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REPORT ON THE CLAY LAYER INVESTIGATION OF THE NYL RIVER ON THE FARM VOLSPRUIT

TO

EScience Associates [Pty] Ltd

INTRODUCTION:

The proposed open cast mine on the farm Volspruit will border the Nyl River. The question is whether water will be lost from the river to the mine pit or to the ground water adjacent to the river when the water table will be lowered due to pumping water from the pit.

An extensive survey of the river bed had previously been carried out determining the permeability of the clay soil in the bed. It had been found that the permeability of the clay soil is low and that very little water will be lost from the river bed over time due to the thick clay layer.

Based on this previous extensive investigation, a request was to investigate the river bed in detail in terms of the presence of the clay layer on the farm Volspruit, the thickness of the clay layer along the river and the extend of the clay layer towards the edges of the riverbed.

SCOPE:

Investigate and evaluate the presence, thickness and permeability of the clay layer in the bed of the Nyl River over a distance of 8 km on the farm Volspruit in area of groundwater cone of depression.

OBJECTIVES

1. To dig profile pits along certain transects in the river bed approximately every 330 meters.
2. To identify and describe the master horizons present in each pit.
3. To measure and note the thickness, as well as, the distance from the surface of the different horizons in each pit.
4. To classify the soil.
5. To take representative sample of the clay layer in the river bed and determine the hydraulic conductivity of the clay layer.

METHODOLOGY

By using a back actor, profile pits were dug in transects across the width of the river bed (from plains next to the river, when present, or from the edges on both sides of the river, whenever there is was a change in the slope along the transect).

The transects were approximately 330 meters apart

At each profile pit, (waypoints) was registered with a GPS. The soil was examined, where possible, up to 3 meters.

The following was recorded at each pit:

The occurrence, depths and thickness of the different major soil horizons were recorded at each pit. For each horizon the following was recorded;: transition between horizons, texture, soil color (using the Munsell notation), moisture content, mottling, soil structure, consistency, cementation, concretions, presence of roots and physical limitations.

Special care was taken to describe the presence and thickness of the different diagnostic horizons, the depth of each horizon, the texture and the underlying material.

After the profile description the diagnostic horizons were identified and depending on the presence and sequence of the diagnostic horizons, the soil was classified according to the South African soil classification system, and the soil form identified.

DETERMINATION OF THE HYDAULIC CONDUCTIVITY (PERMEABILITY) OF THE CLAY LAYER

Soil samples collected from the different horizons from the profile pits were used to pack columns and a constant water head was applied on the soil surface. When water started dripping through the column the rate at which the water leach through the column was measured. The hydraulic conductivity (permeability) K was calculated as mm/hour using D'Arcy law.

The equation setting D'Arcy's law is as follows:

$$Q = V/At - K \nabla H/L$$

Where:

Q=flood

V= volume

A =Surface area of column

T=time hour

∇H = Water head

L= length of soil column

K= permeability mm/hour

Representative samples from different horizons present in profiles from of the first transect were collected. When different horizons were observed along the study area, further samples were taken.

Hence, the hydraulic conductivity/permeability of the different clay layers was determined.

PRESENTATION OF FIELD DATA

The soil survey data was used to classify the soil forms at each waypoint. During the survey special note was made of the presence, depth and thickness of the different horizons. The data was plotted on a photogrametrical map that was supplied on a scale of 1:7500 for horizontal distances. In the case of the vertical scale that represents the elevation; due to the small differences in elevation the scale was multiplied by 100 to be able to present the data visually. It is important to note that the elevation model is not true ground height but includes the vegetation canopy.

On top of this map the flooding of 2008 as detected by Landsat satellite was imposed to evaluate the possible decanting of water from the river. (see attached cross section through river)

RESULTS AND DISCUSSIONS

According to a literature study by EScience and Associates 2013 both Tooth et al and McCarthy et al mentioned the existence of a sediment layer several meters deep in the flood plain. According to this study, the material consists of more coarse material just above the bedrock which gradually changes to fine clay sediment. The presence of especially swelling clay in the flood plain is as can be expected because the soil forming conditions characteristic of the flood plain is conducive to form smectides which is the dominant swelling clay in the river bed.

