DESKTOP GEOTECHNICAL INVESTIGATION FOR THE PROPOSED RIEMVASMAAK HYDRO ELECTRIC POWER FACILITY IN THE AUGRABIES-RIEMVASMAAK AREA, FARM RIEMVASMAAK (497/0 and 498/1), AUGRABIES FALLS NATIONAL PARK

KAI !GARIB (KAKAMAS) REGION, NORTHERN CAPE PROVINCE

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CONTENTS

1. SCOPE OF WORK

HydroSA appointed the Council for Geoscience in January 2015 to conduct a desktop level geotechnical investigation with the view to the construction of a hydro electric power facility on the farm Riemvasmaak (farms 497/0 and 498/1) in the Riemvasmaak/Augrabies Falls National Park area. The following aspects were to be considered: Geological, geotechnical, seismic and topographical properties of the terrain along the site route.

2. LOCALITY

The site is located in the Northern Cape roughly 45 km (by largely gravel road) northwest of the town of Kakamas (Kai !Garib Municipality) – see Fig.1.

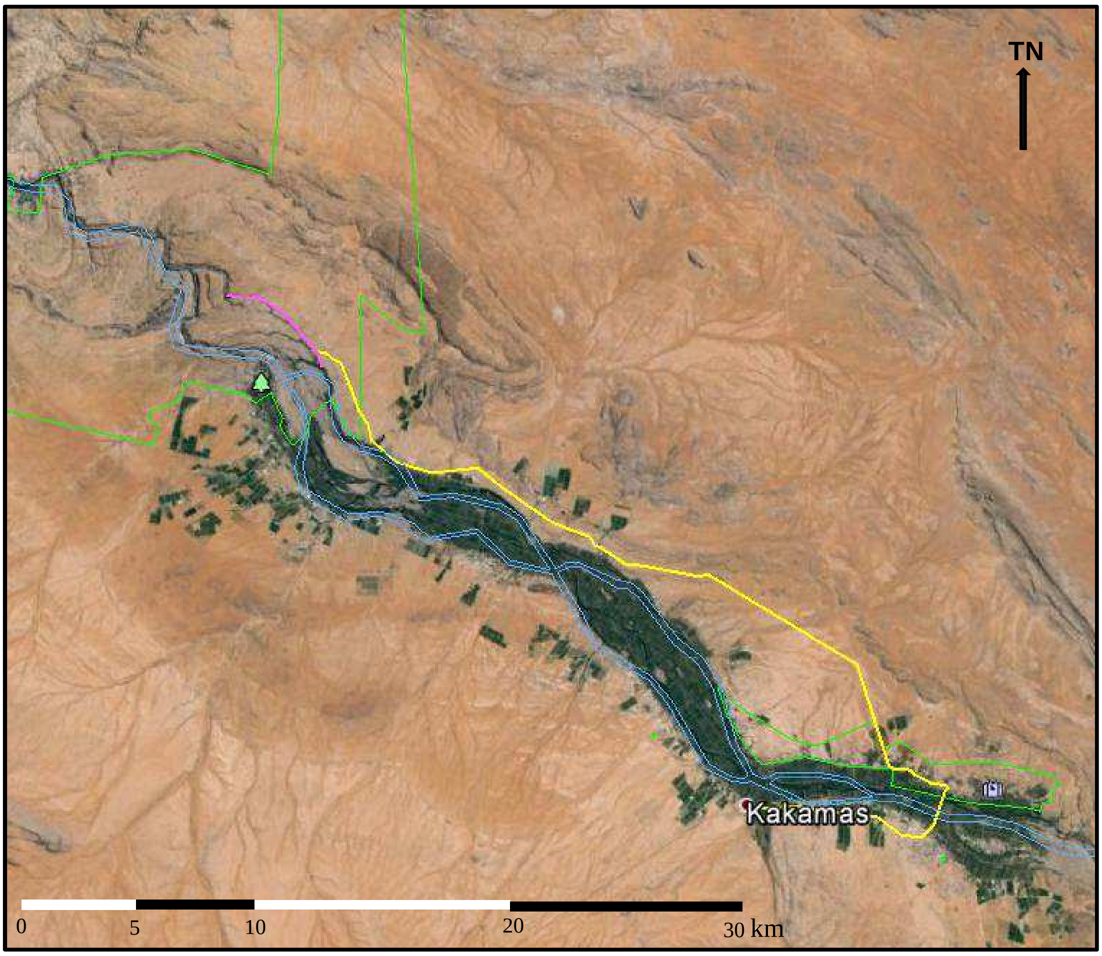

Figure 1: Location of site: The pink line indicates the site location, the yellow line the present access route from Kakamas, the green line the (historical) border of the Augrabies National Park and the blue line the main Orange River channel.

Reference to Fig. 2 (supplied by client) indicates the location of the site elements as described in Table 1 below.

The site lies along a secondary channel north of the main Orange River channel on a linear route covering a distance of 5 500 m and consists of the following main elements:

Table 1: Elements incorporated in the scope of work

Element*	Length/Height/Width/Area	Comment
Weir	100 m x 2,5 m	Located in Orange River Channel 1,8 km upstream of main Augrabies falls
(Twin) pipeline	4 600 m x 3,6 m x 14 m	Adjacent secondary river channel
Headpond	12 ha	
Power station	25 m x 16 m x 25 m	Subterranean “cavern”
Tailrace	675 m x 5,5 m	Reconnects outflow from power station to secondary stream channel 3 km northwest (downstream) of main Augrabies falls
*** A transmission line will connect the power station to the Renosterkop Substation south of Augrabies village. The overhead section of this line (16 km length) but does not form part of this investigation. A subterranean part of the transmission line will in the project area be located next to the twin pipeline feeding the headpond.**		

