.4 Codes of Practice and Standards

The investigation was carried according to standard practice codes and guidelines. Reference has specifically been made to:

- SAICE and IStructE Code of Practice for foundations of single storey masonry buildings
- The 2010 SAICE Geotechnical Division Site Investigation Code of Practice
- SANS 10160-4: Basis of Structural Design and Actions for Buildings and Industrial Structures – Part 4: Seismic Actions and General Requirements for Building
- SANS 1936 -1: General Principles and Requirements
- SANS 1936-2: Geotechnical Investigations and Determinations
- SANS 1936-3: Design and construction of buildings, structures and infrastructure
- SANS 1936-4: Risk Management
- SANS 633 Profiling, percussion borehole and core logging in Southern Africa

1.5 Limitations of Assessment

The services performed by ***SMEC South Africa*** were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical profession practising under similar conditions in the locality of the project. The investigation comprised a limited number of testing positions and is not likely to reveal the detail of the conditions that will become evident during construction. It is thus imperative that a Competent Person inspects all excavations to ensure that conditions at variance with those predicted do not occur and to undertake an interpretation of the facts supplied in this report to apply to on-site conditions as exposed during development of the site.

Our opinions can only be based on what was visible at the time the survey was conducted. This report has been prepared for the exclusive use of the client, with specific application to the proposed project.

2. DESCRIPTION OF SITE AND SURROUNDING AREA

2.1 Information Sources

The following information sources were consulted and made available;

- Geological Map, Sheet 2724 (Vryburg) at a scale of 1:250 000.
- Google Earth images of the site
- Council for Geoscience (CGS) borehole data from the study area, specifically:
    - Report on Bedrock identification Investigation for Vryburg Extension 25, North West Province, 21 June 2012, WSM Leshika, (report no. WH11117).A
    - Report on Geotechnical Conditions on Stand 11883 in Vryburg, for the Proposed Construction of a New Shopping Mall, 08 February 2013, Soil Kraft cc
    - A Report on Geological Materials at the Proposed New Sewerage Treatment Plant in Vryburg, North West Province, to Assess the potential presence of Dolomitic Materials, November 2013, Soil Kraft.
- Previous Vela VKE/SMEC Reports on projects in the area
- Topographical Map, Sheet 2724BB (Lefton) at a scale of 1:50 000
- Layout plans of the solar plant infrastructure.
- Published technical references (listed in Section 8 of this report)

2.2 Location and Site description

The proposed Waterloo Solar Plant is located approximately 10km south east of Vryburg in the North West Province, situated between the N18 highway and the R34 road. The site has approximate coordinates of 27°2'16.02"S and 24°47'22.49"E. The area of the proposed development is a 150Ha section of Waterloo Farm, the 3ha area set aside for the substation, offices, warehouse and other associated infrastructure is situated on the northern corner of the site. The site is currently used as grazing for cattle, and is accessed through farm tracks, which run from the Amalia gravel road (running between Vryburg and Amalia). Access to the site is only practically achievable in a high rise vehicle. A timber supported overhead electricity cable runs along the north eastern boundary of the site and a fence separates the eastern and western sections of the site. The topographic map of the site is shown in Figure 2.1 and a locality plan of the site in Figure 2.2.

2.3 Drainage and Topography

Ground levels on the site are in the order of 1205 mamsl (meters above mean sea level). Drainage is generally in the form of sheetwash and the site is flat to gently sloping in a roughly south to south east direction. The site lies approximately 1km east of the non-perrenial Dry Harts River and runoff from the site drains into this watercourse.

According to the 1:1 500 000 Map Veld Types of South Africa (Acocks, 1975), the area is located in the Kalahari Thornveld. The site was investigated during winter and the vegetation on site consisted predominantly of grassland with intermittent shrubs and scattered trees.

The landowner indicated no sub surface or wet surfaces underlie the site.

Figure 2.1: Extract from topographic map 2724BB with site indicated in red.

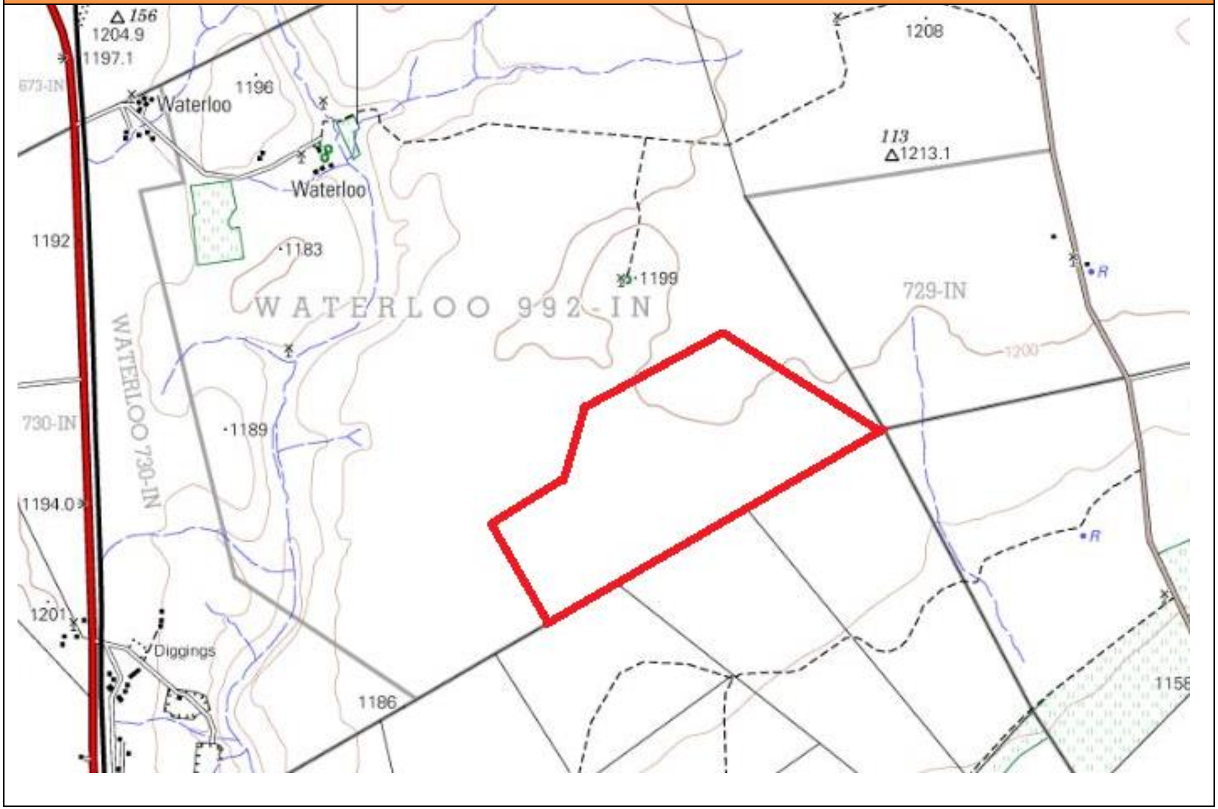
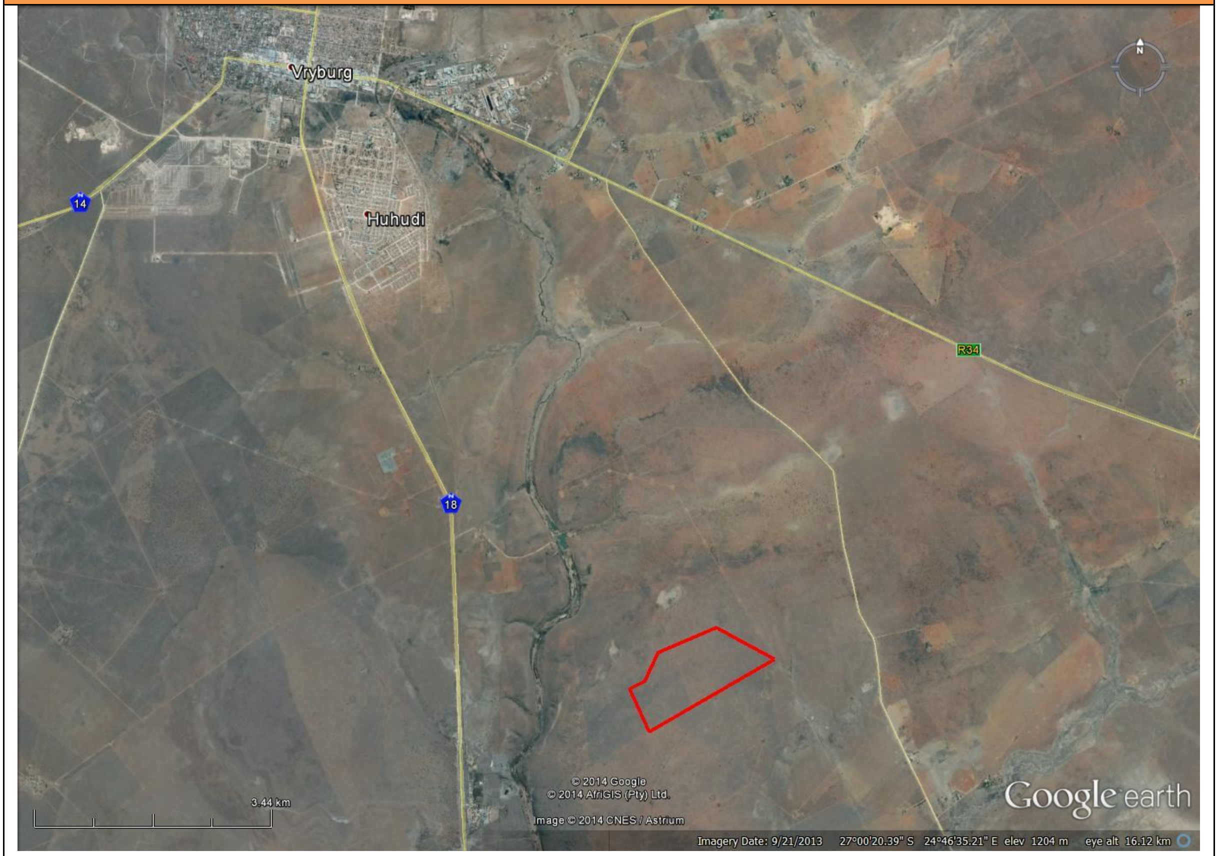


Figure 2.2: Locality plan with site indicated in red.



2.4 Climate

The Vryburg region receives approximately 344mm of rainfall per annum, predominantly in the summer rainy season. Average midday temperatures in the area vary between 32.9°C in January and 19°C in June.

Weinert (1964), through his work on basic igneous rocks in Southern Africa, demonstrated that mechanical disintegration is the predominant mode of rock weathering in areas where his climatic “N-value” is greater than 5, while chemical decomposition predominates where the N-value is less than 5. Weinert’s climatic N-value for the Vryburg is 8.2. This implies that mechanical disintegration is the dominant mode of weathering and accounts for the shallow gravelly soils observed across the site.

2.5 Literature Study and Review of Reports

Through consultation with the CGS, dolomitic stability reports undertaken in the vicinity of the site were obtained, as detailed in Section 2.1. The findings of the reports and the borehole logs were evaluated. All the reports undertaken in the area were undertaken in areas predominantly underlain by tillite/diamictite rock of the Dwyka Group, and are generally some distance from the Waterloo site (>5km). The borehole logs from the initial (WSM Leshika) report in the area indicated the site was underlain by “tillite/diamictite” and minor dolomite at depth, this geological model was opposed in the Soil Kraft reports, which through X-ray diffraction (XRD) testing found the “tillite” to be composed of hornfels. This was assumed to be a result of greenschist facies metamorphism of the tillite/diamictite. The “dolomite” identified in the initial (WSM Leshika) investigation was also found to be tillite/diamictite with dolomite drop stone inclusions. This error in the identification of the materials was attributed to the reaction of the tillite/diamictite with acid, due to the high calcite component of these facies. As these reports generally described different bedrock to that found on the site the bedrock description given is believed to be of little assistance in this report.

The ground water levels identified in the previous investigations varied between 40-80m, and were generally in excess of 50m depth, which are believed to be indicative of the conditions observed on the Waterloo site.

3. GEOLOGY

The geological map of Vryburg (Sheet 2724, scale 1:250 000) indicates that the entire site is underlain by rocks of the Boomplaas formation, this corresponds well with the bedrock observed on site. This formation consists predominantly of stromatilitic and oolitic dolomite interbedded with layers of quartzite, shale and flagstone.

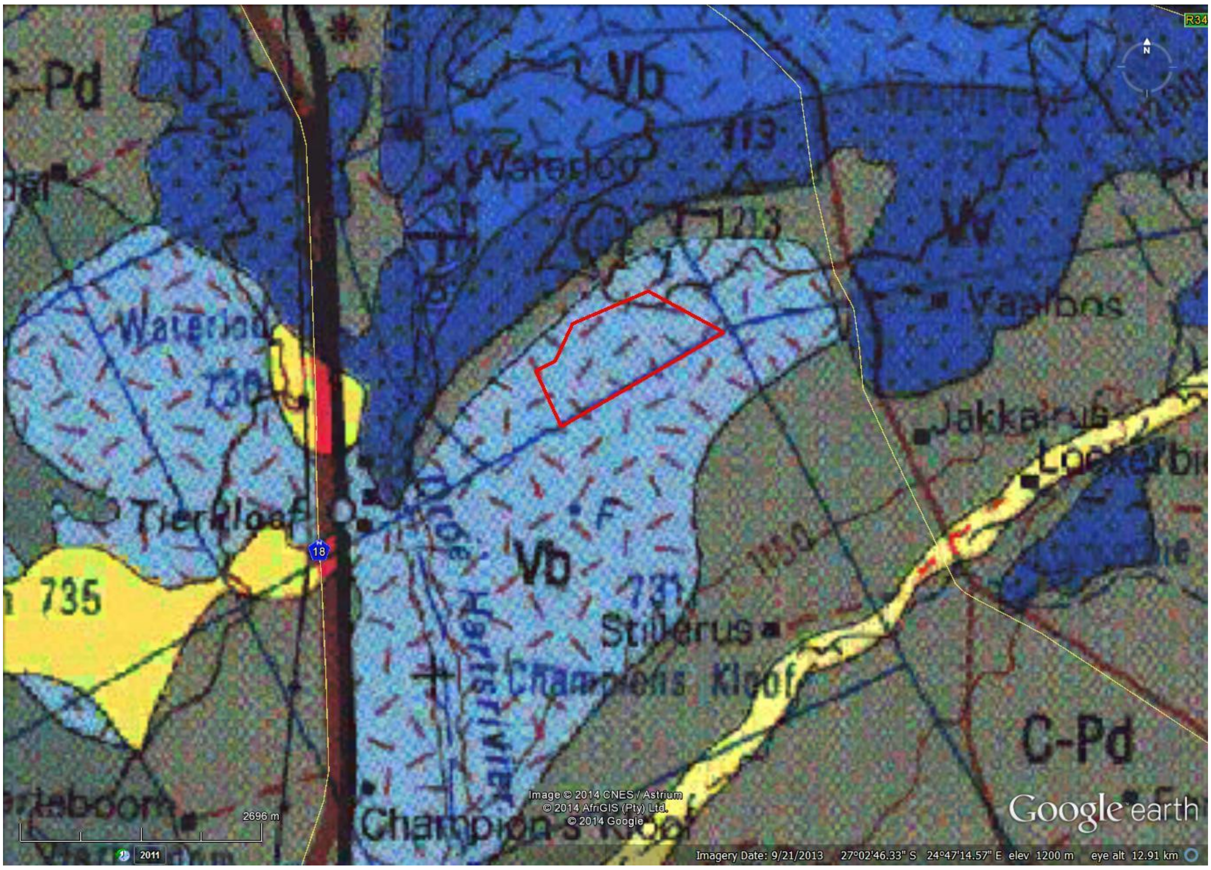
Assessment of the regional geology of the site indicates that the Boomplaas Formation is underlain by the Vryburg Formation, which forms the basal layer of the Ghaap Group.

The Boomplaas Formation rocks under the dry mechanical weathering conditions of the site have weathered to thin gravelly soils grading into shallow bedrock, as would be expected. The soil profiles lack the wad that is a common weathering product of dolomitic rocks in chemical weathering climates.

The description of the bedrock is based on the geological map of the area, observation of chip samples and acid testing. It must be noted that the high disturbance and contamination of chip samples makes these samples difficult to log and at times they are an unreliable indicator of in-situ conditions. There is also notoriously little visual difference between chips derived from tillite/diamictite and dolomitic bedrock in the area, and the tillite/diamictite is acknowledged to react positively to the acid test (as does dolomite). For these reasons it is possible but highly unlikely that tillite/diamictite bedrock was logged as dolomitic bedrock.

The geology of the area is shown in Figure 3.1, overleaf:

Figure 3.1: Geological Map 2724 Vryburg, site outlined in red.



Symbol	Stratigraphy	Lithology
C-Pd	Dwyka Group, Karoo Supergroup	Tillite, mudstone, shale, boulder shale and sandstone
Vb	Boomplaas Formation, Schmidtsdrif Sub-group, Ghaap Group, Griqualand West Supergroup	Oolitic and stromatilitic dolomite, interbedded quartzite, shale and flagstone
Vv	Vryburg Formation, Ghaap Group, Griqualand West Supergroup	Quartzite, flagstone, conglomerate, dolomite, shale and andesitic lava

4. SITE INVESTIGATION

The dolomite investigation was preceded by a preliminary geotechnical investigation, which was reported on in our Report Number 2529 dated August 2014. This investigation comprised test pitting, DPSH soundings, electrical resistivity and laboratory testing of representative samples.

The dolomite investigation was designed following brief consultation with the CGS to clarify the extent of the dolomite investigation required. This was necessary as the planned development as a solar farm does not fall into any of the typical development categories specified in SANS 1936. This discussion confirmed that a “full” dolomite investigation (gravity survey and percussion drilling as per SANS 1936-2) was to be carried out at the site of the electrical substation, offices, warehouse and associated infrastructure. About 2ha is required to cater for these facilities, but in order to allow for possible poor dolomite conditions, a 3ha area was investigated.

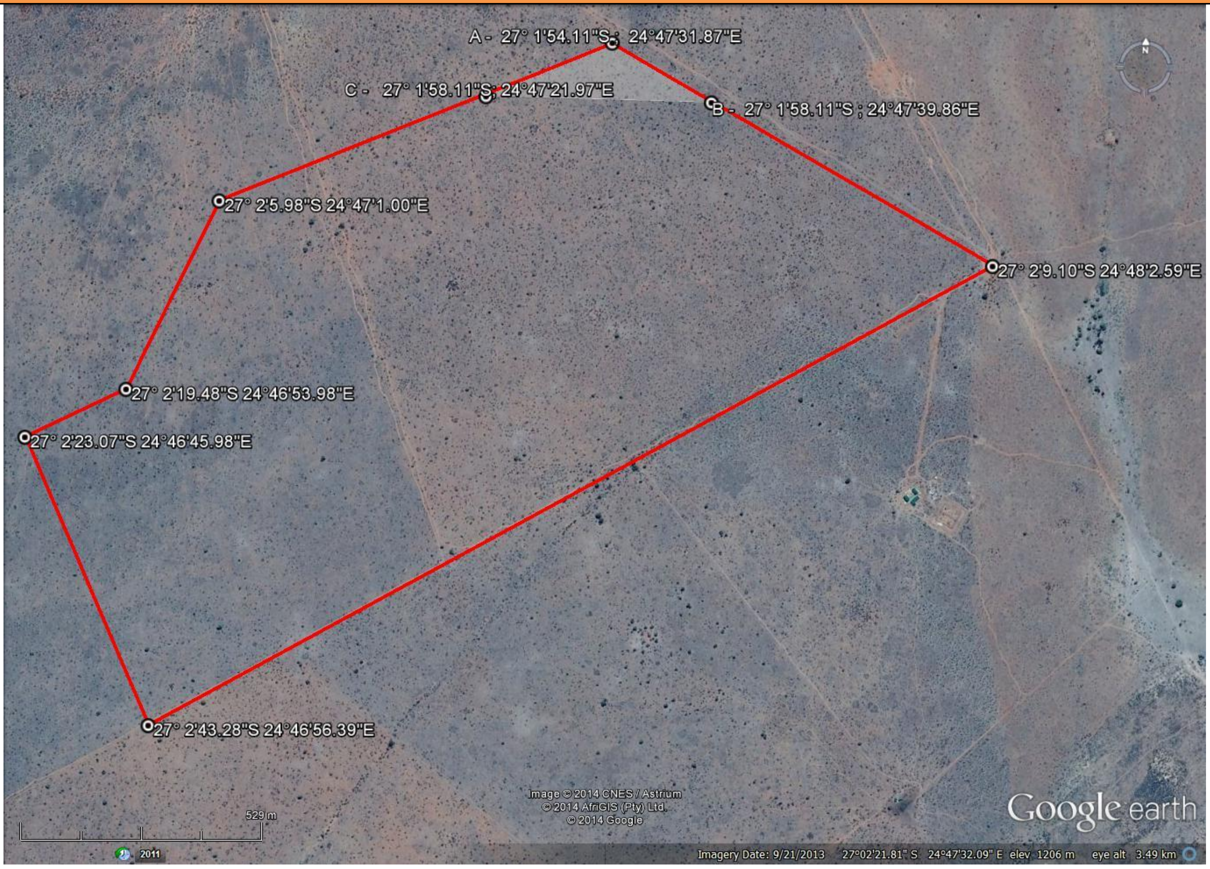
Over the remainder of the site (where minimal human activity will take place), scattered boreholes were to be drilled to obtain an overview of the dolomite conditions in this area.

Accordingly the following investigations were carried out:

- Over 3ha portion of the site:
    - Gravity survey (by EEGS cc) on a 15m grid.
    - Percussion drilling (by JK Developments) of 4 boreholes.
- Over remainder of the site:
    - 6 percussion boreholes.

A site layout plan indicating the boundary co-ordinates of the entire site and the 3ha portion area shown in Figure 4.1.

Figure 4.1: Entire site outlined in red, with 3ha area shaded in white.



4.1 Groundwater

The area falls within the Upper Ghaap Plateau Ground Water Management Area (GMA). There are no boreholes shown in the vicinity of the site. Groundwater information on the area of the site indicates the groundwater level should be approximately 17-25m below surface (DWAF, 2010). The groundwater table was not intercepted in any of the boreholes drilled on site, up to a depth of 50m, and it appears the groundwater level is located deep within the dolomitic bedrock. This correlates well with borehole logs from previous dolomite stability investigations in the area which indicated the groundwater level in the area is generally below 50m.

Data collected from monitoring boreholes between 1984 and 2008 in the Upper Ghaap Plateau GMA shows that groundwater levels have risen by approximately 0.9m in this period. This indicates that dewatering has not taken place.

4.2 Surface Drainage

There are no drainage courses on the site and drainage takes place by surface runoff. The site is fairly flat and may be susceptible to surface ponding. Design of the stormwater system must drain the site without allowing ponding water for a substantial amount of time. Stormwater runoff maybe transmitted in lined impermeable channels or pipes and can only be discharged in a natural water course, non-dolomitic land or dolomitic land designated D1.

4.3 Gravity Survey

The results of the gravity survey are shown in Appendix D, which includes a write-up on the technique employed and maps showing the reduced gravity data. The survey was limited to the 3ha portion in the northern corner of the site.

The results of the survey are presented as a Bouguer Relative Anomaly map and a Residual Anomaly map. These maps show changes in gravity over the 3ha area, which indicates the density of the ground below; red being high and blue being low. The Bouguer Anomaly map was calibrated using the depth to bedrock encountered in the boreholes and the Residual Anomaly map prepared. With these maps it is possible to interpret the relative depths to bedrock; red indicating shallow rock and blue indicating deeper rock, the latter usually characteristic of a significant depth of weathering.

The Bouguer Anomaly map shows distinct high gravity areas in the eastern corner of the 3ha area and a distinct low in the western corner. Despite this the vast majority of the 3ha area falls close to the mean gravity value. Drilling was omitted on the high and low gravity areas on the extreme east and west of the area were as it is anticipated the proposed infrastructure will be placed close to the centre of the site, therefore boreholes were drilled on the gravity high and low positions towards the centre of the site.

The results of the gravity survey indicate that, “Residual gravity varies by 0,1 mGals, equivalent to a variation in bedrock depth of about five metres and suggesting that there is little variation in the depth to dolomite. Drilling intersected rock head from one to five metre below surface. The hole with the shallowest rock was not on a gravity high but a low but this is merely an indication that changes in bedrock depth occur at a finer interval than the spacing between gravity stations” (Exert from gravity survey results attached in Appendix D).

4.4 Percussion Drilling

Following the gravity survey, 4 percussion boreholes were drilled on gravity features (highs and lows) towards the middle of the area where it is anticipated the infrastructure will be constructed. Two boreholes were drilled directly beneath the proposed substation foundation footprint. The drilling rate (time per metre drilled) was recorded and chip samples blown out the top of the hole were recovered for each metre drilled. All boreholes were backfilled with soil and the uppermost 1m sealed with a concrete plug. The borehole number is inscribed on the plug.

In addition 6 holes were drilled over the remainder of the site. It had been anticipated that it would be possible to identify subsurface features on the aeromagnetic map (attached in

Appendix E) obtained from CGS. It was however found that there were no recognisable features on the site and boreholes were, accordingly, positioned at random.

A driller's log was supplied by the drilling company (JK Developments) which, in addition to the penetration rate, recorded percentage sample return, hammer action, percentage air return, the addition of foam and the depths at which changes in the drilling characteristics occurred. This log is crucial to the drilling process as it is vital to interpretation of the profile encountered. Percussion drilling is a destructive technique and a totally disturbed sample is recovered. Only by combining the reported observations with an inspection of the recovered samples is it possible to interpret the profile through which the drilling is being done and to prepare a meaningful borehole log. This is even more so where sample return is lost and the profile is interpreted solely from the remote records supplied by the driller.

Logs of the percussion chips recovered were prepared by an engineering geologist and bound into Appendix F. The profiles encountered are summarised in Table 4.6.

Table 4.6: Summarised borehole profiles

BH no.	Hole depth (m)	Surficial gravel soils (m)	Weathered Dolomite bedrock (m)	Unweathered Dolomite bedrock (m)	Unweathered Chert bedrock (m)	Water strike (m)	Gravity Feature
WB1	15	0-2	2-7	7-15		nil	H
WB2	24	0-2	2-9	9-13	13-27	nil	H
WB3	12	0-1	1-4	4-12		nil	L
WB4	50	0-1	1-15	15-31	31-50	nil	No gravity survey
WB5	14	0-2	2-5	5-14		nil	
WB6	15	0-1	1-4	4-15		nil	
WB7	12	0-2	2-9	9-12		nil	
WB8	12	0-1	1-3	3-12		nil	
WB9	12	0-1	1-5	5-12		nil	
WB10	15	0-1	2-7	7-11	11-15	nil	L

H = gravity high L = gravity low

4.5 Electrical Resistivity

Ten electrical resistivity arrays were undertaken across the site, at positions ER1-ER8, with 2 perpendicular arrays carried out at both ER1 and ER2, beneath the proposed substation. Electrical resistivity is a measure of how much soil resists the flow of electricity and an understanding of soil resistivity and how it varies with depth is necessary to design the grounding system of electrical substations.

The electrical resistivity results including models of the 200m long surveys undertaken at the substation are included in Appendix G.

The resistivity results indicate the site is characterized by horizontal layering with relatively high resistivity values, presumably reflecting a profile of thin dry soils underlain by weathered rock over solid rock (the highest resistivity values). There are interruptions in the bedrock resistor, for example as indicated in cross section ER1 NS, that suggest weathering along fracture zones, which could lead to preferential formation of voids in these areas. Air-filled voids are difficult to identify using electrical resistivity results unless large, would show up as high resistors, none were observed in the results. These results correlate well with the conditions observed on site.

4.6 Dynamic Probe Super Heavy (DPSH) Testing

Twenty seven Dynamic Probe Super Heavy (DPSH) tests, WDP1-27, were undertaken to refusal of the probe, which varied from 0.60m to a maximum of 2.70m below existing ground level (egl.). The DPSH equipment consisted of a 63,5kg weight dropping 750mm onto a string of rods with a 50mm diameter disposable cone with a 90° apex angle. The number of blows required to advance the probe for each 300mm of penetration is recorded as the DPSH N-Value.

The Standard Penetration Test is generally accepted as a more reliable test due to extensive research that has taken place into its use and numerous correlations can be found for the N30SB (DPSH N value). Both tests use the same drive energy over the same length (30cm) and thus the values could be considered equivalent. However, data has shown for a granular soil using the solid cone, values of as much as double could be obtained using the DPSH (i.e. DPSH = 2.0 SPT-N). In South Africa the values of DPSH are thus often halved in the absence of more detailed site specific correlations being developed, which is not possible on this site due to the shallow refusals of the probe.

An aspect of probe testing that should always be borne in mind is that results are affected by the moisture content of the soil profile, as well as any cobbles or rock fragments that may be struck. A dry soil horizon will provide a higher set of results than a similar test undertaken during the rainy season. Moisture content should thus always be noted and made mention of in any DPSH investigation. The majority of the horizons profiled during the course of the investigation were recorded as having ‘dry’ to ‘slightly moist’ moisture contents. The soil horizons on site consisted predominantly of gravels and cobbles, and indicate that DPSH and DPL results may not be accurate.

The number of blows per 300mm have been plotted on graphs, providing a visual interpretation of the consistency of different soil strata encountered. The graphs are presented in Appendix H.

The DPSH results indicate that the site is underlain by solid conditions at depths of between 0.6-2.70m.

5. GEOTECHNICAL CONDITIONS.

Based on the various investigation techniques undertaken a geotechnical model of the site was compiled. The geotechnical and geological conditions were found to be homogenous across the site.

The site profile consisted of a fairly thin layer of gravel hillwash to depths of approximately 0.30-0.60m underlain by gravelly to cobbley residual soils with abundant zones of variably weathered rock. The residual soil graded into dolomite and chert bedrock, with lenses of quartzite and shale, the bedrock was found outcropping in areas to depths of 2.40m. The bedrock was observed to be continuous across the site but undulated over short distances. A 20m long trench was excavated beneath the proposed substation, at this position the bedrock was observed to be continuous and intact but undulated between 0.30-1.20m, as shown in Figure 5.1.

Figure 5.1: Indication of undulation of bedrock

6. DOLOMITE STABILITY CHARACTERISATION

This is essentially limited to the 3ha portion of the site, with only generalised comments regarding the remainder of the site (over which no gravity survey has been conducted).

6.1 Characterisation Procedure.

The gravity data, drilling results and groundwater data are consolidated and reviewed in order to assess the dolomite stability. Factors to be considered when doing so are groundwater fluctuations, ingress of surface water and ground vibrations.

The methodology for the determination of the inherent hazard by the method of scenario supposition is followed here, as detailed in SANS1936-2.

6.1.1 Model for Evaluating Inherent Risk Class

The dolomitic conditions observed across the proposed PV plant were found to be homogenous across the entire site, both the 3ha portion and the remainder of the site. Shallow competent dolomitic bedrock was observed at all testing positions, on both gravity highs and lows.

- **Blanketing layer:** The site is covered by approximately 0.3-2.40m of transported and residual dolomitic soils, these are considered the blanking layer and these soils grade into medium to slightly weathered dolomite and eventually into unweathered dolomite bedrock.
- **Receptacle development:** due to the shallow depth of the blanketing layer, disseminated receptacle development is unlikely. Receptacle development in the bedrock is possible and therefore the maximum depth to the receptacle throat is envisaged to be at the maximum depth to bedrock of approximately 2.50m.
- **Mobilizing agencies:** The mobilizing effect of the ingress of water will be mitigated by the design recommendations for development on dolomitic land (SANS1936-3). The ground water level is anticipated to be in excess of 50m depth. As the groundwater level is well within the dolomite bedrock, this negates the effect of increased groundwater drawdown. A rise in groundwater table of the region indicates that groundwater draw down has not taken place in this area.
- **Maximum potential development space (PDS):** Due to the shallow depth to bedrock a small receptacle size was assigned to a potential worst case subsidence, the blanketing layer was assigned an angle of drawdown of 45 degrees. Based on these parameters a maximum PDS of approximately 2-5m was calculated. Indicating that the site may be conducive to small to medium sized sinkhole development.
- **Groundwater and other factors:** The site is located in the Upper Ghaap Plateau groundwater compartment. There are no boreholes in the immediate vicinity of the site, but it appears that the original groundwater level is at depth. This accords with the fact that no water strikes were recorded in any of the boreholes drilled (to a maximum depth of 50m). Available data indicates the groundwater level has risen by approximately 0.9m since being monitored (1984-2008). Whilst unlikely due to the monitored rising water level within the ground water compartment, if dewatering of the compartment were to take place, this would have little effect on the inherent hazard, as the groundwater level is deep within the unweathered dolomitic rock underlying the site.

  No existing sinkholes/subsidences were observed across the entire site.

6.1.2 Determination of Inherent Hazard

- **Sinkholes (Medium):** Shallow dolomite bedrock occurs in all the boreholes (on both gravity highs and lows) which reflects a low inherent risk of sinkholes for both the ingress and drawdown scenarios.

  The blanketing layer consists of shallow to non-existent gravelly soils which may be susceptible to mobilization, but the underlying outcropping to shallow dolomitic rock has a low susceptibility to mobilization. The low susceptibility of this rock will safe guard against sinkhole formation into a receptacle lying within the dolomite bedrock.

  Whilst shallow bedrock may indicate a high susceptibility of sinkhole formation, the gravity survey, percussion drilling, test pitting and electrical resistivity indicate the site is covered by shallow continuous intact bedrock. This coupled with the fact that the site receives little rainfall and undergoes mechanical disintegration is seen as factors that largely reduce the inherent susceptibility of sinkhole formation.

  According to SANS1936-2, due to the depth of the groundwater level and the absence of a competent blanketing layer between the surface and the dolomitic bedrock the site classifies as having a medium inherent susceptibility to sinkhole formation. The groundwater level is situated below the blanketing layer, deep in the dolomite bedrock. Based on the depth to bedrock and blanketing layer a maximum diameter of sinkholes of 2–5m at surface (i.e. small to medium sized) is anticipated.
- **Subsidence (LOW):** It may be seen that shallow dolomite occurs in all the boreholes (on both gravity highs and lows) which reflects a low inherent risk of subsidence for both the ingress and drawdown scenarios with a maximum diameter of subsidence of 2–5m at surface (i.e. medium size). No groundwater level was observed on site to a depth of 50m, as the water table is located deep within the dolomite bedrock, drawdown of the water table has no effect on the stability.

The information on which the risk characterisation is based is summarised Table 6.2.

Table 6.1: Borehole Profile and Risk Classification

BH no.	Gravel Soils	Weathered Dolomite bedrock (m)	Un-weathered Dolomite bedrock (m)	Un-weathered Chert bedrock (m)	Ground-water (m)	Gravity zone	Risk Characterization Water ingress/ groundwater drawdown		Inherent hazard class (IHC)	PDS (m)
							Doline	Sinkhole		
WB1	0-2	2-7	7-15		dry>15	H	L	M	2/3	5
WB2	0-2	2-9	9-13	13-27	dry>27	H	L	M	2/3	5
WB3	0-1	1-4	4-12		dry>12	L	L	M	2/3	2
WB4	0-1	1-15	15-31	31-50	dry>50	No gravity survey	L	M	2/3	2
WB5	0-2	2-5	5-14		dry>14		L	M	2/3	5
WB6	0-1	1-4	4-15		dry>15		L	M	2/3	2
WB7	0-2	2-9	9-12		dry>12		L	M	2/3	5
WB8	0-1	1-3	3-12		dry>12		L	M	2/3	2
WB9	0-1	1-5	5-12		dry>12		L	M	2/3	2
WB10	0-1	2-7	7-11	11-15	dry>15	L	L	M	2/3	2

L = Low M = Medium H = High G = Gravity gradient PDS = Potential development space

6.2 Inherent Risk Classification (3ha Portion)

Despite the deep dolomitic bedrock underlying the site from shallow depth and great depth to the waters, the bedrock was observed to be intact at all testing positions and the area experiences minimal rainfall. These conditions are interpreted to represent a low to medium susceptibility for small and medium sinkhole development, and a low susceptibility of large, very large and doline development. Based on the conditions observed, data collected and input from the CGS (attached in Appendix I) the 3ha portion of the site classifies as Inherent Hazard Class 2/3 conditions.

The 3ha area will comprise the proposed substation (approximately 1ha), office and warehouse. The substation and office classify as C3 infrastructure “Commercial developments ≤ 3 storeys” and therefore, considering the IHC these class as a Dolomite site class designation of D3-FPI according to SANS1936-2, as shown in Graph 6.3. This requires measures as outlined in Graph 6.2 and Footprint.

The substation requires a total servitude area of 1ha, while the substation equipment itself covers a maximum of 100m x 100m. Only persons carrying out maintenance will be present on this site and then only for short periods. Incoming and outgoing powerlines will be above ground. There will be no water or sewage connections. This structure has a D3+FPI (design level investigation below footprint of structure) designation, as shown in Figure 6.2. Two boreholes were drilled and a number of test pits excavated directly below the footprint of the structure indicating conditions are homogenous, as described above and used in the classification of this area.

The office for maintenance and security personnel will cover an area of about 10 x 10m. Buried services (water, sewage and electricity) will be required for this structure. The exact position of the proposed office within the 3ha had not been determined when this report was compiled. This structure has a D3+FPI designation. The high concentration of testing undertaken in the 3ha area sufficiently indicates that this area is homogenous and that conditions described and classified above will underlie the proposed office building.

The warehouse will cover an area of approximately 20 x 50m. Buried services (water, sewage and electricity) will be required for this structure. The exact position of the proposed warehouse within the 3ha area had not been determined when this report was compiled. This structure has a D3+FPI designation. The high concentration of testing undertaken in the 3ha area sufficiently indicates that this area is homogenous and that conditions described and classified above will underlie the proposed warehouse building.

Details of the precautions applicable to development on dolomite are given in Section 7: References and a summary of the pertinent precautions is given in Section 8: Summary and Recommendations.

6.3 Inherent Risk Classification (Remainder of Site)

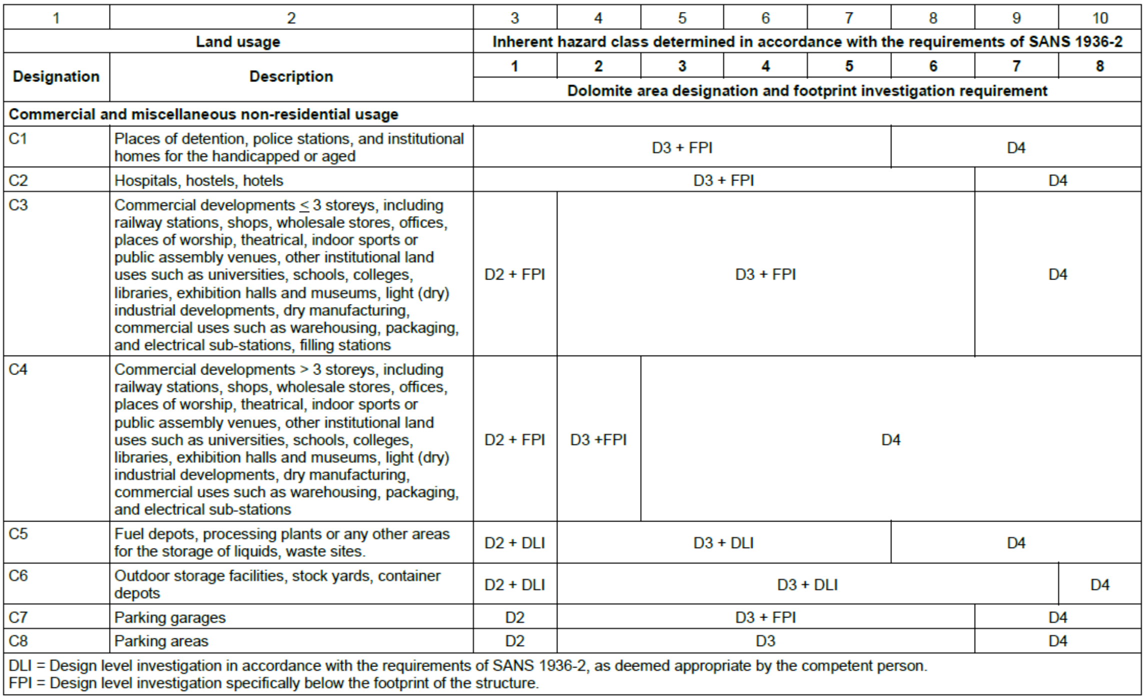
Solar collectors will be installed over the remainder of the site, entailing photovoltaic modules mounted on small frames. Human activity will be limited to access during construction and subsequently for maintenance. Access roads will be gravel.

Over the remainder of the site, no gravity survey was conducted, so the characterisation is based solely on the results of the percussion drilling. The characterisation is given in Table 4.2 above. No air or sample loss was observed in any of the boreholes.

Based on the data gathered from drilling of boreholes, observation of the site and consultation with the CGS the site classifies as Inherent Hazard Class 2/3 for sinkhole and doline formation. Based on previous reports for this type of infrastructure, due to the lack of people entering this area after construction and the lack of wet services, it is anticipated this part of the site may be considered a C8 area (equivalent to a parking area). This area has a D3 designation, as shown in Figure 6.2.

The main concern for drainage in this area will be to ensure that all roads are designed and constructed so as not to channel/concentrate runoff. As there are no drainage courses on the site, no culverts under these roads are foreseen. No signs of subsidence were observed across the site. The lack of wet services on this portion of the site is seen to be particularly pertinent as Buttrick et. al. (2011) found that 643 out of the 650 sinkholes (99%) that were observed were found to be directly attributed to leaking services or humans' negative influences. This data was gathered over a 20 year period (1984 – 2004) across a 3 700 ha urbanized area located south of Pretoria.

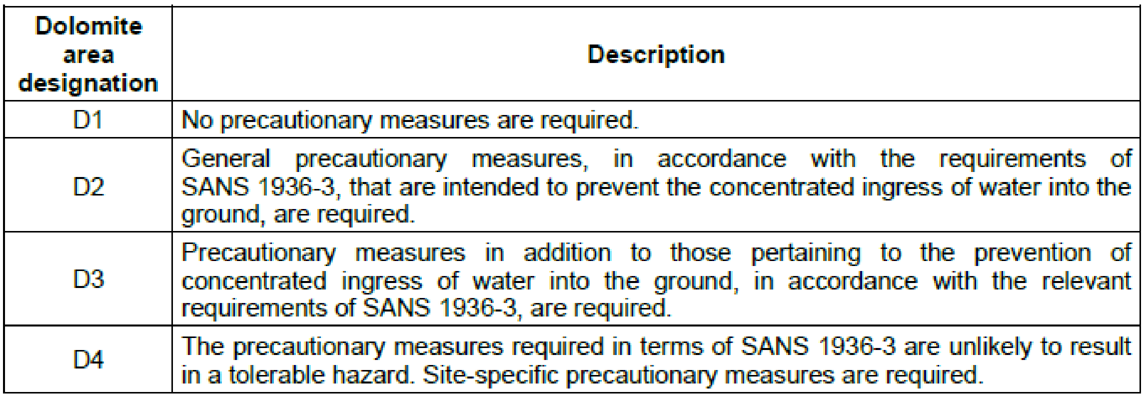
Table 6.2: Permissible land usage vs inherent hazard class indicating required investigation



1	2	3	4	5	6	7	8	9	10
Land usage		**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 and footprint investigation requirement							
Commercial and miscellaneous non-residential usage									
C1	Places of detention, police stations, and institutional homes for the handicapped or aged	D3 + FPI					D4		
C2	Hospitals, hostels, hotels	D3 + FPI						D4	
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, and electrical sub-stations, filling stations	D2 + FPI	D3 + FPI					D4	
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, and electrical sub-stations	D2 + FPI	D3 +FPI	D4					
C5	Fuel depots, processing plants or any other areas for the storage of liquids, waste sites.	D2 + DLI	D3 + DLI				D4		
C6	Outdoor storage facilities, stock yards, container depots	D2 + DLI	D3 + DLI						D4
C7	Parking garages	D2	D3 + FPI					D4	
C8	Parking areas	D2	D3					D4	

DLI = Design level investigation in accordance with the requirements of SANS 1936-2, as deemed appropriate by the competent person.
FPI = Design level investigation specifically below the footprint of the structure.

Table 6.3: Dolomite Area Designations



Dolomite area 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.
D4	The precautionary measures required in terms of SANS 1936-3 are unlikely to result in a tolerable hazard. Site-specific precautionary measures are required.

7. COMMENT FROM THE CGS (COUNCIL FOR GEOSCIENCE)

The CGS reviewed the dolomite stability investigation report and data and concluded:

- The CGS has a no objection to the proposed development, provided the recommendations given in this report and in the CGS report, Appendix I, are complied with.
- The site classifies as having a medium hazard for the formation of small to medium sized sinkholes.
- The entire site (both the 3Ha portion and remainder) classify as IHC 2/3.
- Although based purely on the permissible land usage vs inherent hazard class, Table 6.2, the entire farm portion is classified as a D3 site requiring a FPI (design level investigation specifically below the footprint of structures). But as the:
    - The conditions on site are homogenous.
    - No poor conditions were observed in any of the boreholes.
    - The site will have low human occupancy.
    - No previous sinkholes observed in the area.

  The CGS has specified that **NO** FPI (design level investigation below footprint of structure) is required for structures across the entire site.
- The CGS largely agrees with the recommendations given by SMEC in the initial report, and any amendments requested have been carried out in this report. The CGS review of the initial report is attached in Appendix I.

8. SUMMARY AND RECOMMENDATIONS

A foundation investigation of the site has been undertaken, entailing test pitting, DPSH probing, electrical resistivity survey and laboratory testing (see Report no. 2529). These test methods correlate well with results gathered from the percussion drilling and indicate the site is covered by a thin layer (generally 1-2m deep) layer of transported and residual dolomitic soils underlain by continuous dolomitic bedrock. As both the 3ha area and the remainder of the site is classified as D3 designated areas, the following recommendations are given for both regions.

The design and construction standards to be employed are set out in detail in SANS1936-3 for a D3 designated site, particularly relevant to the proposed development are Sections 4, 6, 7 and 8. These recommendations are included in Appendix A, and are not in their entirety repeated here. The most important aspects to be adhered to are summarised as follows:

a. All planning, design, construction and record (as-built) drawings must be signed by a registered competent person (geo-professional and engineer, as specified as in 1936-1, 2012).

b. Stormwater systems to be designed to handle a 2-year flood frequency, and landscaping must ensure that storm water is channelled away from all structures.

c. Sewage disposal shall preferably be waterborne, or utilise a watertight conservancy tank system. Septic tanks and percolation beds are not permissible.

d. No ponding of surface water is permissible, both during and after construction.

e. Any gravel (borrow) pit to be planned and finished off to be free draining.

f. All wet services to be watertight and designed to minimise maintenance.

g. All wet services must be pressure tested.

h. Water supply and sewer lines to be plastic, and preferably HDPE (PE100).

i. All trenches for services to be backfilled to a density of at least 93% Mod AASHTO, and be less permeable than the surrounding material (except in the case of rock). Bedding material must not be washed sand or crusher dust.

j. It is recommended that cleaning of collector panels be carried out using a sprayer fed by a portable water bowser, to prevent the need for reticulated water in the solar panel section of the site.

k. A competent person must certify those measures implemented comply with SANS1936-3, and during the 1st year after construction visit the site after heavy rain storms.

l. The professional team involved, including SMEC, shall carefully consider the appropriate water precautionary measures and finally certify that these have been implemented.

m. Adequate paving must be installed around all structures.

n. The site must be landscaped to ensure drainage away from all foundations and preferably off site into an existing watercourse or a D1 classified area.

o. A dolomite risk management plan (DRMP) (in accordance with SANS1936-4, attached in Appendix B) must be prepared. This requires an annual (maximum) internal review of the DRMP and every 5 years by an independent competent person (Level 3 or 4 Competent Geo-professional). The DRMP applies for the lifetime of the facility. The DRMP for the solar panel section of the site is anticipated to be far less stringent than that for the substation area.

8.1 Design Input

SANS 1936 (specifically Part 4) requires that a Competent Geo-professional be involved with the design and construction process to ensure that the relevant principles and standards applicable to development on dolomite are employed and adhered to. This is an essential element in the process of minimising the risk of sinkhole formation into the future.