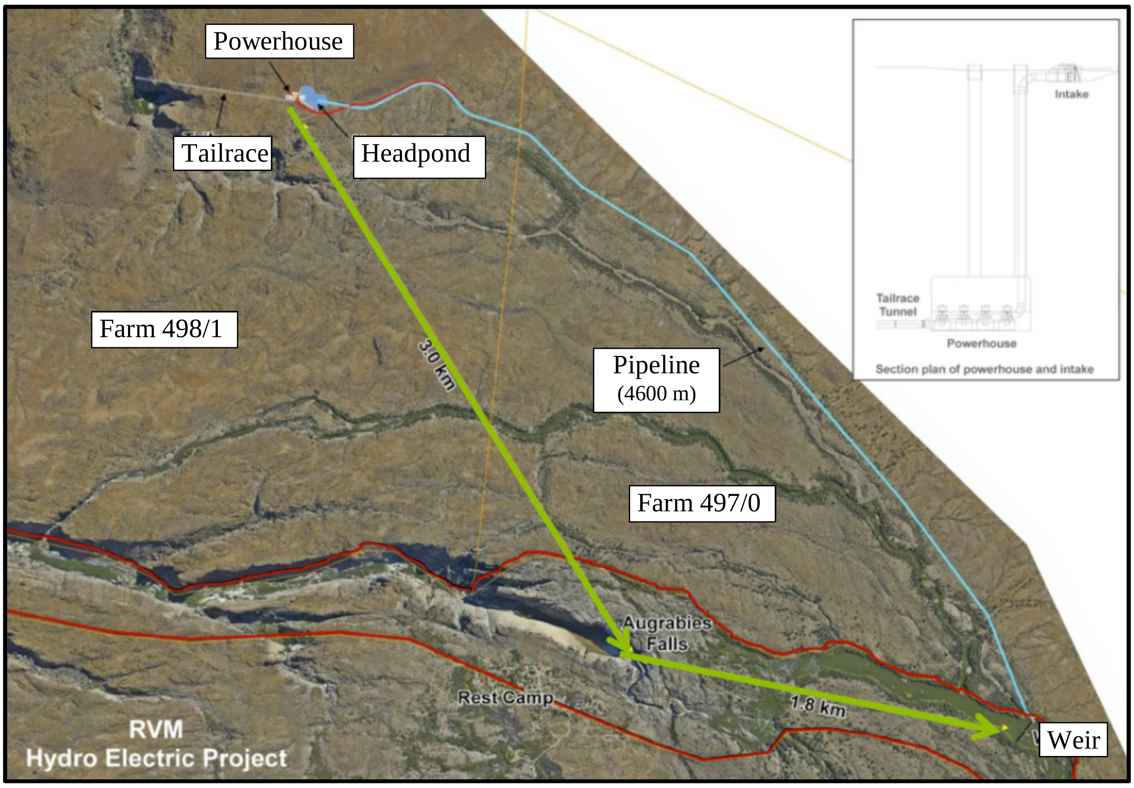

Figure 2: Location of site elements: Weir, pipeline, headpond, powerhouse and tailrace.

3. RESULTS OF THE STUDY

3.1 EXISTING INFRASTRUCTURE

The access road mentioned in Chapter 2 (refer also to Fig. 1) is tarred from Kakamas up to the settlement of Schroder (13 kilometres distance) and continues as a gravel road to the boundary of the Augrabies Park Reserve (27 kilometres distance). Once the road enters the Augrabies National Park/Riemvasmaak Reserve (roughly 4 kilometres southeast of the site), it changes to a dirt track and occurs next to and in the vicinity of the entire pipeline route. However, roughly 500 metres before the pipeline route reaches the headpond, the track turns northwards away from the site route and continues further into the Riemvasmaak Reserve [towards the historical villages of Melkbosrand, Hartbeesvlak and Blousyfer (Aurecon, 2013).] It is apparent that this dirt track is not properly maintained and in a state of disrepair which is exacerbated by the continual crossings of short ephemeral streams draining higher lying terrain northeast of the site towards the secondary channel of the Orange River.

From 500 metres east of the headpond to the end of the site route (i.e. to the end of the tailrace where it re-enters the Orange River channel – i.e. a distance of roughly 1,2 kilometres) access is presently on foot.

3.2 CLIMATE

According to SANPARKS (2015) the average yearly rainfall at Augrabies National Park is 124 mm, with most rains occurring between November and April in the form of heavy thunderstorms of short duration. [Slightly older data from DWA (1985) taken over a 47 year period, gives an average yearly precipitation figure of 146 mm for the Kakamas area]. Weinert (1980) indicates that the site area has a climatic N-value of roughly 45. This means that the area is very dry, with annual evaporation far outweighing precipitation and that *insitu* chemical decomposition of basic rock due to weathering (as would occur in cases where N-values are less that 5) does not occur under present climatic conditions. Consequently, particularly soil and to a large extent also weathered gravel and cobbles occurring in this area are products of physical weathering – i.e. material deposited after transportation thereof by either alluvial or colluvial processes.

3.3 TOPOGRAPHY AND SURFACE DRAINAGE

Reference to data from the local topographical map and aerial photographs (Dept. Rur.; 1971&1976) indicates that the majority of the site route is located in what can be classified as a "nearly flat plain" (TRH2, 1978) with local relief of less than 5 metres and with large areas nearly horizontal. However, near the northwestern end of the pipeline (in the headpond area) this changes to a rolling plain (relatively low relief of 5-100 m and no steep slopes) and eventually to a low (but steep) escarpment of roughly 100 m height at the end of the tailrace.

A number of shallow (ephemeral) streams, draining higher lying terrain lying northeast of the site, cross the pipeline route in a southwestern direction. These channels transport and deposit sandy alluvial material over parts of the pipeline route area. Werger and Coetzee (1977) however refer to the sandy plain north of the Orange River in the Melkbosrand area (i.e. the area bordering the site route to the northeast) and indicate that drainage lines are virtually absent. They assume that the occasional rainwater immediately infiltrates the coarse grained, yellow coloured, compact soil.

A digital terrain model (see Fig. 3 below) indicates the general topographical features along the linear route.