9. REFERENCES

- Brink, A.B.A. (1979), Engineering Geology of Southern Africa, Volume 2. Building Publications, Pretoria.
- D B. Buttrick, N Y. G. Trollip, R B. Watermeyer, N D. Pieterse and A A. Gerber, 2011, A performance based approach to dolomite risk management, October 2011, Volume 64, Issue 4, pp 1127-1138
- Johnson, M.R., Anhausser, C.R., Thomas, R.J. (1996) The Geology of South Africa. The Geological Society of South Africa and the Council for Geoscience.
- SAICE and IStructE Code of Practice for foundations of single storey masonry buildings
- SANS 10160-4: Basis of Structural Design and Actions for Buildings and Industrial Structures – Part 4: Seismic Actions and General Requirements for Building
- SANS 1936 -1: General Principles and Requirements
- SANS 1936-2: Geotechnical Investigations and Determinations
- SANS 1936-3: Design and construction of buildings, structures and infrastructure
- SANS 1936-4: Risk Management
- SANS 633:2012 Soil profiling and rotary percussion borehole logging on dolomite land in Southern Africa for engineering purposes.
- Smith HJ. The Point Load Test for Weak Rock in Dredging Applications. Int. Journal Rock Mech. Min. Sci 34, No. 3-4, 1997, Paper No. 295.
- The 2010 SAICE Geotechnical Division Site Investigation Code of Practice
- Weinert, H. H., (1964), Basic igneous rocks in road construction, Research Report 218, CSIR, Pretoria.

APPENDIX A: EXERT FROM SANS1936-3

4 Requirements and precautionary measures on dolomite areas designated as D2 or D3

4.1 General

The requirements of competent persons (engineer and geo-professional) and the general requirements for the precautionary measures applicable to various elements of the development of buildings, structures and infrastructure and related wet and dry engineering services on dolomite land are given in 4.2. These requirements are extended with the specific precautionary measures given in clauses 5 to 9.

4.2 Design and construction requirements

4.2.1 General

4.2.1.1 Design and construction requirements in this part of SANS 1936 are based on the premise that all services are installed, inspected, maintained and repaired in accordance with the requirements of this part of SANS 1936, and that risk management procedures shall be implemented in accordance with SANS 1936-4.

4.2.1.2 The design and the associated inspection during construction of buildings, structures and infrastructure on parcels of D2 or D3 dolomite area designated land shall

a) be undertaken by one or more competent persons (engineer assisted by geo-professional for elements of the work related to geotechnical site conditions);

b) take account of the content and recommendations of the geotechnical site investigation report prepared in accordance with the requirements of SANS 1936-2; and

c) take account of the content and recommendations of the post-development risk management programme compiled in accordance with the requirements of SANS 1936-4.

4.2.1.3 Extensions, additions and upgrading or maintenance works to existing buildings, structures and infrastructure on developed sites shall be subject to the same precautions as required for new construction works. No extensions, additions or upgrading shall be undertaken unless the resulting development complies with the permissible land use set out in SANS 1936-1.

4.2.2 Design methodology

The design of buildings, structures, infrastructure and related wet and dry engineering services, shall be carried out by a competent person (engineer). The design shall comply with the relevant compulsory specifications (see foreword) and the relevant national legislation (see foreword).

4.2.3 Status of planning, design, construction or record drawings

Competent persons (geo-professional and engineer) shall legibly affix their name, signature, professional registration number, contact particulars and date of signature to all drawings, design details and reports. The competent person shall ensure that as-built information indicating deviations (permitted by the competent person) from the construction drawings, design details and reports are recorded within 60 d of the works being completed. Drawings shall be clearly marked to indicate their intended purpose, e.g. planning, design, construction or as-built drawings.

4.2.4 Drawings of buildings, structures and infrastructure

4.2.4.1 Competent persons (geo-professional or engineer, as appropriate) shall specify on the drawings all the relevant design aspects/parameters that shall be implemented in accordance with this part of SANS 1936.

4.2.4.2 Drawings of buildings, structures, infrastructure and related wet and dry engineering services shall clearly indicate all elements of water, fire, sewer and stormwater drainage installations, as well as all other liquid-bearing infrastructure and dry engineering services. The drawings shall also indicate construction and material specifications. Where roads are to be used as the primary stormwater drainage system, layout drawings shall indicate the level of the lowest drainage point on the site, as well as the road level adjacent to such point.

4.2.5 Designs not compliant with this part of SANS 1936

Should there be any deviations or omissions from the requirements of this part of SANS 1936, the competent person (geo-professional or engineer, as appropriate) shall indicate all such deviations of the drawings and shall prepare a supporting document signed by the competent person, clearly indicating the reasons for the non-compliance.

4.3 Location of infrastructure

4.3.1 Bulk pipelines shall be located at least the following distances from the nearest residential, institutional or commercial property boundary, excluding buildings associated with the pipeline:

a) dolomite area designation D2: 15 m;

b) dolomite area designation D3: 25 m.

Where this is not practically achievable, the bulk service shall be laid in a duct or culvert that will intercept any leakage in a manner that is readily observable or an appropriate rational solution shall be provided by a competent person (engineer).

4.3.2 Dams, reservoirs, liquid-retaining structures, stormwater retention or attenuation ponds and sewer-retaining ponds shall be located at least the following distances from the nearest residential, institutional, industrial or commercial building site boundary, excluding buildings associated with such liquid-retaining facility:

a) dolomite area designation D2: 20 m in all instances;

b) dolomite area designation D3: 20 m for commercial and industrial developments and 30 m in other instances.

NOTE The location of waste and sewer disposal facilities is governed by prevailing legislation.

4.4 Stormwater drainage

4.4.1 Stormwater drainage systems shall discharge into a natural watercourse unless the land upon which it is discharged is

a) not dolomite land; or

b) dolomite land categorized as dolomite area designation D1 in accordance with SANS 1936-1.

4.4.2 Stormwater drainage shall be such that no surface water ponds other than in a natural watercourse, or in an appropriately designed attenuation pond. The retention period of attenuation ponds on dolomite land other than land designated as D1 shall not exceed 6 h.

4.4.3 Stormwater retention and attenuation structures shall be rendered impervious.

4.4.4 The means for the control and disposal of stormwater around buildings shall be in accordance with the requirements of SANS 10400-R. All stormwater shall be controlled and shall drain away from such buildings.

4.5 Sanitation systems

4.5.1 Sanitation systems on dolomite land other than land designated as D1 shall not incorporate evapo-transpirative beds, soakaways or french drains. Conservancy tanks linked to a low flush system that complies with the requirements of SANS 10400-P may be used where municipal water-borne sewerage connections are not available.

4.5.2 If no alternative is available, pit toilets in accordance with the requirements of SANS 10400-Q may be utilized on sites designated as D1 and D2, provided that the design and implementation is approved by the competent persons (engineer and geo-professional) as well the local authority. Such toilets shall be constructed to prevent stormwater gaining access to the pit and shall be placed as far away as possible from any permanent buildings and structures.

NOTE 1 Suitable means of preventing stormwater from gaining access to the pit include the construction of a 0,5 m high earth berm around the upslope section of the pit toilet or construction of the floor slab 500 mm proud of natural ground level.

NOTE 2 Annual reconstruction of pit toilets on new locations is advisable.

NOTE 3 Redundant pits shall be allowed to dry and then be backfilled and compacted with suitable material to a density less permeable than the surrounding natural material.

4.5.3 Pit toilets shall not be provided on sites designated as D3 dolomite land.

4.6 De-watering and groundwater recharging

4.6.1 Before abstracting groundwater on dolomite land, the person or entity undertaking such abstraction shall obtain a water use licence from the relevant national authority (see foreword) in accordance with the relevant national legislation (see foreword). The application for such licence shall clearly state that the ground from which the water is to be abstracted is dolomite land.

4.6.2 Where abstraction or recharging of ground water could result in changes of more than 6 m in the original groundwater level, the person or entity undertaking such abstraction or recharging shall notify the relevant national authorities (see foreword).

4.7 Landscaping and gardens

4.7.1 Gardens within 15 m of buildings and structures shall not include

a) water features, such as fish ponds, except where an impermeable lining is provided in accordance with a design prepared by a competent person (engineer); or

b) water features with automatic replenishment systems.

4.7.2 No automated irrigation systems shall be installed within a distance of 5 m from any structure or building on sites designated as D3 dolomite land.

4.7.3 All trees or shrubs should preferably be situated more than 5 m from any water-bearing service.

4.7.4 Large grassed areas, such as sports fields, shall have a fall to facilitate a free-draining surface.

NOTE A slope of less than 1:80 results in poor drainage characteristics.

4.7.5 Irrigation systems shall be designed in accordance with the requirements for wet engineering services by a competent person (engineer). The design shall ensure that the irrigation intensity and frequency is such that surface ponding of water does not occur.

4.7.6 All portions of the development, including reworked or landscaped areas, shall be free draining.

4.8 Construction

4.8.1 General

4.8.1.1 Measures shall be taken during construction activities to ensure that

a) land which is not to be developed is not disturbed by construction activities or the construction equipment employed to the extent that it is compromised for future developments;

b) water does not pond anywhere on the site;

c) existing wet engineering services are maintained and any damage to such services is promptly repaired;

d) any services that are to be abandoned are dealt with in accordance with the requirements of 4.9;

e) surface water runoff does not interfere with or pose a threat to adjacent properties; and

f) all excavations are backfilled in such a manner that the backfill is less permeable than the surrounding natural ground.

4.8.1.2 All stationary construction plant and facilities (tower cranes, batch plants, storage facilities, wash bays and temporary buildings) shall be designed and constructed in accordance with the requirements of this part of SANS 1936. Wet and dry engineering services to such plant and facilities shall comply with the requirements of this part of SANS 1936.

The provision of construction-related support functions, facilities and activities, including the provision of temporary accommodation, shall not increase the likelihood of subsidence events occurring.

4.8.1.3 Proactive measures shall be taken to mitigate the risk of

a) ingress of water and or other liquids (irrespective of source) into trenches and excavations; and

b) damage to existing wet and dry engineering services during construction.

4.8.1.4 Areas that require surface repairs, such as road layer works or pavements, shall be repaired in such a manner as to minimize the ponding of water on partially repaired surfaces, preferably in a single operation.

4.8.2 Quarries and borrow pits

4.8.2.1 Quarries and borrow pits on dolomite land shall be approved in terms of the required local, provincial and national legislation and shall be established, managed and operated under the direction of the competent person (engineer or geo-professional).

4.8.2.2 Any quarry or borrow pit on dolomite land shall be free draining for the full period of operation and shall, on completion, be rehabilitated to the design and standards specified by a competent person (engineer or geo-professional).

4.8.2.3 The as-built drawings shall indicate and describe the nature of any quarry or borrow pit, including the method used to rehabilitate such quarry or borrow pit.

4.8.2.4 Quarries and borrow pits shall not be permitted on land already zoned (or provisionally allocated) for a specific land usage that does not specifically provide for the establishment of such quarries and borrow pits in the usage definition/description or conditions.

4.8.3 Excavations for infrastructure

4.8.3.1 The competent person (geo-professional) shall issue written instructions that the person responsible for the construction of below-ground infrastructure shall notify the competent person in the event of

a) a sudden change in the colour of the soils;

b) exposure of cavities or of weak or porous soils; and

c) excavation of palaeo-structures.

4.8.3.2 The findings of the excavation inspection by the competent person (geo-professional) shall be fully documented in a concise report that contains

a) details of the area of inspection;

b) layout plans of the area;

c) description of inspection routes;

d) description of inspection findings;

e) photographs to enhance report details;

f) description of soil profile (in general, per chainage length);

g) descriptions of changes in soil colour, density or type; and

h) descriptions of the presence and location of any cavities and palaeo-structures.

4.8.3.3 The length of time excavations are left open or unattended, and the accumulation of water in such excavations shall be kept to a minimum to reduce the likelihood of subsidence. The length of trenches or extent of excavations opened up at any stage shall be limited to achieve this requirement. Backfilling of trenches shall take place as soon as possible after the services have been laid.

4.8.3.4 Backfilled areas shall be inspected at time intervals as specified by the competent person (engineer or geo-professional) for any signs of subsidence. Any subsidence that is found shall be attended to as directed by the competent person.

NOTE Typically, such inspections should, as a minimum, be before, during, and at the end of a rainy season, or as otherwise determined by the competent person.

4.8.4 Blasting operations

4.8.4.1 Uncontrolled blasting could trigger the formation of sinkholes or subsidences**.** Blasting shall be such that the inter-shot delay between rows is not less than 25 ms and the peak particle velocity

(PPV) at any building or buried service is not greater than 25 mm/s at a frequency of not less than 10 Hz unless a higher limit is approved by the competent person (engineer).

NOTE The Geotechnical Division of the South African Institution of Civil Engineers' Code of practice: *Lateral Support in surface excavations* provides guidance on the calculation of the maximum charge mass per relay in relation to a distance from a service.

4.8.4.2 Detonating relays shall have at least a 20 ms delay interval.

4.9 Demolition of buildings and services

4.9.1 Buildings shall be demolished (or deconstructed) under the direction of a competent person (engineer), observing minimum site precautions to ensure that

a) water does not pond on the site,

b) all wet engineering services to the building are disconnected before demolition commences,

c) the risk of wet engineering services rupturing or leaking is controlled,

d) wet engineering services are terminated completely upon completion of the works.

4.9.2 Disused pipes and ducts, including all associated structures, such as manholes and valve boxes, shall be removed and the trenches suitably backfilled and compacted such that the permeability of the trench is less than that of the in-situ soil. Where removal is impractical, or as an alternative to such removal, disused pipes and ducts shall be fully grouted using a suitably designed pumpable/flowable soil cement mixture. The same applies to all associated service structures, such as valve boxes and manholes, if they are not removed entirely.

4.9.3 Pipe replacement techniques that employ methods of deconstructing the in-situ pipe or duct and replacing it along the same route with the new pipe shall only be used if other methods of construction are not practical. Where used, such techniques shall include measures to ensure that no voids are left around the new pipe or duct after completion of the replacement. Typically a cement grout or a sand cement grout shall be injected to fill all voids between the new pipeline and the surrounding material.

NOTE This type of construction is not preferred in the dolomite environment due to the potential for creating a mini-french drain and thus concentrated drainage areas around the pipe.

4.10 Pipe jacking and horizontal drilling

4.10.1 Pipe jacking shall be in accordance with SANS 2001-DP8. The competent person (geo-professional or engineer, as appropriate) shall specify or approve the proposed methodology and precautionary measures.

4.10.2 Water-jetting techniques shall not be used.

4.10.3 The design shall incorporate provisions that ensure that no voids are left around the pipe or duct after completion. A suitably designed, cement grout or sand cement grout shall be injected to fill all voids between the new pipeline and the surrounding material.

NOTE These methods of construction are not preferred (see the note to 4.9.3).

5.2.2.6 The minimum emergency storage capacity in sumps for pump stations shall be equivalent to a 6 h flow at the average flow rate over and above the capacity available in the sump at normal top water level. Where this is impractical, an automatically activated back-up system shall be provided.

5.3 Water supply system

5.3.1 Separate meters shall be provided for each stand to which water is supplied. Water meters shall be easily accessible and any leakage shall be readily detectable.

5.3.2 The number of high and low points shall be kept to a minimum. Pipes should preferably be laid to gradients greater than

a) 0,3 % for pipes that have an internal diameter equal to or less than 200 mm; and

b) 0,2 % for pipes that have an internal diameter in excess of 200 mm.

5.3.3 A suitable means of scouring and venting pipes shall be provided at low and high points, respectively, on all bulk water pipelines.

5.3.4 Water supply systems to townships or interconnected complexes should be designed to allow for detection of leakages in sections that do not exceed flows of 2 000 m^3 per month.

6 Requirements for wet and dry engineering services

6.1 General

6.1.1 Underground wet and dry engineering services shall

a) be designed and constructed so as to minimize maintenance requirements and to circumvent any potential leakages into or from the services at joints or other potential leakage points;

b) as far as possible, be designed to avoid possible disturbance of the underground environment, and where the underground environment is disturbed, the soil shall be compacted to a density not less than the surrounding soil and the backfilled excavations shall be shaped so as to avoid the ponding of water.

6.1.2 The backfilling to service trenches shall, except in rock, be less permeable than the surrounding material.

6.1.3 The number of joints in a pipeline shall be kept to a minimum by using the longest available lengths of pipes.

6.1.4 Wherever feasible, planning for the provisions of future connections to all wet engineering services should be made in order to minimize cutting into pipes at a later stage.

6.1.5 High concentrations of subsurface wet and dry engineering services near buildings shall be avoided. Where unavoidable

a) an engineered soil mattress in accordance with the requirements of SANS 10400-H shall be provided along a 3 m wide corridor within which the services are laid to reduce the permeability of the subsurface and to improve founding conditions; or

b) services shall be placed in watertight sleeves culverts with inspection chambers adjacent to the building and at distances as determined by the competent person (engineer) away from the building. Such sleeves shall slope away from buildings.

6.1.6 The fall (slope/gradient) of the bottom of trenches shall, as far as is practicable, be away from the buildings.

6.1.7 All access chambers, inlet structures, manholes, valve chambers, pump stations, etc. shall be watertight. Where necessary, such structures shall be fitted with a suitable sump pump or drainage pipe that discharges into a suitable discharge system.

6.1.8 Wet and dry engineering services shall be designed and constructed to be watertight (zero leakage) in accordance with the relevant requirements of SANS 2001-DP1, SANS 2001-DP2, SANS 2001-DP3, SANS 2001-DP4, SANS 2001-DP5, SANS 2001-DP6 and SANS 2001-DP8, in addition to any requirements specified in this part of SANS 1936.

6.1.9 The selection of pipes and fittings, as well as their associated attributes, shall take cognizance of factors such as

a) resistance to internal and external environmental agents, including freezing, corrosion and, if relevant, ultraviolet radiation, over its design working life;

b) ability to reliably withstand all direct and indirect actions (forces), including those relating to potential loss of support, to which the system is likely to be subjected over its design working life without losing functionality;

c) ability to withstand differential movements and remain watertight;

d) ability to withstand mechanical damage before and during installation and the implications of any such damage on the performance of the system once in use;

e) design working life;

f) long term reliability of jointing systems even if lateral/vertical movement takes place;

g) workmanship quality assurance requirements and the availability of suitably skilled artisans to execute work in terms of the design specifications and install all components of a service in accordance with the manufacturer’s and the competent person’s (engineer) specifications;

h) means by which quality and manufacturing consistency can be assured;

i) vulnerability and resistance to damage during normal use and maintenance activities;

j) method and ease of repair, maintenance and inspection procedures; and

k) measures which might be required to extend the design working life, should this be necessary.

6.2 Wet engineering services

6.2.1 General

6.2.1.1 Wet engineering services, excluding stormwater systems, shall be capable of spanning the projected notional sinkhole diameter (2 m, 5 m or 15 m, as determined by the geo-professional), which has a high likelihood of formation in accordance with the requirements of SANS 1936-2, without the service rupturing or any joint leaking or separating from the pipeline.

6.2.1.2 The pipe conveyance system (e.g. water supply, stormwater drainage and sewerage systems) shall incorporate measures to ensure watertightness (zero leakage) of the system and all other related components. Provision shall be made in all water-bearing services to accommodate differential movements that can reasonably be expected for the given soil conditions without causing the pipeline or joints to leak.

6.2.1.3 Pipes and associated fittings shall be selected on the basis of their design working life, resistance to damage, workmanship required to produce the required quality of installation and jointing, ease of repair, flexibility and any deterioration (e.g. corrosion) that will inhibit resistance to internal and external agents. The pipe fittings used in pipelines under pressure shall be of the self-anchoring type, i.e. not reliant on thrust blocks (i.e. mechanical anchoring) or friction for anchorage.

6.2.1.4 Wet engineering services should, wherever possible, not be placed parallel to buildings unless they are at least 5 m away (if stand size allows) from the structure. Should this be unavoidable, a rational design shall be performed by the competent person (engineer).

6.2.1.5 The number of different wet engineering service types and connections to a building shall be minimized.

6.2.1.6 Pipes through walls at entry points to buildings shall be sleeved to permit the anticipated relative movement as prescribed by the competent person (geo-professional or engineer). The annulus shall be sealed with a suitable (including rodent-resistant) compressible material. The arrangement of service connections shall allow for movement of the building or surrounding soil without resulting in tension or compression forces that might impact on the performance of the service.

6.2.1.7 Wet engineering service systems may only be placed beneath the footprint of a building where such services are placed in a sealed sleeve, watertight duct or drainage channel which drains towards a point where any leakage of the wet engineering service can be readily detected. Sleeves shall comply with the requirements for sewer design in dolomite area designation D3 sites.

6.2.1.8 Wet engineering service pipes (medium pressure pipe types) shall be subjected to hydraulic pipeline testing after installation, as specified in SANS 2001-DP2 for the selected pipe type, irrespective of application.

6.2.2 Water supply

6.2.2.1 Water supply networks shall be fitted with water meters at suitable locations to allow for the auditing of water losses and the detection of leaks.

6.2.2.2 Underground valves, inline strainers, reflux valves, water meters or any other fitting other than pipe joints shall be placed in watertight chambers. All associated fittings, such as flange adaptors and reducers, shall be within the watertight chamber.

6.2.2.3 Valves and water meters shall be provided at all stand connections. For testing purposes, such connections shall be provided with either a pressure gauge or a connection point for such a gauge on the stand side of the valve. Such point shall be clearly marked and placed to ensure accessibility to maintenance crews without entering the premises.

6.2.2.4 Buried piping shall have a nominal working pressure rating (unless the design/working pressure exceeds the value below) at between 20 °C and 25 °C, of

a) municipal mains: 800 kPa;

b) connections to buildings: 1 200 kPa;

c) irrigation systems that have a cover of 600 mm or less: 1 200 kPa; or

d) irrigation pipes that have a cover of more than 600 mm: 800 kPa.

6.2.2.5 Buried piping from the water mains reticulation to a building shall, as far as possible, be free of joints (other than butt-fusion joints) or other fittings between the water mains and the building. Essential fittings, including any water meters or testing points, shall be installed in watertight chambers. All connections between flexible and rigid pipes shall be provided with flexible, self-anchoring joints. Such connections shall be either within watertight structures or above ground level and not be restrained from movement under conditions of subsidence.

6.2.2.6 Joints between buried and above-ground piping shall be made not less than 100 mm above ground or paving level. A 500 mm × 500 mm concrete slab, not less than 75 mm thick, shall be cast around the exit point from the ground to protect the pipe if this area is not paved.

6.2.2.7 Buried water pipes shall have a minimum soil cover of 600 mm.

6.2.2.8 All external water taps mounted on a wall shall be installed above a gulley which is connected to the drainage system. Free-standing taps shall be provided with a 1,0 m square slab at least 75 mm thick with uniform falls to all sides, centred underneath the tap, and the surrounding area, shaped to prevent ponding of water in the vicinity of the tap.

6.2.2.9 Water pipe entry into buildings shall be designed to allow differential movement (see figure 2.)

6.2.2.10 The type, size and pressure rating of the pipe to be used shall be specified by the competent person (engineer). The preferred pipe types and other requirements for subsurface water reticulation systems are given in table 5.

6.2.2.11 Exposed above-ground pipe installations may be made using any of the following systems:

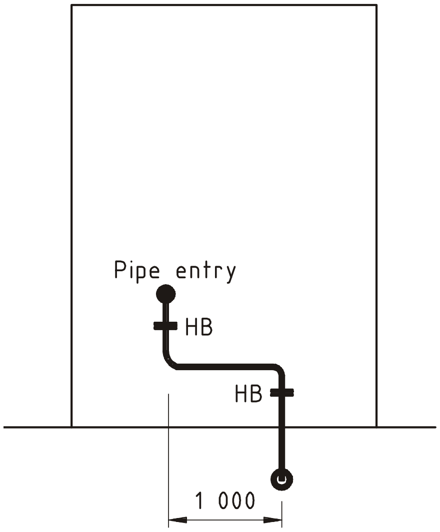
a) hot dipped galvanized steel pipes and fittings manufactured in accordance with the requirements of SANS 62-1, SANS 32 and SANS 121;

b) copper pipes and fittings that comply with SANS 460, SANS 1067-1 and SANS 1067-2;

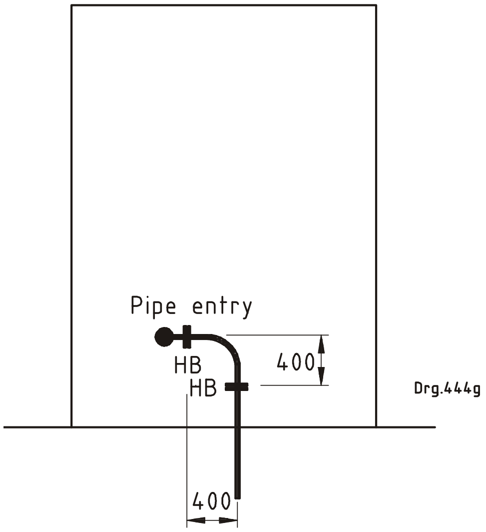
c) polypropylene pipes and fittings that comply with SANS 15874.

6.2.2.12 The overflow from any water storage tanks in a building, including the overflow from toilet cisterns and the discharge from any pressure regulators, shall be piped and discharged into a gulley that is connected to the drainage system.

Dimensions in millimetres



Rigid / semi flexible pipe



Flexible piping

HB = holder bat

Figure 2 — Water pipe entries to buildings

Table 5 — Preferred pipe types for use on sites designated as D2 or D3 dolomite land

1	2	3	4	5	6
Application	**Pipe type and material classification**	**Minimum pressure rating or ring stiffness**	**Applicable standards**	**Pipe joint requirements**	**Additional requirements and comments**
Water supply (see 6.2.2.10)					
Bulk supply: OD $\geq$ 300 mm	Steel pipes	In accordance with design requirements	SANS 719 or SANS 1835	Continuous butt, sleeve or socket welds. Mechanical jointing devices (including flanges) shall be used only in manholes. Screwed joints shall not be used.	Pipes shall be protected against corrosion by means of galvanizing or coatings and, where required, by cathodic protection.
	High density polyethylene (HDPE): PE 100	PN 8[a, b]	SANS 4427	Butt welded, in accordance with SANS 10268-1. Mechanical jointing devices (including flanges) shall be used only in manholes.	Number of joints shall be kept to a minimum.
OD 75 mm to 300 mm	High density polyethylene (HDPE): PE 100	PN 12.5[a, b]	SANS 4427	Butt welded, in accordance with SANS 10268-1. Mechanical jointing devices (including flanges and compression fittings) shall be used only in manholes.	Number of joints shall be kept to a minimum. 75 mm and 90 mm diameter pipes should preferably be supplied in 100 m rolls. 110 mm diameter pipes should be supplied in 50 m rolls.
	Modified poly(vinyl chloride) (PVC-M)	Class 12[a, b]	SANS 966-2	Mechanical devices consisting of sealing rings or grooves (or both) and clamps. Use stainless steel only for metal fittings.	Pipes supplied in 6 m or 9 m lengths.
	Modified poly(vinyl chloride) (PVC-M)	Class 16[a, b]	SANS 1283	Pressed on SG iron victaulic shoulders.	Pipes supplied in 6 m or 9 m lengths.
OD < 75 mm	High density polyethylene (HDPE): PE 100	PN 12.5[a, b, c]	SANS 4427	Electro-fusion or butt-fusion[d] Mechanical jointing devices (including flanges and compression fittings) shall be used only in manholes.	Number of joints shall be kept to a minimum. Pipes supplied in 100 m rolls

[a] The minimum pressure rating shall be as stated or in accordance with design requirements, whichever is higher. The design of the pipe shall make allowance for the design pressure and potential loss of support as required in 6.2.1.1.

[b] On sites designated as D3 dolomite land, the nominal pressure rating shall be one pipe designation or class higher than that which complies with the above requirement (see 6.4(d)).

[c] On residential land, the pressure rating shall not be lower than PN 16 as the applicable pipe sizes are prone to damage by gardening activities.

[d] Small diameter HDPE pipes preferably jointed by electro-fusion instead of butt-fusion.

Table 5 *(concluded)*

1	2	3	4	5	6
Application	**Pipe type and material classification**	**Minimum pressure rating or ring stiffness**	**Applicable standards**	**Pipe joint requirements**	**Additional requirements and comments**
Sewers (see 6.2.3.5)					
All diameters	High density polyethylene (HDPE): PE 100	PN 10 SDR 17[a, b]	SANS 4427	Butt-fusion, electro-fusion or hot gas extrusion welds, in accordance with SANS 10268-1.	Pipes shall be supplied in minimum lengths of 12 m.
	Polypropylene (PP): PPH 100	PN 10 SDR 17[a, b]	SANS 8773	Butt-fusion, flanges or electro-welded sockets, in accordance with SANS 10268-1[e].	Pipes shall be supplied in minimum lengths of 12 m.
	Unplasticized poly(vinyl chloride) (PVC-U)	Class 34[a, b]	SANS 791	Mechanical devices consisting of sealing rings or grooves (or both) and clamps. Use stainless steel only for metal fittings.	Pipes supplied in 6 m or 9 m lengths.
Stormwater drainage (see 6.2.4.11)					
Minimum diameter 300 mm	Solid wall high density polyethylene (HDPE): PE 100	PN 10 SDR 17	SANS 4427	Butt-fusion or electro-fusion fittings or hot gas extrusion welding, in accordance with SANS 10268-1.	Pipes shall be supplied in minimum lengths of 12 m.
	Structured wall high density polyethylene (HDPE): PE 100	Class 8 kN/m^2	SANS 4427	Butt-fusion or electro-fusion fittings or hot gas extrusion welding, in accordance with SANS 10268-1.	Pipes shall be supplied in minimum lengths of 12 m.
	Polypropylene (PP): PPH 100	PN 10 SDR 17	SANS 8773	Butt-fusion, flanges or electro-welded sockets, in accordance with SANS 10268-1.	Pipes shall be supplied in minimum lengths of 12 m.
	Unplasticized poly(vinyl chloride) (PVC-U)	Class 34	SANS 791	Mechanical devices consisting of sealing rings or grooves (or both) and clamps. Use stainless steel only for metal fittings. Rubber joints that comply with SANS 9661 or SANS 9662.	Pipes supplied in 6 m lengths.
	Concrete	Non-pressure Type SC	SANS 677	Spigot and socket with rolling rubber rings or spigot and socket with sliding rubber joints.	Bedding conditions shall ensure that the deflection tolerances are not exceeded as a result of consolidation settlement.

[a] The minimum pressure rating shall be as stated or in accordance with design requirements, whichever is higher. The design of the pipe shall make allowance for the design pressure and potential loss of support as required in 6.2.1.1.

[b] On sites designated as D3 dolomite land, the nominal pressure rating shall be one pipe designation or class higher than that which complies with the above requirement (see 6.4(d)).

[c] On residential land, the pressure rating shall not be lower than PN 16 as the applicable pipe sizes are prone to damage by gardening activities.

[d] Small diameter HDPE pipes shall preferably be jointed by electro-fusion instead of butt-fusion.

[e] Welding of polypropylene pipes can be problematic. Careful inspection and testing shall be undertaken to confirm integrity of welds.

6.2.3 Sewers and gravity drainage systems

6.2.3.1 All manholes shall be watertight and shall be tested for watertightness (zero leakage) during construction.

6.2.3.2 Sewers and gravity drainage systems, inclusive of pipes, sleeves or conduits shall be subjected to hydraulic pipeline testing, after installation, in accordance with SANS 2001-DP2 for the selected pipe type, irrespective of application.

6.2.3.3 Connections from multiple adjoining toilets or washbasins shall made above ground and shall feed into a single downpipe draining into the subsurface system.

6.2.3.4 Toilet pans shall be provided with an external flexible connection at the junction point to the subsurface sewer system.

6.2.3.5 The type, size and pressure rating of the pipe to be used shall be specified by the competent person (geo-professional or engineer). The preferred pipe types and other requirements for subsurface sewers and gravity drainage systems are given in table 5.

6.2.4 Stormwater drainage

6.2.4.1 Channels and canals which are constructed to reroute water from natural drainage paths shall be lined. Any joints in such channels shall be suitably sealed to be watertight.

6.2.4.2 Unlined stormwater cut-off or diversion trenches shall be avoided as far as possible.

6.2.4.3 All concentrated stormwater entering any parcel of land shall be diverted away from any building and structures by means of concrete-lined channels. Where necessary, earth berms and contouring shall be used to enhance site drainage.

6.2.4.4 Stormwater drainage systems shall incorporate measures to ensure watertightness (zero leakage) of conveyance systems, culverts and other compartments, including the sealing of all joints, and shall be designed to minimize the effects of settlement. All manholes, junction boxes and conveyance systems shall be tested for watertightness during construction. Reinforced concrete manholes shall be designed as liquid-retaining structures.

6.2.4.5 Stormwater drainage conveyance systems shall be designed to gradients which are self-cleansing. Such systems shall have an internal diameter equal to or greater than 300 mm.

6.2.4.6 For drainage purposes, surfaced roadways and parking areas should be constructed at a level below the surrounding buildings, developed or landscaped areas and gardens.

6.2.4.7 All stormwater from downpipes and gutters from buildings and structures shall discharge onto concrete-lined channels which, in turn, shall discharge the water at least 1,5 m away from structures onto areas permitting surface drainage away from buildings and structures. Joints between any open channel drains and buildings shall be suitably sealed.

6.2.4.8 Small diameter stormwater drainage pipes shall not be placed parallel to buildings unless they are at least 5 m (if stand size allows) from the structure. If this is not practical. a rational design shall be performed by a competent person (engineer).

6.2.4.9 Buildings and structures without gutters shall be provided with impervious paving not less than 1,5 m wide with a minimum slope of 1:20 all around. Joints between such paving and the building or structure, as well as any joints to control shrinkage/expansion, shall be suitably sealed. The ground surface shall be shaped to fall away from the building at a minimum slope of 1:20 for a further 1 m from the edge of the slab and shall thereafter fall continuously towards the closest drainage point.

6.2.4.10 Water shall not be permitted to accumulate against boundary walls. Suitable drainage ports shall be incorporated in boundary walls, particularly at the lowest point of the site, to permit the passage of surface runoff water. Such ports shall be provided (on both the inlet and outlet sides of the wall or fence) with a concrete slab 1,0 m wide, 100 mm thick, and extending 400 mm beyond the edges of the drainage port along the fence. The concrete slab shall have a minimum fall of 1:15 to ensure self-cleaning drainage characteristics. Any security outlet grids that are provided shall not impede the flow of water through the port.

6.2.4.11 The type, size and pressure rating of the pipe to be used shall be specified by the competent person (engineer). The preferred pipe types and other requirements for subsurface stormwater drainage systems are given in table 5.

6.3 Dry engineering services

6.3.1 Buried dry engineering services or dry engineering service sleeves shall, in all respects, comply with the requirements of the installation of a sewer system.

6.3.2 Sleeve and draw box systems for electrical and communication cables shall be watertight, flexible and comply with the requirements of a sewer system in accordance with this part of SANS 1936. No water shall enter or drain from the dry service system.

6.3.3 Dry engineering services pipes, sleeves or conduits (medium pressure pipe types) shall be subjected to hydraulic pipeline testing, after installation, in accordance with SANS 2001-DP2 for the selected pipe type, irrespective of application.

6.3.4 Cable ducts shall be constructed from the same materials specified for sewer systems, i.e. in accordance with SANS 2001-DP2 and table 5.

NOTE Requirements for excavation and backfilling of dry engineering service trenches are described in 4.8.3 and 6.1.2.

6.4 Additional precautionary measures in dolomite area designation D3 sites

Wet engineering services in dolomite area designation D3 sites shall comply with the following requirements, in addition to those established in 6.1 and 6.2:

a) The preferred pipe type for all wet engineering services, and the sleeve systems for such services, on dolomite area designation D3 sites are polyethylene (PE) pipes and fittings that comply with the material manufacturing requirements of the relevant of parts 1, 2, 3 and 5 of SANS 4427, with a material designation of PE 100 and that are supplied in straight lengths of 12 m, or rolls of 50 m or 100 m with joints made by means of butt-fusion or electrofusion fittings.

b) Structured wall polyethylene (PE) pipes or steel-reinforced spirally wound PE drainage and sewer pipes shall be made from PE 100 material in accordance with SANS 4427-1. Steel-reinforced spirally wound PE pipes shall comply with SANS 674. Specified ring stiffness shall be tested in accordance with ISO 9969.

c) Manholes and inspection chambers should preferably be manufactured from structured or solid wall polyethylene (PE) or steel reinforced spirally wound pipes that comply with the requirements of SANS 4427-1 or SANS 674, as appropriate, with a material designation of PE 100 (or higher), with inlets and outlets that can be joined to compatible pipe systems by means of butt-fusion or electro-fusion fittings.

d) The nominal pressure rating of plastic pipes shall be one pipe designation or class higher than that which complies with the design requirements for a dolomite area designation D2 site.

e) Wet and dry engineering services pipes (medium pressure pipe types) shall be subjected to hydraulic pipeline testing, after installation, in accordance with SANS 2001-DP2 for the selected pipe type, irrespective of application. The test pressure applied over any section of pipeline, taking any differences in elevation along the pipeline into account, shall be such that the pressure at any point along the section is not less than 1,25 × the designated working pressure or 0,4 MPa, whichever is the greater, and not more than 1,5 × the designated working pressure at these points. The field test pressure shall not exceed the appropriate values given in table 6.

NOTE Increasing the nominal pressure rating increases the safety factor and the design life of the pipe and reduces the risk of rupture due to localized stresses or damage.

f) Wet engineering services shall not be placed beneath the footprint of a building or structure.

g) The water supply to a building shall be via a single water supply connection unless otherwise approved by the competent person (engineer). This also applies to other pressurized liquid-bearing services.

h) Water supply for domestic use and fire-fighting inside the building can be combined, provided that there is a distinct, and clearly marked split above ground (mounted on the outside of building) of the two systems. The point of split shall include a shut-off valve for the domestic supply, but no shut-off valve on the fire-fighting supply side.

i) Within 15 m of any building other than a dwelling house, the water supply and other pressurized liquid-bearing service connections shall be placed

1) in a flexible, watertight sleeve if underground;

2) above ground; or

3) in watertight (zero leakage) open ducts.

j) Distribution of water within a building or structure should preferably make use of above-ground piping mounted on walls, in the roof or in above-floor-level service shafts. Service shafts shall be watertight (zero leakage) at ground floor level, have drainage ports that drain visibly into the stormwater system, and shall be supplied with easy access inspection hatches.

k) Sewers and drains shall comply with the following minimum requirements:

1) within 15 m of the footprint of a building, buried pipelines shall not be provided with joints other than specified butt welded joints; and

2) suitable prefabricated small diameter (< 1,0 m) watertight manholes shall be used in place of rodding and cleaning eyes;

l) Stormwater drainage systems shall comply with the following requirements:

NOTE The use of the word “should” in this subclause indicates best practice to be applied where practical.

1) roadways with a gradient flatter than 1:80 should be surfaced or be sealed;

2) no piped stormwater systems should be permitted within 15 m of a building or structure, other than those serving the building or structure in question;

3) natural ponds and watercourses located within 10 m of any structure and within 30 m of a building should either be rendered impervious or diverted so that their location is not within these distances of the structure or building;

4) lined surface canals should be located at least 15 m from buildings;

5) open culverts with grated covering material should be used to traverse any trafficked area within 15 m of buildings or structures;

6) all stormwater from downpipes and gutters from buildings and structures shall discharge into impervious lined channels which, in turn, should discharge the water at least 15 m away from such buildings and structures onto areas that permit free surface drainage;

7) pipelines shall be pressure-tested during construction using the pressure test procedures prescribed in SANS 2001-DP2;

8) manholes shall be tested for watertightness (zero leakage) using the test procedure in SANS 2001-CC1;

9) impervious paved areas or apron slabs shall be provided within 3 m (or greater if deemed appropriate by the competent person (engineer))of structures and buildings, runoff from which shall drain into lined stormwater channels feeding into the a designed stormwater system or shall be spread as sheet flow away from the buildings or structures; and

10) all areas shall be graded to slopes that permit free drainage of water away from structures and buildings.

m) The area immediately below above-ground installed wet engineering services shall be free draining to ensure drainage away from buildings and structures in the event of a burst or leaking pipe.

n) All sleeves or ducts shall be laid to grades that will facilitate drainage away from buildings and structures into designated watertight inspection chambers.

o) Engineered masonry and concrete manholes shall be designed as water-retaining structures and tested for watertightness (zero leakage) using the test procedure in SANS 2001-CC1;

p) Gas pipelines within 15 m of buildings shall be provided with welded joints.

q) Fuel reticulations shall, as far as is practicable, be above ground.

Table 6 — Maximum field test pressures

1	2	3
Type of pipe	**Applicable materials standard**	**Maximum field pressure at any point in the pipeline**
Steel	SANS 62-1, SANS 62-2, SANS 719, SANS 815-1 or SANS 815-2	50 % of the hydraulic test pressure
Ductile iron	SANS 50545	Allowable site test pressure (PEA)
Reinforced concrete	SANS 676	75 % of the hydraulic test pressure
Prestressed concrete	SANS 975	75 % of the hydraulic test pressure
Polyethylene	SANS 4427-2 and SANS 4427-3	100 % of the hydrostatic pressure
Steel mesh reinforced polyethylene	SANS 370	1,6 times the nominal pressure
Polypropylene	SANS 15874-2 and SANS 15874-3	75 % of the hydrostatic pressure
PVC-U	SANS 966-1	75 % of the hydrostatic pressure
PVC-M	SANS 966-2 or SANS 1283	75 % of the hydrostatic pressure

7 Requirements for design and construction of infrastructure

7.1 General

The design and construction of infrastructure on dolomite area designation D3 sites shall, to the extent reasonably practicable, ensure that, in the event of a sinkhole or subsidence with the notional diameter indicated in the geotechnical report occurring,

a) the safety or environmental hazard from the time of the occurrence of such an event to the time that the surrounding area can be secured and made safe is minimized; and

b) the risk of rupture of or leakage from wet services is minimized.

NOTE 1 Consideration should be given to supporting infrastructure or elements thereof on foundations or piles if the infrastructure is not inherently able to span the sinkhole or subsidence.

NOTE 2 Suitably designed ground improvement techniques may be considered, including

a) excavation and compaction of areas below services or pavement layer work to improve soil stability; or

b) the creation of structural arching by means of soil mattresses; or

c) improving subsurface conditions by means of dynamic compaction or subsurface grouting.

NOTE 3 Consideration may be given to the use of geosynthetic reinforcement to retard the propagation of localized subterranean voids to surface thereby increasing the likelihood that the event will be detected before it develops into a sinkhole.

7.2 Aircraft runways

7.2.1 General

7.2.1.1 The concentrated ingress of water on the verges of surfaced runways shall be avoided by suitably reducing the permeability of the gravel shoulder for at least 10 m beyond the edge of the surfaced area.

7.2.1.2 Wet and dry engineering services under runways shall be placed in a watertight sleeve or ducts extending 50 m beyond the edges of the runway. Such sleeves and ducts shall drain away from the runway to specific points or manholes (which may, if necessary, incorporate drainage pumps) that are linked to a suitable stormwater system.

7.2.2 Additional precautionary measures for runways on dolomite area designation D3 sites

7.2.2.1 The subgrade (all earthworks below the sub-base, base and surfacing) of runways and taxiways and associated hardstands for the purpose of aviation and related traffic shall be excavated and replaced with engineered backfill to improve soil stability or to create structural arching by means of soil mattresses. Alternatively, subsurface conditions could be improved by means of dynamic compaction or grouting.

7.2.2.2 No wet engineering services shall be placed under or within a distance of 50 m from the edge of aircraft trafficking areas, unless continuously watertight sleeved or provided for in an enclosed watertight (zero leakage) culvert, which daylights at the distance noted.

7.2.2.3 The gravel shoulder of the runways on dolomite area designation D3 sites shall slope away from the runway, for a distance of at least 5 m at a gradient steeper than the runway cross-fall, and shall be sealed with a suitable bituminous sealant to prevent ingress of stormwater.

8 Requirements for design and construction of buildings and structures on dolomite area designation D2 and D3 sites

8.1 General

8.1.1 All buildings and structures shall be designed and constructed in accordance with

a) SANS 10400-B and SANS 10400-H, to the extent that these standards are applicable;

b) relevant national or international standards; or

c) relevant codes of practice.

8.1.2 The earthworks immediately against buildings shall be shaped to fall in excess of 3 % over the first 3 m beyond the perimeter of buildings or structures, from where it should drain freely away. Apron slabs, where provided, should have the same fall.

8.1.3 Courtyards that require sub-floor level drainage systems should be avoided. All courtyards or spaces less than 4 m between buildings and structures shall be paved and appropriately drained.

8.2 Additional precautionary measures for design and construction of buildings and structures on dolomite area designation D3 sites

8.2.1 Buildings on dolomite area designation D3 sites in which people congregate, work or sleep shall be designed and constructed in such a manner that

a) a sinkhole or subsidence that has a high likelihood of occurring and that has the notional diameter of surface manifestation indicated in the geotechnical report within or adjacent to the footprint of such building, shall not result in the toppling or sliding failure of the building or a portion thereof into such a sinkhole or subsidence; and

b) there is sufficient period of structural stability to allow occupants to escape from such buildings after the occurrence of a sinkhole or subsidence within or adjacent to the footprint of the building;

NOTE 1 SANS 10400-H establishes requirements for the design of foundations for single-storey and double-storey domestic residences and dwelling houses.

NOTE 2 An engineered soil mattress (appropriately selected and graded material compacted to specified standards) should be used in areas of shallow dolomite bedrock due to the highly susceptible nature of the subsurface profile to erosion. This mattress has the dual purpose of improving founding conditions (negating differential movement) and reducing the permeability of the subsurface profile. The construction of the mattress involves the removal and replacement of unsuitable soil beneath and for 3 m beyond the periphery of buildings. The precise specification for the soil mattress as designed by the competent person(s) (geo-professional or engineer) will be dependent on bedrock depth and the nature of the local soil materials (see also SANS 10400-H).

8.2.2 The design of all buildings and structures shall be such that the occurrence of a sinkhole or subsidence with a high likelihood of occurring and that has the notional diameter of a sinkhole and the maximum diameter indicated in the geotechnical report within or adjacent to the footprint of such structure, does not present a safety or environmental hazard from the time of the occurrence of such an event to the time that the surrounding area can be secured and made safe.

8.2.3 Where guttering is not provided, impervious paved areas or apron slabs shall be provided within 3 m (or greater if deemed appropriate by the competent person (engineer)) of buildings or structures, runoff from which shall drain into lined channels feeding into a designed stormwater system or shall be spread as sheet flow. The paved areas or apron slabs shall include areas located below the drip line or the periphery of the building or structure that is subject to draining rainwater.

8.2.4 Stormwater upstream of buildings and structures shall be diverted away from the building or structure in such a manner that concentration of stormwater is minimized or the water is led into a designed stormwater drainage system.

8.2.5 Stormwater shall be controlled and disposed of using suitable means (e.g. by means of contouring and shaping) within 50 m of any element of any bridge or viaduct. All concentrated stormwater should be controlled and disposed of in suitable open stormwater channels.

8.2.6 No wet engineering service shall be constructed underground within 40 m of the foundation piers of any bridge or viaduct unless installed in welded polyethylene or polypropylene sleeves that allow for detection of leakage.

8.2.7 No liquid-retaining structures (excluding elevated storage facilities) shall be constructed within 40 m of the foundation piers of any bridge or viaduct.

8.2.8 Piles, where provided, shall be

a) proof-drilled for a minimum of 6 m of solid rock in order to confirm that the piles are socketed into pinnacles or bedrock, as opposed to floaters, and

b) capable of providing the necessary support despite the frictional drag and loss of lateral support within a sinkhole of the notional diameter given in the geotechnical report.

9 Requirements for swimming pools and liquid-retaining structures

9.1 General

9.1.1 Domestic swimming pools and liquid-retaining structures shall be watertight (zero leakage), constructed without any joints, and shall not be placed closer than 5 m from a building. Alternatively, the design of such pools shall be integrated into the rational design of the foundation of the residential structure.

9.1.2 Public swimming pools and other liquid-retaining structures shall be watertight (zero leakage) and should not be placed closer than 30 m from a building. The design of such structures shall be such that the joints

a) can readily be inspected for leakage;

b) remain watertight with a high degree of reliability; and

c) are able to accommodate all likely differential movements between the wall and floor panels without the joints losing their watertightness.

9.1.3 Backwash and other water from swimming pools shall discharge into drainage systems in a manner acceptable to the local authority.

9.1.4 No subsurface drainage, other than for leakage detection or prevention of floatation, shall be installed beneath swimming pools or liquid-retaining structures. If installed for leakage detection purposes, the liquid shall be capable of draining freely and without the need for pumping from the collector, which shall have a watertight floor installed.

APPENDIX B: EXERT FROM SANS1936-4

ISBN 978-0-626-

SANS 1936-4:2012

Edition 1

SOUTH AFRICAN NATIONAL STANDARD

Development of dolomite land

Part 4: Risk management

Published by SABS Standards Division
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SANS 1936-4:2012
Edition 1

Table of changes

Change No.	Date	Scope

Acknowledgement

The SABS Standards Division wishes to acknowledge the work of the National Department of Public Works, the South African Civil Engineering, Engineering Geological and Geotechnical Engineering Fraternity, and the National Dolomite Risk Management Working Committee established on instruction of the Cabinet Committee on Governance and Administration in developing this document.

Foreword

This South African standard was approved by National Committee SABS SC 59P, *Construction standards – Geotechnical standards*, in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

This document was published in xxxxxx 2012.

Reference is made in 3.5 to the "relevant national legislation". In South Africa this means the National Building Regulations and Building Standards Act, 1977 (Act No. 103 of 1977).

Reference is made in 3.21 to the "relevant national legislation". In South Africa this means the Provincial Government Act, 1961 (Act No. 32 of 1961).

Reference is made in 4.2.5.2 to the "relevant national department". In South Africa this means the Council for Geoscience.

Reference is made in table 1 to the "relevant national authority". In South Africa this means the Local Authority and the Department of Water Affairs.

Reference is made in A.4.1 to the "relevant national department. In South Africa this means the Department of Water Affairs and the Council for Geoscience.

SANS 1936 consists of the following parts, under the general title *Development of dolomite land:*

Part 1: General principles and requirements.

Part 2: Geotechnical investigations and determinations.

Part 3: Design and construction of buildings, structures and infrastructure.

Part 4: Risk management.

Annex A is for information only.

Introduction

The development of dolomite land continues to present a challenge in South Africa. While opportunities exist in the development of such land, the adverse effects relating to the formation of sinkholes and subsidences, whether naturally or as a result of the development, cannot be ignored.

In the absence of risk mitigation measures, sinkhole formation can result in loss of life. In addition, sinkholes and subsidences can cause severe damage to buildings and infrastructure and affect their serviceability.

Avoiding the hazard associated with dolomite land by prohibiting development of any kind on such land is not practical as between four and five million South Africans currently reside or work on such land. Twenty-five per cent of Gauteng, the commercial, mining and manufacturing centre of South Africa, is located on dolomite land. At the other end of the spectrum, undue acceptance of risk is not an option given the potential severity of the consequences and the Government's obligations in terms of the Bill of Rights. Systematic risk mitigation measures are therefore required.

South African research shows that 96 % of sinkholes and subsidences that have occurred to date were man-induced, generated by ingress of water from leaking water-bearing infrastructure, poor stormwater management, etc. or due to artificial lowering of the groundwater level. Consequently, intervention through an integrated, comprehensive and pro-active dolomite risk management strategy has the potential to reduce the incidences of ground instability events (sinkhole and subsidence formation) by reducing the likelihood of water gaining entry into the subsurface profile, or controlling de-watering/recharging of the dolomite aquifer.

The objective of SANS 1936 is to set requirements for the development of dolomite land in order to ensure that people live and work in an environment that is seen by society to be acceptably safe, where loss of assets is within tolerable limits, and where cost-effective and sustainable land usage is achieved.

Contents

Development of dolomite land

Part 4:
Risk management

1 Scope

This part of SANS 1936 establishes requirements for the development of appropriate dolomite risk management systems to reduce the risks associated with developments, and for the provision of infrastructure on dolomite land to acceptable limits.

NOTE 1 Risk management is recognized as an integral part of the management of developments on dolomite. It is an iterative process consisting of steps that, when undertaken in sequence, enable continual improvement in decision making.

NOTE 2 Dolomite risk management strategies encompass pro-active (if and where possible) policies and procedures which govern all facets of development on dolomite land, including planning, the design of structures, site development, design and installation of water-bearing infrastructure, maintenance of infrastructure, abstraction of water and enforcement of any other special precautions, restrictions and provisions deemed necessary in the geological setting. Suitable development and maintenance strategies in relation to dolomite risk avoid fruitless expenditure and protect life and the assets of the state, local authorities and private entities.

NOTE 3 SANS 1936-1 requires the owners of the infrastructure on parcels of land categorized as dolomite area designation D2, D3 and D4 sites or developments located on parcels of land categorized as C1 to C9, RL1 to RL3, RN1 to RN4 and RH 1 to RH3 to establish and implement appropriate dolomite risk management strategies in accordance with the principles and requirements of this part of SANS 1936 in order to mitigate the risks associated with the development of such land. SANS 1936-1 also establishes requirements for local authorities to establish, implement and maintain a dolomite risk management strategy to mitigate the risks associated with the developments on such land.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

SANS 1936-1:2012, *Development of dolomite land – Part 1: General principles and requirements.*

SANS 1936-2, *Development of dolomite land – Part 2: Geotechnical investigations and determinations.*

SANS 1936-3, *Development of dolomite land – Part 3: Design and construction of buildings, structures and infrastructure.*

SANS 2001-BE3, *Construction works – Part BE3: Repair of sinkholes and subsidences in dolomite land.*

3 Definitions

For the purposes of this document, the definitions in SANS 1936-1 (some of which are repeated for convenience) and the following apply.

3.1
acceptable
acceptable to the authority administering this part of SANS 1936, or to the parties concluding the purchase contract, as relevant

3.2
accounting authority
board or other controlling body in charge of an organization

3.3
accounting officer
chief executive officer or person in charge of an organization, or the person delegated in writing by such authority

3.4
appropriate measures
appropriate design measures taken to mitigate the negative impact of development on dolomite land

3.5
building control officer
person appointed or deemed to be appointed as building control officer by a local authority in terms of the relevant national legislation (see foreword)

3.6
competence level
level of competence
measure of proficiency for professionals engaged in work on dolomite land determined in terms of education, category of professional registration, experience, knowledge and recognition by the profession

NOTE The competence levels (1 to 4) are defined in annex A of SANS 1936-1:2012.

3.7
competent person
person who is qualified by virtue of his experience, qualifications, training and in-depth contextual knowledge of development on dolomite land to

a) plan and conduct geotechnical site investigations for the development of dolomite land, evaluate factual data, develop a geological model, derive interpretative data and formulate an opinion relating to the outcomes of such investigations;

b) develop and inspect for compliance, the necessary precautionary measures required on dolomite land to enable safe and sustainable developments to take place;

c) develop dolomite risk management strategies; or

d) investigate the cause of an event and participate in the development of the remedial measures required

3.8
dolomite land
land underlain by dolomite or limestone residuum or bedrock (or both), within the Malmani Subgroup and Campbell Rand Subgroup, typically at depths of no more than

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

b) 100 m in areas where de-watering has taken place or where the local authority has no jurisdiction or control over groundwater levels

NOTE For more information on dolomite land in South Africa, see annex B of SANS 1936-1:2012.

3.9
dolomite risk management strategy
DRMS
process of using scientific, planning, engineering and social processes, procedures and measures to manage an environmental hazard, and encompasses policies and procedures set in place to reduce the likelihood of events (sinkholes and subsidences) occurring on dolomite land

3.10
dolomite risk manager
DRM
person who is suitably qualified by virtue of experience, qualifications, training and in-depth knowledge of the scope and application of risk mitigation principles, and who may be an official of the local authority, organ of state, organization, utility company, etc. or otherwise be externally appointed to perform such functions and duties for and on behalf of such accountable organization

3.11
dwelling house
single dwelling unit and any garage and other domestic outbuildings thereto, situated on its own property

3.12
dwelling unit
unit containing one or more habitable rooms and provided with sanitation and cooking facilities

3.13
event
occurrence of a sinkhole or subsidence

3.14
hazard
source of potential harm

NOTE Hazard can be a risk source, i.e. an element which alone or in combination has the intrinsic potential to give rise to risk.

3.15
hazard rating
number of events that can potentially occur over a 20-year period due to development

NOTE A tolerable hazard rating is one that complies with the requirements for a tolerable hazard as defined in 3.35.

3.16
infrastructure
roads, railway lines, runways, liquid-retaining structures, stormwater systems, power lines, pipelines and associated structures; including water, sewer, fuel and gas lines, reservoirs, public swimming pools, attenuation and retention ponds for stormwater management, dams, reservoirs, artificial lakes or similar constructed works

3.17
inherent hazard
potential for an event (sinkhole or subsidence) to develop in a particular ground profile on dolomite land

3.18
inherent hazard class
IHC
classification system whereby a site is characterized in terms of eight standard inherent hazard classes, denoting the likelihood of an event (sinkhole or subsidence) occurring, as well as its predicted size (diameter)

NOTE Inherent hazard classes are defined in SANS 1936-2.

3.19
interconnected complex
complex of multiple dwelling units, such as terraced or multi-storey complexes, or cluster or retirement-village-type developments, where management of common property is usually exercised by (but is not limited to) a management body (organization)

3.20
likelihood
description of the probability or frequency of occurrence

3.21
local authority
any institution, council or statutory body contemplated in the relevant national legislation (see foreword)

3.22
maintenance
combination of all technical and associated administrative actions during the service life of an item to retain it in a state in which it can perform its required function

3.23
monitor
to check, supervise, observe critically and record the progress of an activity, action or system on a regular basis in order to identify change

NOTE The purpose of such monitoring is to pro-actively introduce intervention, if required.

3.24
monitoring area designation
descriptor of a delineated area of dolomite land based on selected risk reduction measures (and the frequency of such measures), which are based on factors including metastable subsurface conditions or latent sinkhole formation, highly susceptible conditions, poor subsurface conditions, previous sinkhole or subsidence formation, palaeo-sinkhole or palaeo-subsidence structures, geological contact areas, fault zones, anticipated ground settlement or ponding of water

3.25
organization
organ of state including a local municipality (authority), company, firm, enterprise or association, body corporate or other legal entity or part thereof, whether incorporated or not, public or private, that has its own purpose or function(s) and administration

3.26
original groundwater level
OWL
mean groundwater level in the dolomite aquifer, expressed as a depth below natural ground level or elevation above sea level (or both), about which the seasonal natural fluctuation occurs

3.27
parcel of land
tract of land, comprising one or more farm portions or properties registered in a deeds registry, identified for the purpose of development

3.28
return period
recurrence interval
estimate of the average interval of time between events of a certain size

3.29
risk
effect of uncertainty on objectives

NOTE Risk is often expressed in terms of a combination of the consequences of an event and the associated likelihood of occurrence.

3.30
risk management
logical and systematic iterative process of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk associated with any activity, function or process in a way that will enable losses to be minimized and opportunities to be maximized

3.31
risk reduction
selective application of suitable techniques and management principles to reduce the likelihood of an occurrence or its consequences (or both)

3.32
sinkhole
feature that occurs suddenly and manifests itself as a hole in the ground

3.33
subsidence
shallow, enclosed depression

NOTE Most South African literature previously used the term “doline” when referring to a subsidence as defined above. The use of the term “subsidence” is in line with international literature and practice.

3.34
suitable
capable of fulfilling or having fulfilled the intended function, or fit for its intended purpose

3.35
tolerable hazard
where the number of events experienced is less than 0,1 events per hectare per 20 years (preferably tending to zero per hectare), i.e. a return period of an event occurring on 1 ha of more than 200 years

NOTE Mitigating measures might need to be implemented in order to achieve a tolerable hazard rating.

3.36
wet service
engineered or constructed system that conveys fluids or gases from a point of bulk storage to an end user, or from a point of collection to a point of discharge into a natural watercourse, retention pond or sewerage treatment works, and that comprises equipment, pipes or channels and all related system elements, as well as their supporting structures

NOTE Wet services include water pipe networks, water-borne sewer pipe networks, stormwater conduits and channels, fuel pipelines and gas pipelines, and any other liquid-conveyance system.

4 Requirements for risk management

4.1 General

Risk management is commonly understood to be the culture, processes and structures used to effectively manage potential opportunities and adverse effects. In the context of dolomite land, the opportunities include the development potential of the land. The adverse effects include the hazard presented by the formation of sinkholes and subsidences, which result in potential harm or loss (or both).

Broadly speaking, risk on dolomite land can be managed by

a) placing restrictions on land use;

b) ensuring that the development is appropriate in relation to the inherent hazard;

c) establishing requirements for the management of surface drainage;

d) establishing requirements for the control of de-watering and monitoring of groundwater levels;

e) establishing requirements for the installation of below-ground infrastructure, particularly water-bearing services;

f) establishing requirements for the construction and maintenance of above-ground and below-ground water-bearing structures; and

g) establishing design requirements and procedures for buildings and infrastructure to allow, as a minimum, the safe evacuation of occupants and users in the event of a hazard occurring.

4.2 Generic requirements

4.2.1 General

4.2.1.1 Any organization that

a) owns or is responsible for the maintenance of

  1) buildings on dolomite land that is categorized for commercial and miscellaneous non-residential usage C1 to C8 and low-rise dwelling units RL1 to RL3 or high-rise dwelling units RH1 to RH3 in interconnected complexes as defined in SANS 1936-1; or

   2) infrastructure on dolomite land; or

   3) mines on dolomite land or over dolomite; or

b) develops parcels of dolomite land that are categorized as RN1 to RN3 in accordance with SANS 1936-1,

shall ensure compliance with the requirements in 4.2.1.2 to 4.2.1.11 (inclusive).

NOTE Categories of development C, RL and RH are as defined in SANS 1936-1.

4.2.1.2 A systematic dolomite risk management programme (see figure 1) shall be established, documented, implemented and maintained in accordance with this part of SANS 1936 to ensure that

a) the hazard rating remains tolerable; and

b) the current land usage does not compromise the future use of such land.

4.2.1.3 The performance of the dolomite risk management programme shall be regularly reported to the organization's management for review and performance improvement.

4.2.1.4 The occurrence of any sinkholes shall be dealt with in accordance with 4.2.3. to 4.2.5.

4.2.1.5 The responsibility, authority and lines of reporting of all persons who undertake any of the following shall be clearly stated in the DRMS:

a) identify, observe critically and record any incident or situation that occurs in a particular place during a particular interval of time, and which might impact upon the management of risk;

b) initiate action to mitigate risk;

c) initiate, recommend or suggest measures for mitigating risk;

d) direct, supervise or control activities associated with the treatment of hazards to ensure a tolerable hazard rating;

e) audit and record progress or verify the implementation of measures for mitigating risk; and

f) communicate and consult internally and externally regarding an identified source of potential harm or a situation with a potential to cause loss, as appropriate.

4.2.1.6 The organization shall identify resource requirements and provide suitable resources, including the assignment of suitably trained personnel to establish, document, implement and maintain the DRMS.

4.2.1.7 The organization shall identify the support or expertise (or both) available to assist those responsible for managing risks.

4.2.1.8 The organization's accounting officer or accounting authority shall ensure that a review of the dolomite risk management programme is carried out

a) internally at specified intervals not exceeding one year to ensure its continuing suitability and effectiveness in complying with the requirements of this part of SANS 1936, and the organization's stated risk management policy and objectives; and

b) externally every five years by an independent competent person (Competence Level 3 or 4 geo-professional as defined in annex A of SANS 1936-1:2012).

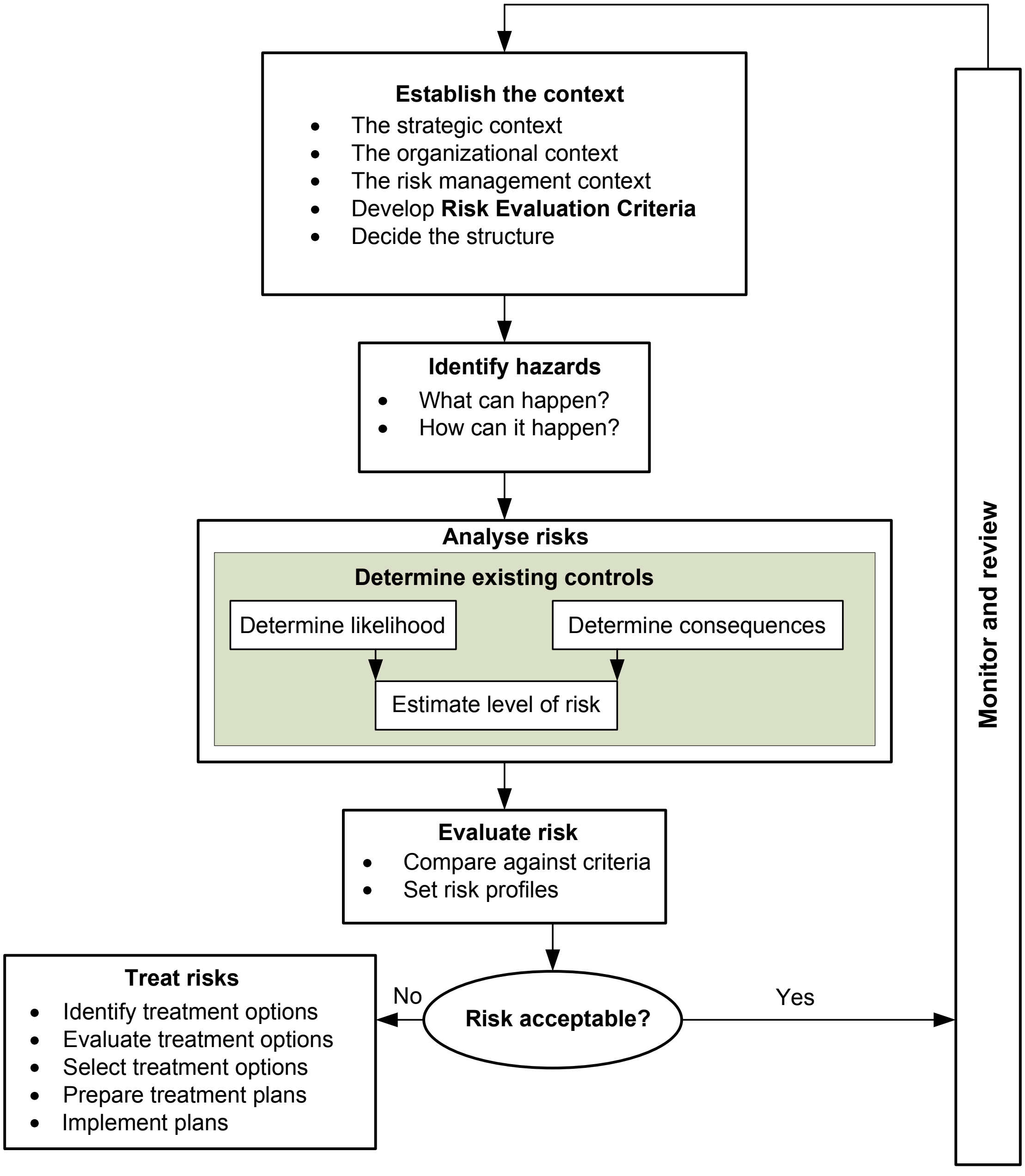

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Figure 1 — The generic process for the establishment and implementation of a Dolomite Risk Management Programme

4.2.1.9 The organization shall retain dated records of the reviews undertaken in terms of 4.2.1.8.

The Dolomite Risk Manager for each authority shall prepare an annual report for the local authority or management body of such authority, and the annual report shall be approved by the accounting officer.

4.2.1.10 The principle applied is that the level of dolomite risk management required shall be such that it results in a tolerable hazard rating. Failure to appropriately manage risk can result in the occurrence of sinkholes and subsidences.

NOTE 1 Sinkhole and subsidence events, apart from leading to loss of life or damage to property, can create negative public perceptions due to their alarming suddenness and scale. These public perceptions can have serious economic consequences, e.g. they can cause a loss in property value and a reluctance to develop areas.

NOTE 2 The average expected loss per annum = annual probability of failure × cost of the failure.

NOTE 3 Loss of human life is typically considered separately from cost.

4.2.1.11 Dolomite risk management shall be implemented at four levels, namely

a) local authority level;

b) bulk service provider, utility organization and government department level;

c) corporate ownership level; and

d) individual development level.

4.2.2 Measures for mitigating risk

4.2.2.1 Risk management strategies shall incorporate steps to pro-actively mitigate risk for the lifespan of the development.

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

NOTE Appropriate design, construction, monitoring and maintenance of any development is fundamental in order to ensure short-, medium- and long-term safety and stability. In addition to this, water precautionary measures, monitoring and maintenance should form part of ongoing risk management.

4.2.2.3 Measures for mitigating risk shall, as appropriate, include

a) placing restrictions on land use and development densities;

b) establishing requirements for the management of surface drainage;

c) establishing requirements for the management and monitoring of groundwater levels;

d) establishing suitable requirements for improving the effectiveness of measures taken in accordance with SANS 1936-3 to mitigate risk;

e) establishing suitable requirements for the maintenance of water-bearing structures and services and auditing measures taken in accordance with SANS 1936-3 to mitigate risk;

f) identification of all relevant risks that are to be managed for the development in perpetuity; and

g) establishing suitable risk management controls, processes, procedures and measures to manage the identified hazards.

4.2.3 Emergency reaction

Responsible persons shall be identified, notified in writing of their duties, and trained to respond to emergency situations as a result of sinkhole formation or a subsidence event.

NOTE Responsible persons should know, for example, where to cut off the water supply if piping is ruptured, and when and how to activate processes and procedures to safely evacuate affected areas or buildings and structures (or both).

4.2.4 Dealing with the occurrence of a sinkhole or subsidence

4.2.4.1 Despite every effort to minimize the occurrence of instability, sinkholes, subsidences, and severe cracking of structures or of the ground surface cannot be totally precluded. Treatment of dolomite-related instability shall consist of five components:

a) emergency reaction;

b) timely notification and reporting;

c) investigation of the incident;

d) rehabilitation; and

e) ongoing monitoring.

4.2.4.2 In the event of a dolomite-related instability event (severe distress, subsidence or sinkhole formation) occurring within the jurisdiction of a local authority, the accounting officer or owner, as relevant, shall report such occurrence to such authority without delay.

4.2.4.3 Where water-borne services have suffered damage, the local authority shall react without delay in accordance with the requirements of 4.4.4.

4.2.4.4 The accounting officer or owner shall appoint a competent person to investigate the occurrence of the formation of any sinkhole or subsidence. Such investigation shall initially focus on the cause and sphere of influence of a sinkhole or subsidence so that the detailed investigation and subsequent rehabilitation can take place without undue delay.

NOTE For safety reasons, a “waiting period” may be required for the stabilization of the sinkhole base or side walls to ensure the safety of people and equipment involved with specified rehabilitation works.

4.2.4.5 The competent person shall

a) investigate the occurrence and recommend the method by which the sinkhole shall be rehabilitated;

b) ensure that the rehabilitation intent is satisfied when the sinkhole within a development is repaired in accordance with the requirements of SANS 2001-BE3; and

c) monitor the rehabilitated sinkhole for a period of time, as specified by the competent person, to ensure the satisfactory performance of the repair.

4.2.5 Records

4.2.5.1 The accounting officer shall ensure that detailed records are kept of all dolomite-related instability events (severe occurrences, subsidence or sinkhole formation) including

a) date and time of occurrence;

b) location, preferably in terms of coordinates (the coordinate system used shall be stated);

c) plan extent (dimensions or diameter);

d) depth of feature (sinkhole or subsidence);

e) probable cause (if due to leakage from service, describe the type, diameter and material of construction of the service);

f) extent of damage to property, injury to persons or loss of life;

g) ground conditions in which event occurred; and

h) nature of remedial works.

4.2.5.2 The accounting officer shall ensure that all records of events (sinkholes or subsidences) are forwarded to the relevant national department (see foreword) on the prescribed form for the compilation of a national database.

4.2.5.3 Records shall be kept of all incidences of failure to comply with the requirements of the dolomite risk management strategy and of corrective action taken.

4.2.5.4 All records shall be kept at a place of systematic collective record keeping, such as the local authority, organ of state, organization, or utility company.

4.3 Minimum requirements for the preparation of a dolomite risk management strategy (DRMS)

4.3.1 A competent person shall compile a DRMS for the proposed development in accordance with the requirements of SANS 1936-2 that shall cover the full life of the development from inception to end of life and rehabilitation of the land. The DRMS shall result in perpetual, continuous, mandatory obligations on the organization to establish and keep in place processes and procedures to constructively avoid and, if necessary, to attend to ground movement events (sinkholes and subsidences) should these occur.

4.3.2 This DRMS shall address at least the following, as relevant,

a) hazard zoning and permissible land usage in accordance with the requirements of SANS 1936-2;

b) any restrictions that may be placed on developments for reasons of dolomite risk management, e.g. building line restrictions over rehabilitated sinkholes;

c) hazard zoning in relation to a site development plan;

d) hazard zoning in relation to the provision of infrastructure;

e) all precautionary measures required to support development for designated and potential future land uses;

f) stormwater management requirements taking account of

  1) topography of site (ground elevations);

  2) location of stormwater pipes and canals;

  3) points of discharge onto adjoining properties;

  4) areas of anticipated poor drainage;

  5) points of discharge into the local authority's stormwater system;

  6) design specifications;

  7) priority maintenance areas; and

  8) linkages to and integration with regional stormwater management arrangements;

g) the delineation of areas of restricted access, such as highly susceptible areas (high inherent hazard classes) or existing or latent sinkholes;

h) the identification and demarcation of monitoring areas in accordance with the monitoring area designations derived from tables 1 and 2, based on the inherent hazard class and knowledge of problems or sensitive areas that might exist;

i) groundwater monitoring requirements (see also annex A);

j) inspection schedule of water-bearing services, stormwater drainage systems and structures, as relevant, indicating the scope of inspection and monitoring activities;

k) maintenance programme which takes account of short-, medium- and long-term maintenance requirements in relation to the purpose, age and type of services and structures, prioritizing maintenance activities/duties in accordance with monitoring area designations, and establishes work procedures associated with the following:

  1) routine replacement of services;

  2) repair after damage;

  3) repair after instability; and

  4) responsibilities for undertaking repairs etc.;

l) emergency reaction programme, which includes emergency procedures;

m) dolomite risk awareness training programme;

n) recording of incidents, such as sinkhole or subsidence formation, damage, and actions taken in accordance with the requirements of 4.2.5;

o) arrangements to lodge records relating to routine service replacement and the repair of services after damage or instability, ground subsidence events and structural damage in an accessible database in accordance with the requirements of 4.2.5; and

p) the identification and contact details of all owners of registered wet or dry services in servitudes which are not maintained by the local authority.

4.3.3 The monitoring area designations shall be clearly demarcated on the site development plan.

Table 1 — Risk reduction measures component of the monitoring area designation

1	2
Monitoring area aesignation	**Risk reduction measures**
A	Visual inspections of ground, structures and above-ground infrastructure (e.g. roads, stormwater canals, ditches), surface runoff, obstructions to free flow, etc. Any evidence of cracking or ground settlement shall immediately be reported and investigated.
B	Visual inspection of stormwater system for blockages, leaks, misalignment and ponding. Any evidence of blockages, leaks, misalignment and ponding shall be reported and cleared immediately.
C	Testing of wet services for leaks. Any leaks shall be reported and repaired immediately.
D	Visual inspection of dry services sleeves, ducts, manholes and facility chambers for water ingress. Any water ingress shall be reported and point of entry repaired/blocked immediately.
E	Monitoring of structures and ground levels. Any evidence of sustained movement shall be reported and investigated.
F	Monitoring of the groundwater level. Evidence of lowering shall be reported to the relevant national authority (see foreword). On de-watered compartments, such as on the Far West Rand, monitoring of levels need only commence once de-watering has ceased and water level rise takes place.

NOTE 1 The monitoring area designation is described in terms of the risk reduction measures and the frequency of activities, as follows:

(Monitoring area designation from table 1) $^{\text{Frequency designation from table 2}}$ e.g. (A)$^{\text{DAILY}}$ or; (E)^{24}

NOTE 2 Measures associated with monitoring area designations A to D are intended to monitor, control and, therefore, prevent concentrated ingress of water.

NOTE 3 Measures associated with monitoring area designation E aim to monitor the potential effects of triggering mechanisms (i.e. water ingress or level drawdown) by means of, for example, detailed levelling.

NOTE 4 Measures associated with monitoring area designation F are intended to monitor groundwater level drawdown. In the case of compartments being de-watered, monitoring would track the pace of de-watering and signify a time period during which related ground movement events could take place.

Table 2 — Frequency designations component of the Monitoring Area Designation

1	2
Frequency designation	**Frequency of activities**
DAILY	Daily
WEEKLY	Weekly
1	Once a month
3	Quarterly
6	Bi-annually
12	Annually
24	Once every two years
0	No action required
TBD	To be determined

NOTE 1 The monitoring area designation is described in terms of the risk reduction measures and the frequency of activities, as follows:

$(\text{Monitoring area designation from table 1})^{\text{Frequency designation from table 2}}$ e.g. $(A)^{DAILY}$ or; $(E)^{24}$

NOTE 2 Areas with a D1 dolomite area designation in accordance with SANS 1936-1 require no monitoring from a dolomite risk management perspective. For example, areas on thick Karoo shale or younger intrusive rock may be designated as such, indicating that no action is required to lower the risk of dolomite-related instability.

NOTE 3 Areas with a D2 dolomite area designation are assigned a low priority and require basic monitoring and maintenance activities at long intervals. For example, areas on thick Karoo Supergroup cover (in excess of 30 m) overlying dolomite bedrock directly may be designated as $(ABC)^{24}(DE)^{0}$ indicating that all identified activities which control ingress of water need only be undertaken once every two years and detailed structure and groundwater level monitoring are not required.

However, where such strata overlie dolomite residuum below the original groundwater level, a designation of $(ABC)^{24}(E)^{1}$ might apply, indicating that monitoring activities which control the ingress of concentrated water remain necessary once every two years, but groundwater level monitoring is critical and should be undertaken once a month. Within an already de-watered compartment such monitoring should only commence once de-watering has ceased and the groundwater level is allowed to recover to a level where monitoring is possible.

NOTE 4 Areas with a D3 or D4 dolomite area designation are assigned high priority in terms of monitoring and maintenance should receive attention more frequently (see 3.17).

For example, an area in which various sinkholes have already been reported, a $(ABCD)^{3}(E)^{0}$ or even $(AB)^{DAILY}(D)^{3}(E)^{0}$ designation might apply, indicating the need to undertake activities controlling ingress of water quarterly, or even DAILY, with no action required to monitor the groundwater level.

NOTE 5 In areas where it was not possible to assign an inherent hazard class at the time of reporting, a difficulty presents itself in terms of the determination of monitoring and frequency thereof. In such a case, a designation $(ABCDE)^{TBD}$ should be assigned, indicating that these are yet to be determined as no data or insufficient data exist and the inherent hazard classification is undetermined.

4.3.4 A database, be it in electronic or hard copy format, is an important part of a DRMS as it allows for continuity of meaningful management. All information included in such database shall be suitably dated and correctly referenced geographically. It should, as a minimum (but not limited thereto), contain the following:

a) dolomite stability and soils investigation reports;

b) previous reports and correspondence, if still relevant;

c) a layout plan showing the position and unique identification of facilities, structures, buildings, and infrastructure;

d) a layout plan with location and details of services;

e) the dolomite hazard zoning map;

f) the stormwater layout plan;

g) records of inspection and testing;

h) records of maintenance (detailing when, where, how and what was undertaken);

i) a register of identified damaged structures, buildings, infrastructure and distressed land portions;

j) a record of sinkhole and subsidence occurrences (with rehabilitation taken);

k) monitoring designation areas (land portion with monitoring area designation)

l) groundwater monitoring records;

m) "no-go" and restricted access areas; and

n) photographic records.

NOTE The DRMS should be specific because, by the time that a Phase 2 investigation is undertaken, the development plan, as well as services designs, are formalized. Only under exceptional circumstances may the DRMS be generic and present the principles only, for example, commercial developments where individual properties are to be sold and developed at a later stage.

4.4 Specific requirements for local authorities

4.4.1 Regional dolomite risk management strategy

4.4.1.1 Every local authority with dolomite land in its area of jurisdiction shall establish and implement an active, regional DRMS that

a) is contained in a policy signed off by the accounting officer and which is accepted by the council of such authority;

b) addresses

  1) development planning and policy, and

  2) the dolomite risk management strategy applicable to all owned or managed land parcels (or both), buildings, structures and infrastructure, located in both new and existing townships;

c) focuses on land usage, buildings and infrastructure owned by or under the control of the local authority, and the day-to-day operations of the local authority that have a potential impact on dolomite risk;

d) facilitates the incorporation of any individual DRMS developed for new townships or developments (or both);

e) contains the local authority's policy and procedures on the enforcement of restrictions on developments in respect of complexes and individual erven, including suitable restrictions relating to swimming pools and other water-retaining amenities;

f) devises measures to prevent land invasion (unlawful occupation of land) on dolomite area designation D4 sites;

g) establishes procedures for dealing with situations where dolomite area designation D4 sites are illegally invaded or used as areas of temporary settlement;

h) permeates and assigns responsibilities to every decision-making level and decision-making process within the organizational structure of the local authority;

i) links the approval of new developments, where suitable, to the submission and implementation of a DRMS and the compliance certification by competent persons responsible for applying any aspect of SANS 1936-2 or SANS 1936-3, as relevant, on all township and construction drawings;

j) ensures that building control officers are notified of any specific construction requirements and precautionary measures relating to new and existing developments, as well as any restrictions relating to existing developments so that these requirements and measures can be effectively enforced;

k) is reported on annually by the DRM to the local authority and accepted by the local authority and signed by the accounting officer; and

l) provides for the monitoring of any large scale ground water abstraction or de-watering.

4.4.1.2 The regional DRMS shall be informed and supported by

a) the creation of a database system that stores relevant geotechnical and infrastructural data within the local authority's area of jurisdiction, and which preferably can be cross-referenced in an interactive manner;

   NOTE This requires that all database elements should be correctly referenced geographically in terms of all other elements as well as cadastral data and relevant topocadastral data.

b) the collating of all available dolomite hazard mapping in dolomite land falling within the local authority's area of jurisdiction;

c) an understanding and documenting or recording of the geological, geohydrological and hazard zoning of the dolomite land falling within the local authority's area of jurisdiction;

d) the dolomite hazard characterization of all developed areas in accordance with the requirements of SANS 1936-2;

e) the local authority's database system, be it in electronic or hard copy format, that as a minimum (but not limited to), shall contain the following:

   1) the local authority's area of jurisdiction;

   2) topocadastral information of the subregion;

   3) simplified geology of the region;

   4) gravity of the subregion (where available);

5) borehole and piezometer distribution;

6) geohydrological basin or aquifers (where available);

7) hydrological basins (where available);

8) records of sinkholes, subsidences, slump structures, etc.;

9) provisional hazard characterization of available data;

10) town layout superimposed on the hazard zoning;

11) infrastructure, including bulk and internal reticulation superimposed on the hazard zoning;

12) primary monitoring areas; and

13) “no-go” and restricted access areas.

4.4.1.3 The regional DRMS shall, as necessary, be complemented by

a) an emergency reaction plan that is integrated with the local authority’s disaster management plan;

b) a value assessment of the infrastructure in the context of risk and useful future lifespan;

c) the implementation of projects to rehabilitate life-threatening open sinkholes;

d) the introduction of a wet services master plan which defines the budget requirements of individually prioritized and targeted wet services upgrading projects in respect of dolomite land within a phased upgrading programme;

e) the systematic investigation of wet services for current serviceability state and appropriateness of design in accordance with SANS 1936-3, in relation to the assigned dolomite area designations in SANS 1936-1;

f) devising detailed upgrading programmes for services in key installations;

g) devising and implementing groundwater level monitoring programmes; and

h) devising and implementing precise monitoring programmes in problematic areas determined to be priority monitoring areas, including visual inspection and reporting programmes.

NOTE Managers of emergency services should be provided with information regarding dolomite land and briefed on the implications thereof. These managers and emergency services personnel should fully understand what a sinkhole is, the possible stages of development of a sinkhole, and how large an area to evacuate around a potential event.

4.4.2 Designation of a dolomite risk manager and officers

4.4.2.1 The accounting officer of the local authority shall designate, in writing, a risk manager to implement the local authority’s DRMS, and any other risk management officers that might be required to execute various tasks and report actions and outcomes, including the performance of maintenance checks on infrastructure, and the detection and repair or rectification of leaking services.

NOTE These officers may represent various departments that are affected by development on dolomite land, e.g. Water and Sanitation, Roads and Stormwater, Town Planning, Building Inspectorate, Disaster Management, Treasury.

4.4.2.2 Dolomite risk management officials shall submit written reports on their findings to the dolomite risk manager, who will ensure that all reports are entered into a database.

4.4.2.3 The dolomite risk manager shall be responsible for ensuring that risk management officers are conversant with all relevant procedures (including whom to contact and when evacuation is necessary in the event of a sinkhole formation), and that they understand their duties and what preventative and remedial actions need to be taken in any given circumstance.

4.4.3 Wet services in servitudes that are not maintained by the local authority

The local authority shall notify owners of registered wet or dry services in servitudes that are not maintained by the local authority, of the risk that such services pose to developments.

4.4.4 Maintenance and repair requirements for water-borne services

4.4.4.1 Leaks in sewer and water reticulation systems shall be repaired on a prioritized basis. In the case of water reticulation systems, the affected section of pipe shall be isolated (i.e. the flow of water stopped) within the following time periods:

a) 1 h for pipes of diameter 75 mm and greater; and

b) 1,5 h for pipes of diameter less than 75 mm;

measured from the time that a leak is reported.

4.4.4.2 Sewer mains shall be tested for watertightness (zero leakage)

a) on completion of any new installation, and

b) after repairs have been carried out,

before taking the system into service.

4.4.4.3 The stormwater and sewage systems shall be inspected to assess the integrity of the system, including checking for blockages and leaks at intervals that do not exceed two years, and repairs or cleaning shall be undertaken where required.

4.4.4.4 All bulk services (nominal diameter of 300 mm or more) shall be inspected for watertightness or blockages at intervals that do not exceed two years and shall be cleared or repaired, where required.

4.4.4.5 Officials who receive and log reports from the public on disruptions in services and similar incidents, shall be provided with contingency plans, including maps showing the monitoring areas, and shall be briefed on the implications of leaks and similar incidents in these areas. Special reporting procedures shall be established to ensure that maintenance teams are promptly advised of leaks and similar incidents in dolomite areas.

4.4.5 Requirements for building control officers

Building control officers within local authorities shall, once every two years, carry out visual inspections to ensure that water is not damming up on properties within their area of jurisdiction.

4.4.6 Notification to persons residing on dolomite land

4.4.6.1 The local authority shall inform residents of dwelling houses categorized as RN1 to RN4 and the responsible entity, organization or owner of such developments every two years in writing of the risks and their responsibilities in relation to

a) prompt repair of any detected leaking wet service on the occupied property;

b) refraining from making illegal connections and proceeding with the erection of new buildings and the installation of swimming pools without local authority permission;

c) ensuring that water does not dam up on their properties and that stormwater flow is not impeded or confined.

Whenever notified, building control officers shall inspect the influence and effect(s) of leaking wet services, stormwater ponding and possible ground instability events.

4.4.6.2 The local authority shall brief councillors whose wards fall on dolomite land, as well as leaders of community structures and organizations whose constituents reside on such land, of the potential risks and maintenance requirements for services in these areas and the necessity to report any leakages, blockages or ponding of water in these areas to designated council officials.

4.5 Specific requirements for new developments

4.5.1 The DRMS for a new development shall be prepared by a competent person who shall base the framework of such a strategy on the generic risk management strategy contained in the geotechnical report prepared in accordance with the requirements of SANS 1936-2. Such a strategy shall record the names, professional registration numbers and contact particulars of all competent persons appointed to ensure that the development proceeds in accordance with the requirements of SANS 1936-1 and SANS 1936-3, and that suitable construction procedures, methods, techniques and controls are exercised during construction.

4.5.2 The DRMS shall be reviewed and, if necessary, modified during and after construction.

4.5.3 The developer shall remain responsible for the implementation of the DRMS until such time that this responsibility can be transferred to and accepted in writing by the owner of the development or the accounting authority and, in the case of municipal services, the local authority.

4.5.4 The DRMS shall be submitted by the organization to the local authority, who shall systematically and safely keep and file such reports for auditing and reference purposes.

4.5.5 The successor in title from any transactions involving transfer of ownership or management (or both) of dolomite land, shall adhere to all requirements specified in the DRMS associated with that parcel of dolomite land.

4.6 Specific requirements for interconnected complexes

4.6.1 The accounting authority shall ensure that residents are aware of the risks associated with living on dolomite land, with particular reference to the impact of concentrated infiltration of surface water on the stability of the area. New residents shall be briefed on such risks within one month of moving into a complex.

4.6.2 The body corporate or any other organization that acts as a body corporate shall be responsible for implementing and undertaking a DRMS in its area of responsibility. The local authority shall be informed annually of the status of risk management in the complex.

Annex A

(informative)

Guidelines for monitoring of dolomite land

A.1 General

A.1.1 Monitoring comprises three activities:

a) infrastructure monitoring, which entails the inspection of water-bearing services, buildings, roads etc.;

b) ground surface monitoring, which entails the inspection of the ground surface as it is disturbed and affected by man's activities; and

c) groundwater level monitoring, which entails the measuring and recording of the dolomite groundwater level in boreholes together with, where appropriate, the record keeping of volumes of water pumped per unit measure of time for specific time periods.

A.1.2 Monitoring practices differ from site to site but might also differ from one monitoring designation area to another within a site. Some inherent hazard class areas might require more stringent precautionary measures and might, as such, need to be monitored on a more frequent basis. This monitoring may be monthly, quarterly, yearly or as designated by a competent person.

A.2 Infrastructure monitoring

A.2.1 The following infrastructure monitoring should be considered on

a) a seasonal interval basis:

   1) visual checks for debris in open stormwater channels at the start of the rainy season and after heavy storms;

   2) visual checks for water flowing out of stormwater manholes at the start of the rainy season and after heavy storms; and

   3) the examination of buildings for cracks at the start of the rainy season.

b) a short interval basis (weekly/monthly):

   1) visual checks for dripping taps and pressure valves outside;

   2) visual checks for damp or moss-grown areas;

   3) visual checks for debris in open stormwater channels;

   4) visual checks for water flowing out of sewer and stormwater manholes;

   5) the examination of buildings, paving, walls, etc. for cracks;

   6) visual check for over-wetting of gardens; and

   7) visual check for blocked drainage ports in garden walls.

c) an intermediate interval basis (four-monthly or six-monthly/annually):

   1) the activities in A.2.1(b); and

   2) the activities in A.2.2 and A.2.3.

d) a long interval basis (every two years):

   inspection to assess the integrity of the system including checking for blockages and leaks.

A.2.2 In certain instances, visual inspections might not be sufficient. It might be necessary to undertake air and water tests on wet services. Consideration should also be given to the design of the infrastructure so that these tests might be possible.

A.2.3 Many high density residential developments have only one water meter for the entire development, which does not allow for the testing of services of individual units and renders identifying the location of a leak difficult. In such circumstances, the following procedure is recommended:

a) Close all taps in the buildings or stopcocks controlling the water supply to buildings, if fitted, for 1 h and monitor the water meter, or monitor meter late at night when residents are normally asleep. A slow increase in the water meter reading or continued operation of the meter will indicate that there is a leakage between the meter and the taps or stopcocks.

b) Open all manholes on the property and observe if waste water or stormwater flows normally.

A.3 Ground surface monitoring

A.3.1 Ground surface monitoring should be undertaken visually on a regular basis by inspecting paved areas after rainstorms (ponding water indicates an area of differential settlement) and by looking for cracks in the ground or in lined and unlined channels.

A.3.2 In areas that have been rehabilitated after an event or where signs of ground settlement have been observed, visual inspections might not be sufficient and ground surface levelling by a surveyor might be required. The results of such levelling should be recorded and stored in the database. Suitable actions should be taken if the levelling surveys show signs of ongoing or accelerating movements.

A.4 Groundwater level monitoring

A.4.1 In certain townships, one or more boreholes should be equipped with the necessary equipment to measure fluctuations in groundwater level. The measurement of the groundwater level in such boreholes should be recorded by a designated person (appointed by the local authority) at predetermined intervals. The actual measurements should ultimately be reported to the relevant national department (see foreword).

A.4.2 The local authority should monitor the effect(s) of any large scale abstraction of ground water for irrigation, water supply or other purposes whether such abstraction is undertaken by the local authority or others. The local authority should also check that the necessary permits have been obtained for any new water abstraction schemes.

Bibliography

Standards

ISO 31000, *Risk management – Principles and guidelines.*

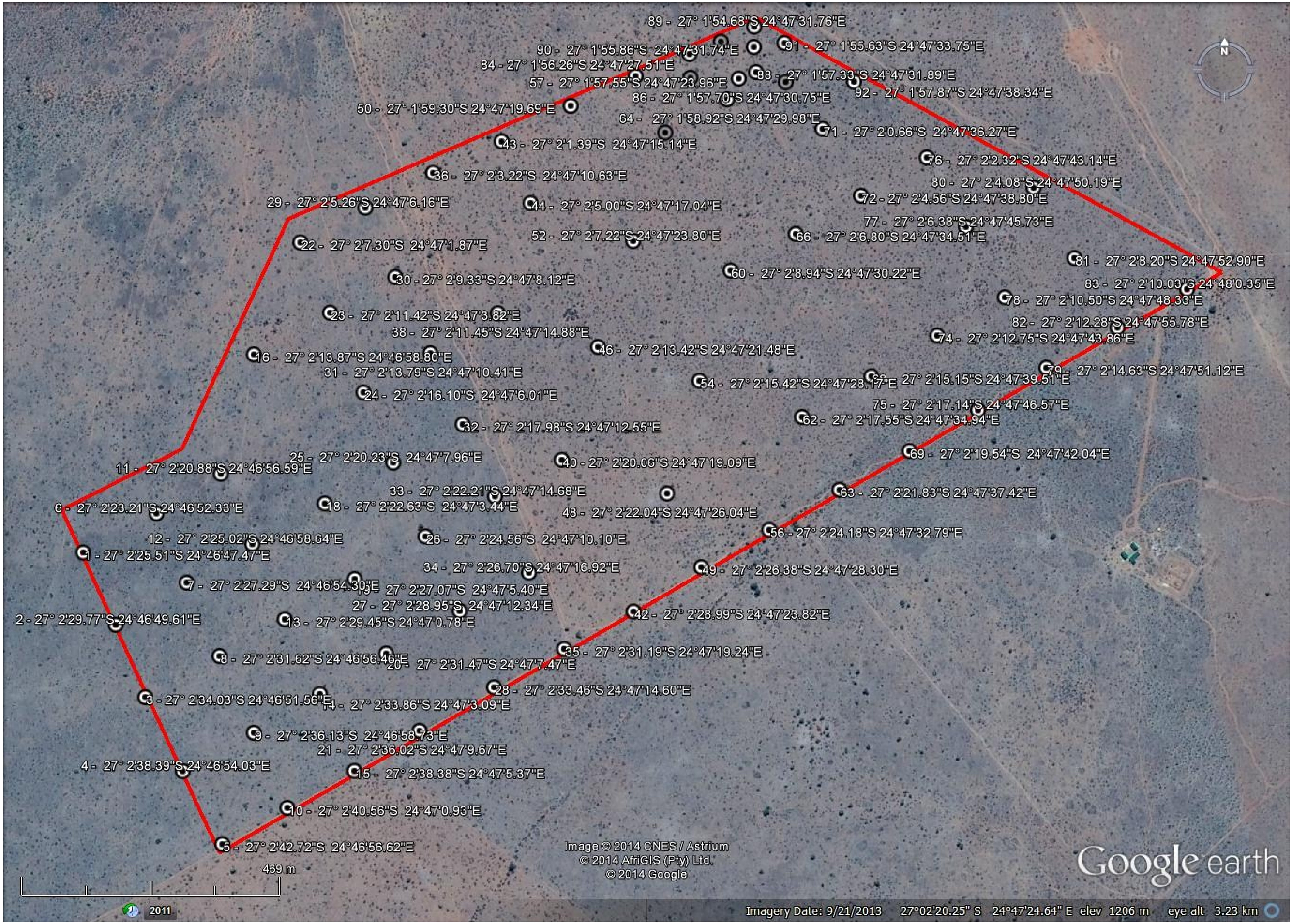
Other publications

Buttrick, D.B., Van Schalkwyk, A., Kleywegt, R.J. and Watermeyer, R.B., *Proposed method for dolomite land hazard and risk assessment in South Africa*. Journal of the South African Institution of Civil Engineering, 43(2) 2001.

Department of Public Works. *Appropriate development of infrastructure on Dolomite: Manual for Consultants – PW 344*. September 2010. Department of Public Works, Pretoria.