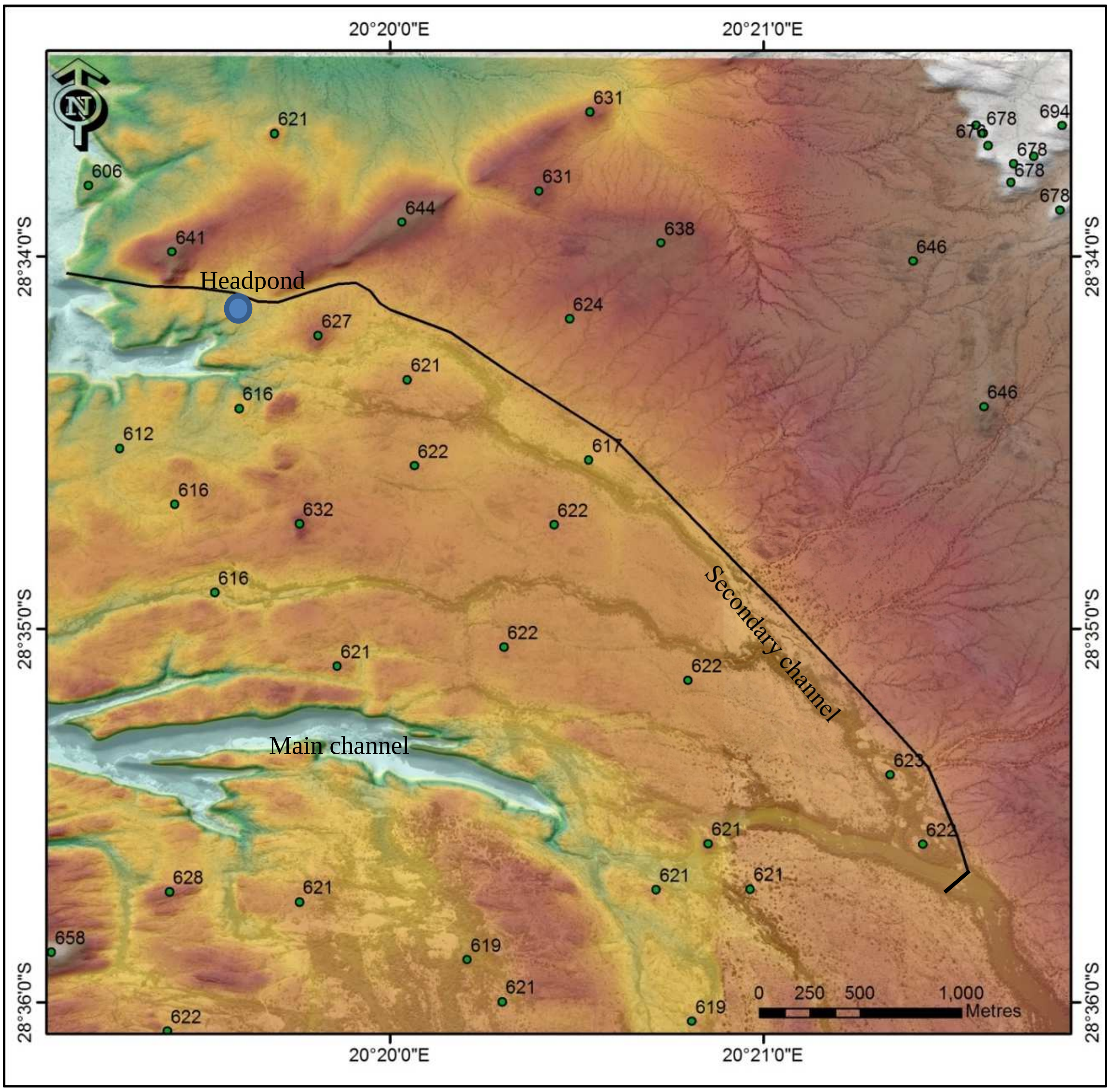

Figure 3: Digital terrain model: The linear site route (black line) adjacent to the secondary Orange River channel indicates denuded topography and a very slight surface gradiënt from the weir to near the headpond (refer to spot heights indicated in metres above sea level). Down slope from the headpond the surface slope down to the re-entrance into the Orange River gorge is steep. The plain northeast of the site route gradually rises to higher elevations and steeper topography several hundred metres northeast of the site.

Slabbert and Malherbe (1983), indicate that the lattice-type drainage pattern (roughly angular when viewed from above) of the Orange River in the vicinity of Augrabies Falls is caused by two sets of steeply inclined geological master joint sets – one with an east-west and the other with a north-south strike direction. (Lesser northeast-southwest and northwest-southeast striking joint sets as well as two geological faults contribute towards the drainage pattern in the area). In the site area in particular the preferential north-south and east-west drainage is however not immediately clear – with the exception of the locality where the tailrace re-joins the secondary Orange River channel. At that position an acute change in the direction of the erosion channel (deep gorge) direction from west-east to south-north is apparent. However, in the main Orange River channel (gorge) the pattern is more apparent – refer to Figs. 1 and 4. The influence of geology on drainage and physiography is further explored in chapter 3.4 below.

3.4 GEOLOGY AND SOILS

Rocks in the region are generally highly deformed metamorphosed sedimentary and volcanic rocks intruded by granitoids and the region is further characterized by numerous geological faults and shear zones. The area forms part of the Namaqua Metamorphic Province and lies within the Kakamas terrane of the Gordonia Sub-province (of the Namaqua Metamorphic Province).

Reference to the published 1:250 000 scale geological map (Moen, 1988; 2007) - see Fig. 4 for an extract from the map, indicates that the site route is located on only one bedrock type namely Augrabies Gneiss, and that alluvial cover material occurs over the southeastern parts thereof.

Figure 4: Geology of the area (from 1:250 000 scale map): Linear route (pink line): Located on Augrabies Gneiss bedrock (purple polygons with red cross hatching) with alluvial cover material (yellow polygons). Other geological units portrayed in Figure 4 are: The Riemvasmaak Gneiss (pink polygons), Omdraai Formation [gneiss and quartzite] (pale green polygons towards the east), and undifferentiated basic intrusive [gabbroic] (dark green polygon - marked Mga - towards the west).

3.4.1 Augrabies Gneiss

The Augrabies Gneiss is a member of a number of intrusive rocks (including the Riemvasmaak Gneiss and basic intrusives – refer to Fig 4) all with ages of between 1 300 million years and 1000 million years. Mineralogically the Augrabies Gneiss consists of quartz, microcline and plagioclase with varying amounts of biotite and hornblende and with rare opaque minerals (apart from allanite which is a common accessory). The rock is a medium grained granitoid gneiss and has been partly re-foliated which lends a distinctive wavy pattern to the fabric and imparts a more massive character (than normal for foliated rock) thereto [some (Praekelt, 1984) refers to the rock as “granite” rather than gneiss]. The texture and and fabric is remarkably uniform throughout the outcrop area – which underlies the majority of the southeastern parts of the Augrabies National Park and extends southeastwards outside the Park boundaries over a distance of roughly 8 kilometres in the direction of Augrabies village. The rock generally weathers to a greyish colour in contrast to the pinkish weathering colour of the Riemvasmaak Gneiss (which let some earlier researchers refer to the last mentioned as “pienk gneiss”). The Augrabies Gneiss is well exposed and indeed forms the rock type into which the the main Augrabies falls and canyon have been cut. An important feature of the Augrabies Gneiss is its tendency to form large exfoliation domes – the most well known of which is the “Moon Rock” occurring within the Park (south of the Orange River).