APPENDIX C: SITE PLANS

TEST PIT POSITIONS



BOREHOLE POSITIONS

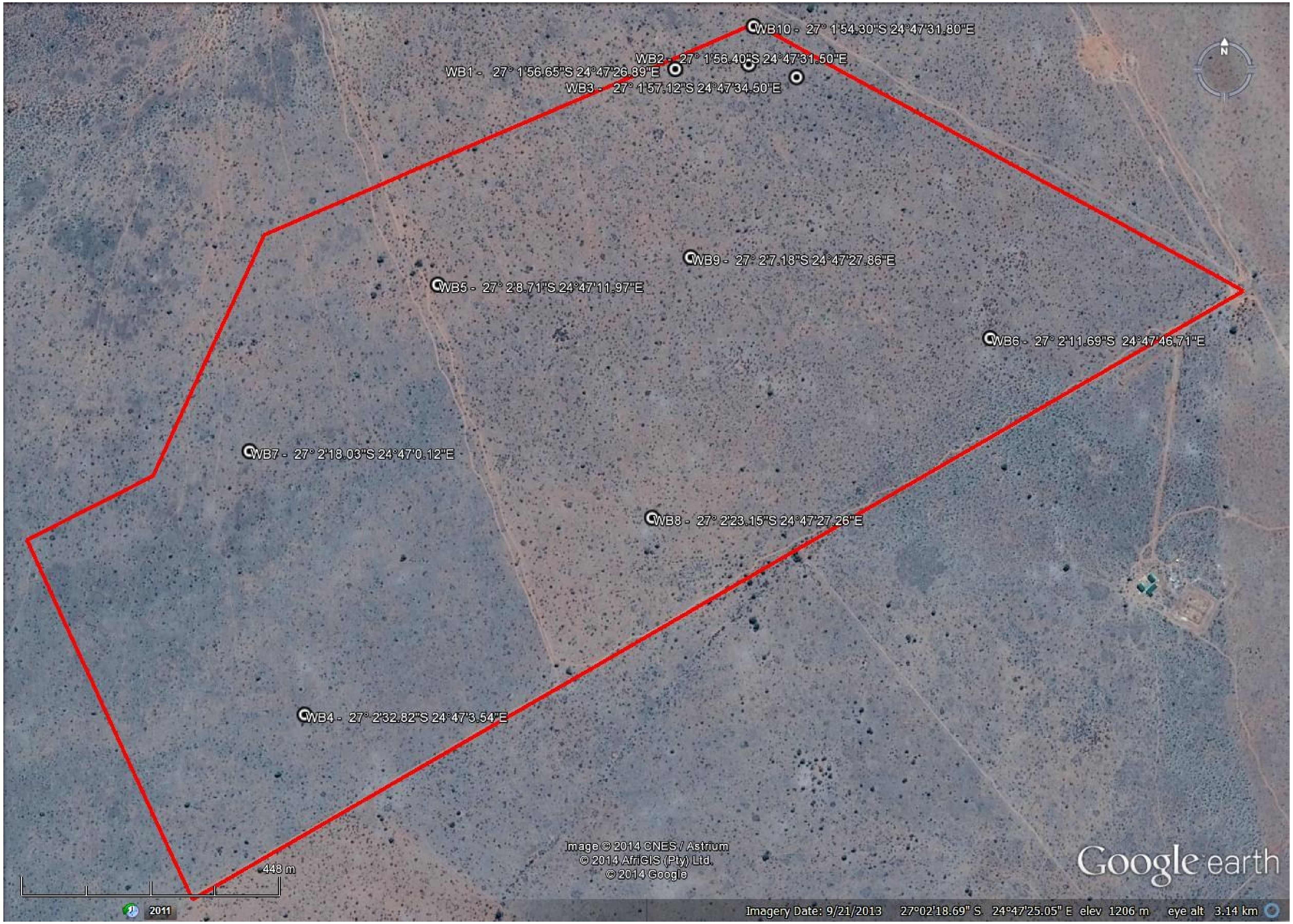


Image © 2014 CNES / Astrium
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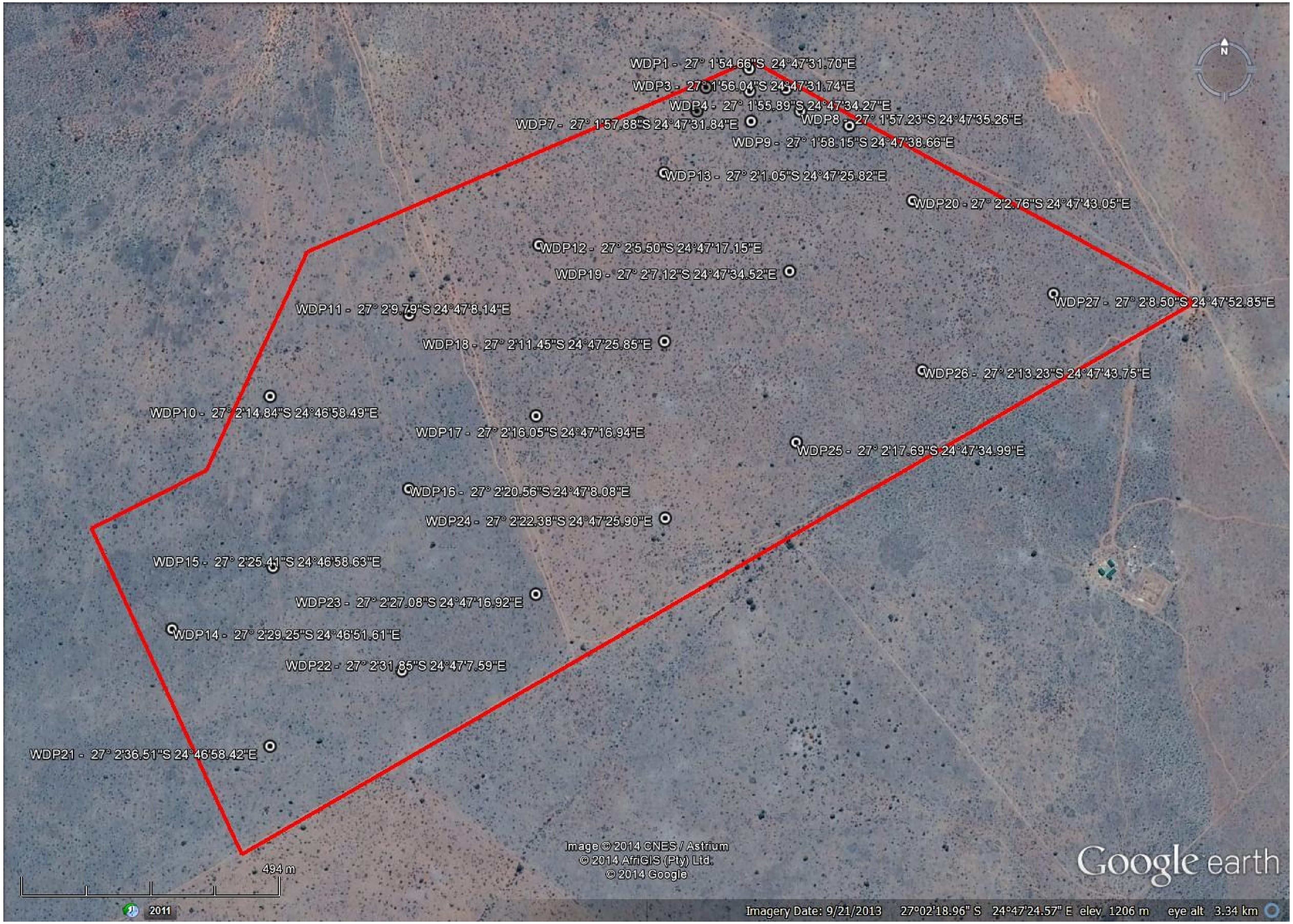
© 2014 Google

DPSH POSITIONS



ELECTRICAL RESISTIVITY POSITIONS

APPENDIX D: GRAVITY SURVEY DATA

ENGINEERING & EXPLORATION GEOPHYSICAL SERVICES cc
CK94/10526/23 Geophysical Contractors
[redacted]

170, Jakaranda Street,
Doringkloof,
Gauteng, 0157.
012 - 6673369 (tel.) 6675186(fax)
E-mail: eegs@iafrica.com

31st August, 2014

SMEC South Africa (Pty) Ltd,
P O Box 72927,
Lynwood Ridge, 0040.

Attn: Mr Ryan Freese

Dear Sir,

WATERLOO: GRAVITY SURVEY

A gravity survey has been carried out as part of dolomite-stability investigation of the power block for the Waterloo Wind Generation Plant, which lies approximately 10km to the south-east of Vryburg.

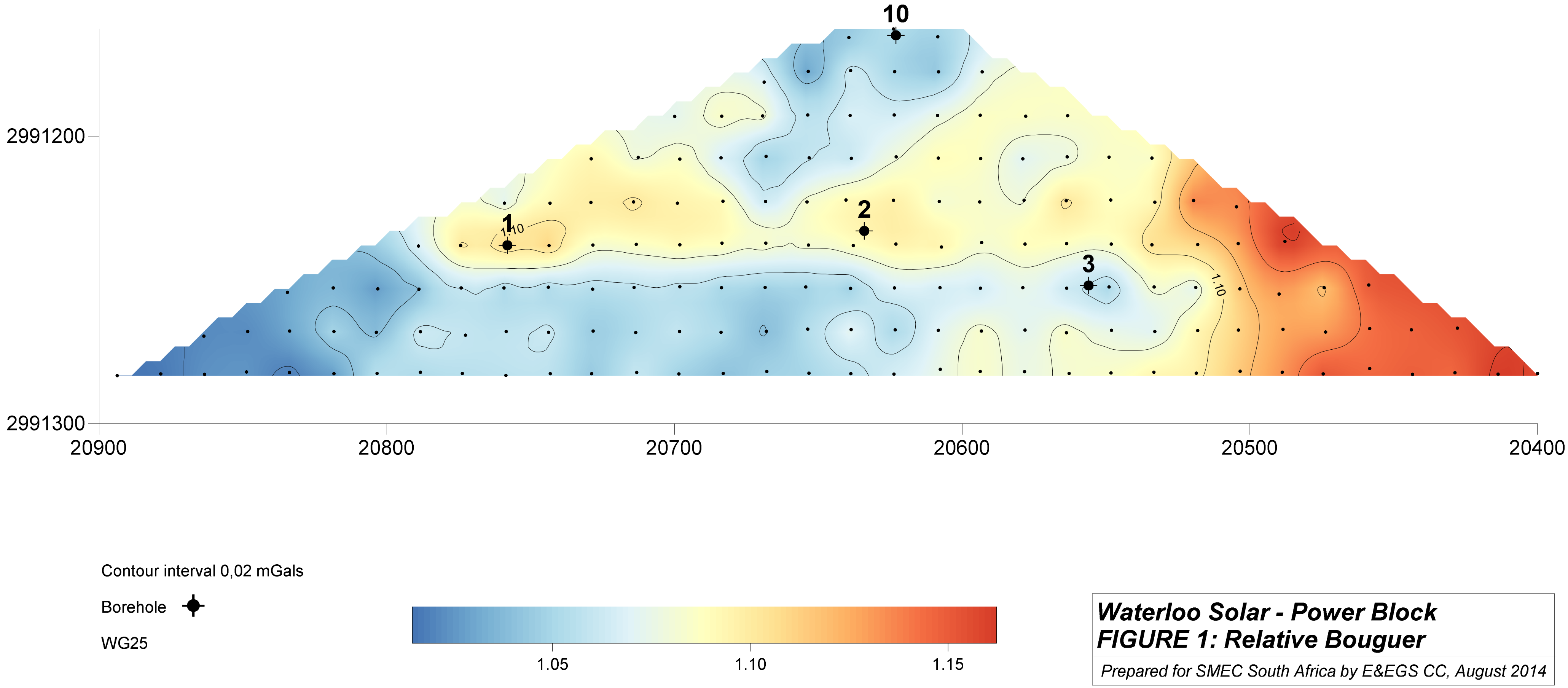
Fieldwork was performed at the end of July. The survey consisted of 162 stations set fifteen metres apart. Gravity was observed with a Scintrex Autograv and station coordinates were determined with Javad DGPS.

Data reduction followed the usual procedures associated with dolomite studies, the field data being reduced to relative Bouguer values using an elevation correction of 0,189 and a theoretical gravity gradient of 0,00065 mGals per metre. A plane was fitted to and removed from the Bouguer data to derive a provisional residual gravity map. The residual data set was later adjusted by a constant so that the maximum gravity values are just less than zero. The results of these operations are shown in Figures 1 and 2.

Residual gravity varies by 0,1 mGals, equivalent to a variation in bedrock depth of about five metres and suggesting that there is little variation in the depth to dolomite. Drilling intersected rock head from one to five metre below surface. The hole with the shallowest rock was not on a gravity high but a low but this is merely an indication that changes in bedrock depth occur at a finer interval than the spacing between gravity stations.

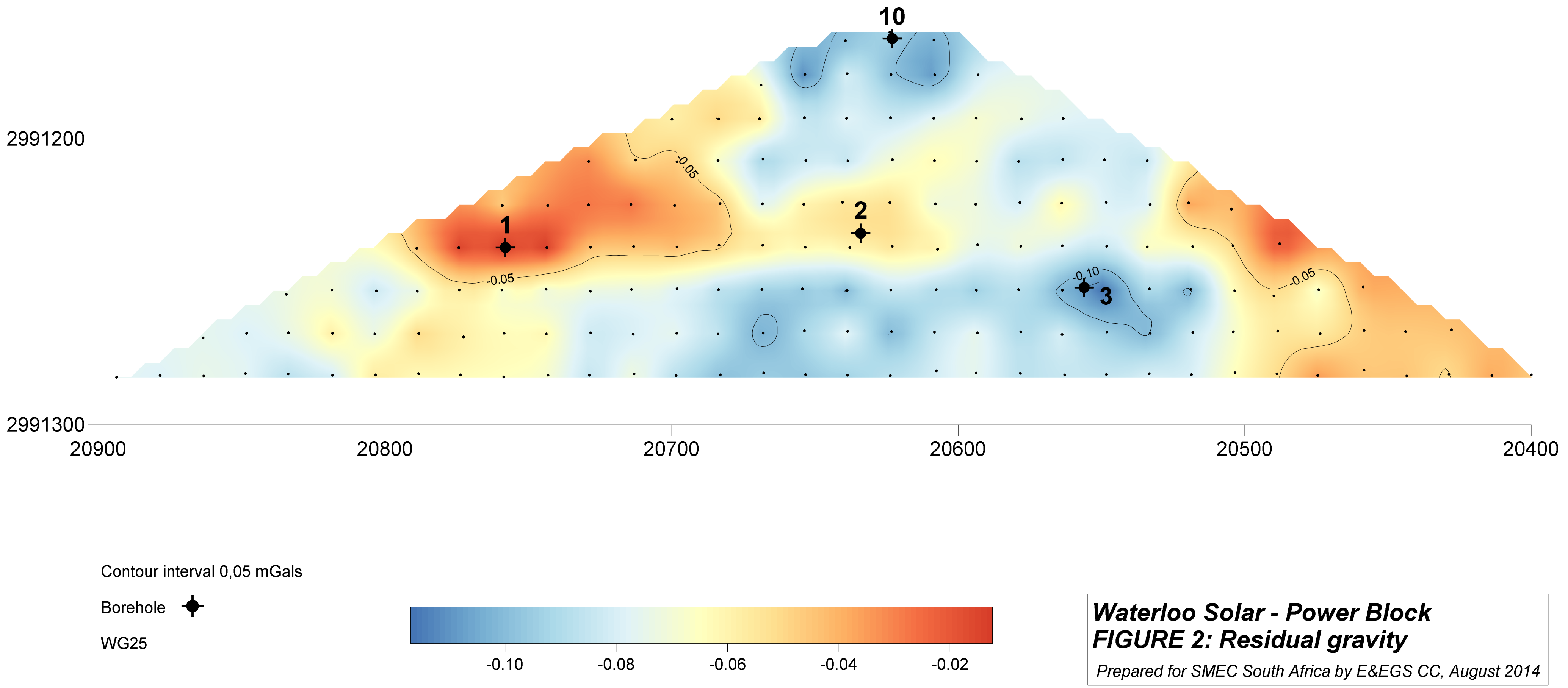
Yours sincerely,

R.W.Day. Pr.Sci.Nat.



Waterloo Solar - Power Block
FIGURE 1: Relative Bouguer

Prepared for SMEC South Africa by E&EGS CC, August 2014



Waterloo Solar - Power Block
FIGURE 2: Residual gravity

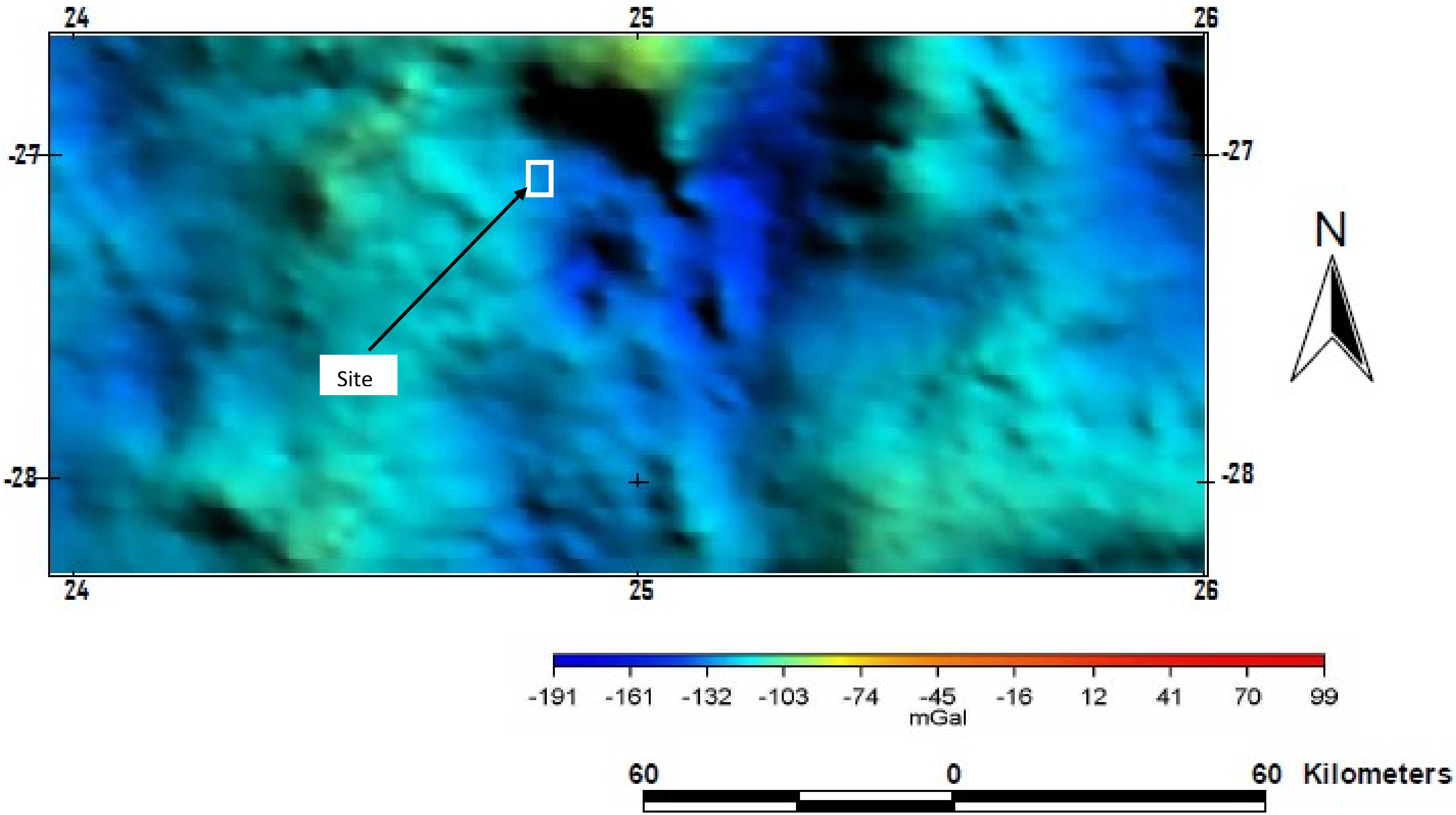
Prepared for SMEC South Africa by E&EGS CC, August 2014

Dolomite Stability Investigation

Waterloo Solar Plant, Waterloo Farm, Near Vryburg, North West Province

September 2014 REF: JG0002/02/8/2014/

Gravitational map of the 2724 Christiana Sheet

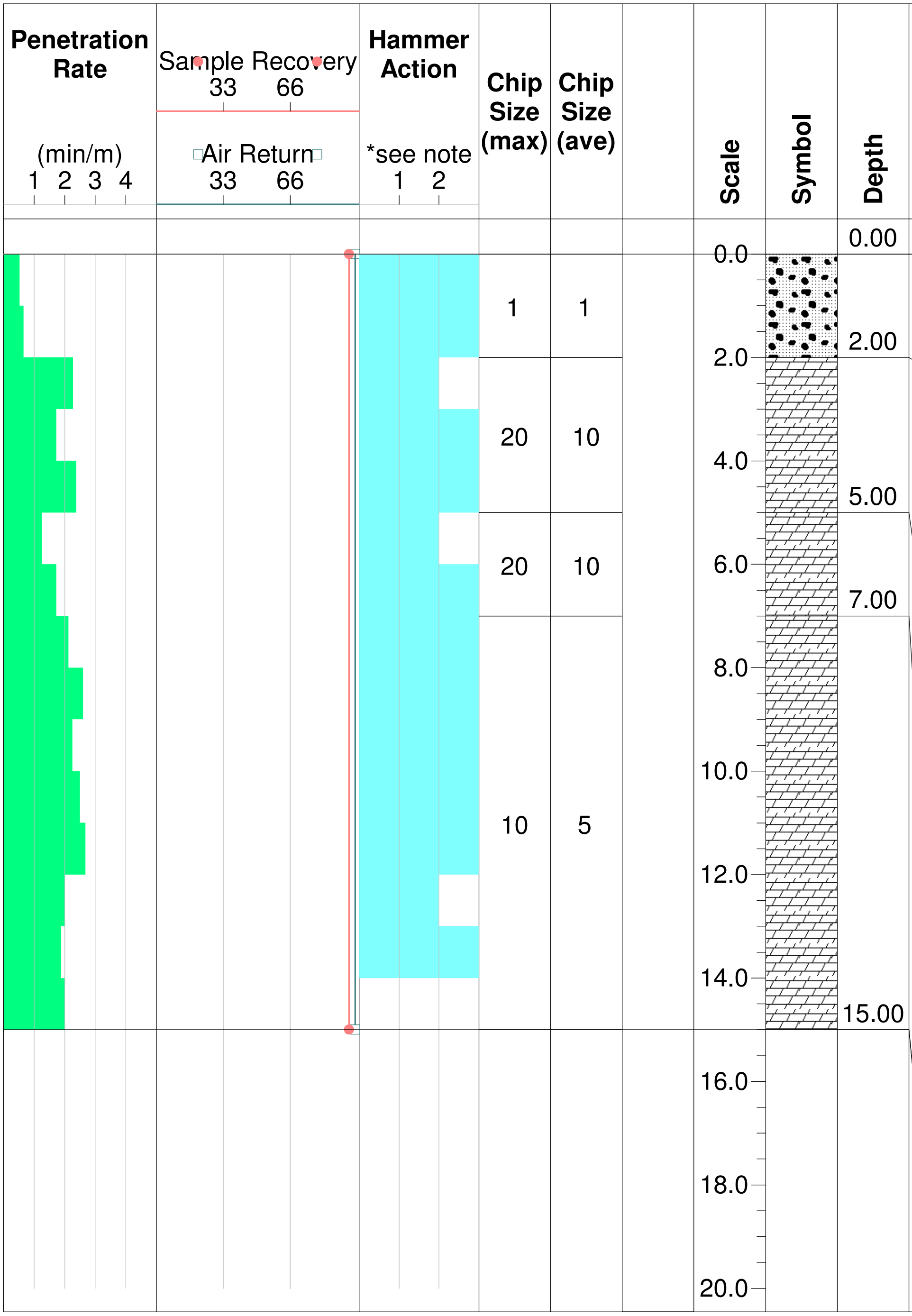


APPENDIX F: PERCUSSION BOREHOLE LOGS

PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB01
X COORD: E24°47'26.9"
Y COORD: S 27° 2'25.51"
ELEVATION:
PAGE 1 of 1



Depth	Chip Size (max)	Chip Size (ave)	Description
0.00			Ground Surface
2.00	1	1	**Sandy GRAVEL** Orange brown, predominantly medium to coarse gravels, with minor cobbles, blocky, sub-rounded.
5.00	20	10	**Hard rock DOLOMITE** Dark grey to black, stained red on joints, medium to slightly weathered, dolomite with traces of chert, shale and quartzite, fine grained, angular, platy or bladded. Matrix=15%; Grey silty sand, rock flour. Interpreted as medium to slightly weathered dolomite bedrock. Drill penetration indicates hard rock.
7.00	20	10	**Hard rock DOLOMITE** Dark grey to black, stained red on joints, medium to slightly weathered dolomite with traces of shale and quartzite, with minor chert, fine grained, angular, platy to bladed. Matrix=15%; Light brown, silty sand with weathred zones or residual soil contamination. Interpreted as medium to slightly weathered dolomite bedrock.
15.00	10	5	**Very hard rock, DOLOMITE** Dark grey to black, unweathered, dolomite with traces of shale, chert, fine grained, angular, platy to bladed. Matrix=30-40%; Gravelly silty sand, rock flour. Interpreted as unweathered dolomite bedrock. Drill penetration indicates very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular No water struck
2: No BH collapse
3: Sample taken every 1.0m
4:
5:
6:

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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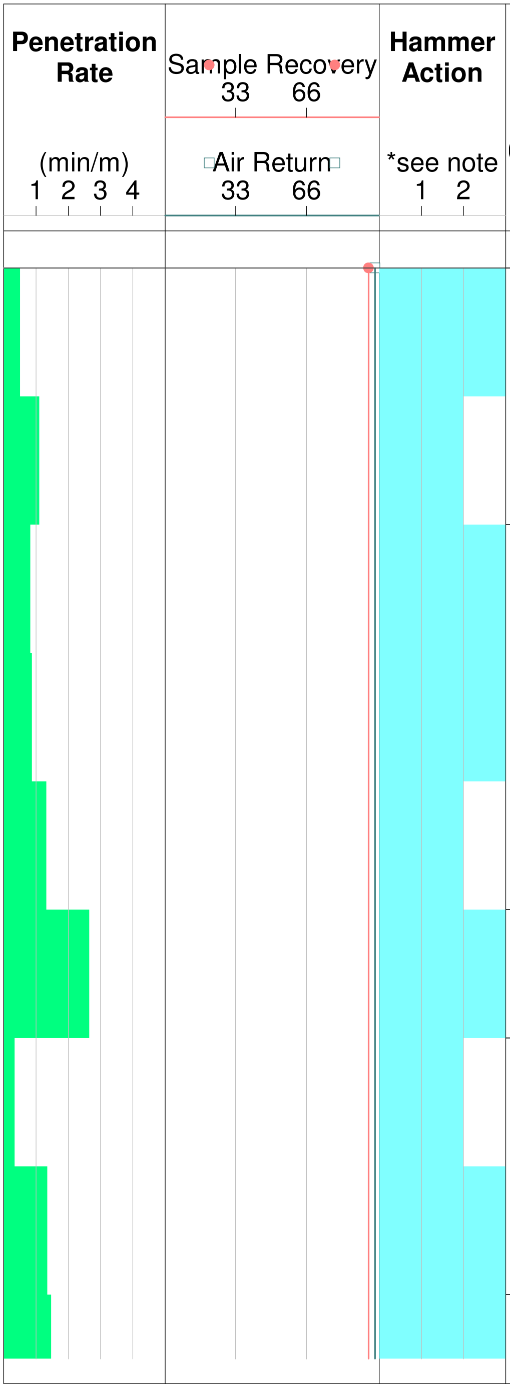
Template: SMEC P02

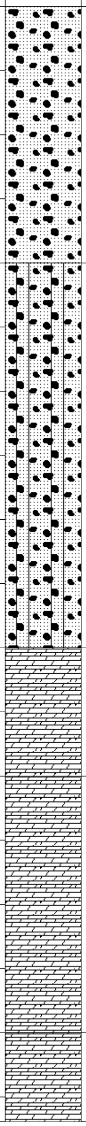
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB02
X COORD: E24°47'31.4"
Y COORD: S27° 01'56.5"
ELEVATION:
PAGE 1 of 3



Scale	Depth	Chip Size (max)	Chip Size (ave)
0.0	0.00	70	20
2.0	2.00	40	20
4.0	5.00	20	10
6.0	6.00	40	10
8.0	8.00	20	5



Description

Ground Surface

Silty sandy GRAVEL
Orange brown, mottled black, speckled grey, predominatly course gravel.
Gravels; Light brown to grey, highly to medium weathered dolomite and quartzite, traces of tillite and shale, soft rock, blocky, moderately to slightly weathered dolomite, fine grained, angular, platy to bladed interpreted as residual dolomite soils wih dolomite boulders.

Soft rock DOLOMITE
Dark brown, mottled grey, residual dolomite.
Gravels; Llight to dark grey, highly to slightly weathered dolomite, with traces of chert, fine grained, angular, platy to bladed.
Interpreted as medium to slightly weathered dolomite bedrock, interlayered with residual dolomite soils.
Drill penetration indicates variable hardness, generally soft rock.

Hard rock DOLOMITE
Light grey, slightly to medium weathered, dolomite with traces of chert, fine grained, angular, platy to bladed.
Abudant to equal amounts matrix; light grey, silty sand, rock flour.
Interpreted as medium to slightly weathered dolomite bedrock.
Drill penetration indicates hard rock.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular No water struck.
2: No BH collapse.
3: Sample taken every 1.0m
4:
5:
6:

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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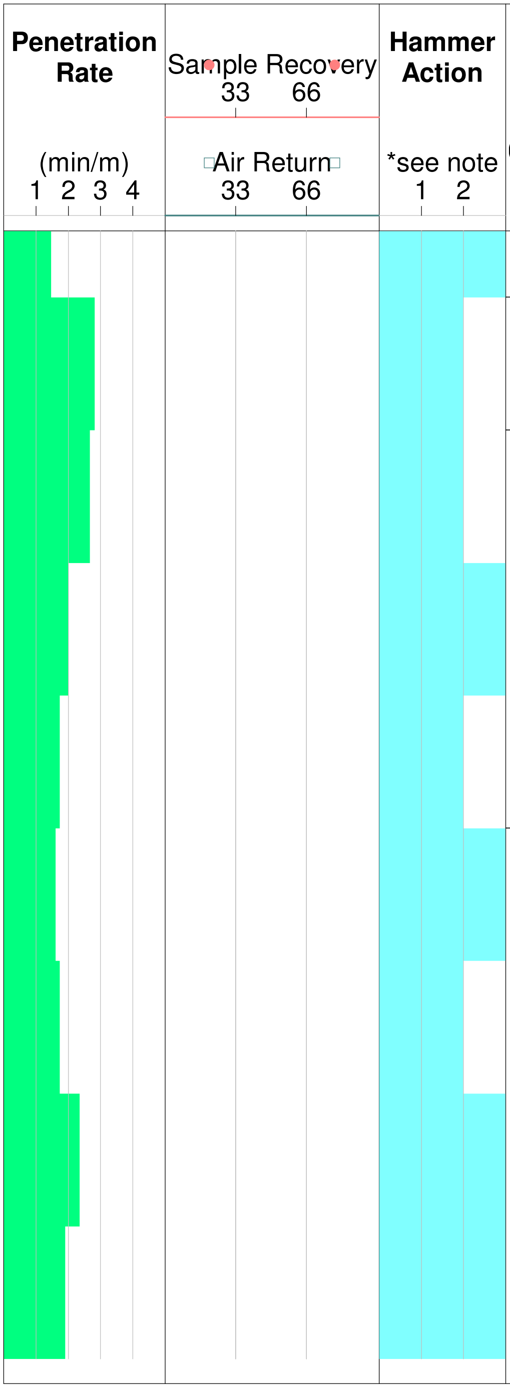
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB02
X COORD: E24°47'31.4"
Y COORD: S27° 01'56.5"
ELEVATION:
PAGE 2 of 3



Chip Size (max)	Chip Size (ave)
15	5
10	5
20	5

Scale: 10.0, 12.0, 14.0, 16.0

Symbol

Depth: 9.00, 10.00, 12.00

Description

Soft rock DOLOMITE
Dark brown, mottled grey, residual dolomite.
Gravels, Llight to dark grey, highly to slightly weathered dolomite, with traces of chert, fine grained, angular, platy to bladed.
Interpreted as medium to slightly weathered dolomite bedrock, interlayered with residual dolomite soils.
Drill penetration indicates variable hardness, generally soft rock.

Hard rock DOLOMITE
Dark grey, unweathered, dolomite, fine grained, angular, platy to bladed.
Traces of matrix; light grey, silty sand, rock flour.
Interpreted as unweathered dolomite bedrock.
Drill penetration indicates hard rock.

Hard rock DOLOMITE
Dark grey, mottled black, unweathered dolomite, fine grained, angular, platy to bladed.
Traces of matrix; Grey, silty sand, rock flour.
Interpreted as unweathered dolomite bedrock.
Drill penetration indicates hard rock.

Hard rock DOLOMITE
Dark grey, mottled black, unweathered dolomite, fine grained, angular, platy to bladed.
Equal amount matrix; Grey, sandy silt, rock flour.
Interpreted as unweathered dolomite bedrock.
Drill penetration indicates hard rock.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular No water struck.
2: No BH collapse.
3: Sample taken every 1.0m
4:
5:
6:

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
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LOGGED BY: R.FREESE
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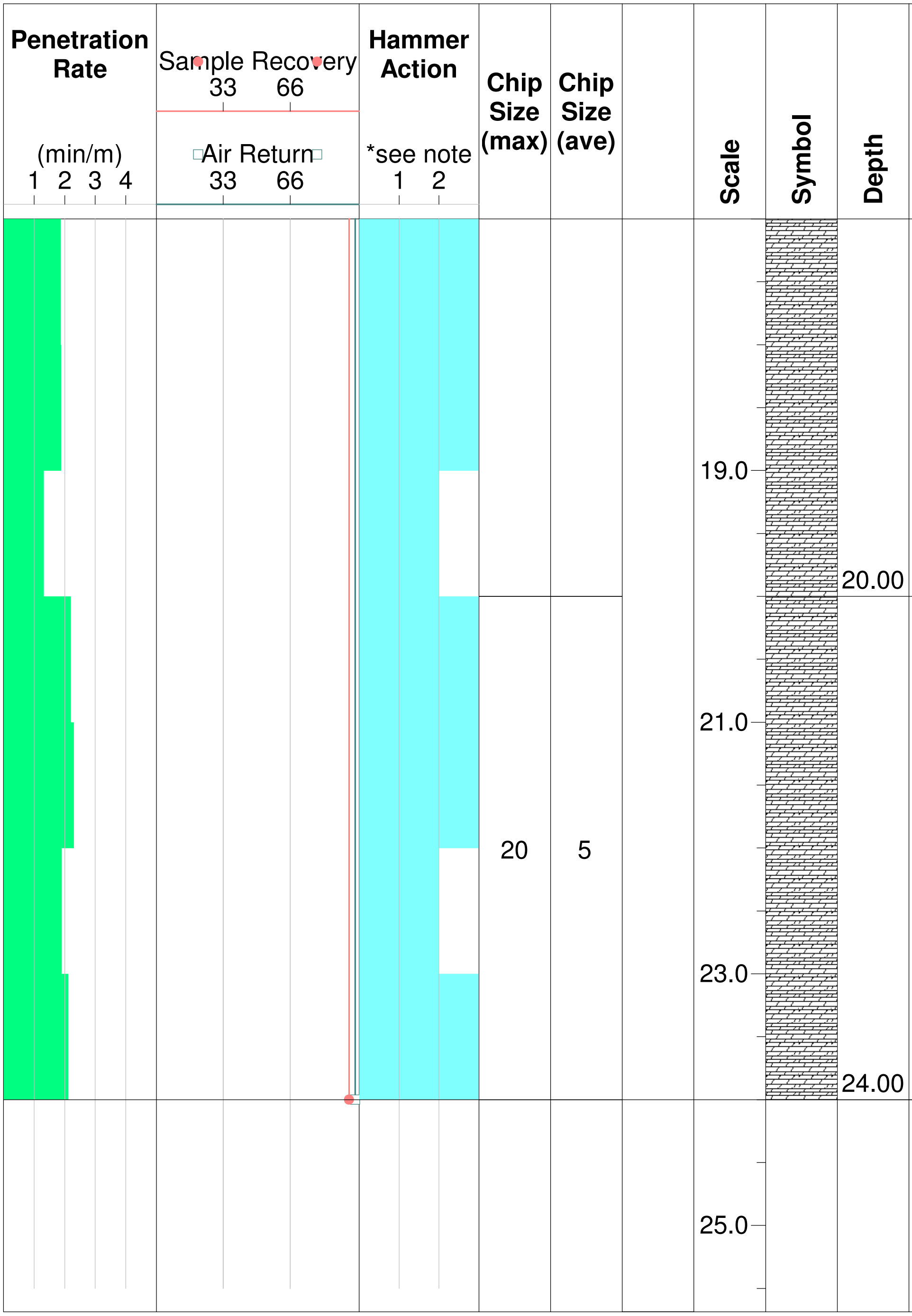
Template: SMEC P02

PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB02
X COORD: E24°47'31.4"
Y COORD: S27° 01'56.5"
ELEVATION:
PAGE 3 of 3



Chip Size (max)	Chip Size (ave)	Depth	Description
		20.00	**Hard rock DOLOMITE** Dark grey to black, mottled light grey to white, angular, unweathered andesite, fined grained, platy. Equal amounts matrix, light grey, sandy silt, rock flour. Interpreted as unweathered dolomite bedrock. Drill penetration indicates hard rock.
20	5	24.00	**Hard rock DOLOMITE** Dark brown, mottled grey, residual dolomite. Gravels,Llight to dark grey, highly to slightly weathered dolomite, with traces of chert, fine grained, angular, platy to bladed. Matrix; Light grey, silty sand, rock flour. Interpreted as medium to slightly weathered dolomite bedrock, interlayred with residual dolomite soils. Drill penetration indicates variable hardness, generally soft rock.
			End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular No water struck.
2: No BH collapse.
3: Sample taken every 1.0m
4:
5:
6:

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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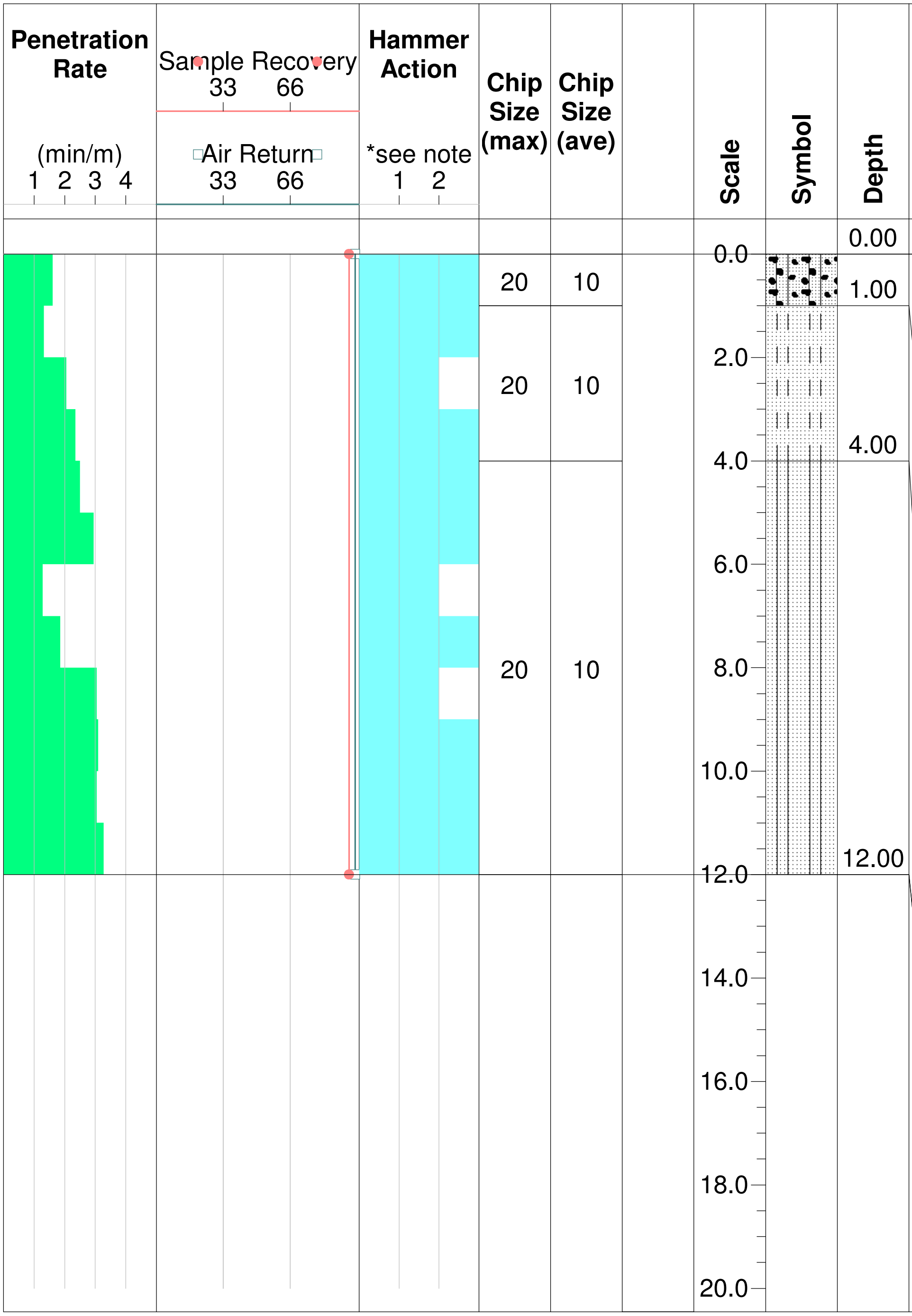
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB03
X COORD: E24°24'34.2"
Y COORD: S27° 01'57.3"
ELEVATION:
PAGE 1 of 1



Chip Size (max)	Chip Size (ave)	Depth
		0.00
20	10	1.00
20	10	4.00
20	10	12.00

Description

Ground Surface

Silty sandy GRAVEL
Orange brown, mottled light grey.
Gravel 1; soft rock, blocky dolomite quartzite.
Gravel 2; angular, platy to bladed, dolomite and chert, medium weathered, fine grained, medium hard rock. Interpreted as residual dolomite chert soils and dolomite boulders.

Hard rock DOLOMITE
Grey, mottled brown/red, medium to slightly weathered dolomite and chert, fine grained, angular, platy to bladed.
Minor matrix; orange brown, residual dolomite.
Interpreted as slightly to medium weathered dolomite bedrock.
Drill penetration indicates hard rock

Very hard rock DOLOMITE
Dark grey to mottled light grey, unweathered dolomite and chert.
Minor matrix, fine grained, platy to bladed.
Interpreted as unweathered dolomite chert bedrock with traces of shale.
Layer of minor orange brown silty SAND matrix at 7.0-9.0m.
Drill penetration indicates very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6:

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
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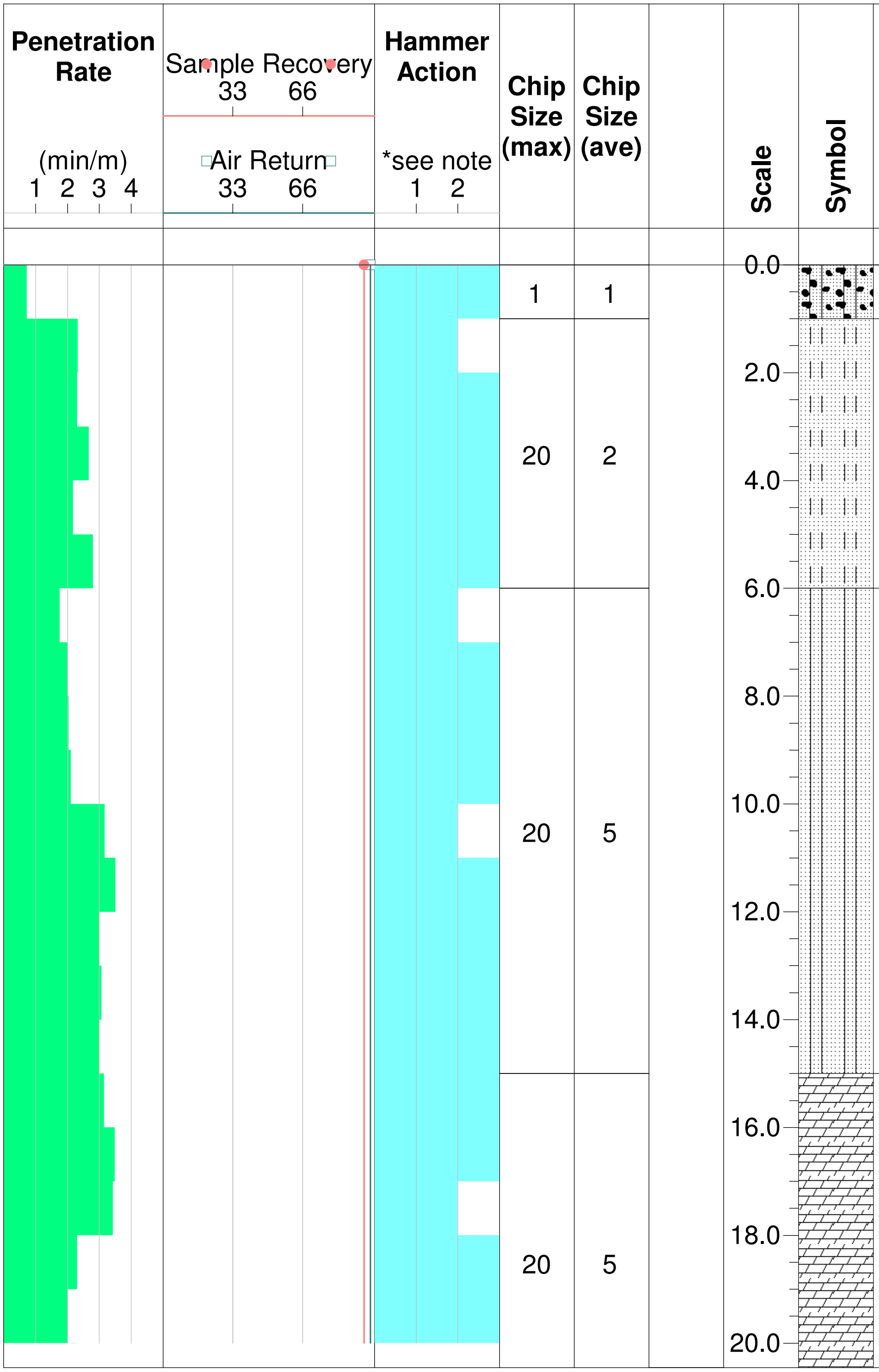
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB04
X COORD: E24°47'03.3"
Y COORD: S27° 02'33.0"
ELEVATION:
PAGE 1 of 3



Chip Size (max)	Chip Size (ave)	Depth	Description
		0.00	Ground Surface
1	1	1.00	**GRAVELS and COBBLES** Orange brown, mottled white, medium to completely weathered dolomite, chert and quartzite, sub-rounded. Minor matrix; orange brown silty sand, residual dolomite, chert and quartzite.
20	2	6.00	**Hard rock DOLOMITE** Light to dark grey, slightly to medium weathered dolomite and chert, with minor quartzite, angular, medium to coarse gravel. Matrix; abudant, medium to slightly weathered dolomite, rock flour. Interpreted as hard rock dolomite bedrock. Drill response indicates hard rock dolomite.
20	5	15.00	**Hard rock DOLOMITE** Dark grey, mottled light grey, unweathered dolomite and chert, with minor quartzite, angular. Traces of matrix; light grey, silty sand, fock flour. Interpreted as unweathered dolomite chert bedrock with quartzite lenses.
20	5		**Very hard rock DOLOMITE** Dark grey, mottled white and light grey, unweathered dolomite, chert and quartzite, angular. Minor matrix grey, silty sand, rock flour.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
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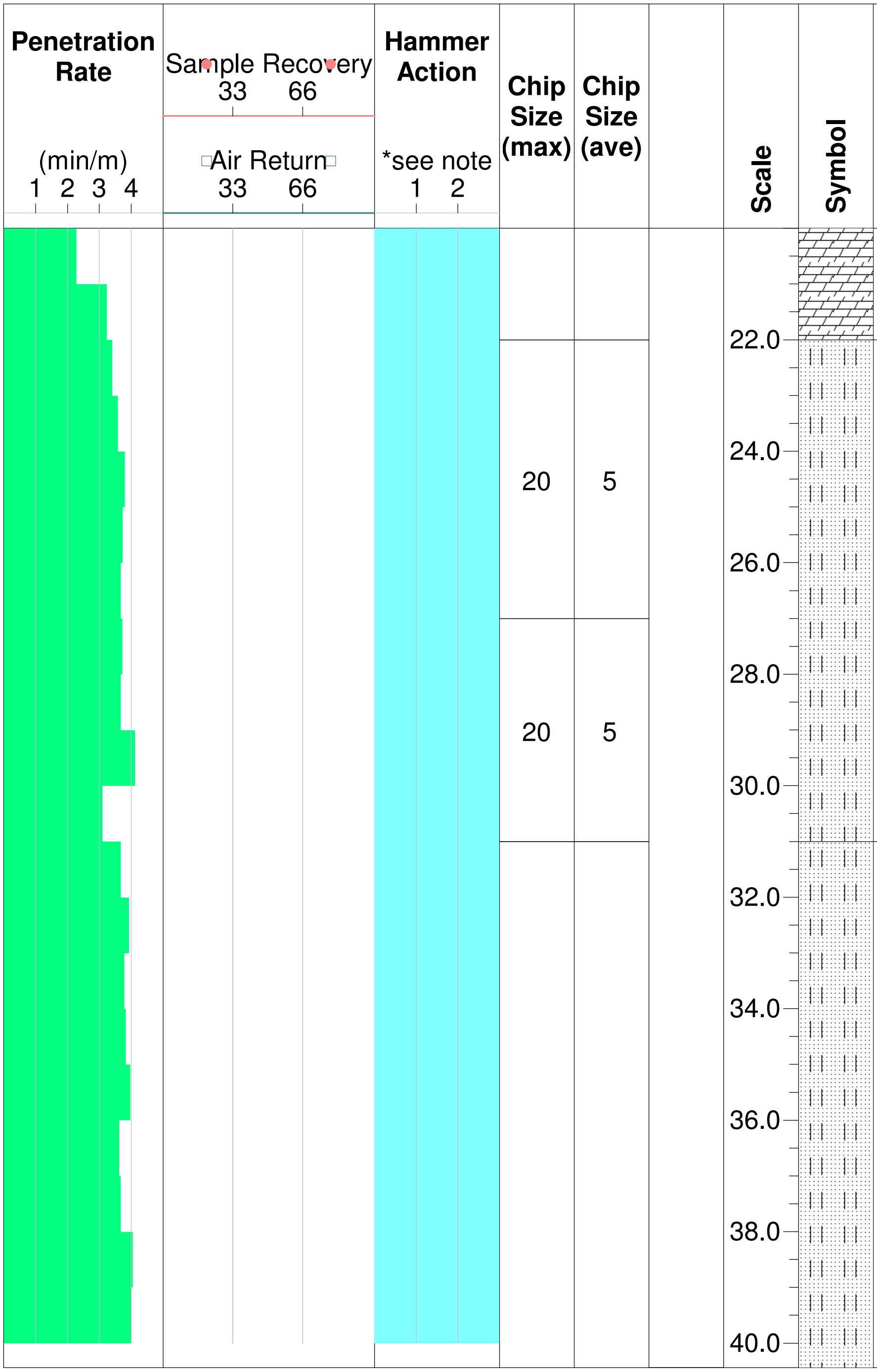
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB04
X COORD: E24°47'03.3"
Y COORD: S27° 02'33.0"
ELEVATION:
PAGE 2 of 3



Chip Size (max)	Chip Size (ave)	Depth	Description
		22.00	
20	5		**Hard rock DOLOMITE** Dark grey, unweathered dolomite chert, medium to very coarse grained, angular. Minor matrix; light grey, silty sand, rock flour. Drill penetration indicates hard to very hard rock.
20	5	31.00	
			Hard rock CHERT Light grey, unweathered, fine to coarse gravel, sub-angular chert with minor dolomite. Equal parts matrix, light grey, silty sand, rock flour. Interpreted to as hard rock chert. Drill penetration indicates hard rock.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER
DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
Prof Reg: 400051/14
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FILE REF:

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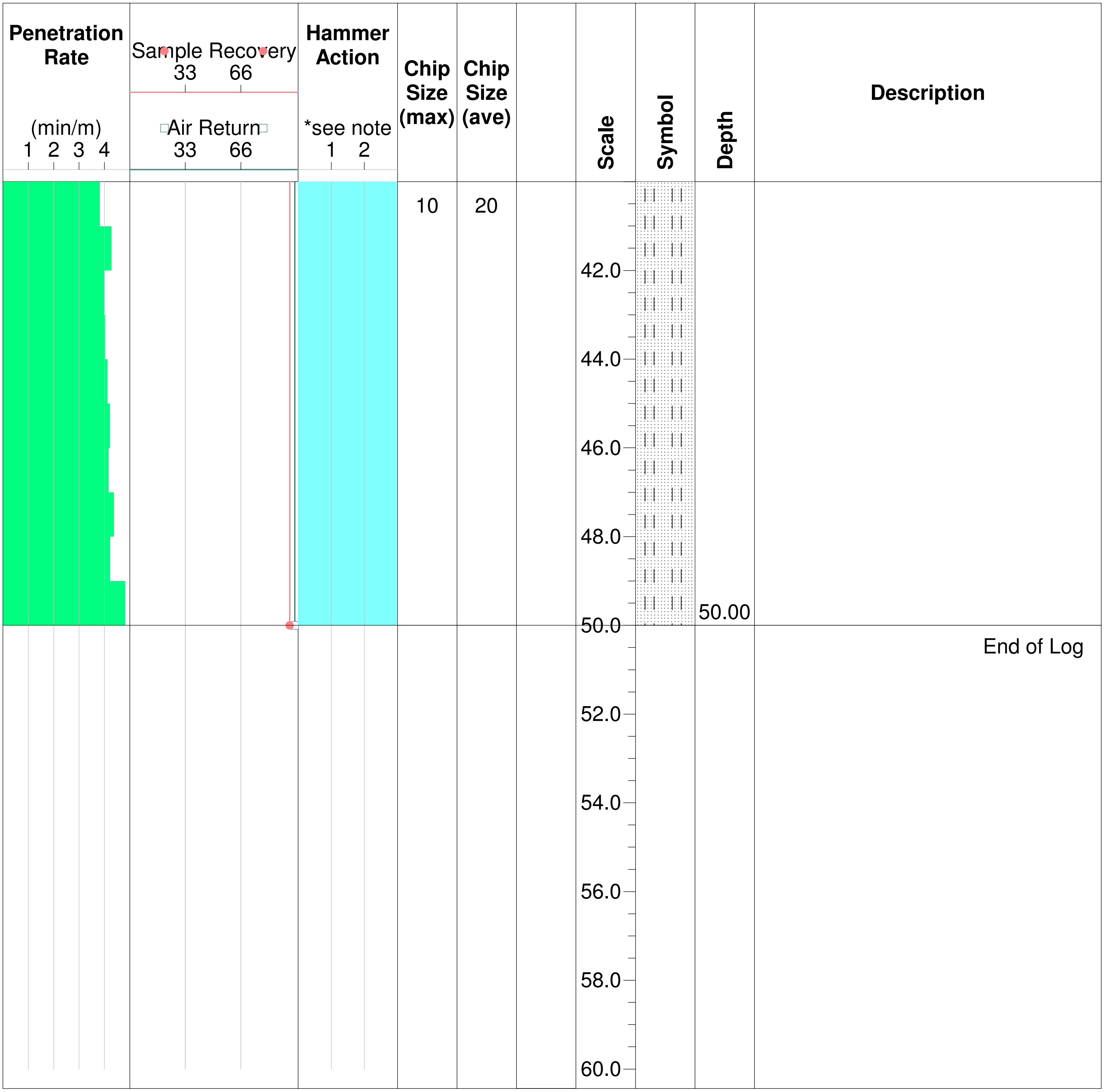
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB04
X COORD: E24°47'03.3"
Y COORD: S27° 02'33.0"
ELEVATION:
PAGE 3 of 3



NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE Prof Reg: 400051/14
CHECKED BY: Prof Reg:
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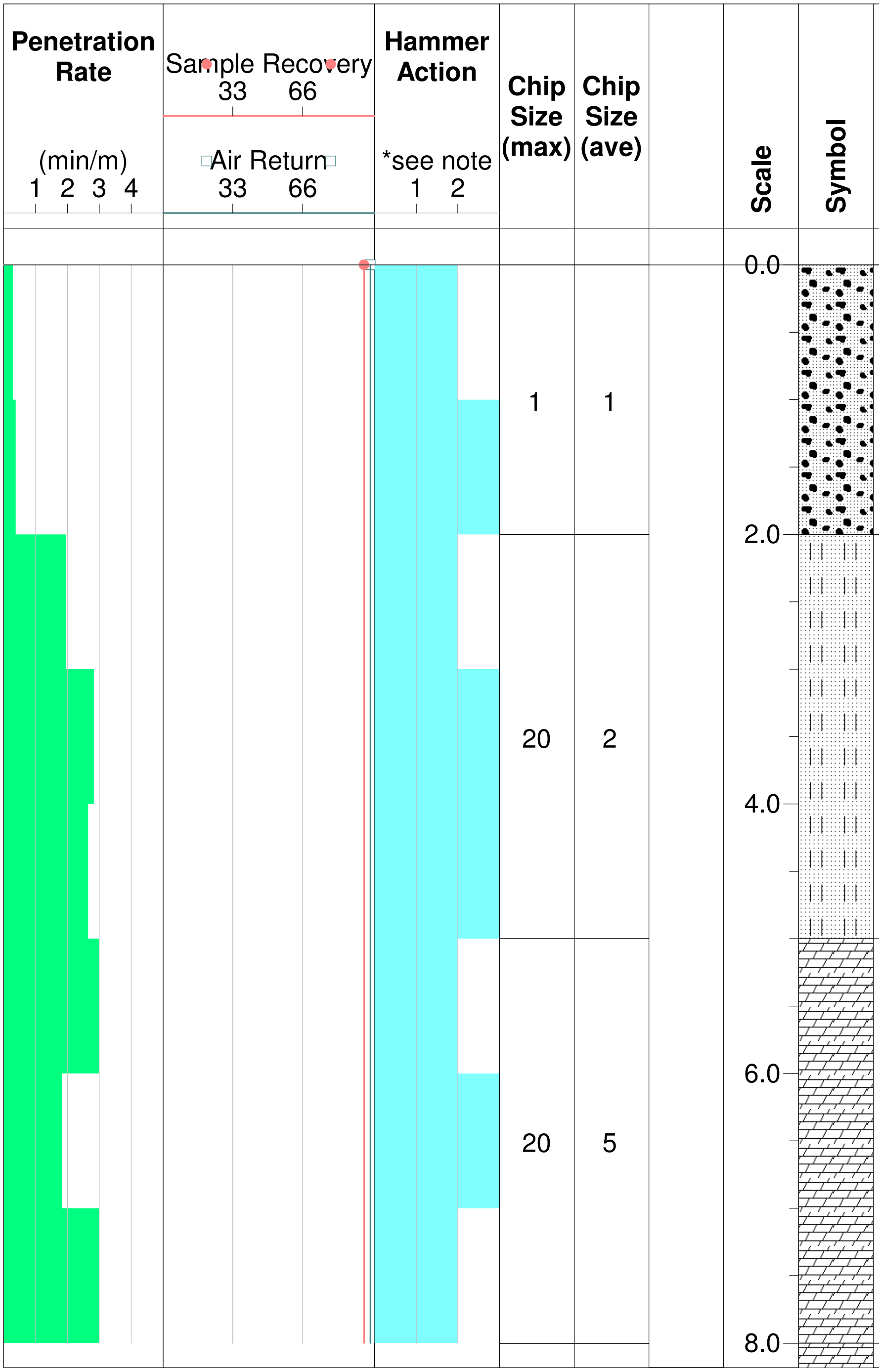
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB05
X COORD: E24°47'12.0"
Y COORD: S27° 02'08.6"
ELEVATION:
PAGE 1 of 2



Depth	Chip Size (max)	Chip Size (ave)	Description
0.00			Ground Surface
0.00–2.00	1	1	**Sandy GRAVEL** Orange brown, mottled black, abundant medium to coarse gravel, with traces of cobbles. Interpreted as residual dolomite, chert and quartzite.
2.00–5.00	20	2	**Hard rock DOLOMITE** Light grey to black, slightly to medium weathered, dolomite, chert, with minor quartzite, angular, fine grained, platy to bladed. Minor matrix of orange brown silty sand, residual dolomite, chert and quartzite. Interpreted as slightly to medium weathered dolomite, chert and quartzite bedrock. Drill penetration indicates hard rock.
5.00–8.00	20	5	**Hard rock DOLOMITE** Dark grey, unweathered dolomite chert, angular, fine grained, platy to bladed. Minor matrix, grey sand, rock flour. Interpreted as unweathered dolomite, chert and quartzite, dolomite dominant. Drill penetration indicates hard rock.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
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FILE REF:

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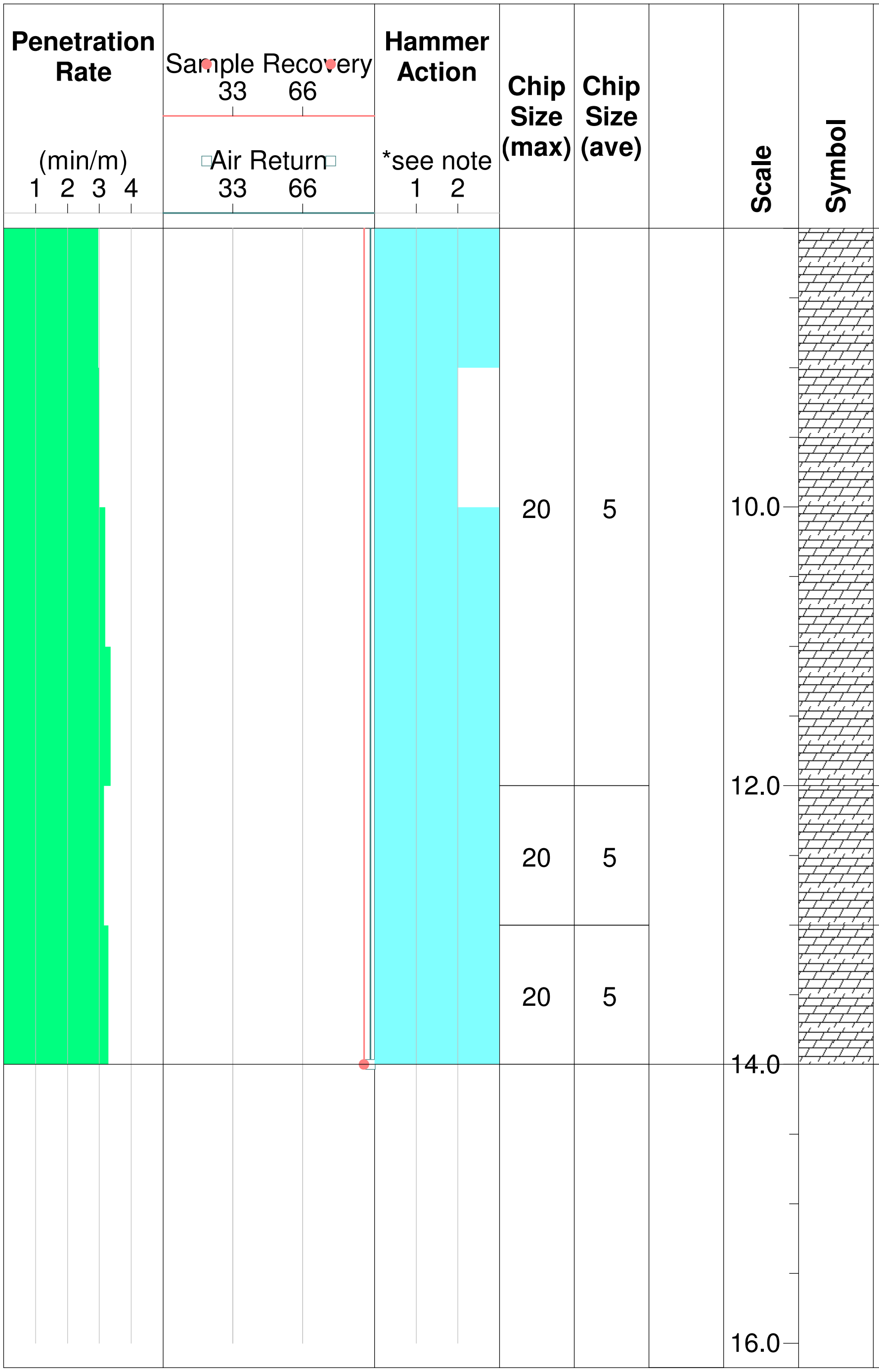
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB05
X COORD: E24°47'12.0"
Y COORD: S27° 02'08.6"
ELEVATION:
PAGE 2 of 2



Chip Size (max)	Chip Size (ave)	Depth	Description
20	5	12.00	**Very hard rock DOLOMITE** Dark grey, unweathered dolomite chert, angular, fine grained, platy to bladed. Abundant to equal parts matrix, grey, sand, rock flour. Interpreted as unweathered dolomite, chert and quartzite, dolomite dominant. Drill penetration indicates very hard rock.
20	5	13.00	**Very hard rock DOLOMITE** Dark grey, unweathered dolomite chert, angular, fine grained, platy to bladed. Minor matrix, grey sand, rock flour. Interpreted as unweathered dolomite, chert and quartzite, dolomite dominant. Drill penetration indicates hard rock.Dark grey, unweathered dolomite chert, angular, fine grained, platy to bladed. Minor matrix, grey sand, rock flour. Interpreted as unweathered dolomite, chert and quartzite, dolomite dominant. Drill penetration indicates hard rock.
20	5	14.00	

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

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Prof Reg:

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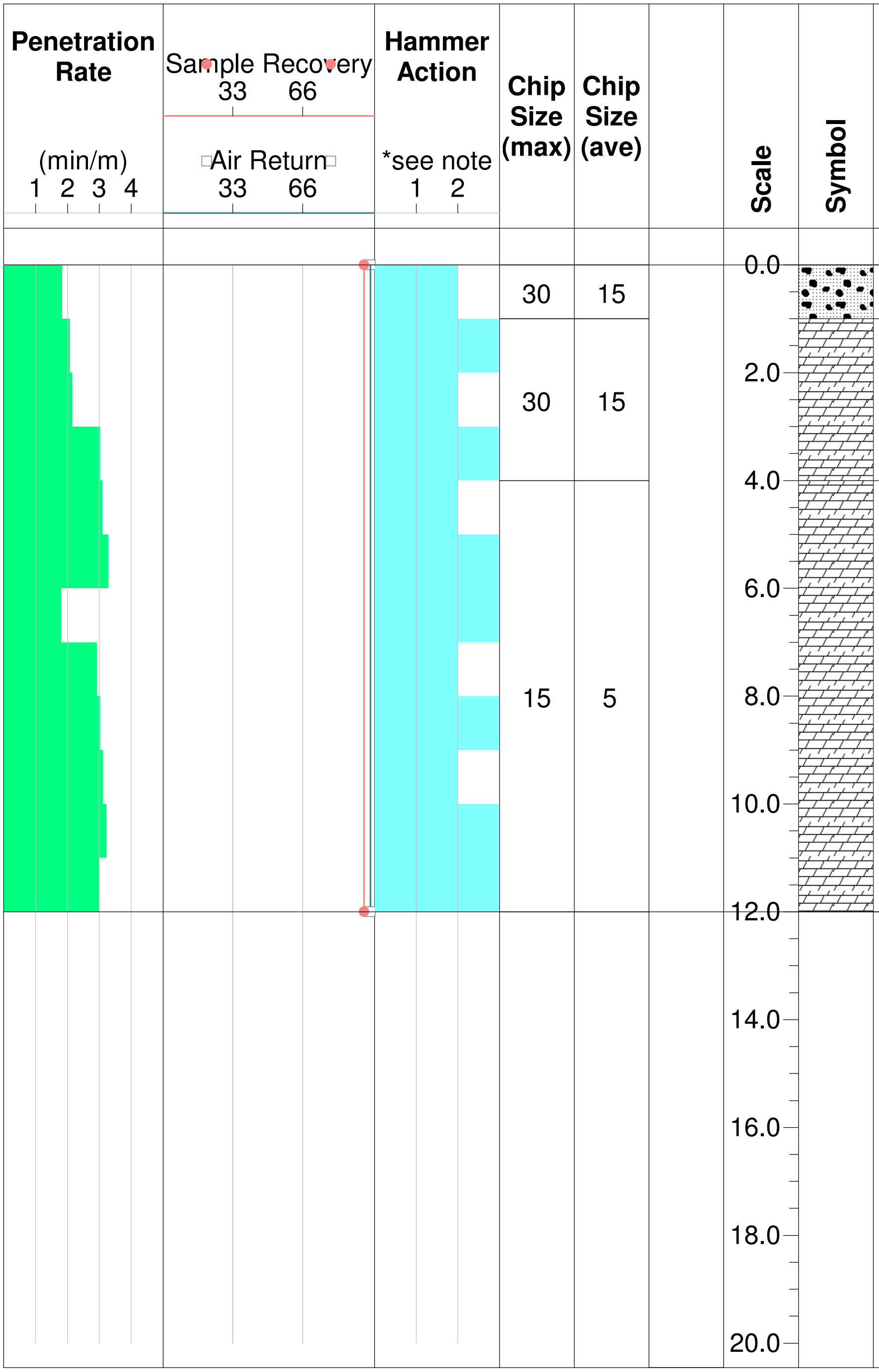
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB06
X COORD: E24°47'46.4"
Y COORD: S27° 02'11.9"
ELEVATION:
PAGE 1 of 1



Chip Size (max)	Chip Size (ave)	Depth	Description
		0.00	Ground Surface
30	15	1.00	**Silty sandy GRAVEL** Orange brown, residual dolomite and quartzite. Gravels; sub-rounded, medium to coarse gravel, blocky. Interpreted as residual dolomite and quartzite soils.
30	15	4.00	**Hard rock DOLOMITE** Light grey, mottled orange brown and red, medium to slightly weathered, dolomite and chert with traces of quartzite, fine grained, angular, platy to bladed. Traces of matrix, orange to brown to grey, sand mix of residual soils and rock flour. Drill penetration indicates hard rock
15	5	12.00	**Very hard rock DOLOMITE** Dark grey to black, unweathered dolomite with chert, angular, fine grained, platy to bladed. Traces of matrix, grey, sandy silty, rock flour. Interpreted as unweathered, dolomite. Drill penetration indicates, very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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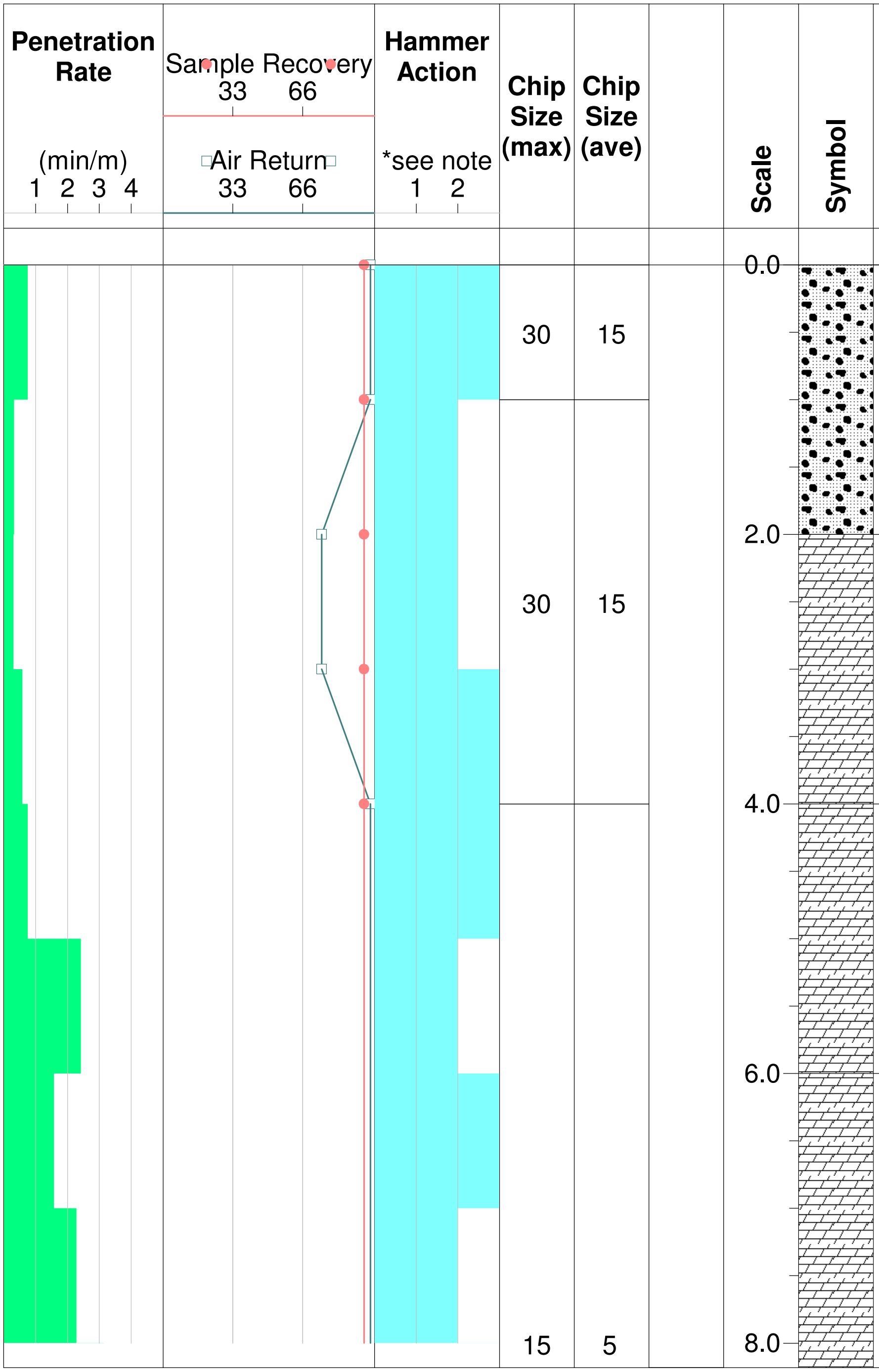
Template: SMEC P02

PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB07
X COORD: E24°47'50.2"
Y COORD: S27° 02'8.0"
ELEVATION:
PAGE 1 of 2



Depth	Description
0.00	Ground Surface
	Clayey sandy GRAVEL Orange brown, predominsnlty medium to coarse gravels, with traces of cobbles, gravel, rounded to sub-rounded, dolomite and quartzite. Sample wet due to drilling water, Interpreted as residual dolomite quartzite.
2.00	**Very soft rock DOLOMITE** Dark brown, gravelly silty sand, residual dolomite, chert and quartzite, minor gravels and cobbles of highly to completely weathered dolomite, chert and quartzite, sub-rounded. Interpreted as highly to completely weathered dolomite bedrock. Drill penetration Indicates, very soft rock.
4.00	**Medium hard rock DOLOMITE** Light grey, mottled orange brown, medium weathered, fine grained, angular, platy, dolomite and quartzite. minor matrix of orange brown to grey, very silty sand. Interpreted as medium weathered dolomite bedrock.
6.00	**Very hard rock DOLOMITE** Light grey, slightly weathered, angular, fine grained, platy dolomite cher, and quartzite. Interpreted as slightly weathered, dolomite and quartzite bedrock. Drill penetration indicates, hard to very hard rock.

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample at 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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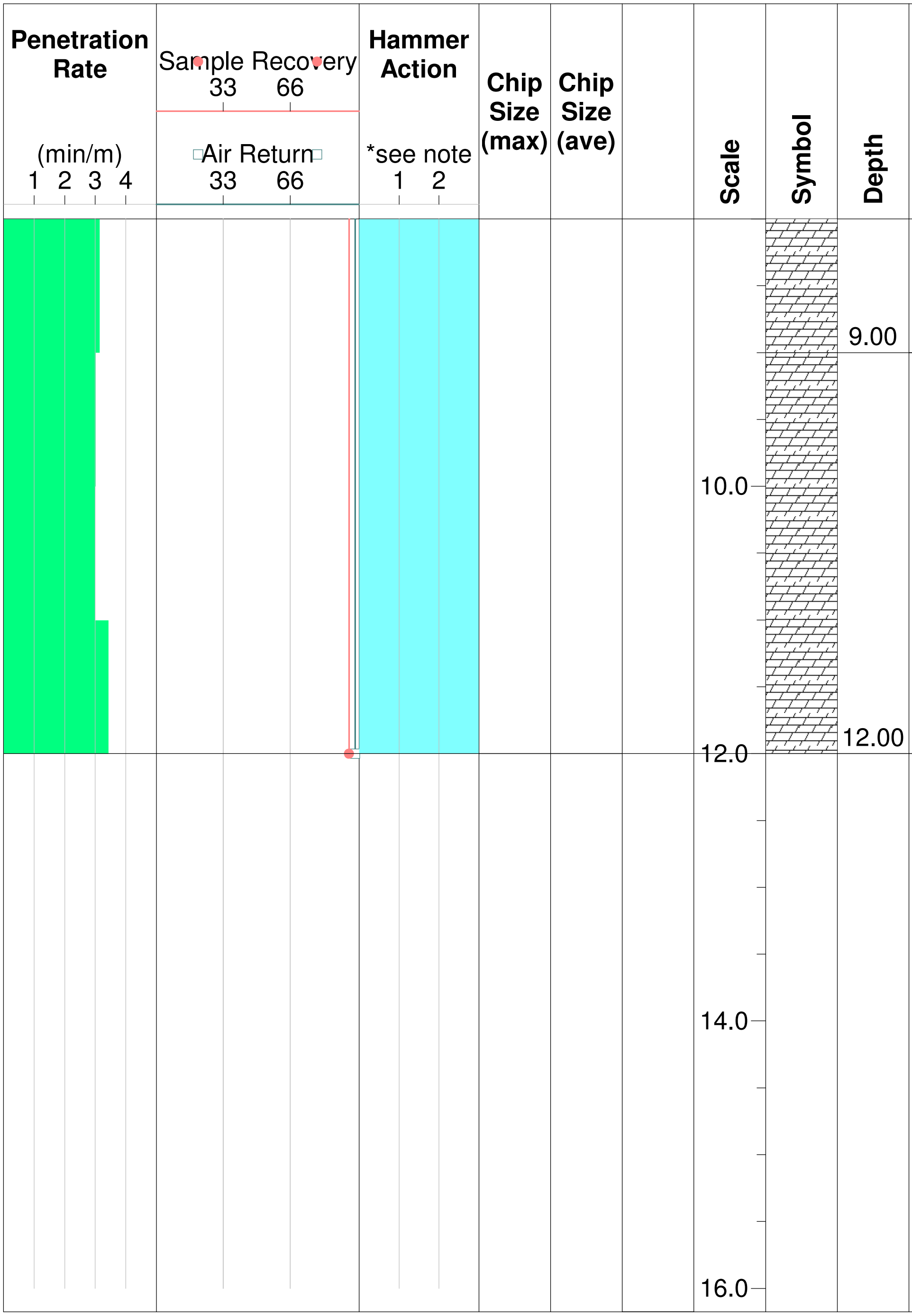
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB07
X COORD: E24°47'50.2"
Y COORD: S27° 02'8.0"
ELEVATION:
PAGE 2 of 2



Depth	Description
9.00	
12.00	**Very hard rock DOLOMITE** Light grey, unweathered, angular, fine grained, platy dolomite chert, and quartzite. Interpreted as unweathered, dolomite and quartzite bedrock. Drill penetration indicates hard to very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample at 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
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Prof Reg:

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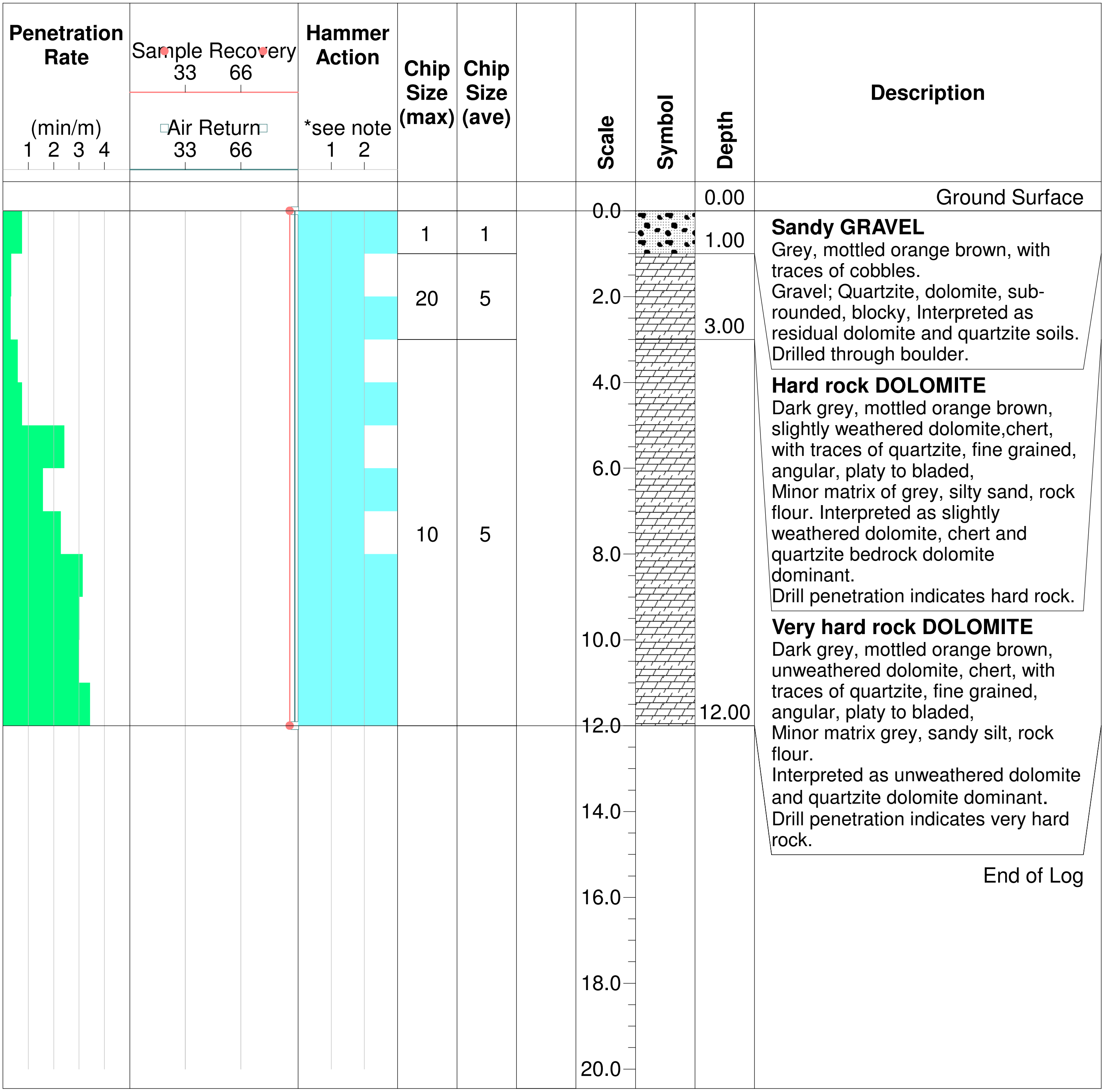
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB08
X COORD: E24°47'27.3"
Y COORD: S27° 02'23.4"
ELEVATION:
PAGE 1 of 1



Depth	Chip Size (max)	Chip Size (ave)	Description
0.00			Ground Surface
1.00	1	1	**Sandy GRAVEL** Grey, mottled orange brown, with traces of cobbles. Gravel; Quartzite, dolomite, sub-rounded, blocky, Interpreted as residual dolomite and quartzite soils. Drilled through boulder.
3.00	20	5	**Hard rock DOLOMITE** Dark grey, mottled orange brown, slightly weathered dolomite,chert, with traces of quartzite, fine grained, angular, platy to bladed, Minor matrix of grey, silty sand, rock flour. Interpreted as slightly weathered dolomite, chert and quartzite bedrock dolomite dominant. Drill penetration indicates hard rock.
12.00	10	5	**Very hard rock DOLOMITE** Dark grey, mottled orange brown, unweathered dolomite, chert, with traces of quartzite, fine grained, angular, platy to bladed, Minor matrix grey, sandy silt, rock flour. Interpreted as unweathered dolomite and quartzite dolomite dominant. Drill penetration indicates very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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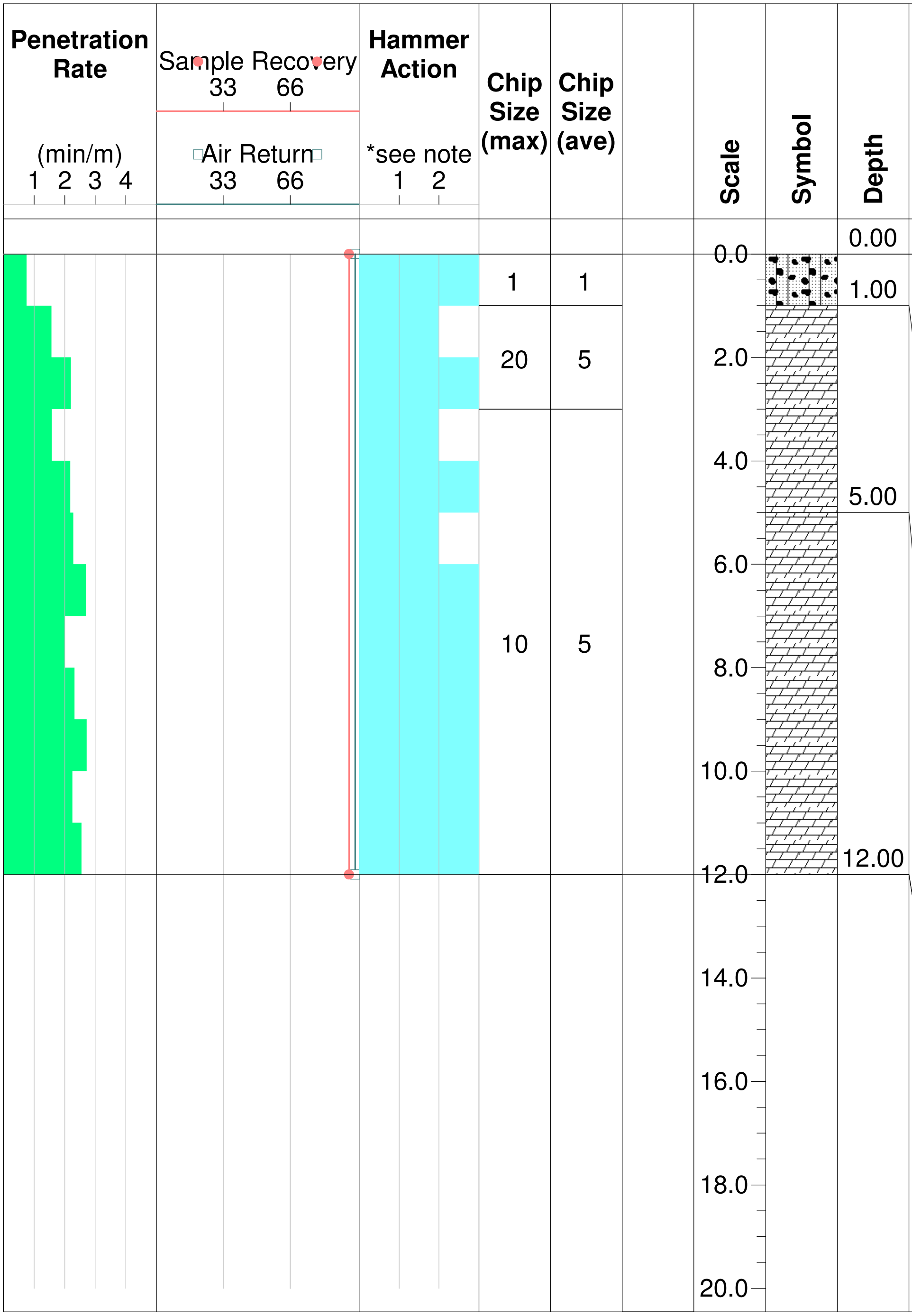
PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB09
X COORD: E24°47'28.0"
Y COORD: S27° 02'07.2"
ELEVATION:
PAGE 1 of 1



Chip Size (max)	Chip Size (ave)
1	1
20	5
10	5

Depth	Description
0.00	Ground Surface
1.00	**Silty sandy GRAVEL** Orange brown, mottled black, yellow, speckled grey. Gravels; Orange brown, yellow and black, highly to completely weathered dolomite, chert, with traces of quartzite, sub-rounded, blocky, friable.
5.00	**Hard rock DOLOMITE** Dark grey to black, medium to slightly weathered dolomite with minor chert, angular, platy to bladed. Interperted as medium to slightly weathered dolomite. Matrix equal amounts; light grey, silty sand, rock flour. Drill penetration indicates medium to hard rock.
12.00	**Very hard rock DOLOMITE** Dark grey, to black, unweathered dolomite, with traces of chert and shale, angular, platy to bladed. Minor matrix; light grey, sandy silt, rock flour. Interpreted as unweathered dolomite bedrock. Drill penetration indicates hard to very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample taken every 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

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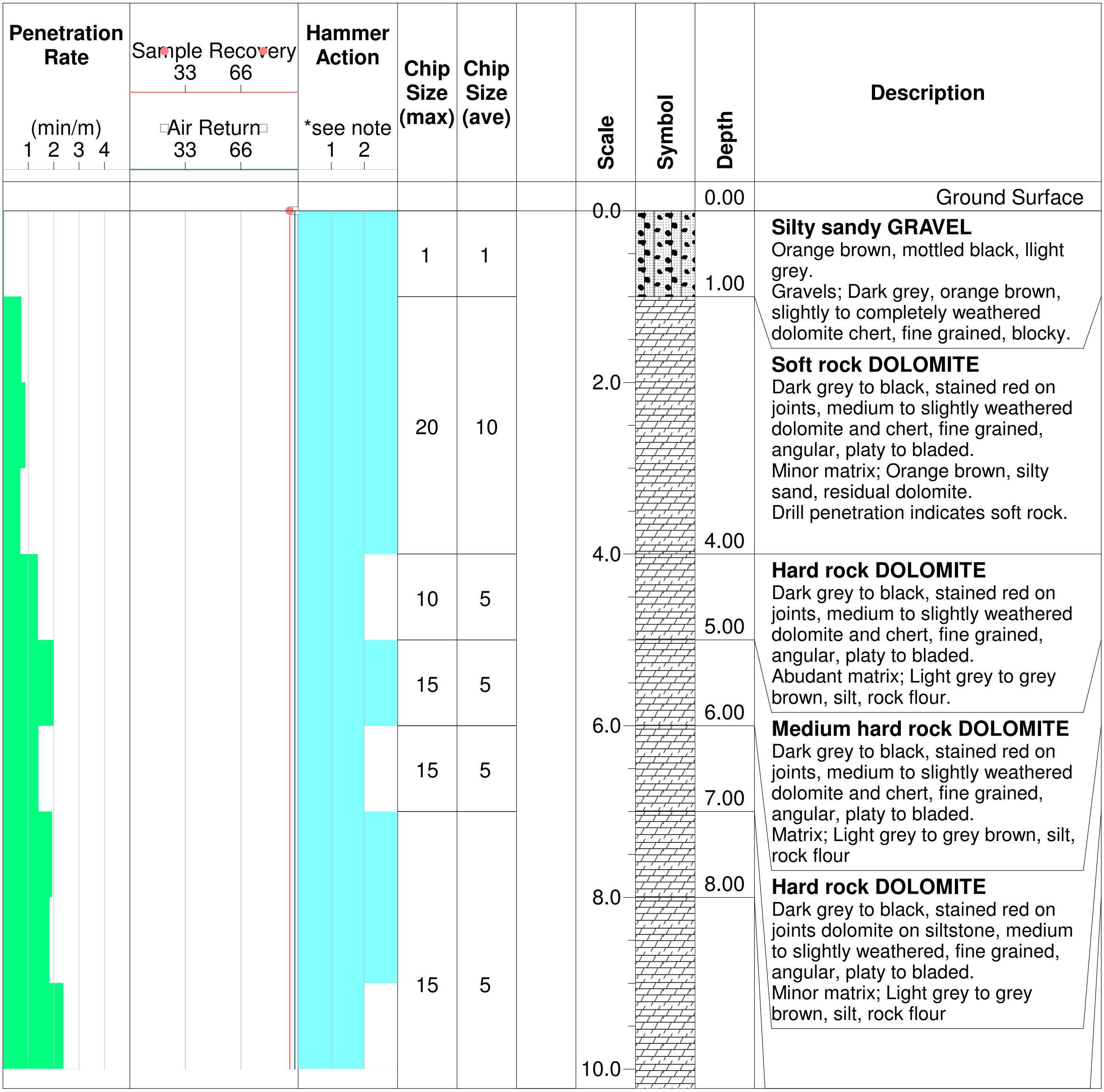
Template: SMEC P02

PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB10
X COORD: E24°47'32.0"
Y COORD: S27° 01'53.9"
ELEVATION:
PAGE 1 of 2



Depth	Chip Size (max)	Chip Size (ave)
0.00		
1.00	1	1
4.00	20	10
5.00	10	5
6.00	15	5
7.00	15	5
8.00	15	5

Depth	Description
0.00	Ground Surface
0.00 – 1.00	**Silty sandy GRAVEL** Orange brown, mottled black, llight grey. Gravels; Dark grey, orange brown, slightly to completely weathered dolomite chert, fine grained, blocky.
1.00 – 4.00	**Soft rock DOLOMITE** Dark grey to black, stained red on joints, medium to slightly weathered dolomite and chert, fine grained, angular, platy to bladed. Minor matrix; Orange brown, silty sand, residual dolomite. Drill penetration indicates soft rock.
4.00 – 6.00	**Hard rock DOLOMITE** Dark grey to black, stained red on joints, medium to slightly weathered dolomite and chert, fine grained, angular, platy to bladed. Abudant matrix; Light grey to grey brown, silt, rock flour.
6.00 – 8.00	**Medium hard rock DOLOMITE** Dark grey to black, stained red on joints, medium to slightly weathered dolomite and chert, fine grained, angular, platy to bladed. Matrix; Light grey to grey brown, silt, rock flour
8.00	**Hard rock DOLOMITE** Dark grey to black, stained red on joints dolomite on siltstone, medium to slightly weathered, fine grained, angular, platy to bladed. Minor matrix; Light grey to grey brown, silt, rock flour

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample at 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

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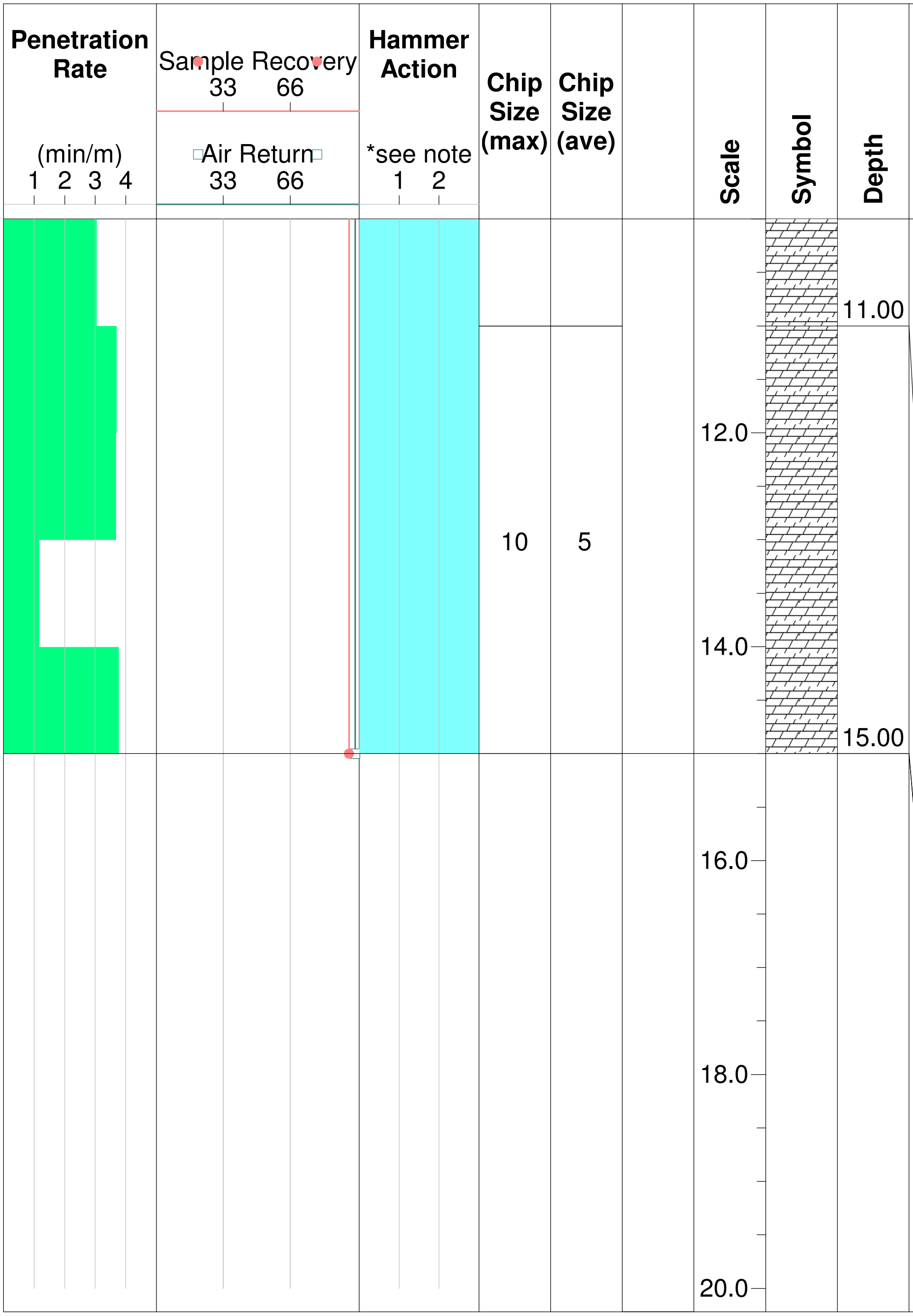
Template: SMEC P02

PERCUSSION BOREHOLE LOG

CLIENT: SUNEDISON
PROJECT: SUNEDISON PV GEOTECH
PROJECT NO: JG0002
SITE: VRYBURG

HOLE NO: WB10
X COORD: E24°47'32.0"
Y COORD: S27° 01'53.9"
ELEVATION:
PAGE 2 of 2



Description

Very hard rock DOLOMITE
Dark grey to black, stained red on joints, medium to slightly weathered dolomite and chert, fine grained, angular, platy to bladed.
Minor matrix; Orange brown, silty sand, residual dolomite.
Drill penetration indicates soft rock.