3.4.2 Alluvium

Reference to and a excerpt from an unpublished 1: 50 000 scale geological field map of the Augrabies area (Praekelt, 1981 and Agenbacht, 1987) indicate that the alluvium extends much further northwestwards along the linear route than indicted on the smaller scale[1] (1:250 000) published geological map (compare Fig. 5 below to Fig. 4), covering bedrock over the first 3,5 kilometres of the pipeline area and up to roughly 1 kilometre southeast of the headpond area. The discrepancy between the two sources may be attributed to:

- The scale effect – a narrow strip of alluvial material surrounding the (secondary) Orange River channel may perhaps be difficult to depict accurately on the smaller scale map and was for that reason edited out of the 1:250 000 scale map.
- The thickness of the alluvial material along the channel may be thin and thinning out towards the northwest so that a decision had to be taken about a cutoff thickness below which the indication as “alluvium” would not accurately portray the geology on the smaller scale map when compared to other areas indicated as “alluvium” on the published map. This would have led to editing out small areas on the smaller scale map.

  The mapper may have been unsure whether the sedimentary material in the northwestern part of the channel and surrounds is actually “alluvium” or whether it should rather be seen as “gullywash” or even “hillwash”. Keep in mind the study of Werger and Coetzee (1977) who refer to <u>coarse sand</u> covering the plain north of the linear route in the Melkbosrand area (compare chapter 3.2 here above), which indicates that the sediment may perhaps emanate not from the Orange River, but from

[1] Note that 1: 250 000 is a smaller scale than 1: 50 000.

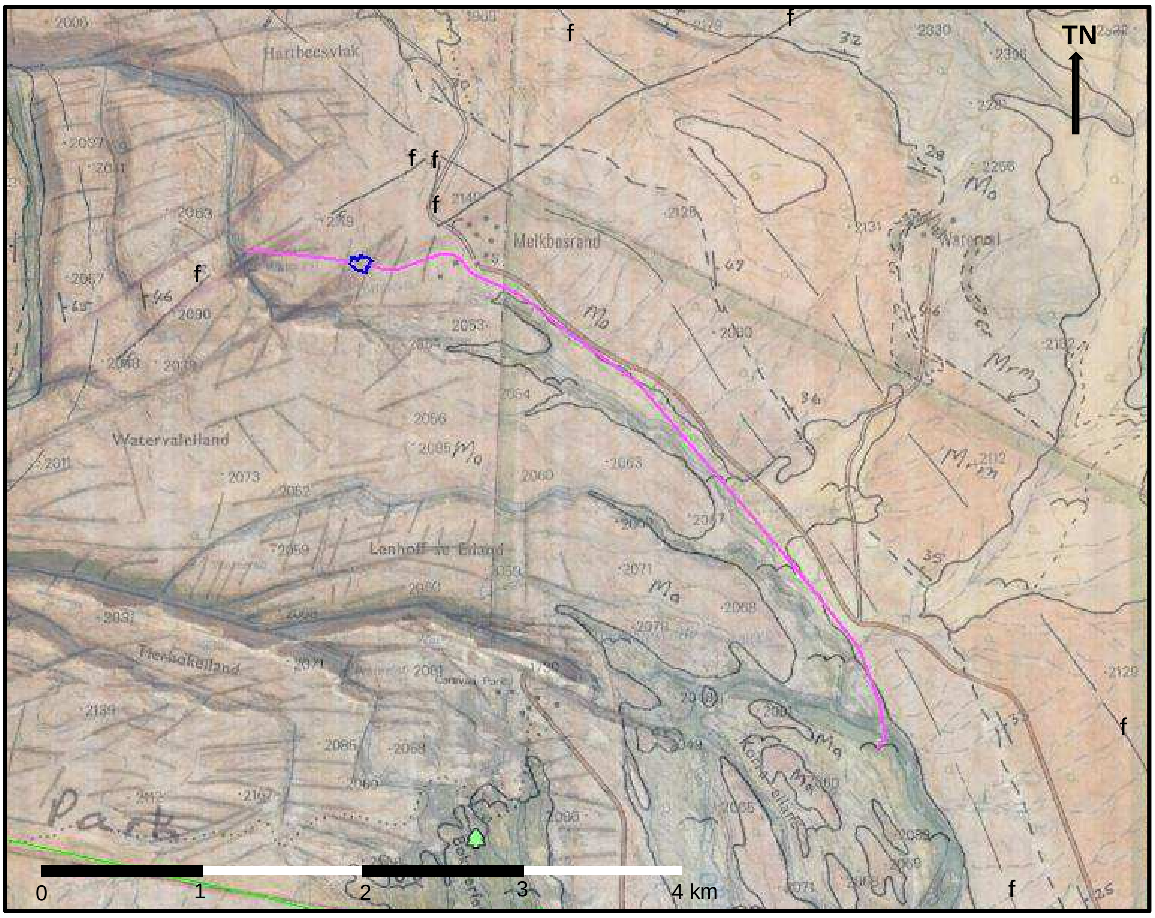

Figure 5: Geology of the line route area (from 1:50 000 scale map): Linear route (pink line) indicating alluvial cover in field map (polygons denoted by symbol) occurring much further towards the northwest in the pipeline area than indicated in the smaller scale published geological map. The field map also indicates the direction of the master joint sets (short grey linear stripes), geological fault lines (longer continuous thick grey lines denoted f) and possible/concealed geological faults (longer discontinuous grey lines denoted f)

transportation (over a short distance) of surface material from northeast of the linear route – in which case it could be expected to be a <u>coarse</u> sand (which may well be “thick” – as they put it – in comparison to other sand horizons in the Park). Moen (1988, 2007) on the other hand indicates that alluvium covering bedrock over the the southern part of the linear route (as indicated in Fig. 4) is derived from short streams originating northeast of the pipe route (and would thus be <u>relatively coarse</u>). However, alluvium deposited during flood events along the Orange River (i.e. alluvium covering bedrock over the central section of the linear route as indicated in Fig. 5) could be expected to be loose and <u>fine grained</u> (of silt size).

Accurate comparison of the linear route locality with Google Earth images indicates that in the 3,5 kilometres section mentioned above, unconsolidated sedimentary materials appear to be covering bedrock over some parts, whilst being absent and merely bordering (in close proximity) the linear route to the southwest of the route. Further towards the northwest along the linear route however (i.e. northwest of the 3,5 kilometres section mentioned above) unconsolidated material appears to be absent with bedrock (rock outcrop) dominating surface exposure.

3.4.3 Structural geology

As mentioned previously (chapter 3.3) a number of master joint sets as well as geological faults occur in the general area of the site. Due to the localized size of these features compared to the scale of larger structural features in the Gordonia Sub-province, they are not indicated on the small scale (1: 250 000) published geological map of the area. However, they have been mapped previously during field work and are indicated on the field map as indicated in Fig. 5.