Very hard rock DOLOMITE
Dark grey to black, unweathered dolomite with traces of chert, fine grained, angular, platy and bladed.
Minor matrix; Light grey, sandy silt, rock flour.
Interpreted as unweathered dolomite bedrock.
Drill penetration indicates hard to very hard rock.

Very hard rock CHERT
Light grey to black, unweathered chert with minor dolomite, fine grained, angular, platy to bladed.
Minor matrix; Light grey, silt, rock flour with traces of dolomite contamination.
Interpreted as unweathered chert bedrock.
Drill penetration indicates very hard rock.

End of Log

NOTES 1: Hammer Action: 0 = none, 1=v.irregular, 2=irregular, 3=regular
2: No water struck.
3: No BH collapse
4: No light probe
5: Sample at 1.0m
6: Camera used.

CONTRACTOR: JK DRILLING
INCLINATION: VERTICAL
DIAM/COMP: 1.65m
MACHINE: THOR RIG (2014)
HAMMER TYPE: TOP HAMMER

DATE DRILLED: 05/08/2014
DATE LOGGED: 05/08/2014
LOGGED BY: R.FREESE
CHECKED BY:
FILE REF:

Prof Reg: 400051/14
Prof Reg:

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SMEC South Africa
Consulting Engineers
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APPENDIX G: ELECTRICAL RESISTIVITY RESULTS

ENGINEERING & EXPLORATION GEOPHYSICAL SERVICES CC
CK94/10526/23 Geophysical Contractors

170 Jakaranda Street,
Doringkloof,
Gauteng,0157
012 - 6673369 (tel.) 6675186(fax)
E-mail: eegs@iafrica.com

15th August, 2014

SMEC South Africa (Pty) Ltd,
P O Box 72927,
Lynwood Ridge 0040

Attn: Mr. Ryan Freese

Dear Sir,

WATERLOO: SOIL RESISTIVITY SURVEY

1. Introduction

The methods and results are given here of a soil resistivity survey carried out on the site of the proposed Waterloo Wind Generation Plant which lies approximately 10km south, south east of Vryburg in the North West Province. The object of the survey is to supply information about ground resistance that is to be used to confirm the grounding design.

Fieldwork was performed at the end of July 2014. The required test positions were indicated by coordinates supplied by the client, as listed in table 1.

Table 1: Centre points of resistivity test positions Lo 25, WGS84

Ym	Xm	Position
20358	2991614	ER3
20968	2991471	ER4
20722	2991823	ER5
21272	2991637	ER6
21093	2992037	ER7
21475	2992257	ER8
20625	2991195	ER1_sub
20617	2991192	ER1_200
20623	2991227	ER2_sub
20635	2991195	ER2_200

2. Instrumentation, data collection methods and reduction procedure

2.1 Instrumentation

An ABEM LS resistivity meter was used to collect the resistivity data. Resistivity measurements are obtained by injecting a current into the ground through two electrodes and measuring the resulting potential between another electrode pair. By systematically increasing the electrode separation in a fashion otherwise known as a vertical electrical sounding, a picture is obtained of resistance variations with depth. A set of adjacent soundings is known as a continuous vertical electrical sounding (CVES) and such a data set provides a resistivity image or cross section of the ground. The ABEM system automates the collection of such data set by accessing multiple electrodes through a multicore cable.

2.2 Data collection

A Wenner configuration (equally spaced electrodes set in a line) was used for the resistivity imaging as is required for this type of survey. An electrode separation of one-quarter metre were employed with two lines set perpendicular to each other at each site, centred on the test position. The measurement range was 0.25, 0.5, 0.75, 1 and then by half metre increments to 6 metres. At two sites on a substation footprint, additional readings were collected using a five metres electrode spacing and readings with separations of 5, 10, 20, 30, 40, 50 and 60 metres were collected.

2.3 Data reduction and presentation

An average apparent resistivity (ρ) was calculated for each electrode separation on all the sites. Resistances (R) were calculated from the averages using the relationship $\rho = 2\pi aR$, where 'a' is the electrode separation. The resistance values were then graphed against electrode separation.

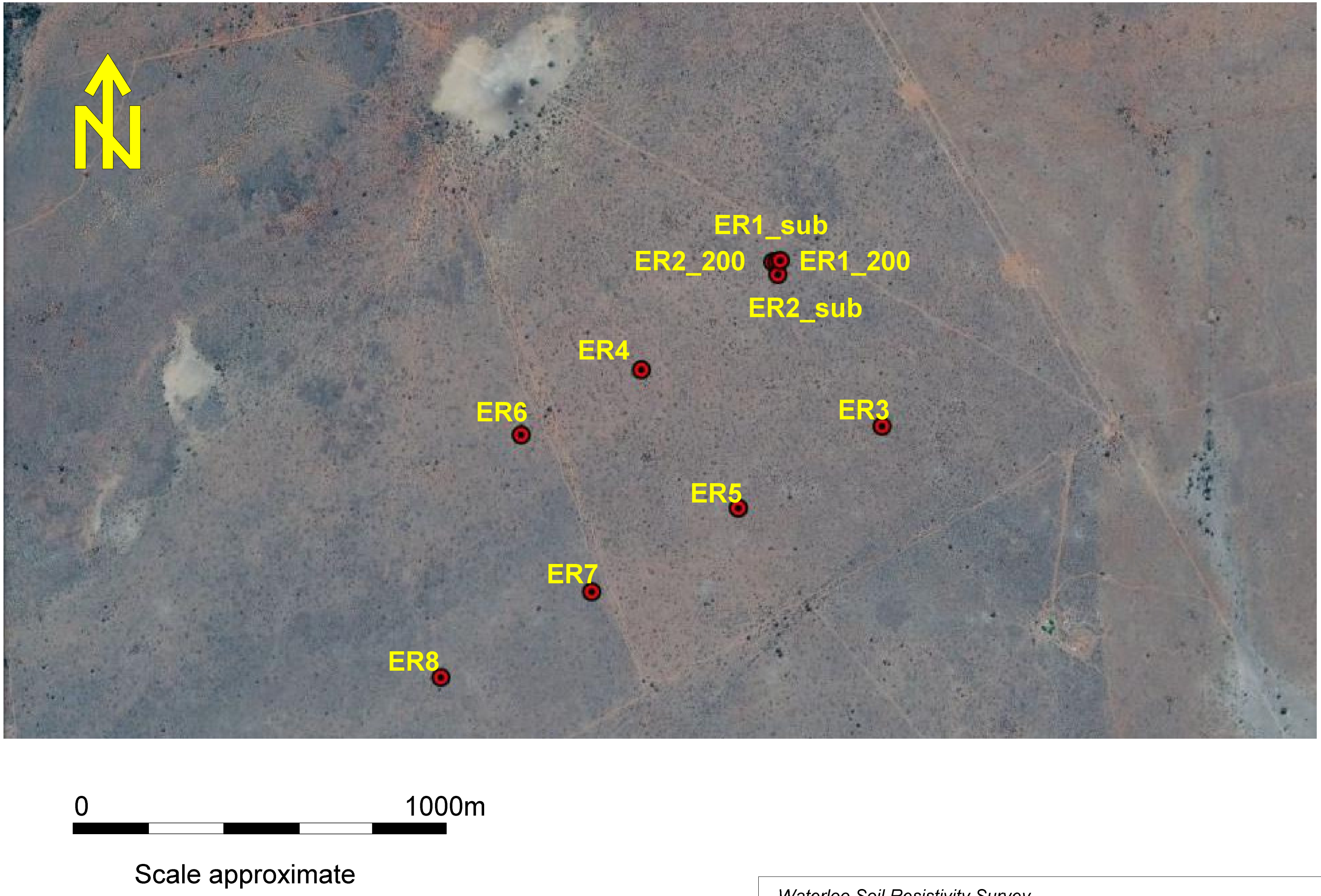
3. Results

The locations of the test sites are shown on figure 1. The summarized readings are in the tabulated and graphed in an appendix.

In a homogeneous or layered earth, resistance decreases with increasing electrode separation. In those circumstances, when resistance is plotted against electrode separation, the curve falls smoothly as electrode separation increases. Lateral changes in ground resistivity, however, will distort an otherwise smoothly declining curve.

Yours sincerely,

R.W.Day. Pr.Sci.Nat.



Waterloo Soil Resistivity Survey

Figure 1: Distribution of soil resistivity test sites

Prepared for XXXXX South Africa (Pty) Ltd by E&EGS CC August 2014

APPENDIX

SUMMARISED DATA FOR EACH TRAVERSE
WATERLOO

Tables

1: ER1_200 (5m electrode separation)
2: ER2_200 (5m electrode separation)
3: ER1_SUB
4: ER2_SUB
5: ER3
6: ER4
7: ER5
8: ER6
9: ER7
10: ER8

Tabulations
Spacing = distance in metres between electrodes (MN) used to measure potential difference.
Count = number of samples.
Resistance in ohms from average apparent conductivity.
The left three columns are from lines orientated north-south, the right three columns are summarises of data from lines orientated west-east.

Graphs
Horizontal axis - electrode separation in metres;
Vertical axis - resistance in ohms.

Table 1: ER1_200 (NS-WE)

Separation	Count	Resistance	Separation	Count	Resistance
5	30	81.97	5	32	87.36
10	31	60.96	10.00	35	61.02
15	29	50.25	15.00	32	49.08
20	26	42.95	20.00	29	42.15
30	21	33.59	30.00	23	33.49
40	15	26.67	40.00	17	27.00
50	10	21.25	50.00	11	21.94
60	5	17.05	60.00	5	17.77

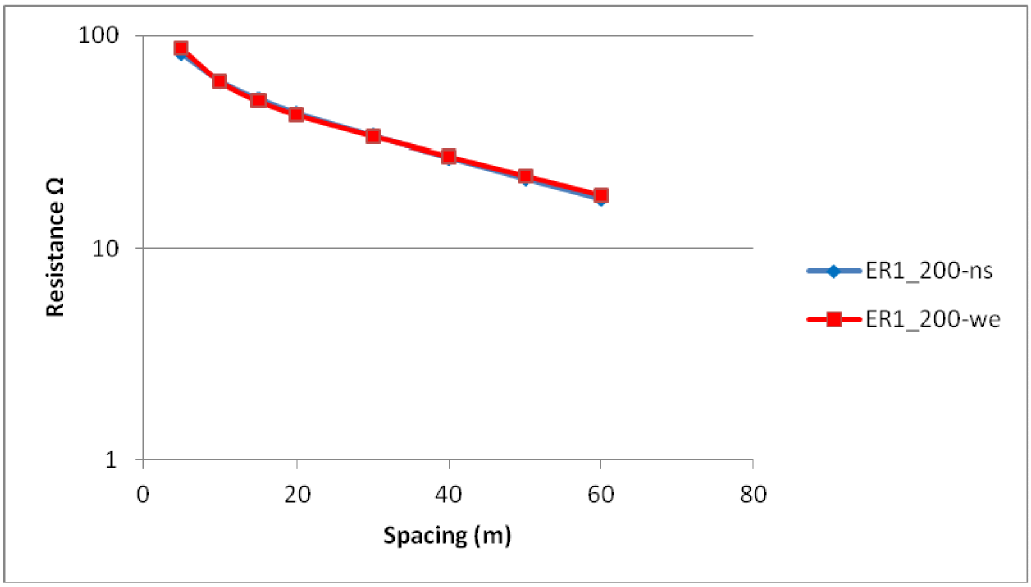


Figure 2: Curves for ER1_200

Table 2: ER2_200 (NS-WE)

Separation	Count	Resistance	Separation	Count	Resistance
5	30	81.97	5	33	91.09
10	31	60.96	10	35	62.39
15	29	50.25	15	32	49.13
20	26	42.95	20	29	41.20
30	21	33.59	30	23	31.64
40	15	26.67	40	17	25.84
50	10	21.25	50	11	21.57
60	5	17.05	60	5	17.86

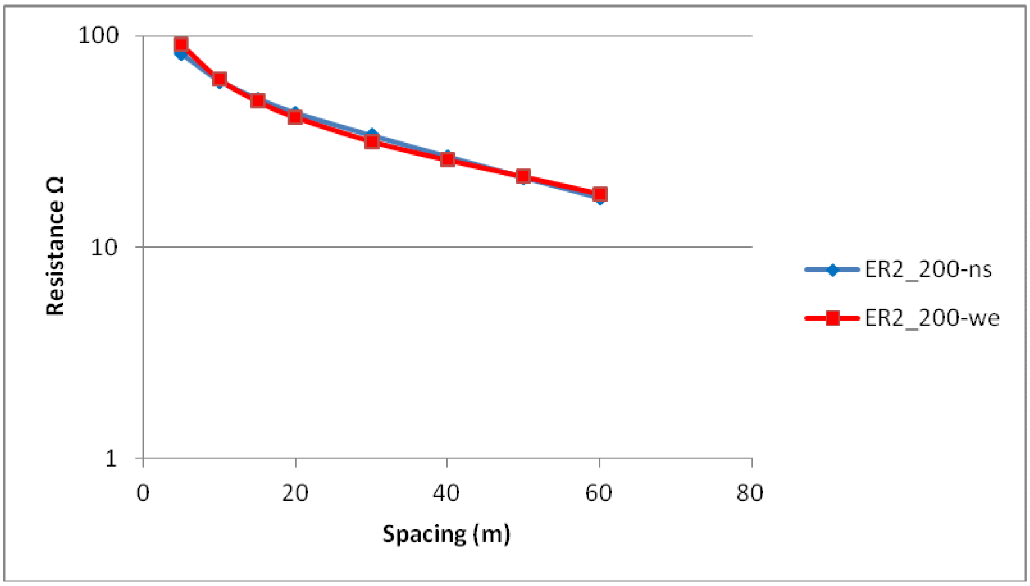


Figure 3: Curves for ER2_200

Table 3: ER1_SUB (NS-WE)

Separation	Count	Resistance	Separation	Count	Resistance
0.25	25	2443.36	0.25	31	2459.18
0.50	41	879.37	0.50	46	821.84
0.75	23	439.20	0.75	27	442.03
1.00	27	312.03	1.00	31	315.13
1.50	24	194.51	1.50	28	199.91
2.00	23	148.71	2.00	26	153.14
2.50	19	129.34	2.50	23	131.58
3.00	20	116.83	3.00	20	118.83
3.50	15	108.71	3.50	18	110.96
4.00	13	101.72	4.00	15	104.72
4.50	11	93.44	4.50	12	98.20
5.00	8	88.11	5.00	10	93.10
5.50	5	82.72	5.50	7	88.92
6.00	4	79.94	6.00	5	87.00

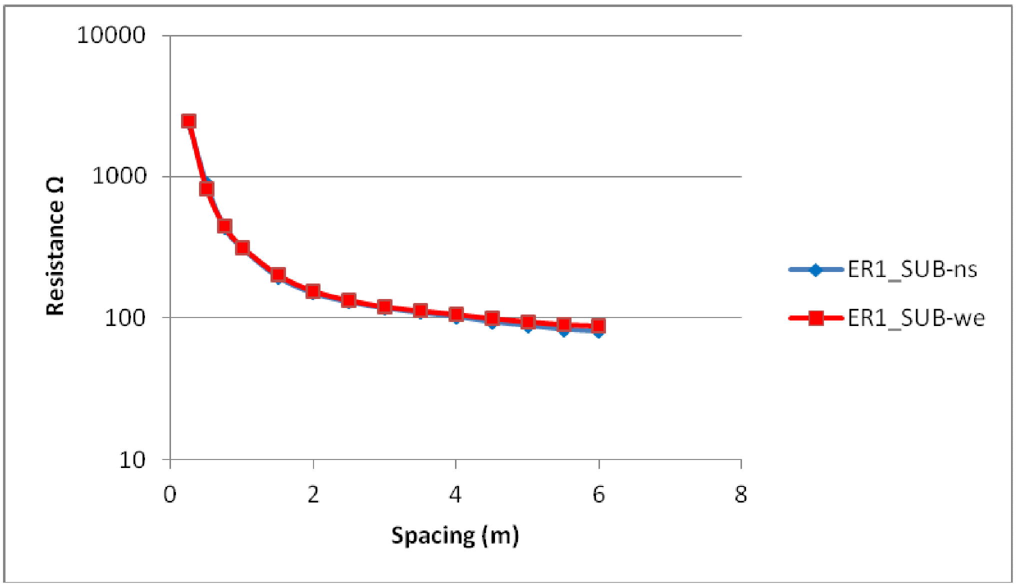


Figure 4: Curves for ER1_SUB

Table 4: ER2_SUB (NS-WE)

Separation	Count	Resistance	Separation	Count	Resistance
0.25	28	3636.15	0.25	29	2638.60
0.50	44	985.88	0.50	47	1141.87
0.75	27	578.75	0.75	27	732.82
1.00	27	362.07	1.00	29	410.74
1.50	24	243.23	1.50	27	253.87
2.00	22	195.32	2.00	24	189.74
2.50	21	165.22	2.50	22	161.88
3.00	19	145.78	3.00	19	144.56
3.50	16	130.53	3.50	17	130.76
4.00	13	121.45	4.00	15	121.41
4.50	12	114.13	4.50	12	116.59
5.00	9	110.41	5.00	10	112.53
5.50	7	102.29	5.50	7	106.07
6.00	4	95.88	6.00	4	100.14

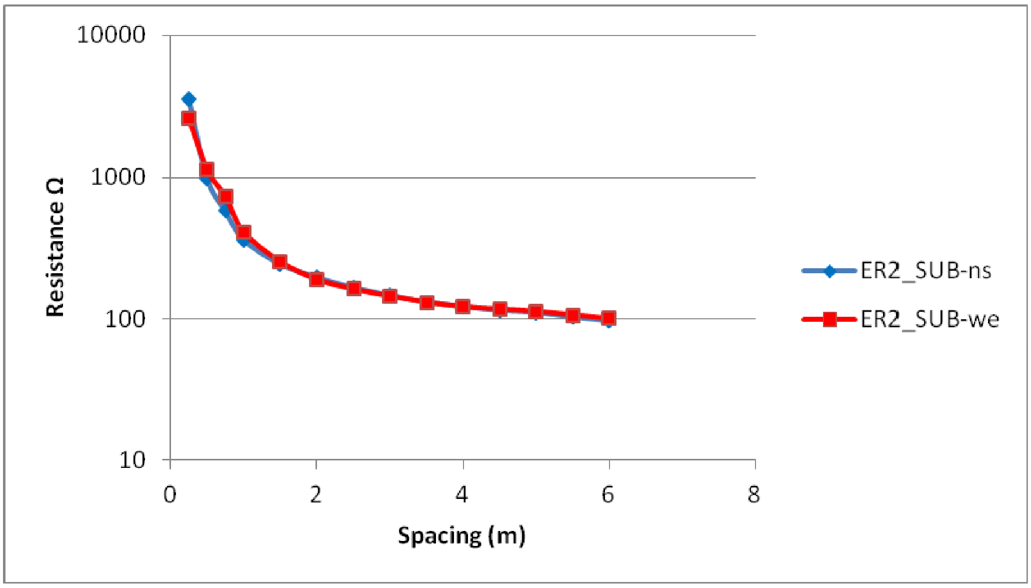


Figure 5: Curves for ER2_SUB

Table 5: ER3 (NS-WE)

Separation	Count	Resistace	Separation	Count	Resistance
0.25	28	3793.20	0.25	22	4585.28
0.50	45	1021.50	0.50	43	936.61
0.75	25	405.55	0.75	23	412.14
1.00	31	260.04	1.00	31	236.30
1.50	28	166.34	1.50	28	148.00
2.00	26	135.65	2.00	26	125.33
2.50	23	120.13	2.50	23	114.09
3.00	21	110.93	3.00	21	107.14
3.50	18	104.59	3.50	18	102.58
4.00	13	98.35	4.00	15	98.95
4.50	11	93.69	4.50	12	96.25
5.00	9	89.80	5.00	10	93.54
5.50	6	86.39	5.50	7	92.43
6.00	5	85.09	6.00	5	92.16

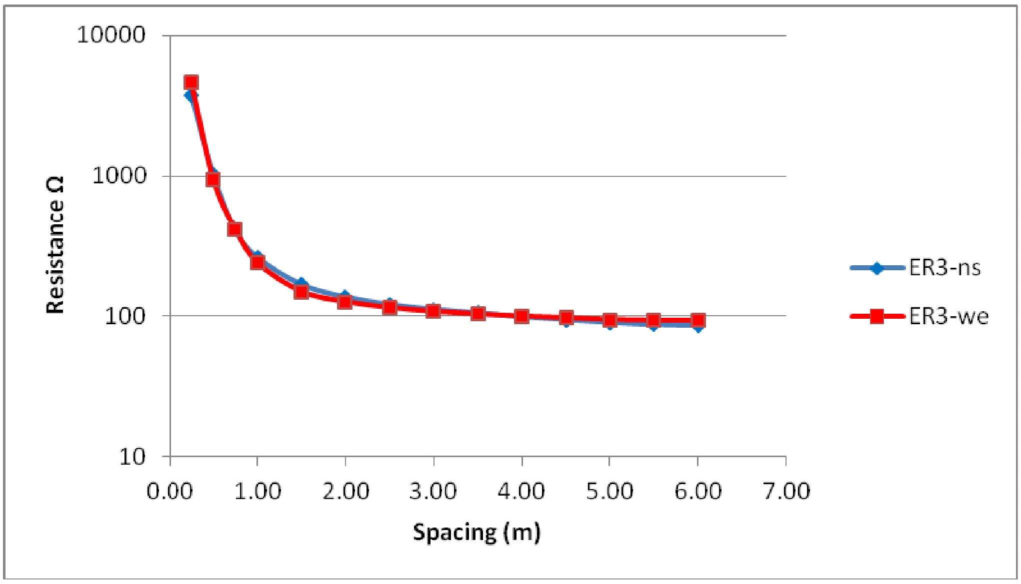


Figure 6: Curves for ER3

Table 6: ER4 (NS-WE)

Separation	Count	Resistance	Separation	Count	Resistance
0.25	26	3402.28	0.25	24	4291.08
0.50	40	1074.95	0.50	33	1344.87
0.75	23	668.62	0.75	19	1003.62
1.00	27	428.29	1.00	27	430.00
1.50	25	250.00	1.50	25	246.45
2.00	22	190.58	2.00	22	179.12
2.50	19	162.22	2.50	19	154.39
3.00	17	147.89	3.00	17	136.62
3.50	16	136.19	3.50	16	127.27
4.00	13	126.07	4.00	13	124.06
4.50	12	119.75	4.50	12	119.20
5.00	8	113.35	5.00	8	113.58
5.50	7	106.94	5.50	7	109.43
6.00	5	100.12	6.00	5	105.59

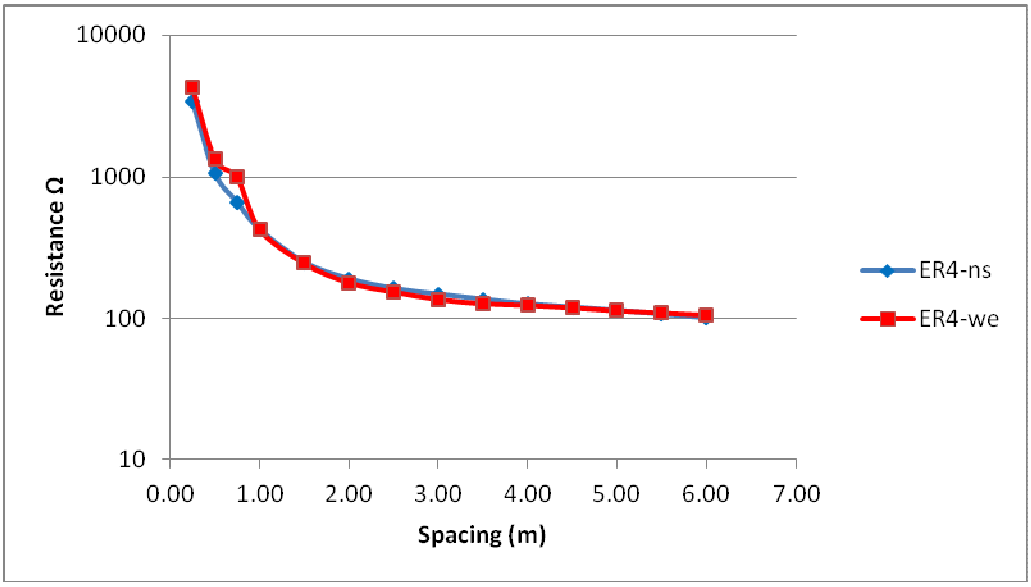


Figure 7: Curves for ER4

Table 7: ER5

Separation	Count	Resistance	Separation	Count	Resistance
0.25	23	5736.93	0.25	24	6627.09
0.50	40	1295.10	0.50	42	1398.04
0.75	22	624.70	0.75	23	675.67
1.00	31	334.99	1.00	31	353.77
1.50	28	188.29	1.50	28	200.53
2.00	26	142.15	2.00	26	151.16
2.50	23	122.31	2.50	23	128.43
3.00	21	113.63	3.00	21	114.69
3.50	18	107.41	3.50	18	106.66
4.00	15	101.03	4.00	15	100.78
4.50	12	96.92	4.50	12	96.52
5.00	10	95.26	5.00	10	92.78
5.50	7	94.17	5.50	7	90.56
6.00	5	92.41	6.00	5	88.72

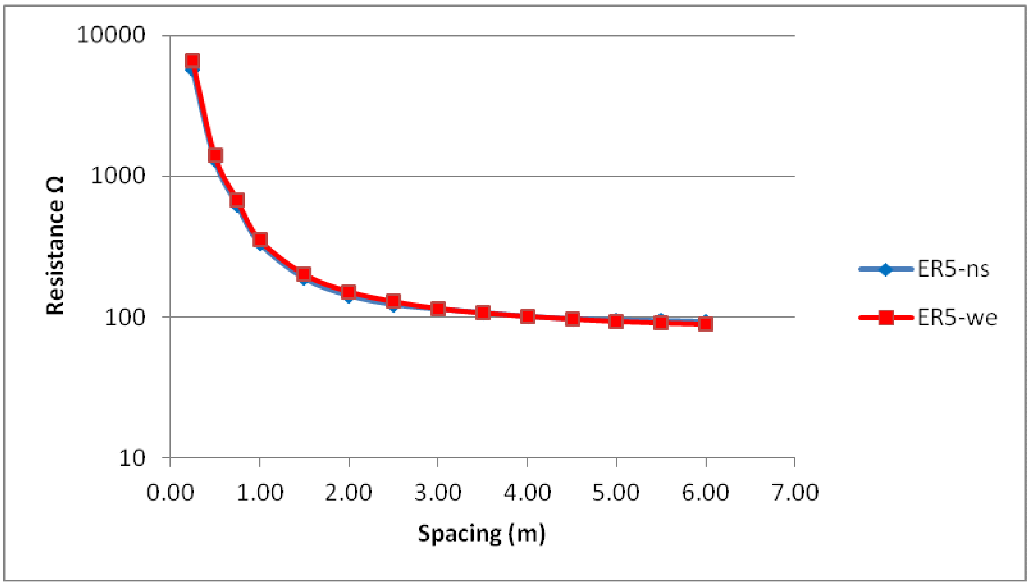


Figure 8: Curves for ER5

Table 8: ER6

Separation	Count	Resistance	Separation	Count	Resistance
0.25	30	1912.24	0.25	22	1821.45
0.50	38	883.54	0.50	39	1009.00
0.75	24	596.58	0.75	23	681.80
1.00	25	493.66	1.00	26	548.05
1.50	26	367.47	1.50	25	374.75
2.00	24	294.36	2.00	22	293.41
2.50	21	246.50	2.50	19	244.66
3.00	21	208.96	3.00	17	205.99
3.50	17	179.83	3.50	16	178.66
4.00	13	161.75	4.00	13	159.37
4.50	11	148.35	4.50	12	145.00
5.00	9	134.76	5.00	8	132.80
5.50	6	119.82	5.50	7	119.90
6.00	5	104.73	6.00	5	110.87

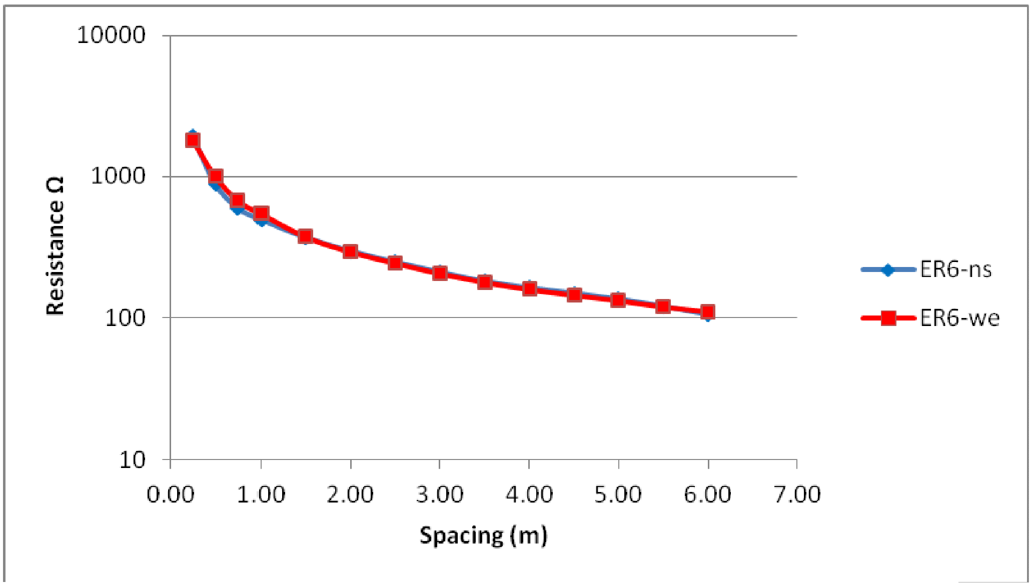


Figure 9: Curves for ER6

Table 9: ER7

Separation	Count	Resistance	Separation	Count	Resistance
0.25	25	3550.97	0.25	25	3651.18
0.50	42	1724.82	0.50	36	1299.44
0.75	23	1262.74	0.75	26	914.80
1.00	27	706.75	1.00	26	556.65
1.50	24	424.60	1.50	26	322.36
2.00	22	263.49	2.00	26	210.04
2.50	21	183.57	2.50	20	164.32
3.00	18	151.46	3.00	20	140.59
3.50	14	128.92	3.50	15	126.01
4.00	12	116.84	4.00	12	114.55
4.50	11	108.14	4.50	10	106.42
5.00	8	99.76	5.00	9	102.15
5.50	6	93.18	5.50	6	99.17
6.00	4	91.87	6.00	4	89.83

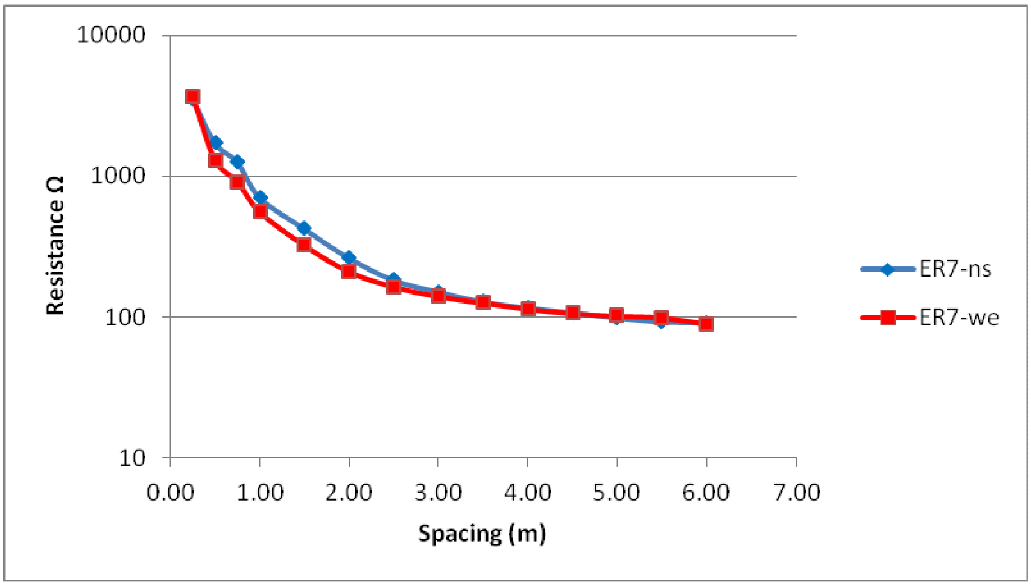


Figure 10: Curves for ER7

Table 10:E R8

Separation	Count	Resistance	Separation	Count	Resistance
0.25	25	5591.83	0.25	28	4607.62
0.50	35	2590.78	0.50	38	2272.96
0.75	21	1833.45	0.75	27	1458.91
1.00	23	1157.11	1.00	26	843.07
1.50	21	531.67	1.50	24	415.30
2.00	19	244.79	2.00	22	241.48
2.50	17	165.27	2.50	19	165.84
3.00	15	121.38	3.00	17	129.31
3.50	14	101.90	3.50	16	107.56
4.00	12	94.05	4.00	13	98.60
4.50	11	89.28	4.50	12	94.55
5.00	6	89.88	5.00	8	92.98
5.50	6	86.11	5.50	7	87.84
6.00	4	81.72	6.00	5	82.24

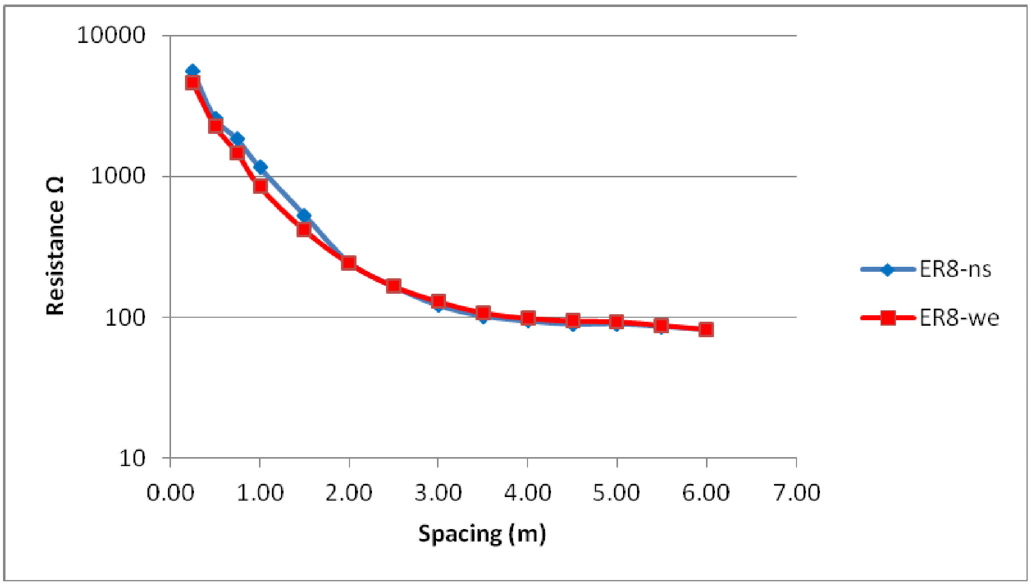
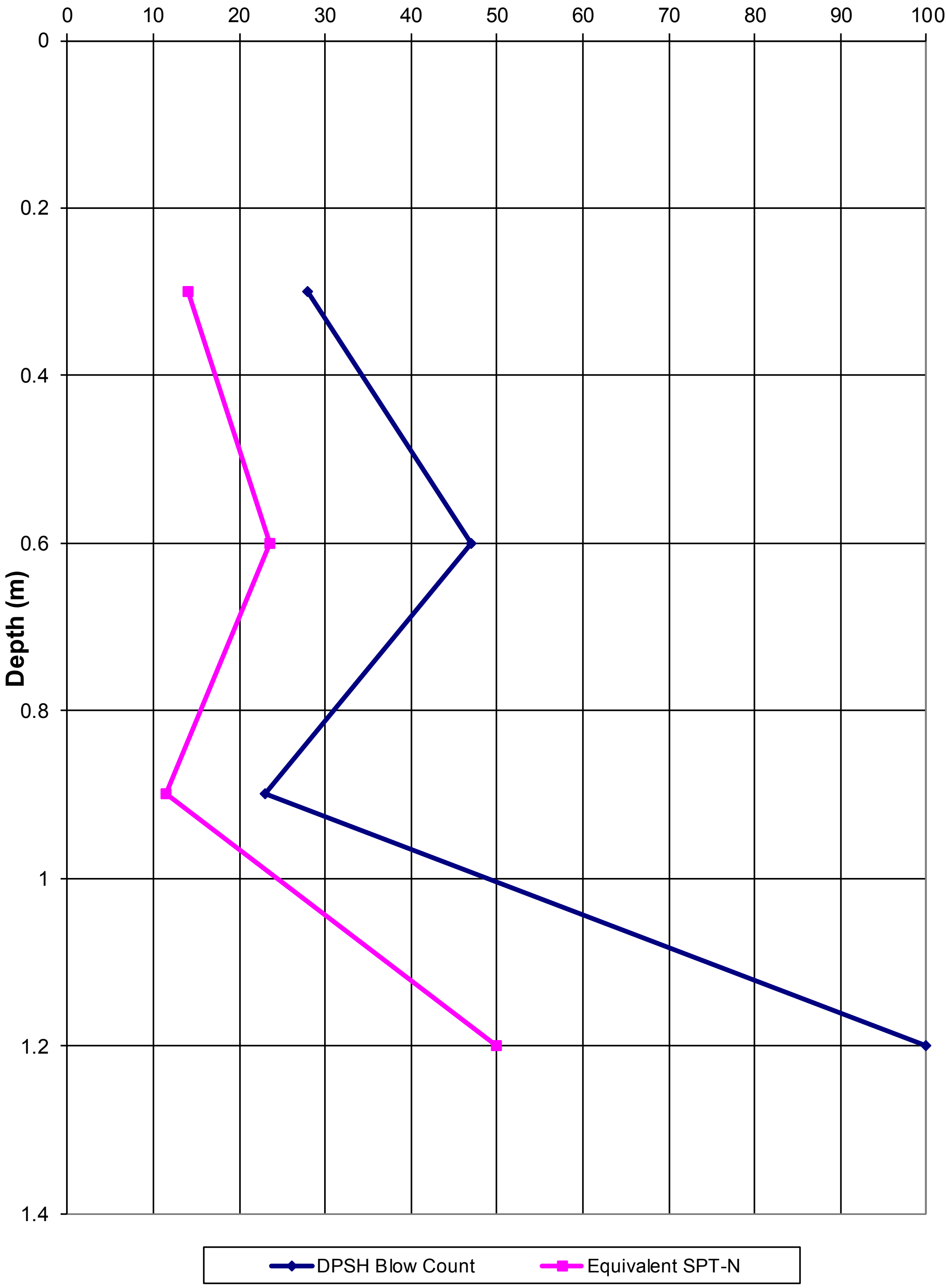


Figure 11: Curves for ER8

APPENDIX H: DPSH RESULTS



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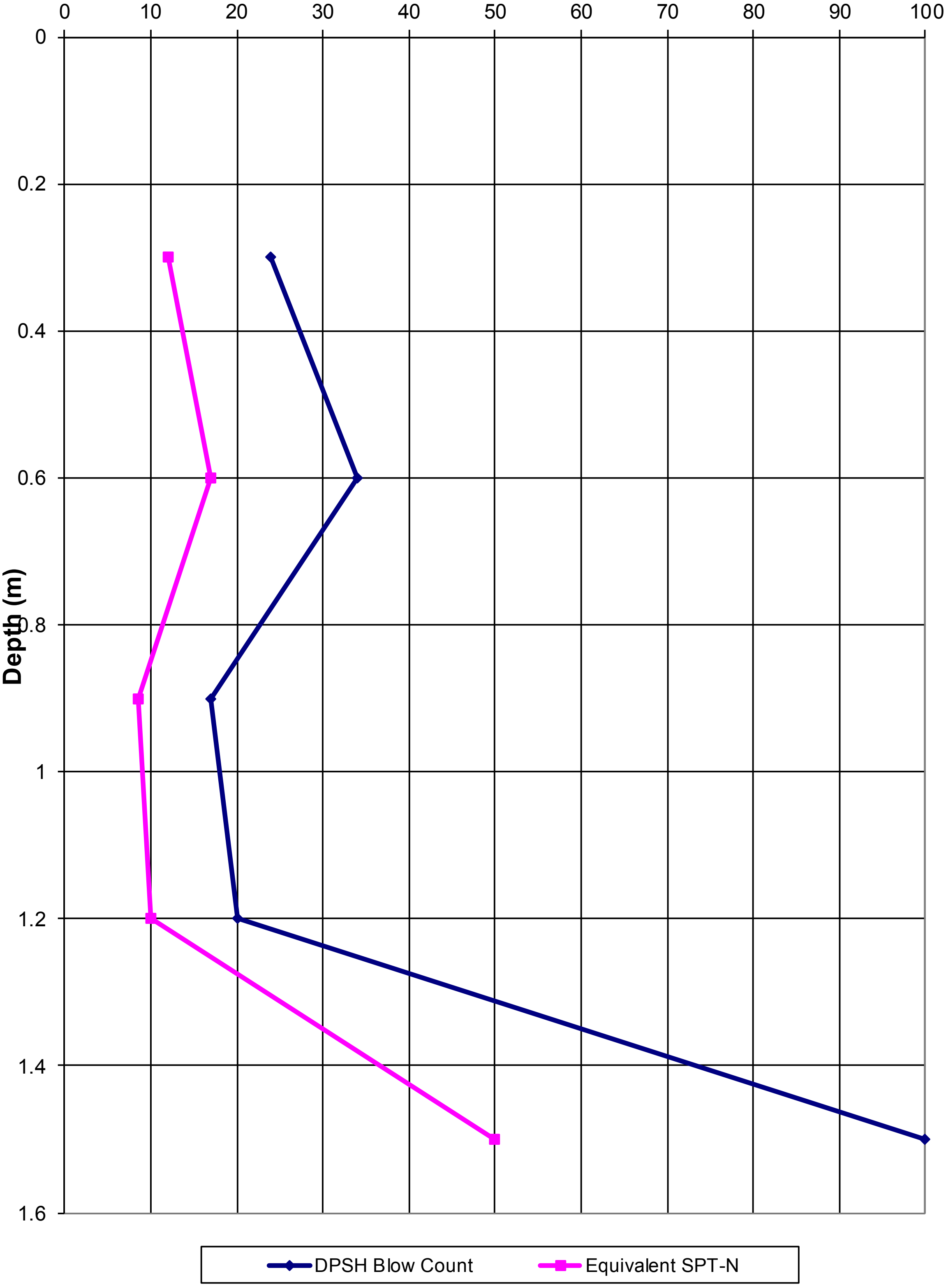

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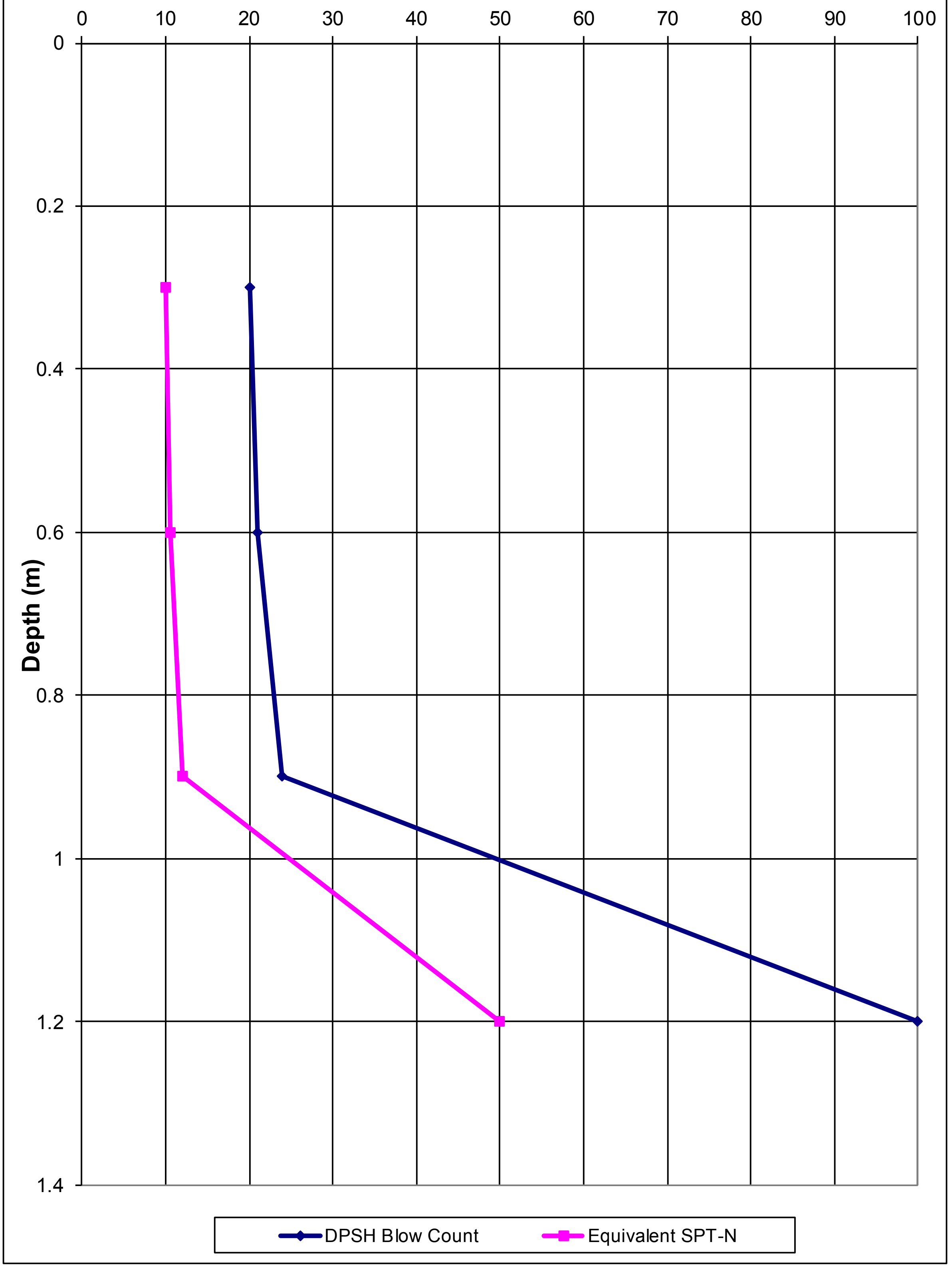
	Checked	fp	12/08/2014

SMEC



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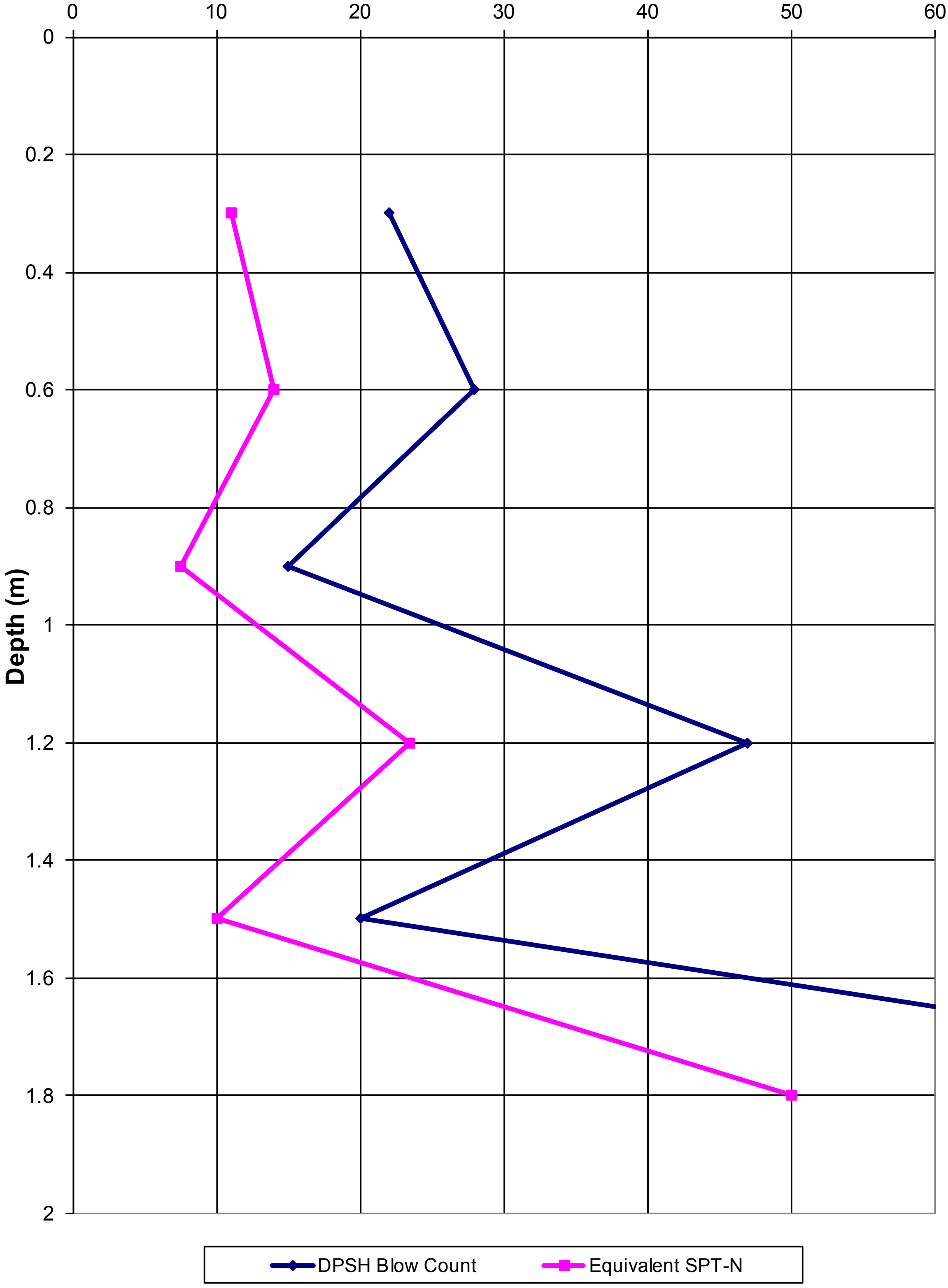
SMEC



DPSH GRAPH

WDP4

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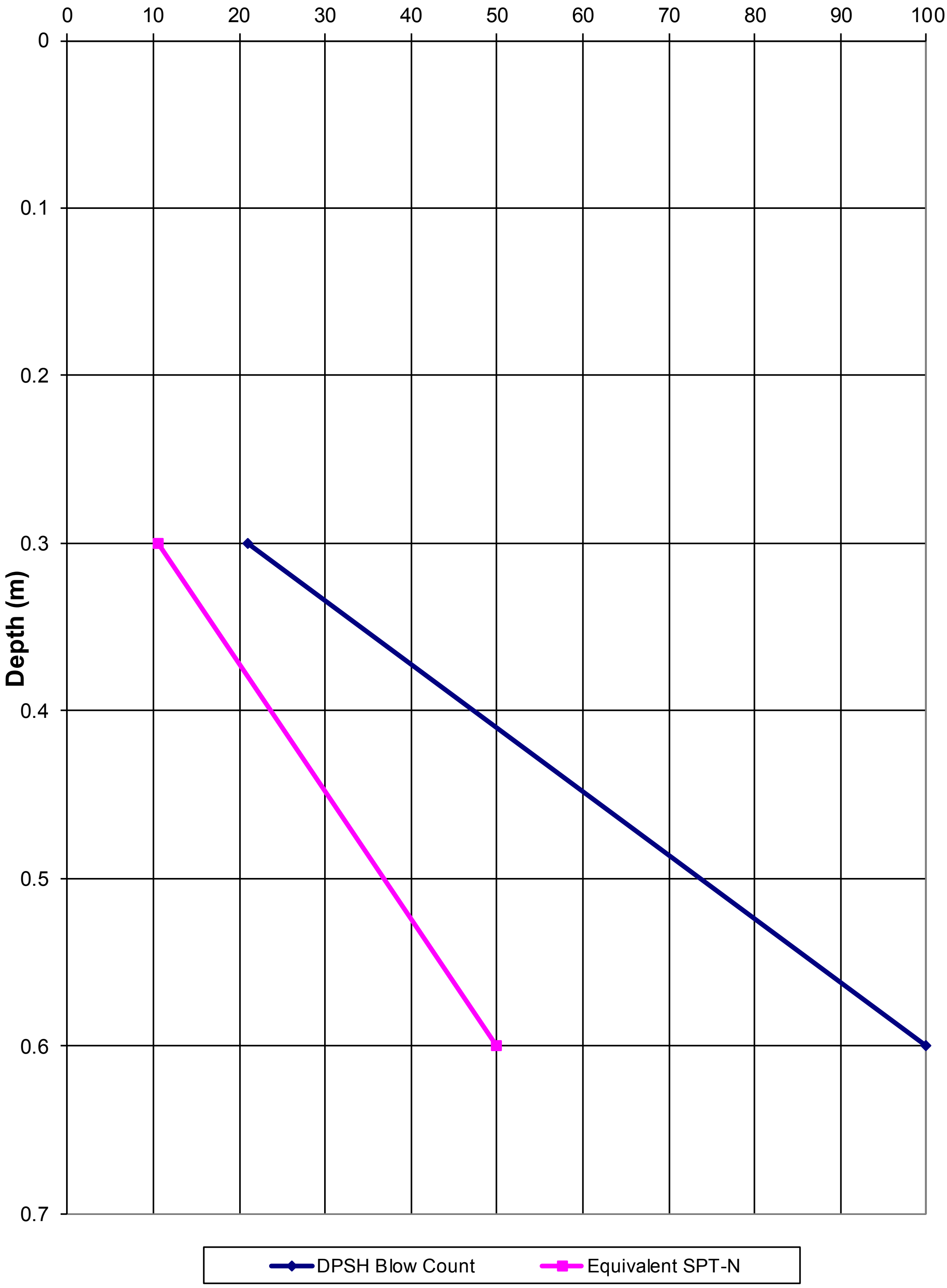
Checked	fp	12/08/2014



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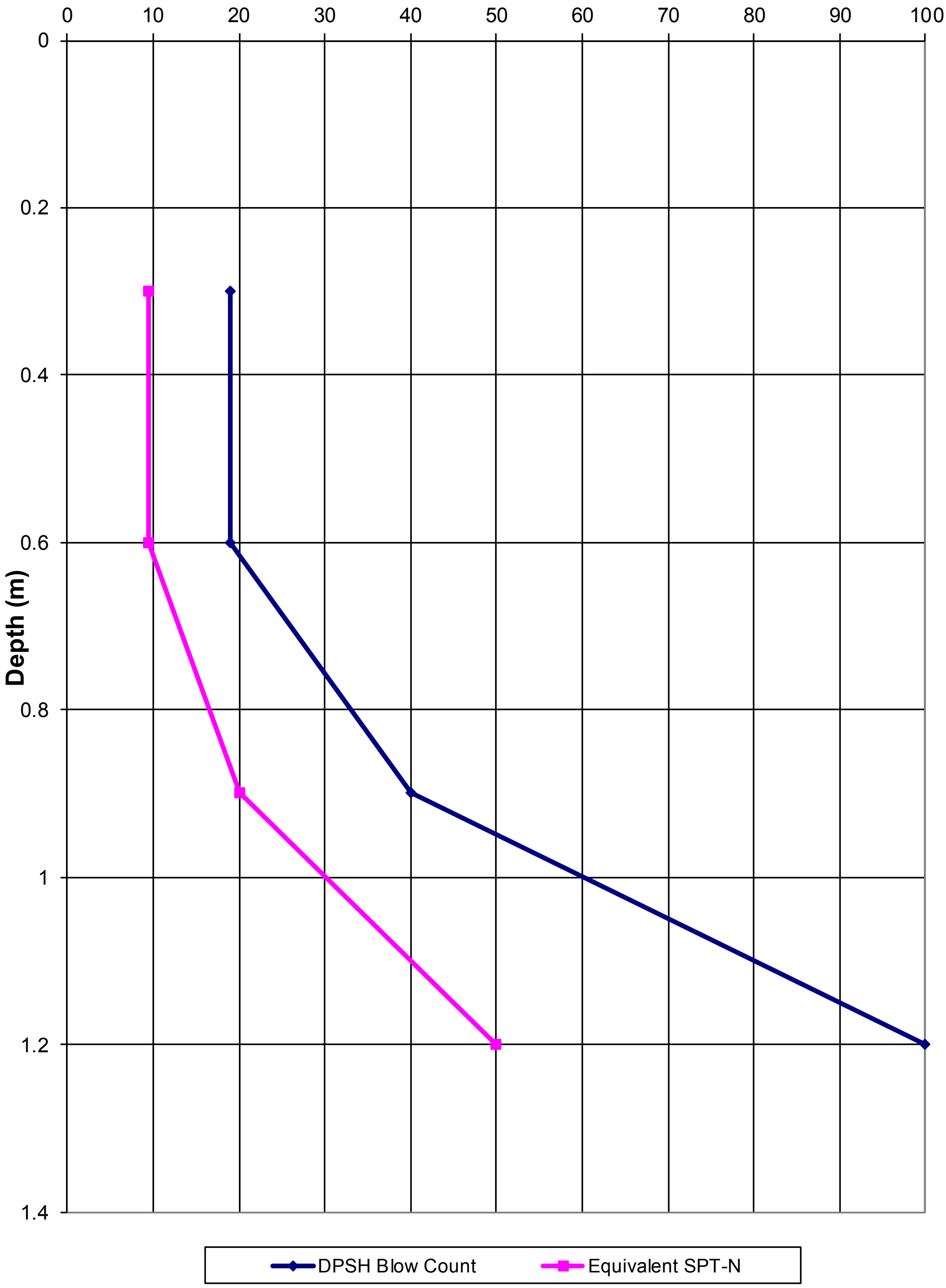

DPSH GRAPH

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

WDP6

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Checked	fp	12/08/2014

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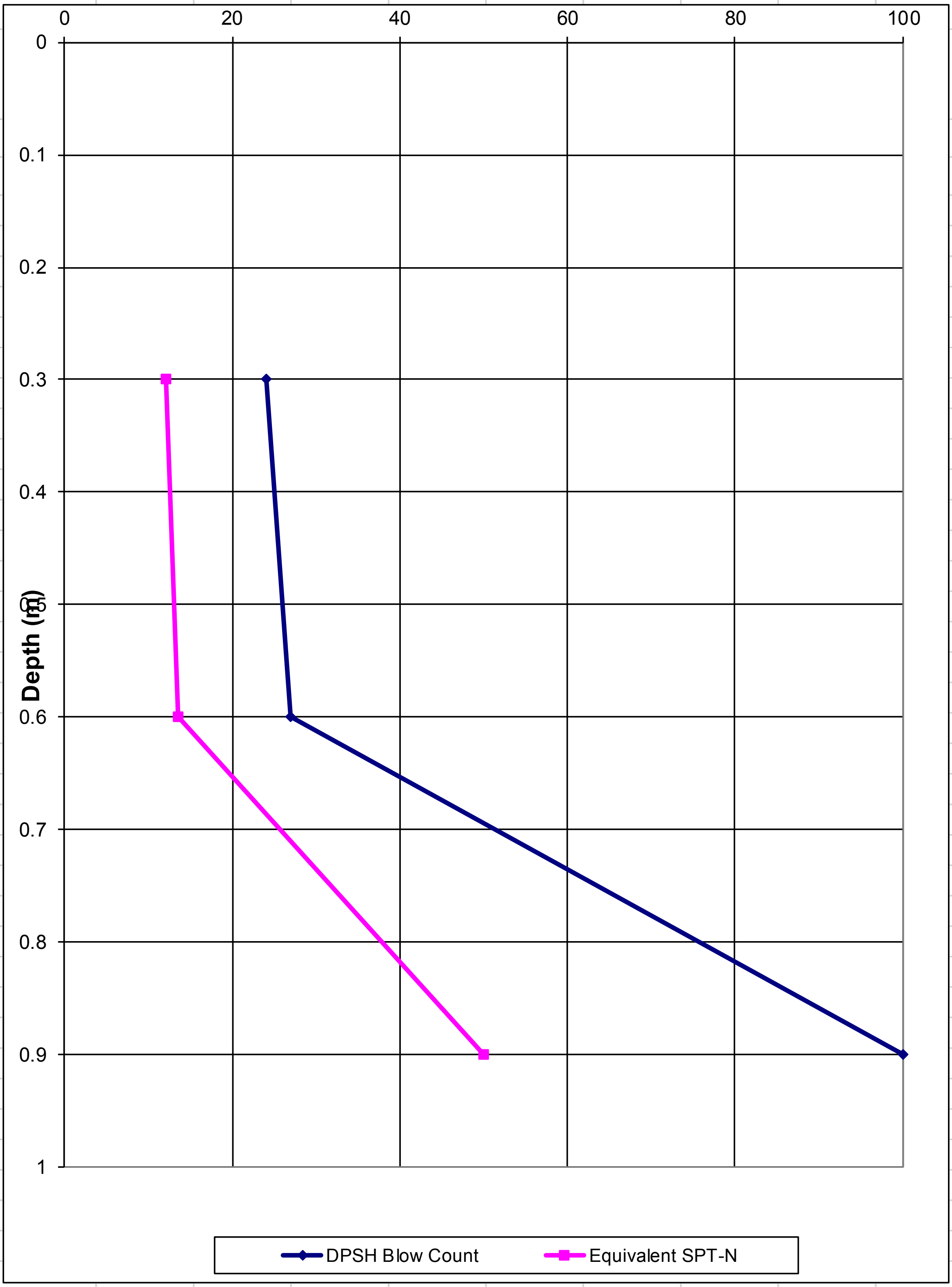

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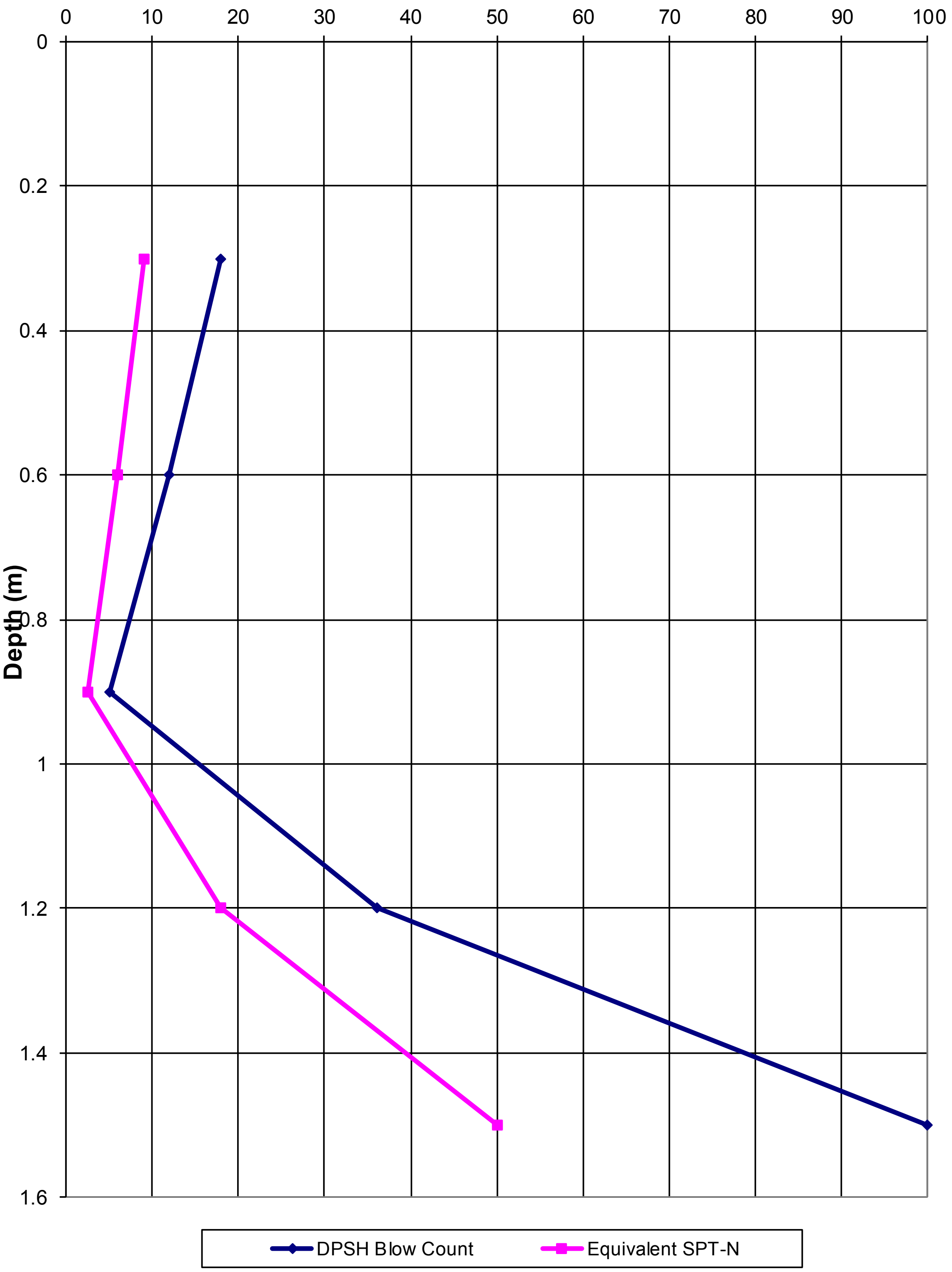
	Checked	fp	12/08/2014

SMEC



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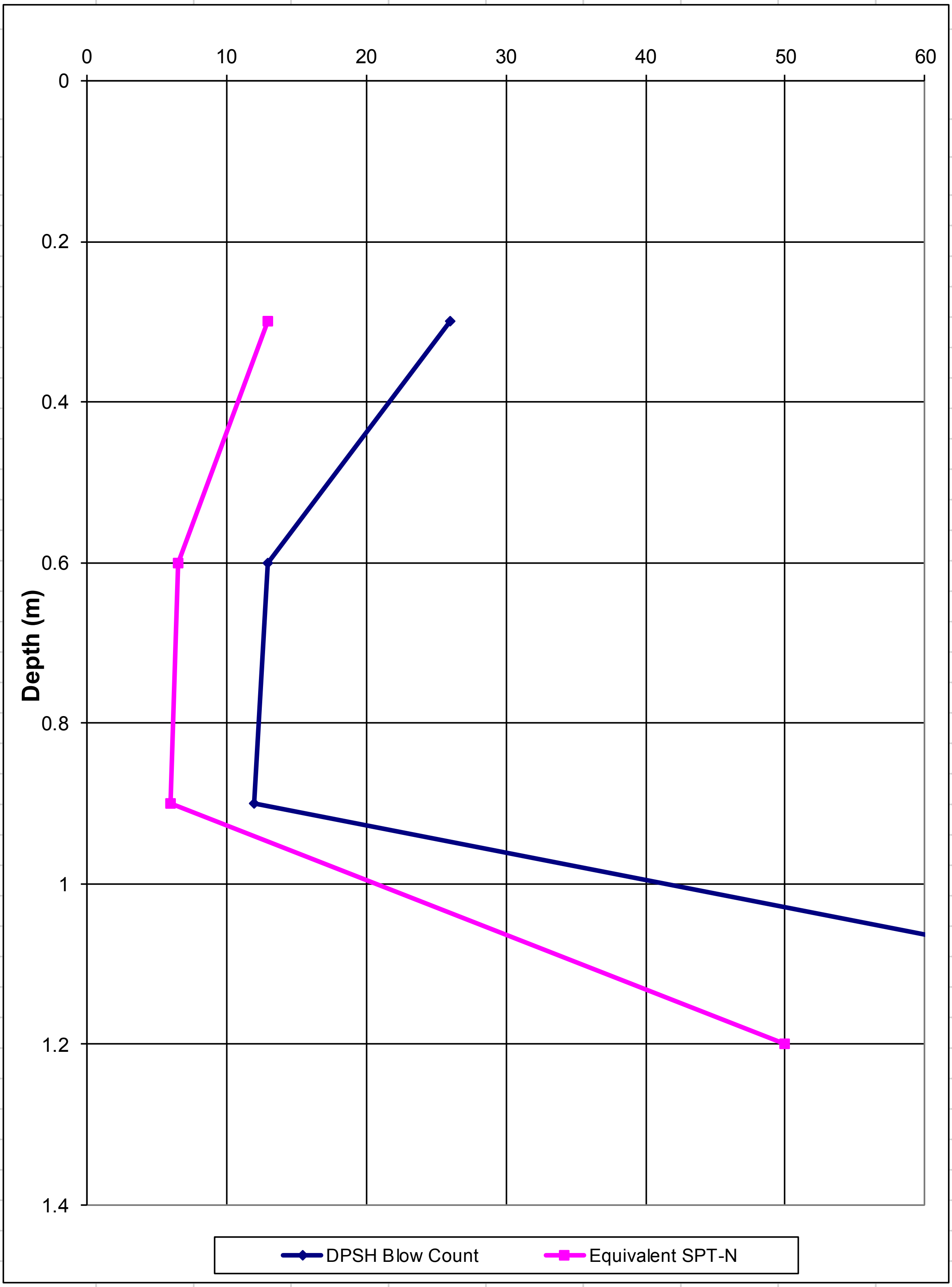
Checked	fp	12/08/2014

SMEC



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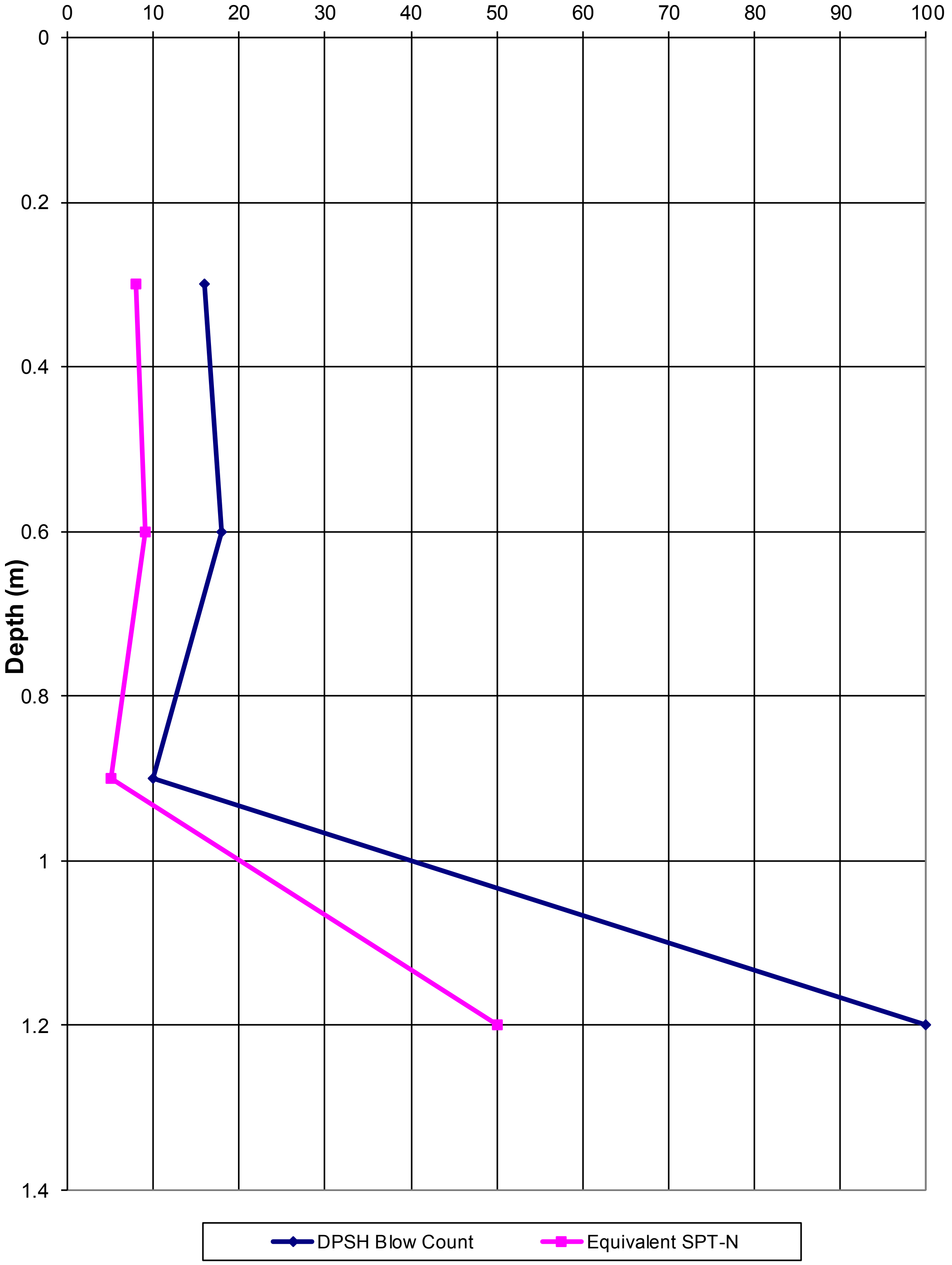


DPSH GRAPH

WDP10

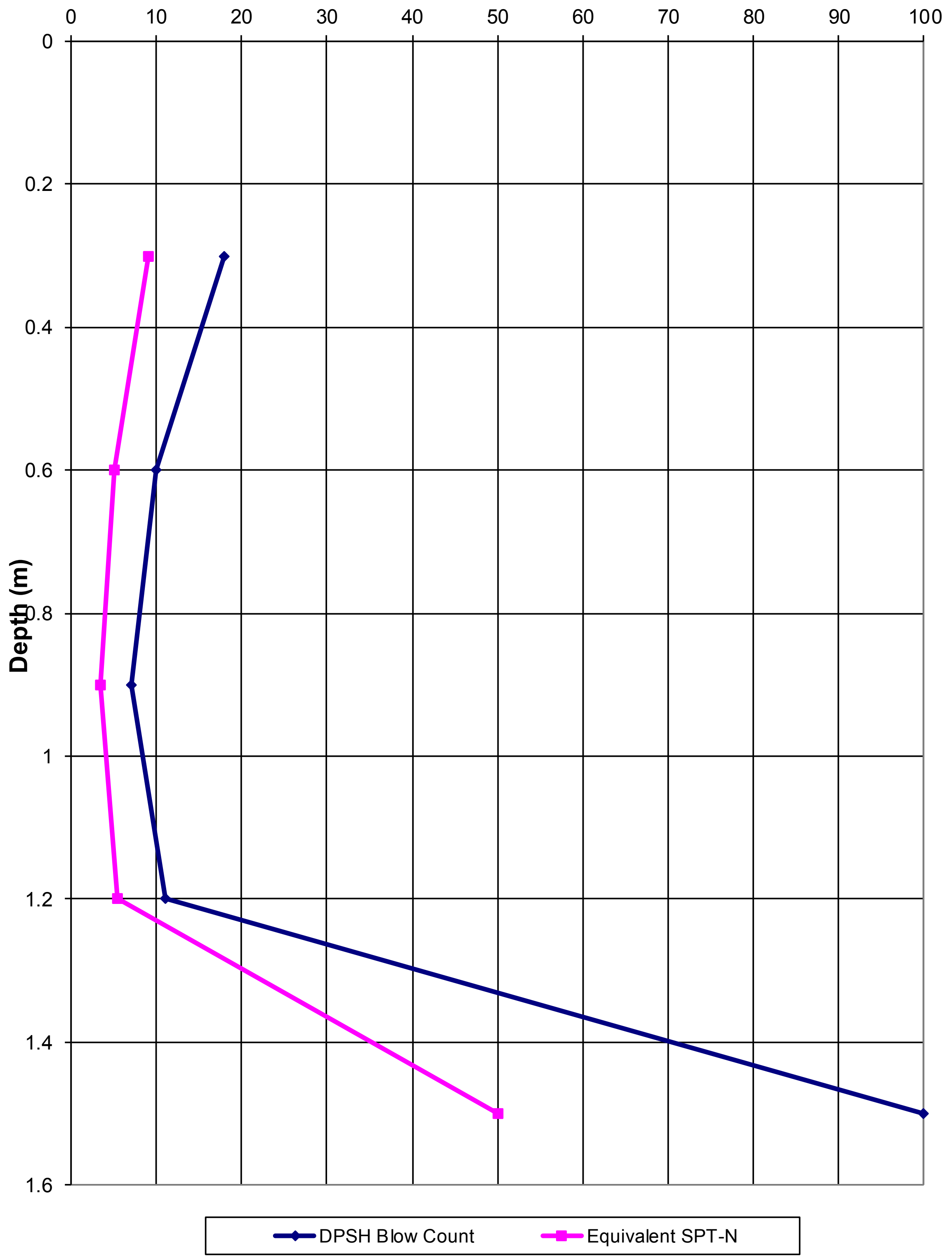
SMEC

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014

DPSH GRAPH	WDP11		
GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK	Compliled	rf	12/08/2014
	Checked	fp	12/08/2014

SMEC



DPSH GRAPH

WDP12

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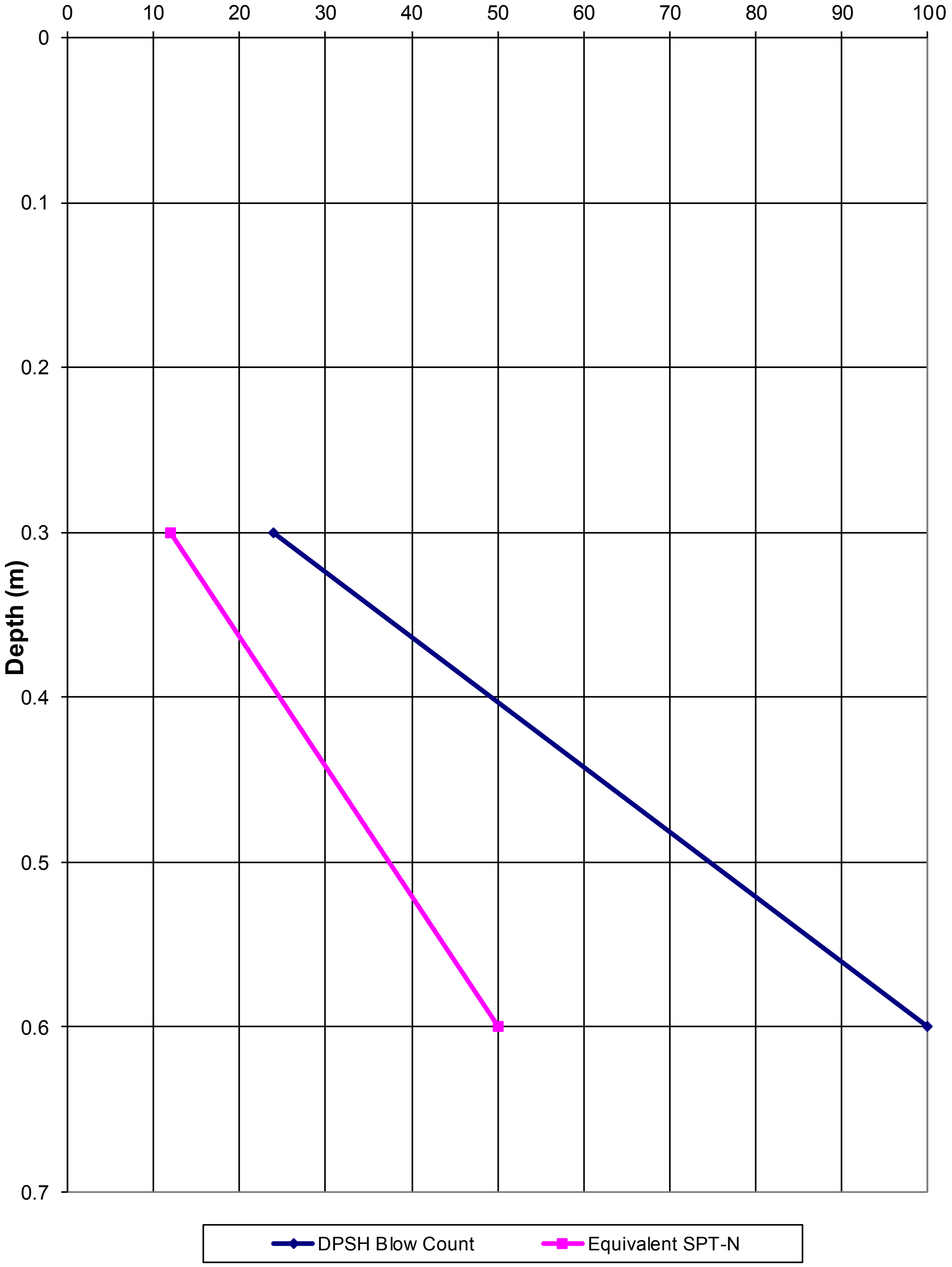
Checked	fp	12/08/2014



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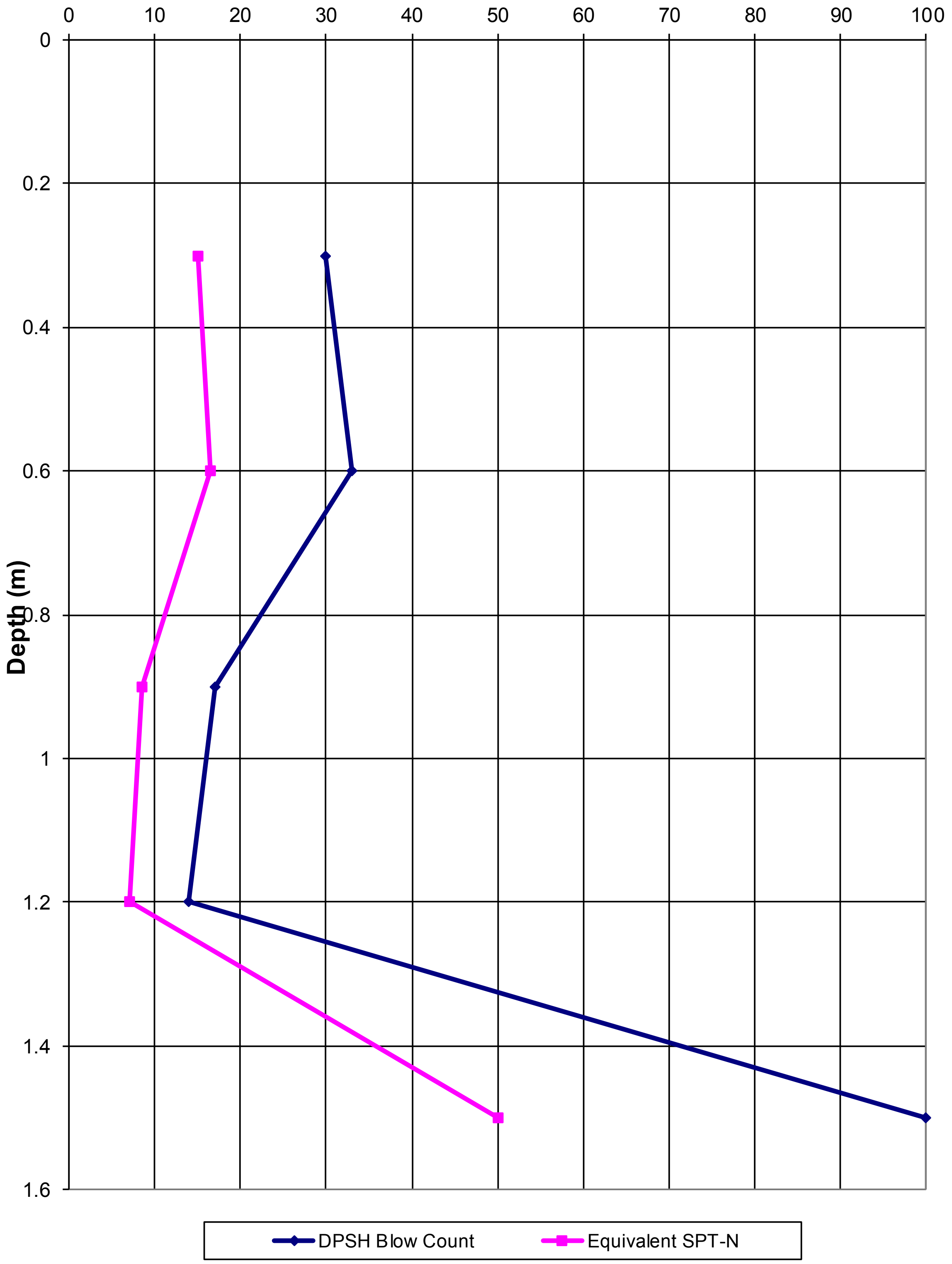
	Checked	fp	12/08/2014



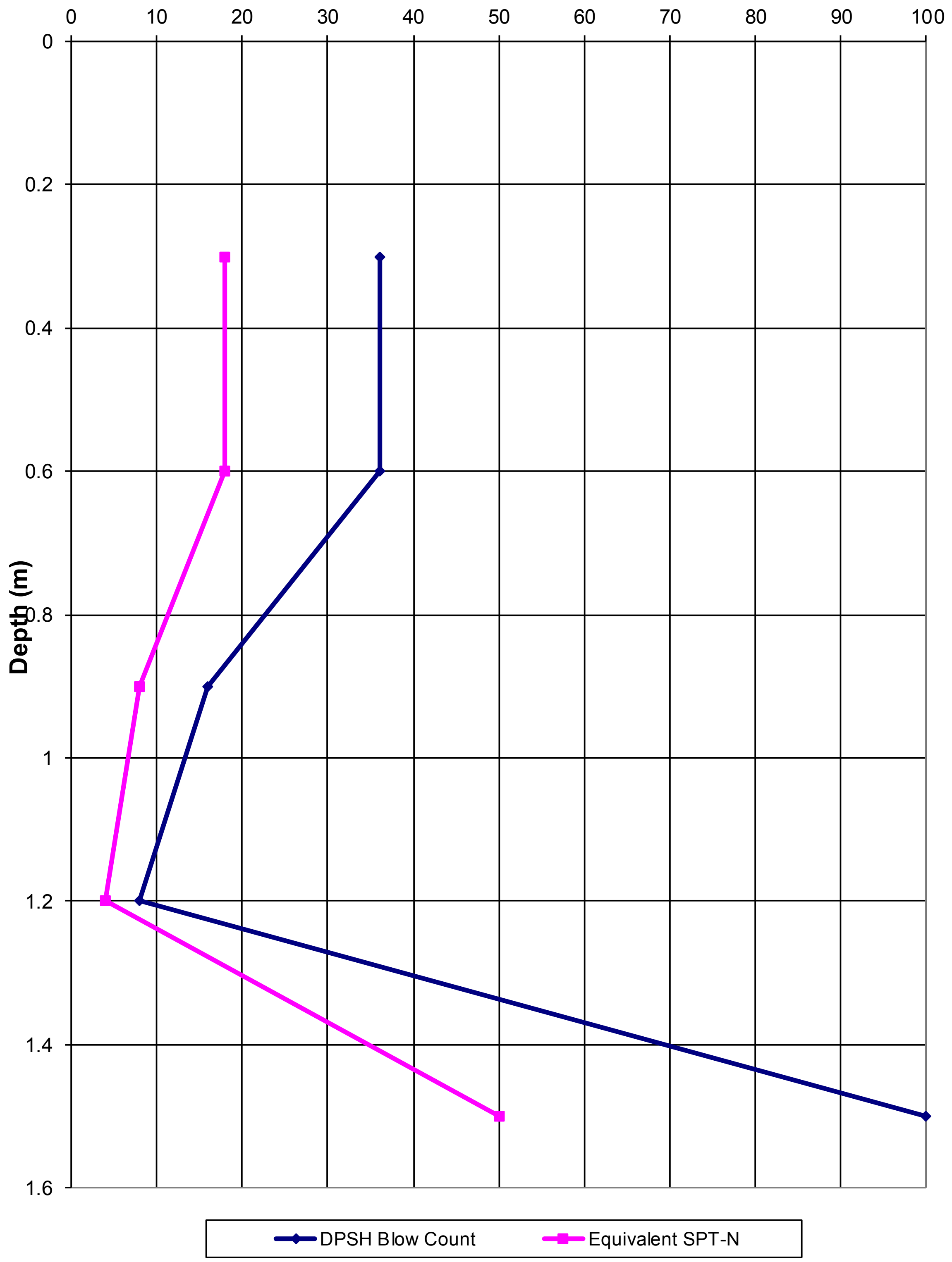
DPSH GRAPH

WDP14

GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014

SMEC



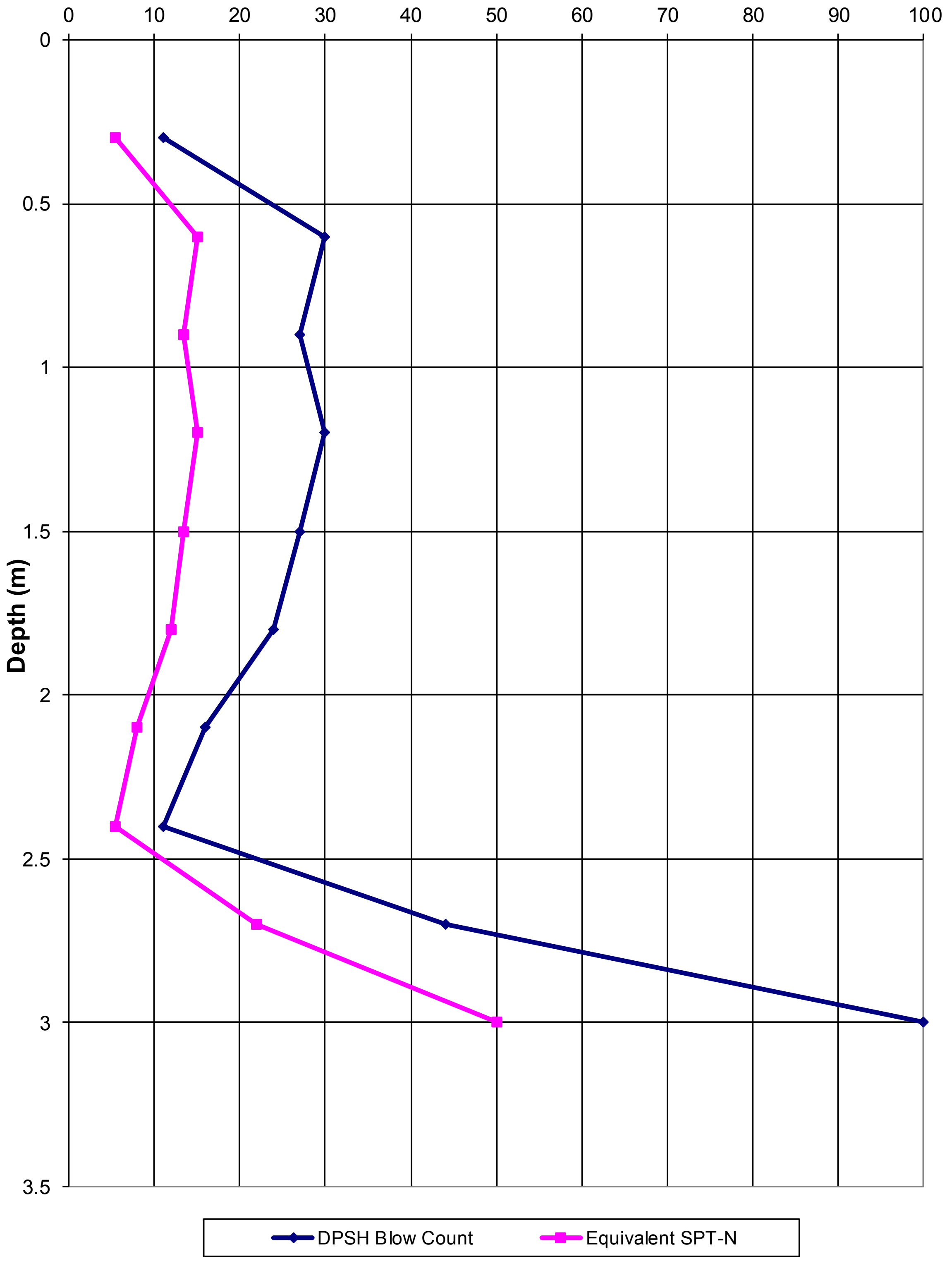
DPSH GRAPH

WDP15

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014

SMEC



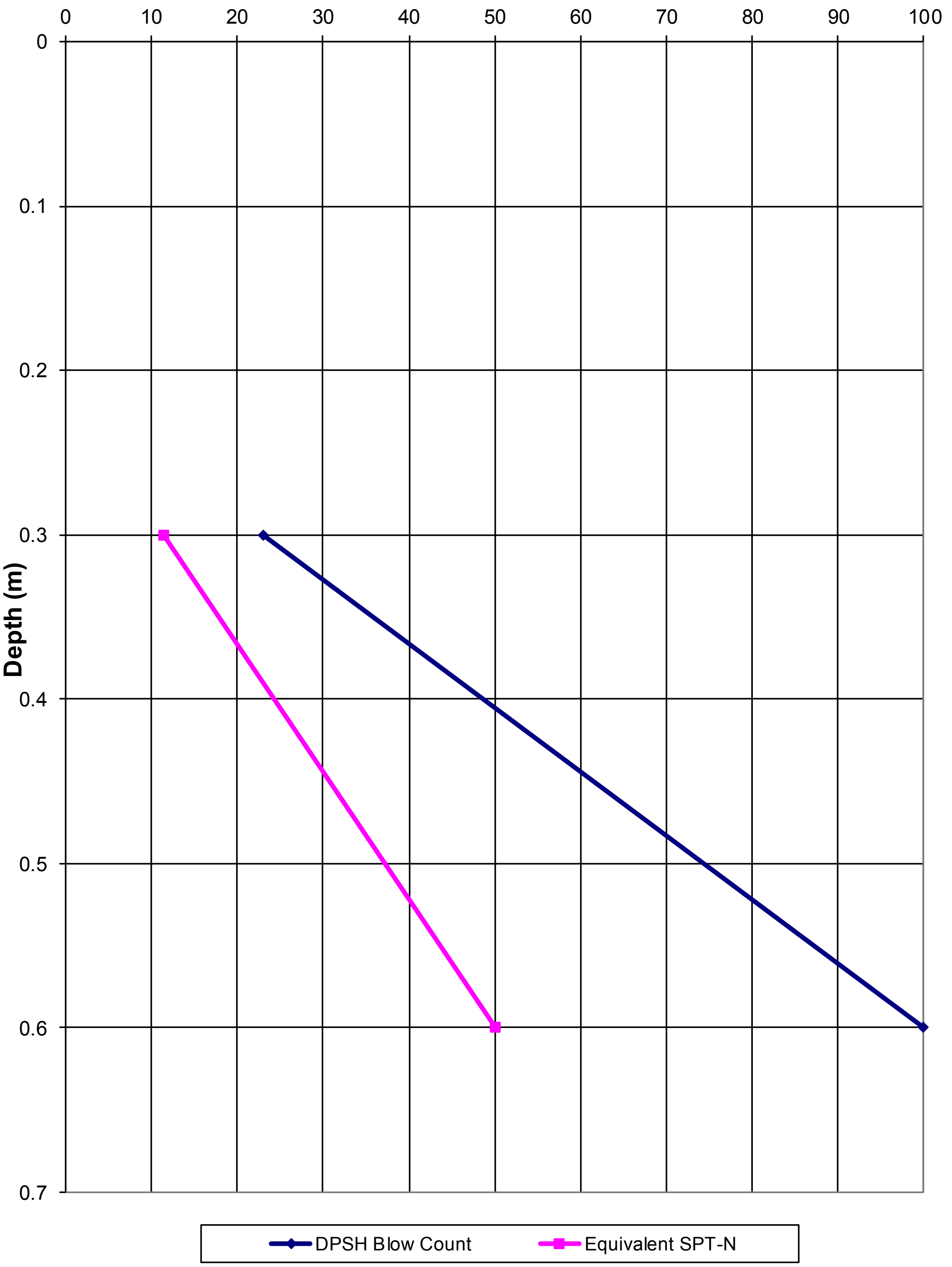
DPSH GRAPH

WDP16

GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK

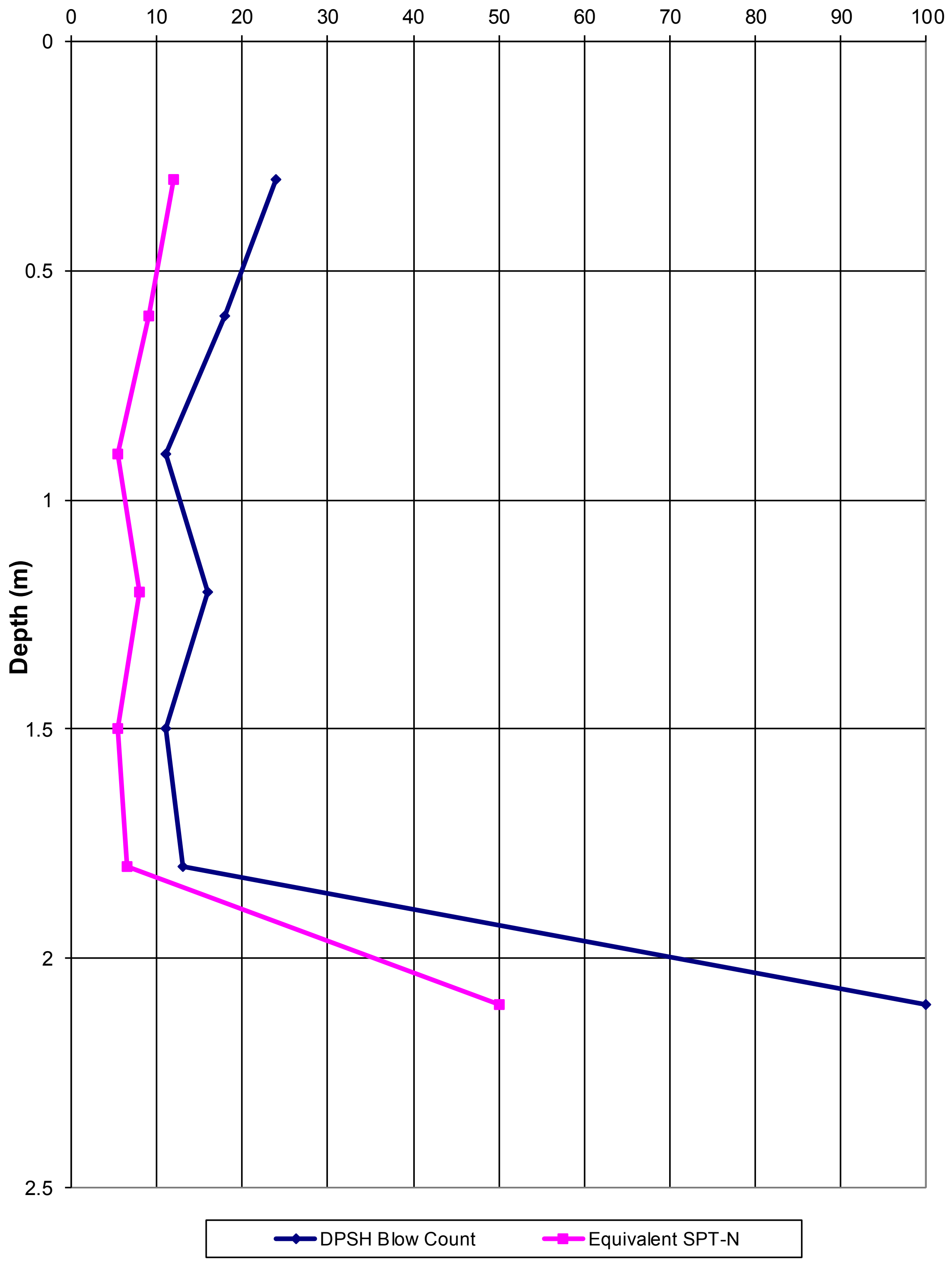
SMEC

Compliled	rf	12/08/2014
Checked	fp	12/08/2014



DPSH GRAPH	WDP17		
GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK	Compliled	rf	12/08/2014
	Checked	fp	12/08/2014