Apart from joint sets which lead to differential weathering rates and has indeed influenced the drainage pattern in the Augrabies area (see chapter 3.3), additionally, geological faults are important to consider when designing and building structures. Faults may (apart from having similar preferential weathering effects on rocks as joint sets), additionally be subject to re-activation or micro movements which could cause stress or strain in structures erected in their vicinity. Two sets of faults could be of importance in the site area namely:

1) The inferred fault indicated in Fig. 5 to occur roughly parallel to the pipeline direction and between 250 and 600 metres to the northeast of the pipeline (indicated as a discontinuous line contained within the polygon depicting the Augrabies Gneiss).
2) A fault zone referred to as the Ararat Fault by Slabbert and Malherbe (1983) and which is shown in Fig. 5 to consist of three roughly parallel lines striking in a northeastern direction and spaced 250 to 375 metres apart. They cross the site route near the northern end thereof. The most prominent and southeastern one of these faults appear to underlie the headpond area and cuts northeastwards across the Augrabies Gneiss, the Riemvasmaak Gneiss and into the Omdraai Formation. It can be followed over a distance of 7 kilometres.

   The middle member of these parallel faults cuts across the site route in the extreme northwestern end of the site route, whilst the northwestern-most one lies roughly 350 metres to the northwest of the tailrace.

3.5 ROCK FOR CONSTRUCTION MATERIALS

Due to low chemical weathering rates in the area (see chapter 3.2) and the roughly granitic chemical composition of the bedrock on site, it can be assumed that a large percentage of bedrock will be unweathered or slightly weathered – i.e. have high strength and durability. Furthermore, the the apparent massive fabric (see chapter 3.4.1) indicates that it will probably break to spherical or cubic clasts (not shardy). Hence, rock from excavations is expected to serve as excellent source of coarse aggregate. This will particularly be the case in the tailrace area where excavation will be relatively deep (into unweathered rock). On the other hand, faults occurring in the headpond and tailrace area (see chapter 3.4.3) may reduce aggregate qualities of rock excavated from that area (it will probably be shardy and may be at a more advanced state of weathering – i.e. softer and less durable rock).

3.6 HYDROGEOLOGY

Surface runoff along the (secondary) Orange River channel (as well as from the streams located northeast of the pipeline route – see chapters 3.3 and 3.4.2) may have a scouring effect along parts of the twin pipelines where they are located adjacent to the channel. Groundwater may possibly effect particularly the deep excavation for the power station cavern (at least 25 metres deep) and tailrace connecting it (at a lower elevation) to the deeply eroded channel downstream.

Potgieter *et al*. (2001) during a study of groundwater resources in the Riemvasmaak area drilled 53 exploration boreholes of which none were in Augrabies Gneiss. However, two holes drilled in vaguely similar Riemvasmaak Gneiss 8 kilometres north of the present site have water recharge levels (in effect the permanent water table) at between 26 and 51 metres below ground level, and weathered rock zones to 34 to 60 metres below ground level. One of the conclusions from their study is however that groundwater strikes can be expected to occur within the zone of weathered rock within the first 20 metres below ground level and furthermore that gneisses (jointed and fractured rock) have better water bearing characteristics than granites.

Stapelberg (2013), during a site investigation 12 kilometres southwest of the present site in an area partially underlain by Riemvasmaak Gneiss, came to similar conclusions (from existing data) regarding groundwater level variability. He indicates than the regional groundwater level in that area occurs at a depth of 30-60 metres below ground level, but that the water table depth locally varies significantly due to structural and metamorphic variance of bedrock and that groundwater may locally be intercepted at depths of between 7 and 67 metres below ground level.

To summarize: It is unlikely for the present site that groundwater in bedrock will be encountered in excavations for the pipeline (at depths of less than 3,6 metres). However, subsurface drainage could be expected to occur from time to time within surficial soil cover. Additionally, due to strong geological structure in the headpond and tailrace areas, water strikes (temporary elevated water levels) in bedrock could be expected in those excavations at depths of as shallow as 7 metres.

3.7 SEISMIC HAZARD

According to Fernández and Du Plessis (1992), long term seismic data indicate that the present site area has a low seismic hazard with only a 10% probability of a peak horizontal acceleration of 50 cm/s^2 and highest Modified Mercalli scale of V seismic intensity being exceeded once every 50 years. According to their classification all areas in South African have Modified Mercalli Scale hazard classifications of VIII or less (the Modified Mercalli Scale spans between I and XII - see comparison between Modified Mercalli intensity and Richter magnitude in Table 2). [Modified Mercalli scale V events (i.e. the zone in which the site is classified – see Fig. 6a) are not considered intense enough to cause damage to built structures, while scale VI events may cause slight damage to plasterwork.]

Table 2: Comparison: Richter Scale: vs. Modified Mercalli Scale

Modified Mercalli Scale Intensity	Richter Scale Magnitude	Description of physical effects
I	1,0 - 3,0	Not felt.
II-III	3,0 - 3,9	Felt indoors on upper floors. Vibration like passing of a truck. Standing cars rock slightly.
IV-V	4,0 - 4,9	Felt outdoors. Hanging objects swing. Vibration like heavy truck striking building. Unstable objects overturned. Standing cars rock noticeably. Some windows broken.
VI-VII	5,0 - 5,9	Weak plaster and masonry cracked. Some chimneys broken. Slight to moderate damage in well-built ordinary structures; considerable damage in poorly built or badly designed structures.
VIII-IX	6,0 - 6,9	Damage slight to considerable in specially designed structures with partial collapse. Buildings shifted off foundations.
X and higher	7,0 and higher	Damage varies from “masonry and frame structures destroyed with foundations and rails bent” (X) to “total destruction” (XII).

(after USGS, 2015)

In a more recent discussion of seismic hazard in South Africa Brandt (2011) refers to and supports the earlier work of *inter alia* Fernández and Du Plessis. He supplies probability maps (citing those authors) of seismic intensity and peak horizontal acceleration on a country wide scale (see Figs. 6a&b) and furthermore points out the occurrence of a recent earthquake swarm in the Augrabies area. This swarm started in July 2010 and consisted of continual small seismic tremors. It has according to data supplied by Saunders (pers. comm., 2015)[2] up to December 2014 included 16 events with magnitude of between 4,0 and 5,0 (Richter scale). Reference to Fig. 7 indicates that the swarm occurred in a north-northwest elongated belt of 55 km long and 17 km wide starting from south of Kakamas, continuing roughly parallel to the course of the Orange River and up to roughly 6 kilometres north of the present site (pink line). However, if all smaller tremors are included, it is clear that the belt has a much larger footprint (of 290 x 65 km and elongated in the said direction).