SMEC



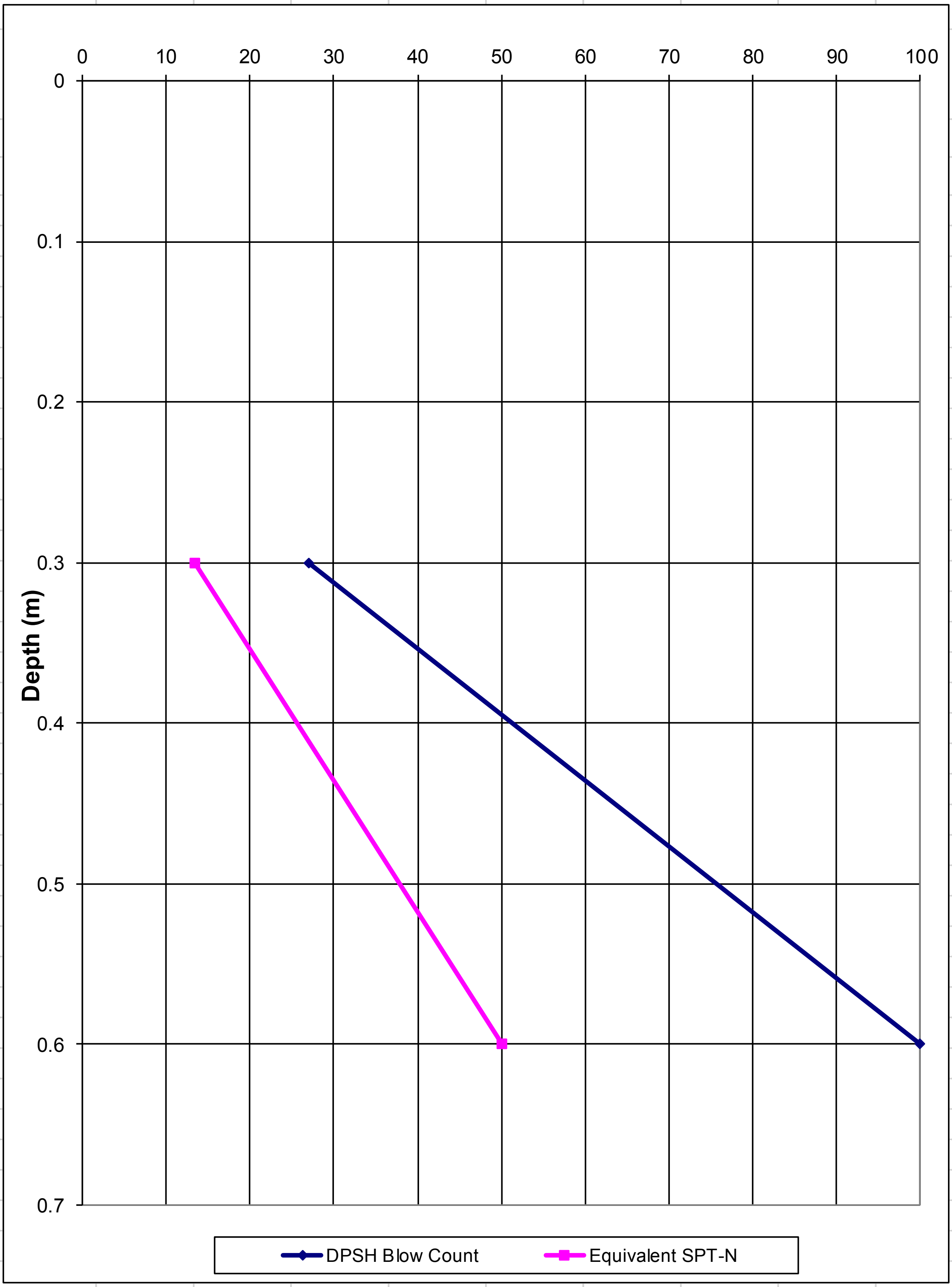
DPSH GRAPH

WDP18

SMEC

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014



DPSH GRAPH	WDP19		
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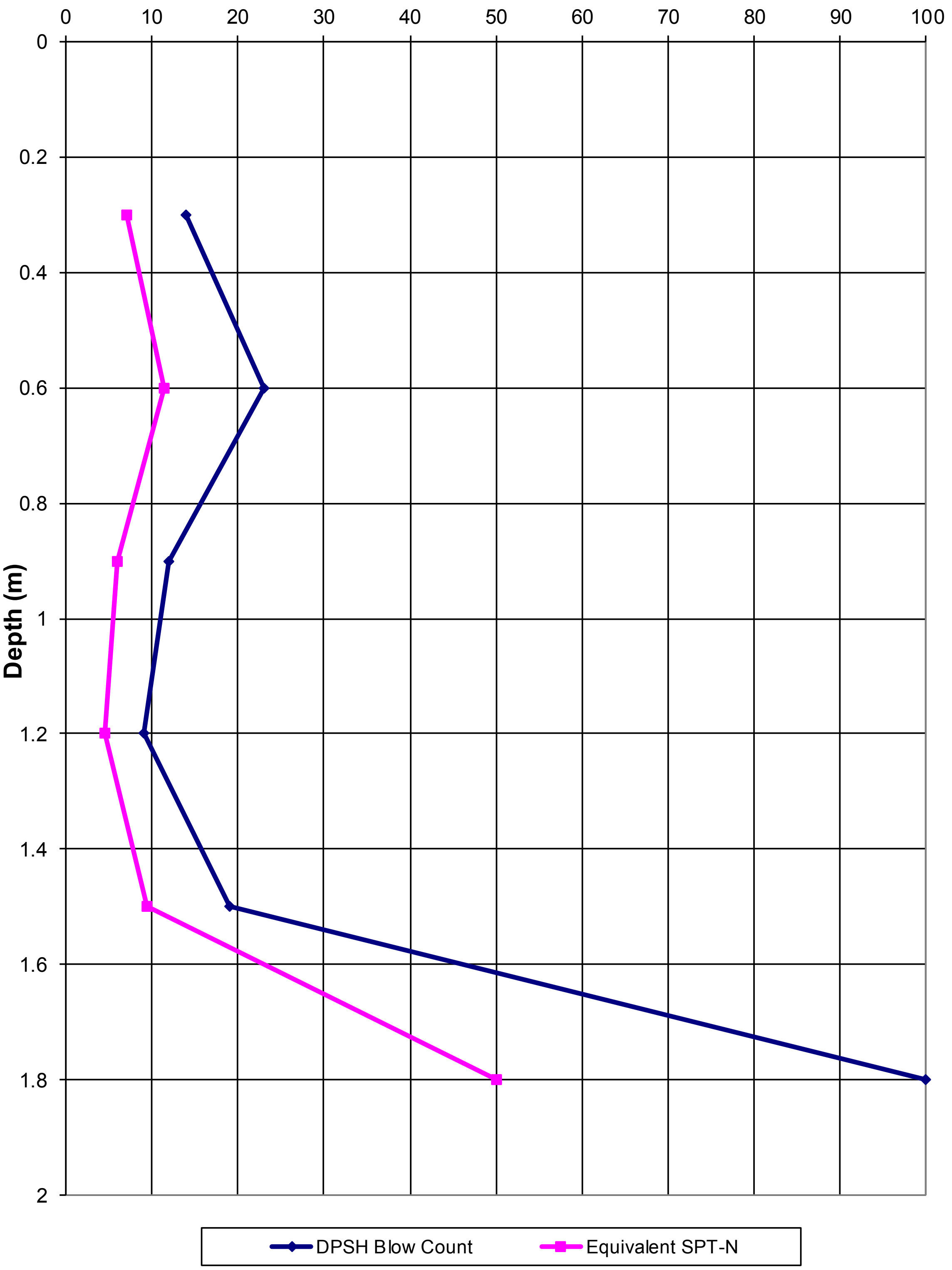
	Checked	fp	12/08/2014

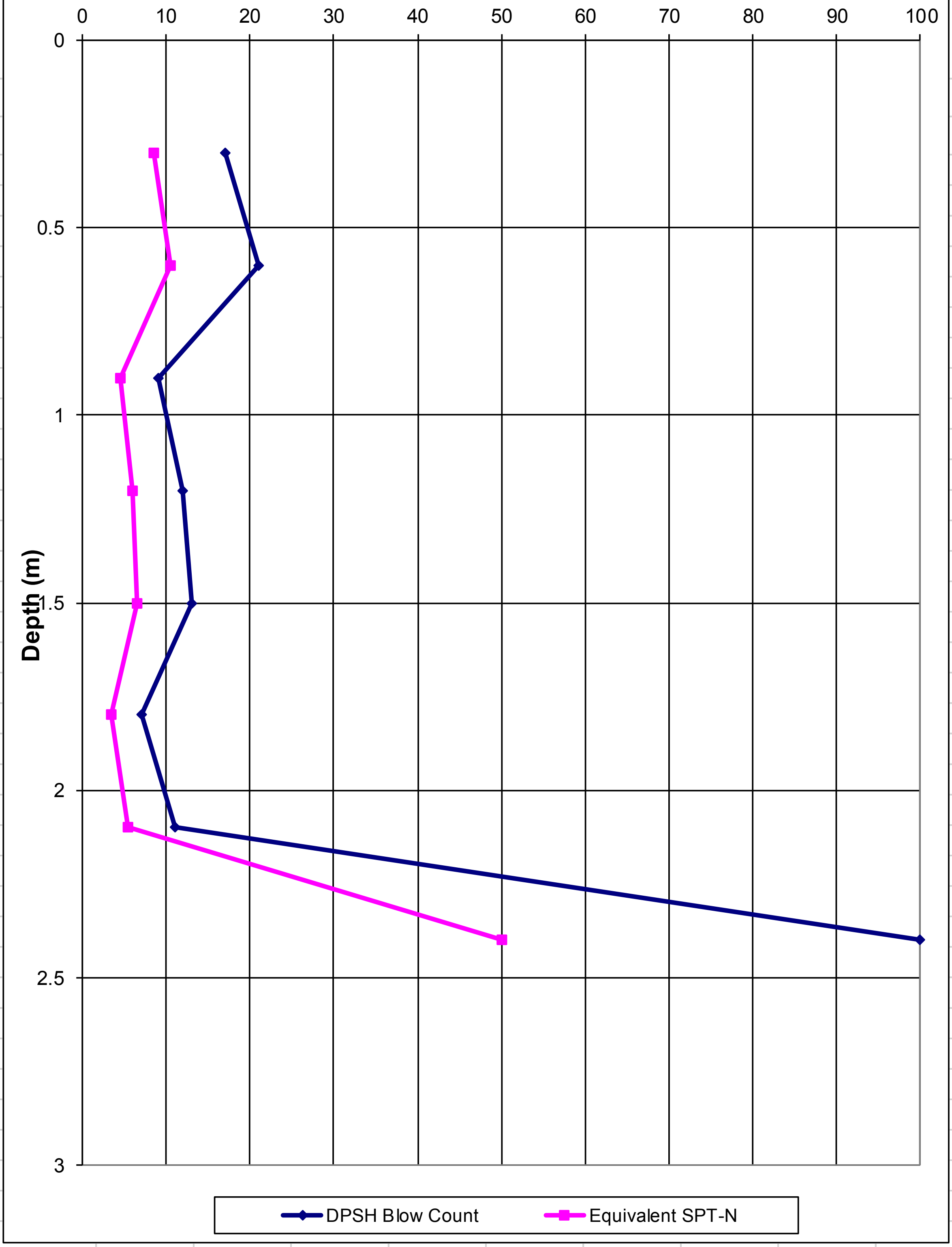


DPSH GRAPH

WDP20

GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014



DPSH GRAPH	WDP21		
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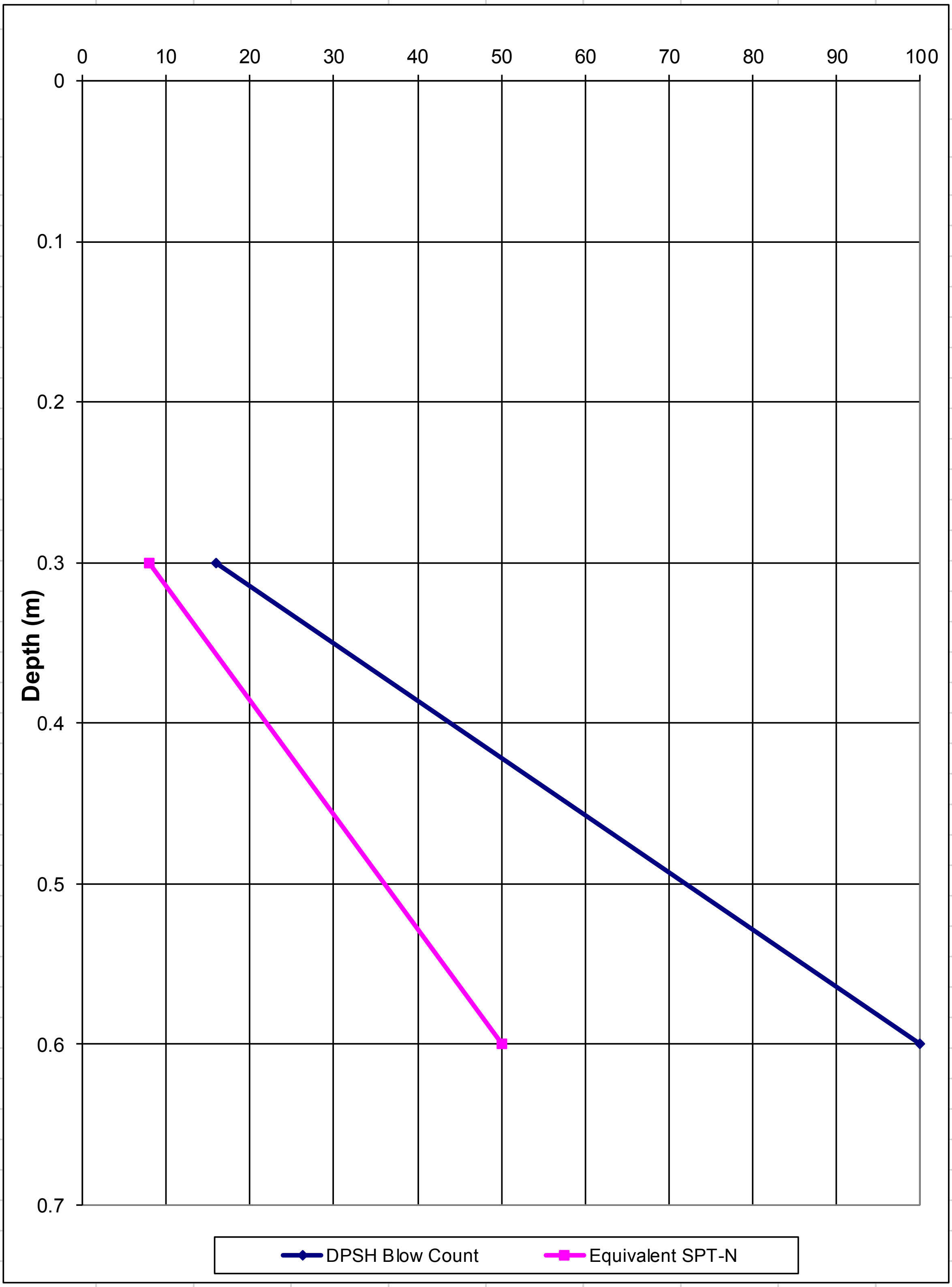
	Checked	fp	12/08/2014

SMEC



DPSH GRAPH	WDP22		
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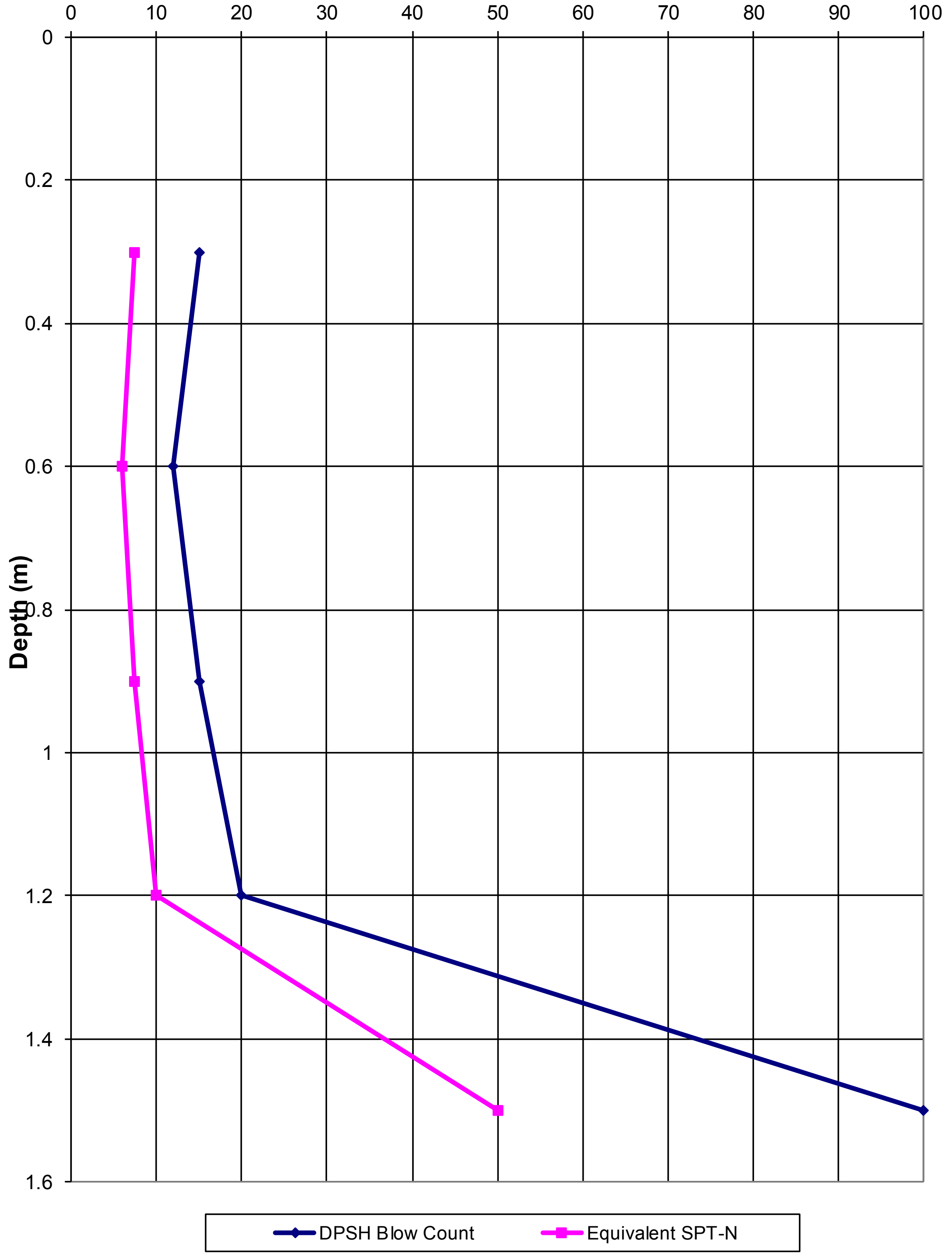
	Checked	fp	12/08/2014



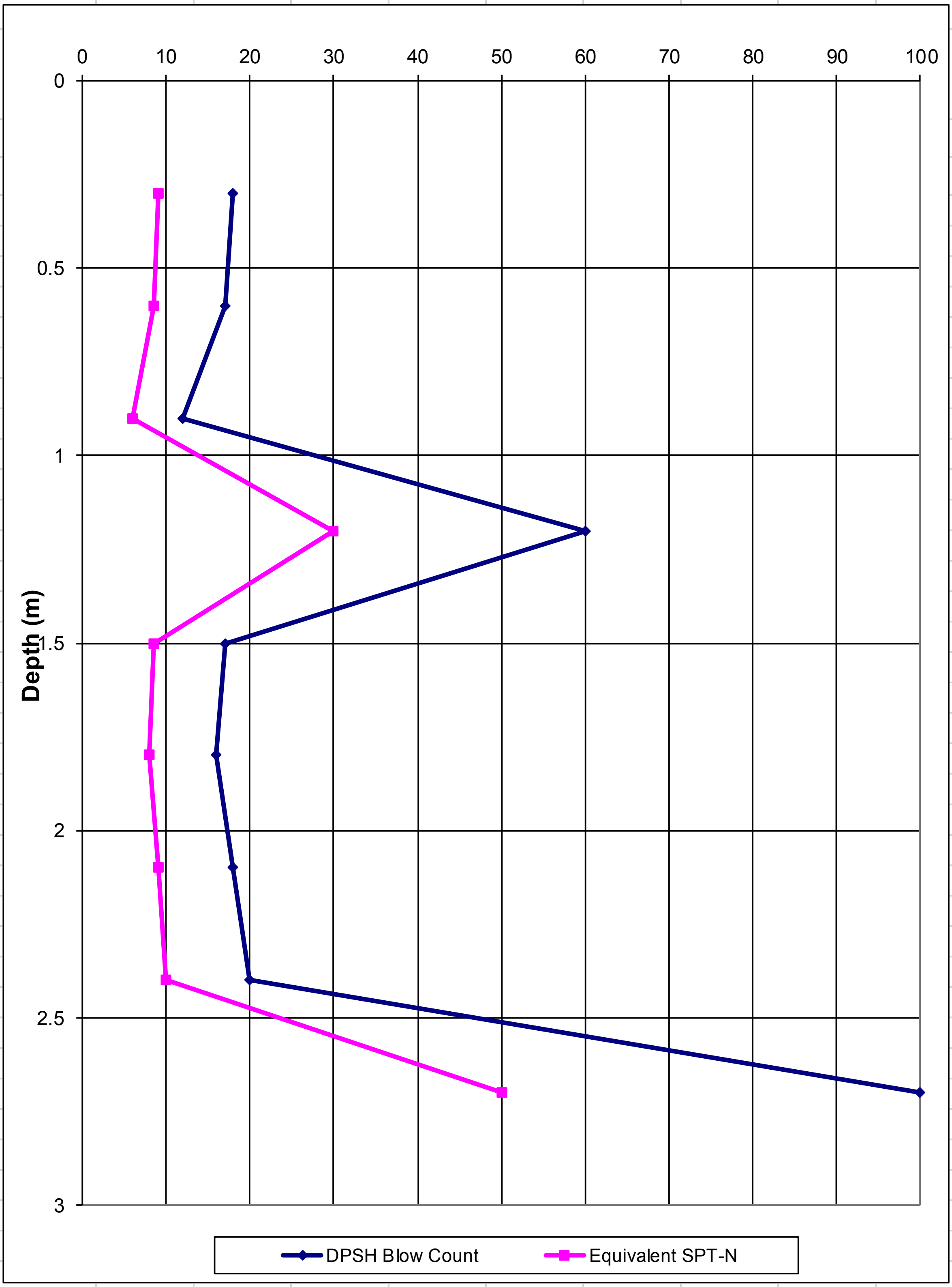
DPSH GRAPH

WDP23

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

Compliled	rf	12/08/2014
Checked	fp	12/08/2014

SMEC



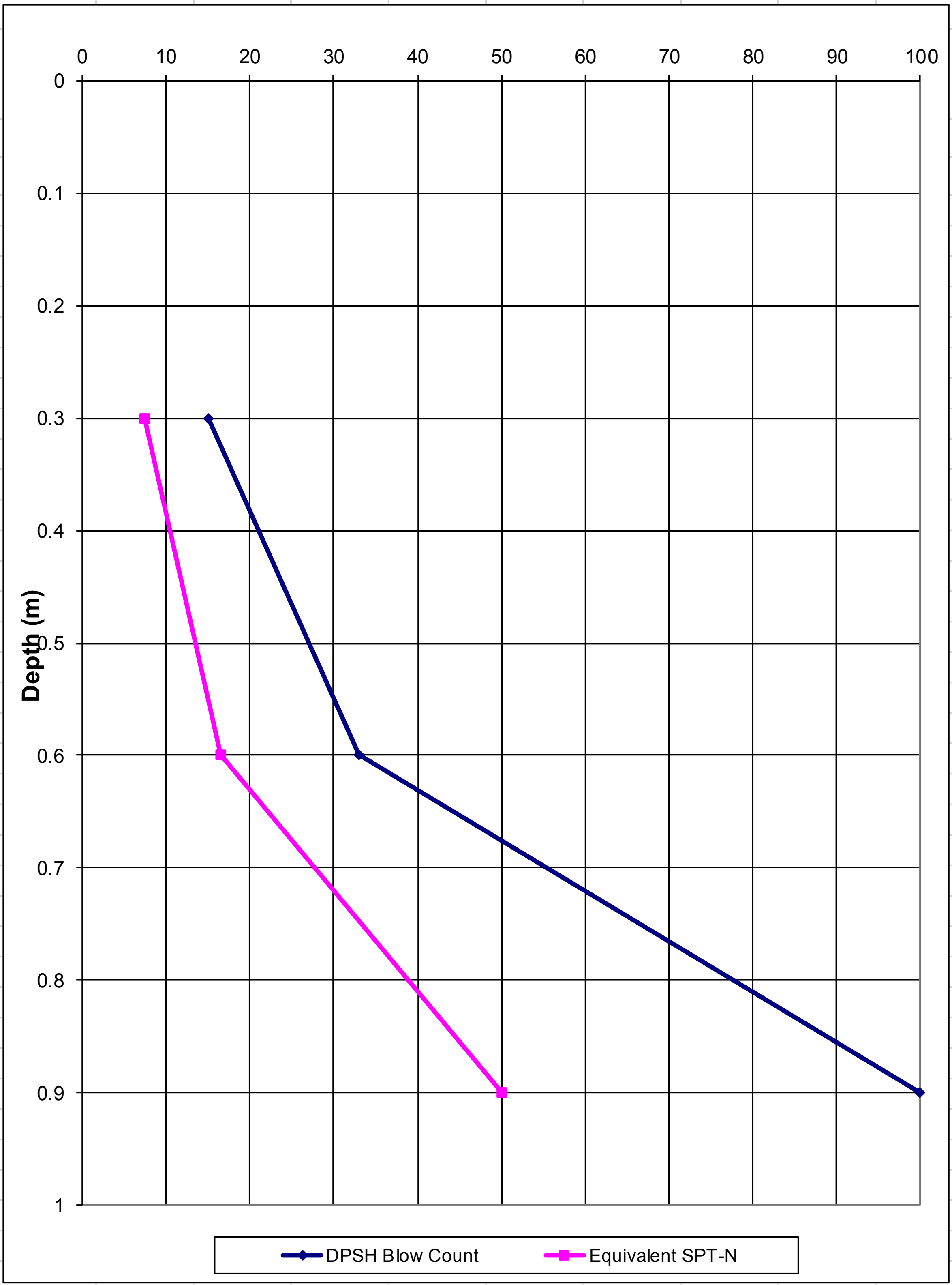
DPSH GRAPH

WDP24

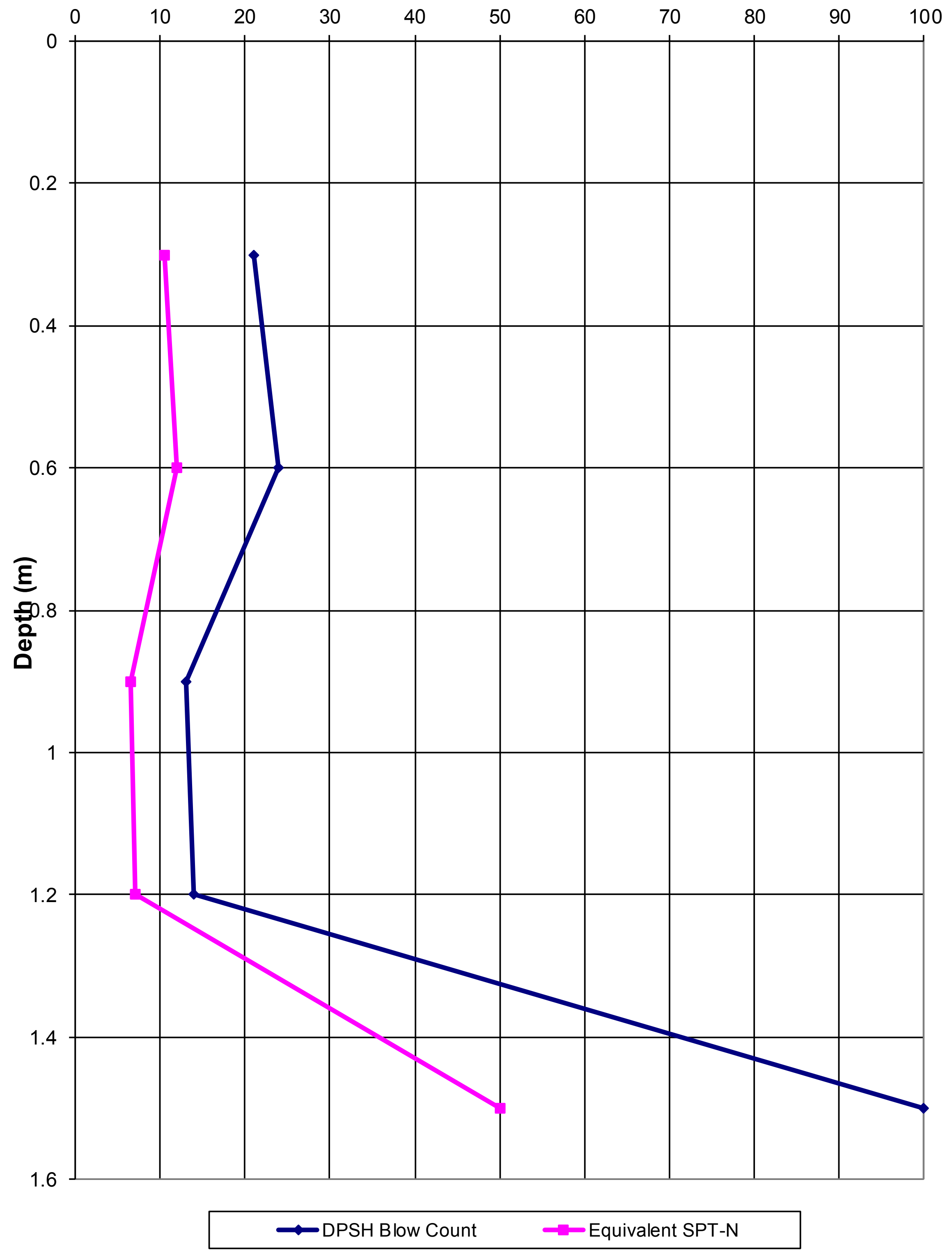
SMEC

GEOTECHNICAL INVESTIGATION WATERLOO
SOLAR PARK

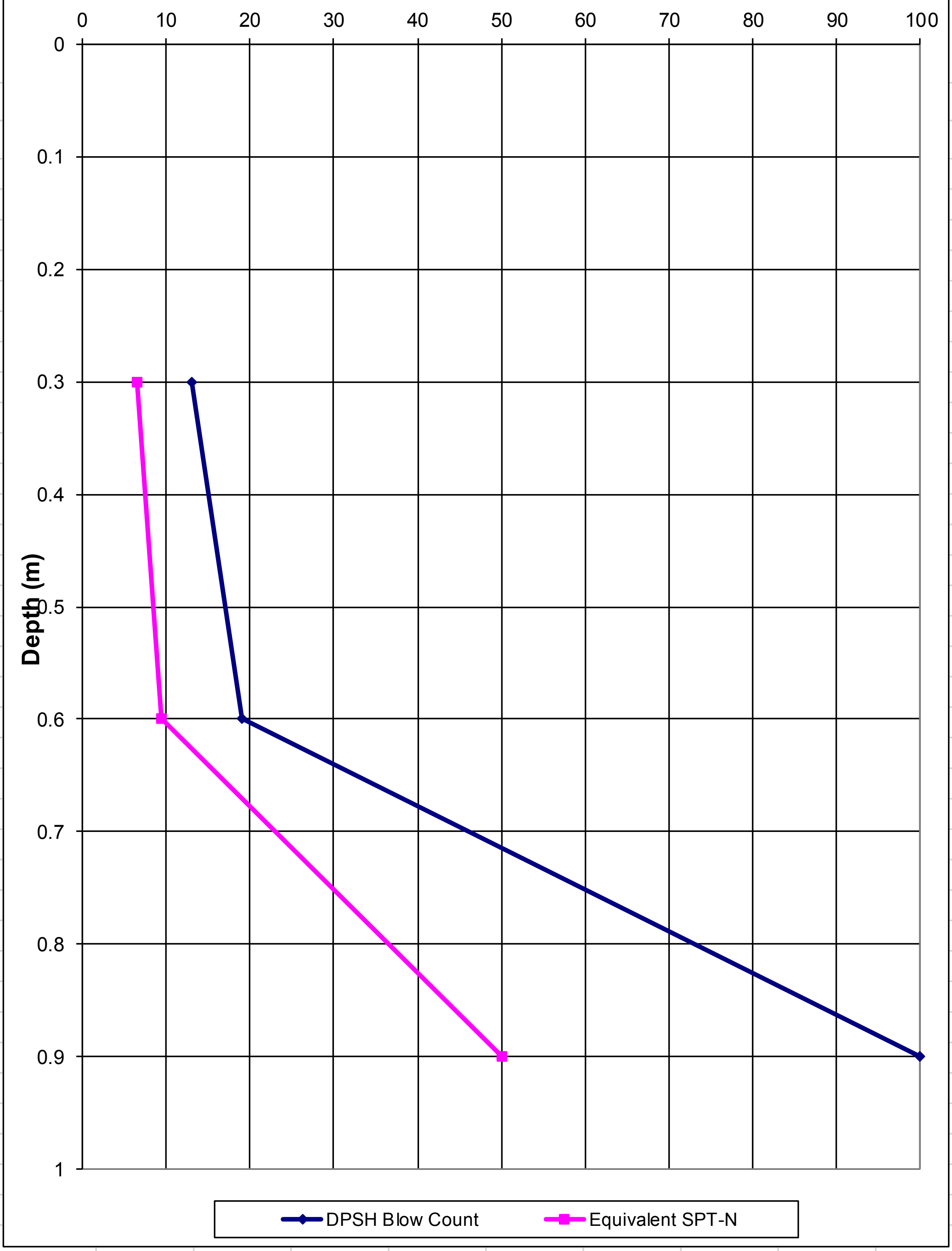
Compliled	rf	12/08/2014
Checked	fp	12/08/2014



DPSH GRAPH	WDP25		
GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK	Compliled	rf	12/08/2014
	Checked	fp	12/08/2014



DPSH GRAPH	WDP26	
GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK	Compliled rf 12/08/2014 Checked fp 12/08/2014	SMEC



DPSH GRAPH	WDP27		
GEOTECHNICAL INVESTIGATION WATERLOO SOLAR PARK	Compliled	rf	12/08/2014
	Checked	fp	12/08/2014

SMEC

APPENDIX I: CGS REVIEW OF REPORT

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Council for Geoscience

Our Reference: F4498.1
Waterloo Solar Plant
Your Reference: JG0002/02/09/2014/2536
Enquiries: T Oosthuizen
Tel: 012 841 1160
Fax: 086 615 6682
No. of Pages: 5

8 October 2014

SMEC SOUTH AFRICA
PO Box 1462
Pinegowrie
2123

ATTENTION: Mr. R Freese

By email: Ryan.Freese@smec.com

Dear Sir

WATERLOO SOLAR PLANT

Your firm, SMEC South Africa, submitted the report: "Dolomite Stability Investigation: Waterloo Solar Plant, Waterloo Farm, near Vryburg, North West Province", dated September 2014 to this office for comments. This office acts as an agent to state authorities in reviewing dolomite stability investigations on their behalf.

The report presents the findings of a dolomite stability investigation for the proposed Waterloo Solar Park. The site is located near Vryburg in the North West Province and covers an approximately 150 ha portion of the Waterloo Farm. The development will comprise ground-mounted single axis tracker solar photovoltaic panels, with a substation, office, warehouse and associated infrastructure.

The following is noted from the SMEC report:

1) The objective of the study was to evaluate the dolomite stability conditions on the site - with particular reference to the south-eastern corner where the electricity substation, office, store and other 'manned' infrastructure will be situated.
   - A gravity survey (on a 15 m grid spacing) was conducted across 3 hectare portion of the

site, located in the south-eastern corner of the site;
- Percussion drilling was carried out in areas where gravity anomalies were present in the 3 hectare portion (4 boreholes) of the site and limited drilling across the remainder of the site at random localities (6 boreholes).
- Ten electrical resistivity arrays were undertaken across the site.

2) The geological map of the area (Christiana Sheet 2724) indicates that the entire site is underlain by rocks of the Boomplaas Formation. SMEC indicates that this corresponds well with the bedrock observed on site. This formation consists predominantly of stromatilitic and oolitic dolomite interbedded with layers of quartzite, shale and flagstone.

3) In Section 4.1 of the report SMEC indicates that the area falls within the Upper Ghaap Plateau Ground Water Management Area. Groundwater information on the area of the site indicates the groundwater level should be approximately 17 m to 25 m below surface (DWAF, 2010).

   SMEC indicates that the groundwater table was not intercepted in any of the boreholes drilled on site, up to a depth of 50 m, and it appears that the groundwater level is located deep within the dolomitic bedrock. According to SMEC this correlates well with borehole logs from previous dolomite stability investigations in the area which indicated the groundwater level in the area is generally below 50 m. Data collected from monitoring boreholes between 1984 and 2008 in the Upper Ghaap Plateau GMA shows that groundwater levels have risen by approximately 0.9 m in this period. This indicates that dewatering has not taken place.

4) SMEC indicated the following in Section 6 of the report, regarding the hazard classification and use of the site:
   - The dolomitic conditions observed across the proposed PV plant were found to be homogenous across the entire site, both at the 3ha portion and the remainder of the site. Shallow competent dolomitic bedrock was observed at all testing positions, on both gravity highs and lows.
   - Shallow dolomite bedrock occurs in all the boreholes (on both gravity highs and lows) which reflects a low inherent risk of sinkholes for both the ingress and drawdown scenarios.
   - Shallow dolomite occurs in all the boreholes (on both gravity highs and lows) which reflect a low inherent risk of subsidence for both the ingress and drawdown scenarios with a maximum diameter of subsidence of 2–5m at surface (i.e. medium size).
   - SMEC has assigned an Inherent Hazard Class (IHC) 4 to all the boreholes in Table 6.1 of the report.

5) The following structure specific comments are made in Section 6.2 of the report:
   - The 3 ha area will comprise the proposed substation (approximately 1ha), office and warehouse. The substation and office classify as C3 infrastructure "Commercial developments ≤ 3 storeys" as per SANS 1936-1:2012. This requires measures as outlined in SANS 1936-3 and footprint investigations.

- * The *substation* requires a total servitude area of 1ha, while the substation equipment itself covers a maximum of 100 x 100m. Only persons carrying out maintenance will be present on this site and then only for short periods. Incoming and outgoing power lines will be above ground. There will be no water or sewage connections. This structure has a D3+FPI (design level investigation below footprint of structure) designation. Two boreholes were drilled and a number of test pits excavated directly below the footprint of the structure indicating conditions are homogenous.

- * The *office* for maintenance and security personnel will cover an area of about 10 m x 10 m. Buried services (water, sewage and electricity) will be required for this structure. The exact position of the proposed office within the 3 ha had not been determined when the report was compiled. This structure has a D3+FPI designation. The high concentration of testing undertaken in the 3 ha area sufficiently indicates that this area is homogenous and that conditions described and classified above will underlie the proposed office building.

- * The *warehouse* will cover an area of approximately 20 m x 50 m. Buried services (water, sewage and electricity) will be required for this structure. The exact position of the proposed warehouse within the 3ha area had not been determined when the report was compiled. This structure has a D3+FPI designation. The high concentration of testing undertaken in the 3ha area sufficiently indicates that this area is homogenous and that conditions described and classified above will underlie the proposed warehouse building.

6) In Section 6.3 of the report SMEC indicates that solar collectors will be installed over the remainder of the site, entailing photovoltaic modules mounted on small frames. Human occupancy will be limited to access during construction and subsequently for maintenance. This area has been classified as IHC 4. SMEC classified this development type as a C8 as per SANS 1936-1:2012 and assigned a dolomite area designation D3.

7) In Section 7 of the report SMEC recommended that the substation and other 'manned' buildings on site are founded on a soil rafts built up from bedrock level, and designed to bridge a maximum envisaged sinkhole of 5 m in diameter.

<u>Having reviewed the report, we submit that:</u>

a) Although the electrical resistivity is discussed in Section 4.5 of the report, the results were not submitted as part of the report. It is also noted that DPSH was conducted as part of the geotechnical investigation. The results of the DPSH will add value to the overall dolomite stability assessment. This office would like to request that this data be submitted in order to ensure that all the information of the site is recorded in the CGS Dolomite Databank as well as for the sake of completeness.

b) This office is of the opinion that the generally classifies as having a medium hazard for the formation of small to medium size sinkholes. Therefore, in our opinion, the site generally represents IHC 2/3 conditions. SMEC assigned an IHC 4 to the entire site. IHC 4 implies a medium hazard for up to large size sinkholes.

   Although this office has a slightly different opinion on the hazard classification of the site, the site as a whole is considered suitable for the proposed land use of a solar farm and plant. Although footprint investigations are required for most of the structures in the 3 hectare portion of the site, this office would like to indicate that (i) due to the homogeneity of the conditions encountered on the site; (ii) no poor conditions were encountered in any of the boreholes drilled on the site; (iii) the site will generally have a low human occupancy; and (iv) no previous sinkholes have been observed in this area; the current investigation is considered as adequate. Therefore, this office confirms that no additional drilling in the proposed footprint areas is considered necessary.

c) SMEC's recommendations regarding the design of the structures, as indicated in (7) above are supported. An engineer will have to certify that the foundations have been designed to span the required 5 m loss of support.

d) SMEC's recommendations as listed in Section 7 of their report are generally supported.
   - It is essential that the necessary precautionary measures, as stipulated in SANS 1936-3:2012 are implemented and complied with.
   - The Dolomite Risk Management Plan (DRMP) should comply to the requirements as stipulated in SANS 1936-4:2012. This should be implanted during the construction phase as well.

This Office has no objection to the proposed Waterloo Solar Plant in North West Province, conditional to the points above and the following:

e) The application of stringent water precautionary measures across the site is essential. The Competent Person must certify those measures implemented and complies with the requirements of SANS 1936-3:2012.

f) The professional team involved, including SMEC, shall carefully consider the appropriate water precautionary measures and then ensure and finally certify that these have been implemented.

g) Adequate paving around the structures should always exist and all storm water must be discharged in the municipal storm water system. Roof water may thus not cascade off the apron and directly into the soil. The site should be landscaped in a way that the storm water is channelled away from the structures and in principle as shown on the drawings submitted. The Competent Person should, during the first year after completion of construction, visit the site after heavy rain storms to check that the storm water control system works effectively and should implement changes as deemed necessary.

This letter reflects the Council for Geoscience's view and approach to development on dolomite at this time, as reflected by the above date. These comments may not be viewed as open-ended. If a property changes ownership or land-use changes are made, the comment may in part or wholly no longer apply. This Office should be informed of such changes and the Competent Person responsible for the dolomite stability investigation should be given the opportunity to indicate the influence such changes could have on the overall stability.

If you have any further queries, please do not hesitate to contact this office.

Yours faithfully,

A C OOSTHUIZEN
Engineering Geologist
for Dr S DIOP
Acting Engineering Geoscience Unit Manager