[2] I. Saunders, Seismograph Network Manager, Geophysics Competency Unit, Council for Geoscience, Tel. (012) 841 1456

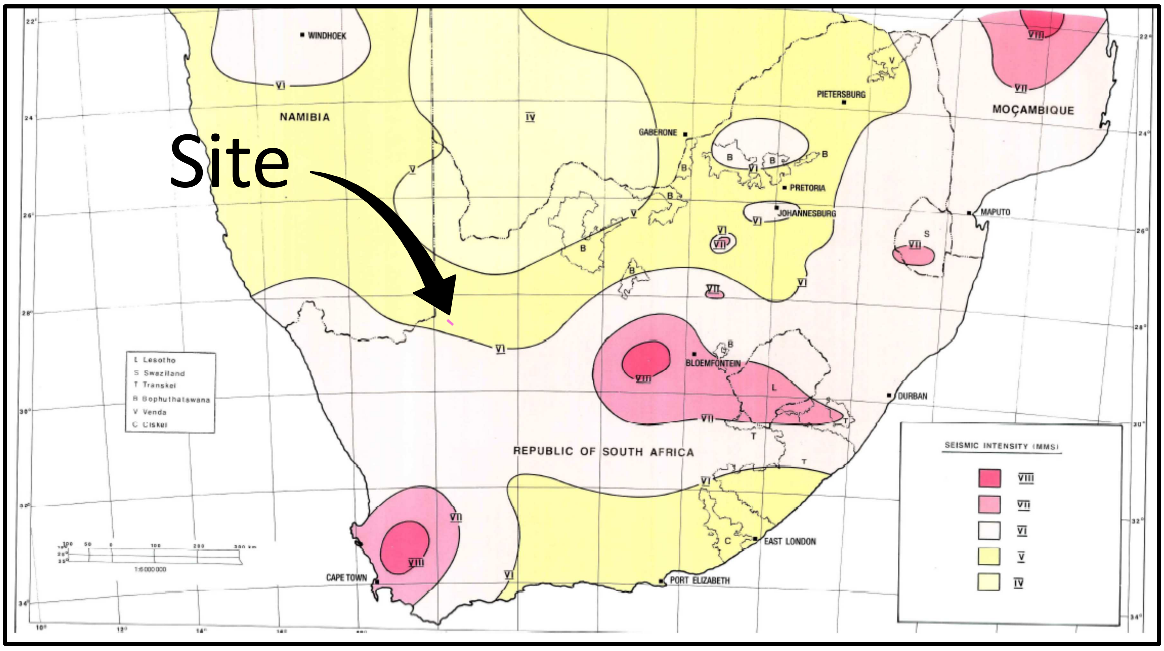

Figure 6a: Seismic intensities in Southern Africa: (from Brandt, 2011)

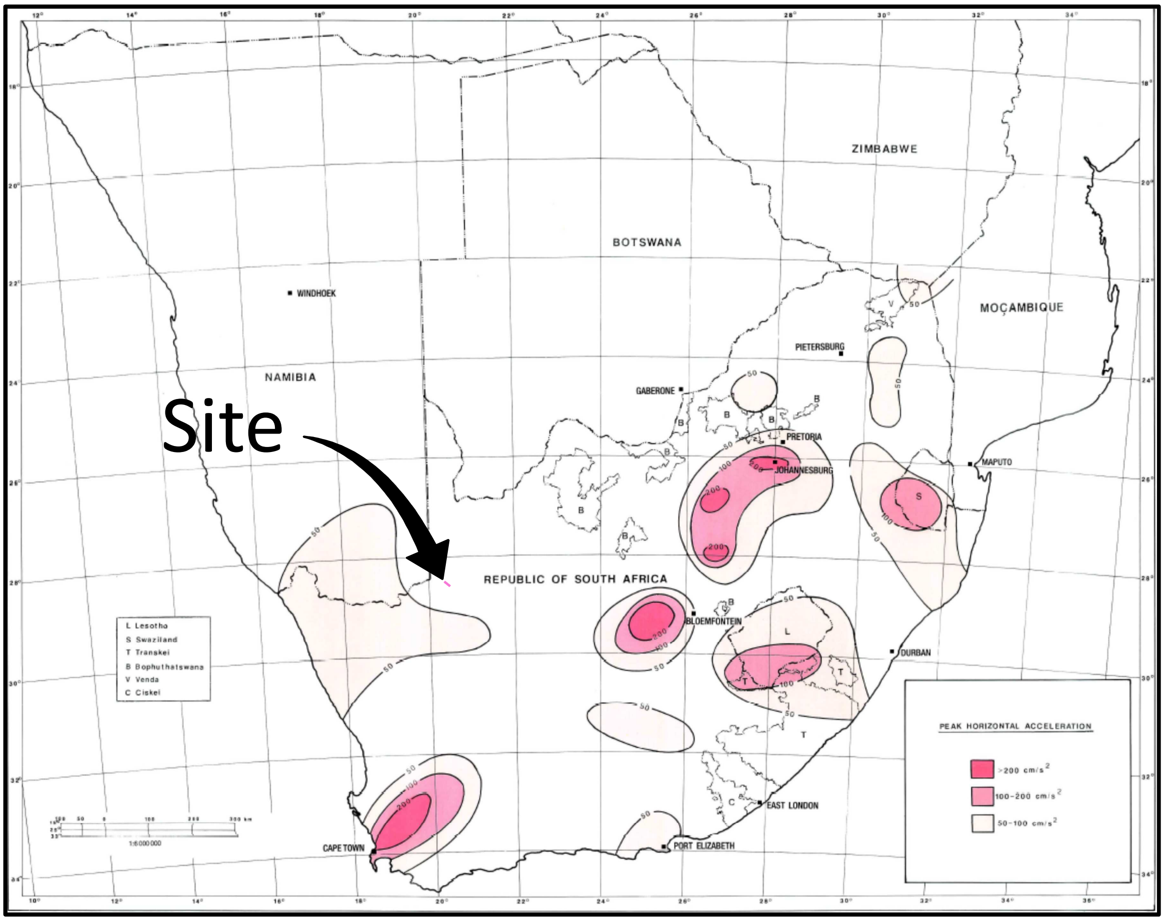

Figure 6b: Southern African peak horizontal acceleration zones: Zones of peak horizontal acceleration (in cm/s^2) with a 10% probability of being exceeded once in a period of 50 years (from Brandt, 2011)

Considering the timing of the swarm, reference can be made to Fig. 8 which indicates that the majority of events (in both number and magnitude of events) occurred in the period 2010 to 2012.

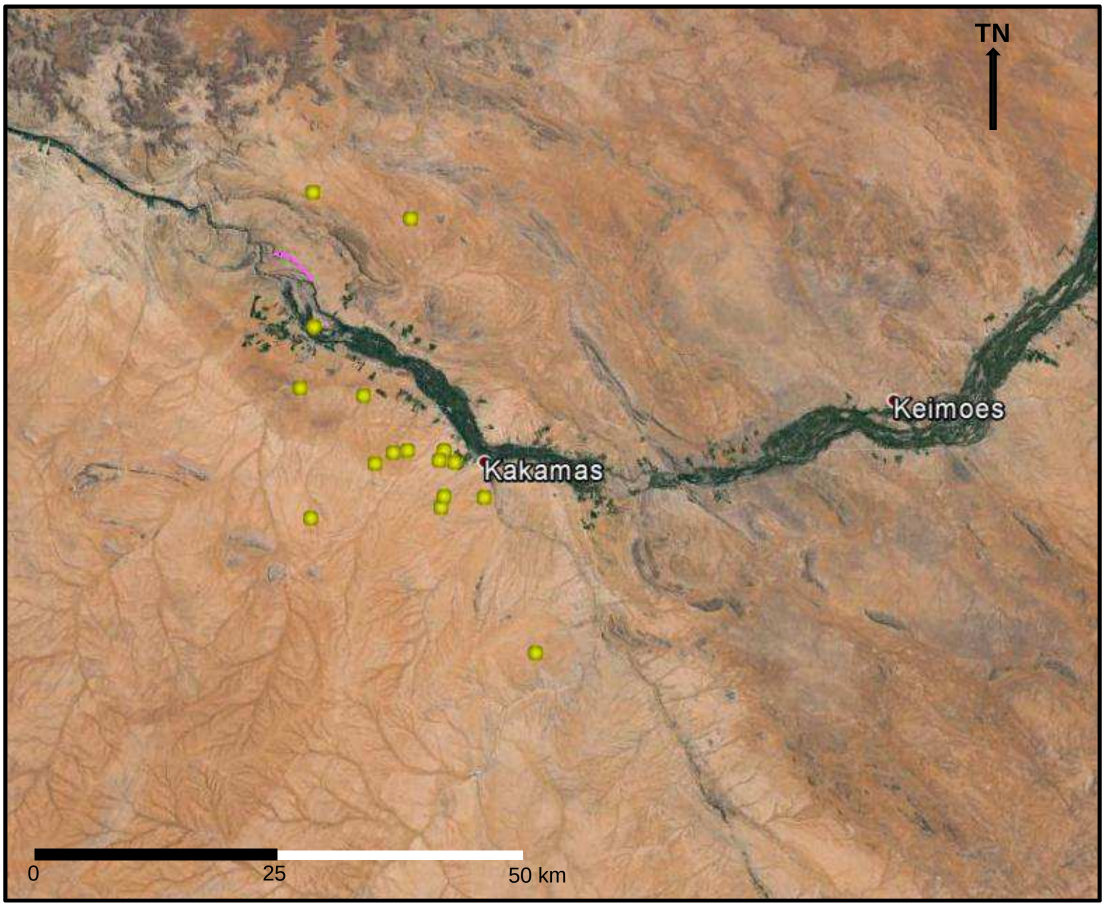

Figure 7: Locality of the recent earthquake swarm in the Kakamas area: Indicating only the epicenters of events > 4 (yellow dots). It is clear that the present site area (pink line) is located within the elongated belt depicting the swarm

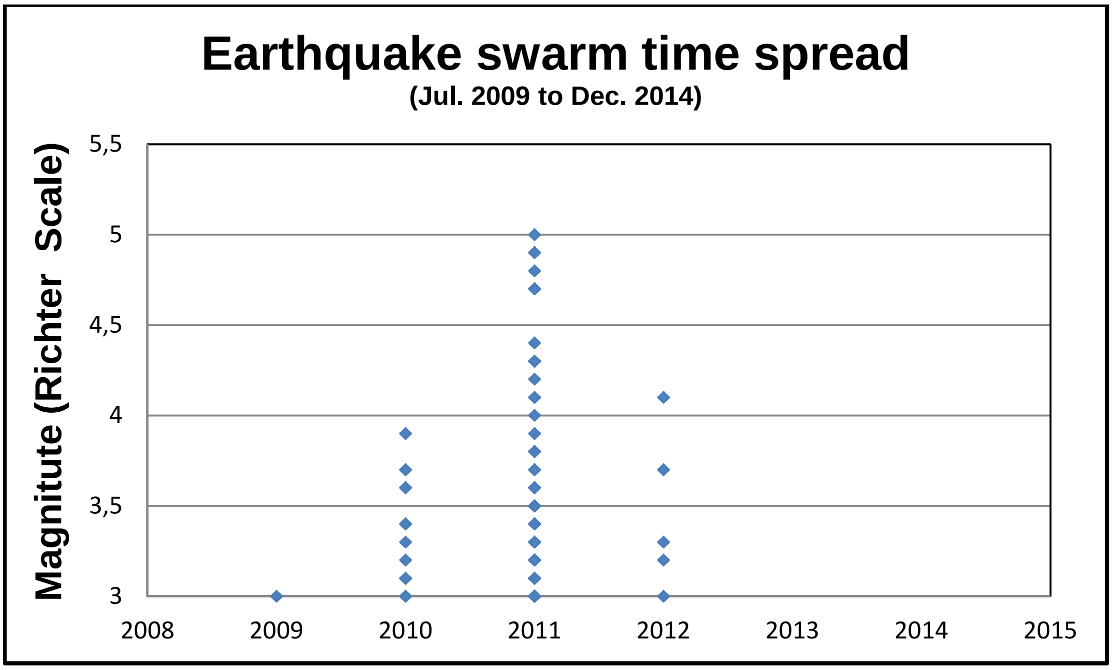

Figure 8: Timing of the earthquake swarm: Indicating the number of events in excess of 3 (Richter Scale magnitude) per year (data from Council for Geoscience, Geophysics Competency)

It further shows that no events of magnitude ≥ 3,0 have occurred after 2012.

Brandt theorises that the reason for the swarm may be reactivation of a relatively wide zone of geological faults in this historically (assessed in geological time – i.e. millions of years tolerance) active tectonic region and continues to say that this type of swarm is not uncommon. He further mentions that a similar earthquake swarm occurred in 1952 over a period of a few months in the the Sutherland area.

What is important to recognize is that during the recent swarm not a single event in excess of 5,0 occurred, - i.e. the integrity of the intensity zonation for the area as depicted in Fig. 6 is intact.

3.8 HAZARD OF CAVITIES AND POSSIBILITY OF SLOPE FAILURES

It is considered highly unlikely that cavities could form as the local geology is not conducive to the formation of cavities or sinkholes (not dolomitic terrain). Due to the very low surface slope over the fist 3,5 kilometres of the pipe pipe route, rock slope failures will not occur over that section. However, side slopes of the excavation for the pipeline may be locally unstable during construction, particularly in areas where sand cover occurs on top of the bedrock. The excavation side slopes may have to be shored in those areas.

Due to the steep slopes and geological jointing/faulting occurring over parts of the northern section of the site route, small scale rock slope failures of both the natural ground surface and excavation sides may readily occur. To ensure safety during construction, assessments need to be continually undertaken on site by a suitably qualified person.

3.9 PRESENCE OF BURIED STRUCTURES

The site is remote and the likelihood of buried structures crossing the site route is extremely small – particularly since bedrock generally occurs at shallow depth.

4. RECOMMENDED FURTHER INVESTIGATIONS

This report serves as an initial desktop study for the site area. It is however important to note that the study relies on previously documented information provided by a number of sources. A detailed and accurate account of the site specific geotechnical and geophysical conditions and possible constraints need to be determined through additional site testing.

It is therefore suggested that, where not already undertaken, follow-up studies include the following:

4.1 A local topographical survey along the centre line of the linear route and including a strip of 50 metres surrounding it. In the headpond area the survey should be extended to include the surface area of the pond as well as the pond wall and a strip of 50 metres surrounding it. The aim of the survey is to record localized steep slopes which may impact on the site route elements and construction activities.

4.2 Local geological surface mapping along the site route in order to better establish site conditions and recommend test pit/drill spacing (see recommendations 4.3 and 4.4).

4.3 Determination of the rock profile in the river in order to establish conditions for construction of the weir. Diving with a stave and camera should be considered.

4.4 Test pit digging as well as rock core drilling and logging along the centre line of the site route prior to construction in order to establish thickness and properties of soil cover and rock mass properties including degree of weathering, hardness, discontinuity properties and rock type variation. The digging/drilling needs to be as deep as final construction depth for the specific site element (see Table 1) and needs to be spaced at short enough lateral distances along the route to ensure a proper prediction of site conditions along the entire route. Closer spacing is expected to be used in the headpond-tailrace area due to the expected poorer rock mass properties and location of more sensitive structures in this area. Pit/hole spacing could be increased (numbers reduced) by undertaking a geophysical travers (electrical resistivity?/seismic?) survey along the site route.

4.5 Definition of site specific soil/rock conditions through on-site and laboratory testing to determine engineering characteristics of the materials. This can include soil grading and shear strength as well as compressive strength and durability of rock and deformability of the rock mass. These parameters can be of use for both establishing excavation properties of soil/rock mass and material properties for use in construction.

4.6 In view of the recent earthquake swarm in the area and also the location of the headpond/power station/tailrace area on a suspected geological fault zone, a site specific seismic assessment should be undertaken.

4.7 Determination (measurement) of water table depths as well as rock permeability in boreholes. This is particularly of relevance in the headpond/power station/tailrace area.

4.8 Slope stability analysis of specific locations with steep topography (see recommendation 4.1) and poor rock mass properties where either fixed structures (pipelines/headpond/ tailrace) or infra-structure elements (access road) are planned for such areas. This is expected to be particularly relevant to the northern parts of the site route.

5. REFERENCES

Aurecon, 2013. Proposed Hydropower Station on the Farm Riemvasmaak (Remainder of Farm no. 497 and Portion of Farm no. 498), on the Orange River in the Vicinity of Augrabies, Northern Cape: Final Scoping Report: Report No. 8177, 102 pp.

Brandt, M.B.C., 2011. Seismic hazard in South Africa. Council for Geoscience. Report No. 2011 - 0061, 22 pp.

Department of Rural Development and Land Reform. National Geospatial Information.
Topographical Map 2820 CB Augrabies 1:50 000 (1971)
Aerial photographs 1881-1883,1918-1920; Strips 8&9; Task 771; Scale 1:30 000 (1976)

Department of Water and Sanitation, 1985. Hydrological Information Publication No. 13.

Evaporation and Precipitation Records, Kakamas pp.274-276.

Dept Rur, 1971 & 1976 – see Department of Rural Development….

DWA, 1985 (Department of Water Affairs) – see Department of Water and Sanitation…..

Fernández L.M., and Du Plessis A., 1992. Seismic hazard maps for Southern Africa. Published by the Government printer for the Geological Survey of South Africa (presently known as the Council for Geoscience).

Moen, H.F.G., (compilation), 1988. The Geology of the Upington area. Scale 1: 250 000 Geological series. Sheet 2820 with accompanying 160 pp Explanation, (Exp. published in 2007). Geological Survey of South Africa (predecessor to Council for Geoscience, South Africa).

Potgieter T.D., Van Wyk, E., and Van Dyk, G.S., 2001. Hydrogeological investigation for Riemvasmaak: available groundwater resources, Technical Report GH 3964 of Department of Water and Sanitation, July 2001, 33 pp.

Praekelt, H.E., 1981 – revised by Agenbacht, A.L.D., 1987. Geological field map sheet 2820 CB Augrabies, Scale 1: 50 000. Unpublished – used in compilation of published 1: 250 000 scale geological series (see Moen H.F.G.)

Praekelt, H.E., 1984. Die geologie van die gebied rondom Augrabies (2820C), M.Sc. thesis, University of the Free State, May 1984, 80 pp.

SANPARKS, 2015. Refer to http://www.sanparks....

Slabbert, M.J. and Malherbe, S.J., 1983. Die invloed van nate op die loop van die Oranjerivier in die omgewing van die Augrabiewaterval Nasionale Park. Koedoe 26, pp. 1-7.

Stapelberg, FDJ, 2013. Geotechnical investigation for Padrooi solar photo voltaic site, Augrabies, Northern Cape. Unpublished report of the Council for Geoscience done for Messrs. Aurora Power Solutions. 20 June 2013, 16 pp.

TRH2, 1978. Geotegniese en grondingenieurswese kartering vir paaie en die bewaring van materiaaldata. National Institute for Transport and Road Research, CSIR, p. 24.

USGS, 2015. Refer to http://www.earthquacke.......

Weinert, H.H., 1980. The natural road construction materials of Southern Africa. National Institute for Transport and Road Research, CSIR, Pretoria, pp. 36-39 and 56-59. National Book Printers.

Werger M.J.A., and Coetzee, B.J., 1977. A phytosociological and phytogeographycal study of Augrabies Falls National Park, Republic of South Africa, Koedoe 20, pp. 11-55.

http://www.earthquacke.usgs.gov/learn/topics/mag_vs_int.php, web page visited 30/01/2015

http://www.sanparks.co.za/parks/augrabies/tourism/climate.php, web page visited 30/01/2015