In this study it was only possible to dig holes up to 2.5 meters with the available back actor. Thus, the deeper part of the sediment could not be examined, however through drilling of boreholes for groundwater monitoring piezometer installation it was found that sedimentary gravels were absent from the study area. However, it is the surface layers of soil that determines the hydraulic conductivity of the profile which is important in this study.

Based on the observations made during the river bed study, the following observations and interpretations were made.

FARM RONDEBOSCHJE 295 KR - Mr Abdul Tayob

Cross Section A

The first profile on the left (West) was of a Hutton soil and was made outside the river bed.

The second profile was a shallow Katspruit with an orthic A over a G horizon indicating permanent wetness. The red coloured instead of a black vertic soil of this profile could probably be ascribed to the gravitational movement of red soil from the West, causing the top clay layer to be mix with the vertic clay. This mixing caused the top clay layer to lose its swelling properties, but still with a relatively high clay content which sows hydromorphic properties.

The third profile in the middle of the river bed was classified as a Rensburg soil form which consists of a fairly deep vertic horizon; follow by a G horizon which again presents a permanent water table or wetness.

A fourth profile, further to the right contained a deep vertic soil that represents an Arcadia soil form.

A fifth profile reveals an Estcourt which is a duplex soil without any hydromorphic properties. This profile indicate that the river bed consist of a deep clay layer that will seal off the river from its surroundings. The presence of a G horizon indicates that there must be an impervious layer underneath or a water table that prevents the water from draining deeper down the profile (out of river bed).

From this set of profiles it can also be concluded that there is a source of water from the West (left) that causes the permanent wetness. This is confirmed by the fact that the G horizon on the West was closer to the surface and higher than in the middle of the river bed and disappears to the right. This observation is in line with the finding of Blight G E of the University of the Witwatersrand who conclude that in a water balance study of the Nylsvlei (Blight 2004), water was supplemented by capillary movement from an aquifer underneath the clay layer in the wetland.

This set of profiles also confirm the hypotheses made during a previous survey that the river bed is sealed off from its surroundings and that only when the river overflow its bed, water will be able to decant out of the river. According to the flood line of 2008 imposed on the river water may decant on the West but not on the East of the river.

Cross Section B

The profile near the fish dams is a Rensburg form followed by a Shortland with the saprolite approximately 1 meter deep. This indicates that there is a little island that divides the river. This may be an area where some decanting can occur with as flood such as in 2008. No further profiles were made further to the West to demarcate how far the Rensburg soil extends to the West. Thus, how far the Rensburg soil extends is not certain. If a flood such as of 2008 exceeds this area it would decant to the Western periphery whilst peripheral area is under water. The Shortland soil to the west has a high hydraulic conductivity and explains why the fish dams never hold water. The next profile is a deeper Arcadia and then the next three profiles were classified as Rensburg with the wet G horizons followed by a Hutton which is outside the river bed. This transect does not show any water flow from the West which caused the shallower G horizon on the western side of the previous transect. The profiles with the G horizons in this transect is in the flood line which seems normal.

This again confirms the hypotheses that the river bed is sealed off and water cannot leak from the river into the surrounding area.

Cross Section C

This is an area where the river made a wider flood plain with an Arcadia to the left followed by three equally deep (3m) Rensburg profiles. This was followed by a Glenrosa form and then a very shallow Arcadia on solid rock. The surface profile of this transect is misleading because on the right the vegetation was higher indicating a misleading steep slope. Both the B and C transects show no lateral inflow of water from the West. The deep clay layer in the river bed will prevent leakage from the river to the surrounding area. It can be expected that toward the left the Arcadia soils will extend further than up to where the last profile was made. The fact that, according to the flood line of 2008, water levels extends beyond the survey area, it is expected that only limited water will be decanted on the western side.

FARM VOSSLPRUIT 326 KR Portion 1: Mr Phillipie de Klerk

Cross Section D

The transect start with a shallow Rensburg soil form on the West which is outside the river bed and flood level of 2008 followed by a Rensburg with relatively shallow G horizon. The G horizons in the next profiles were deeper while the last profile outside the riverbed was a Shortlands which does not have a G horizon.

Here again, the shallow G horizon outside the river bed on the West is an indication that water must come from outside to supply enough water to form such a shallow G horizon while in the center of the river bed the G horizons are deeper down the profile and is caused by the presence of a natural water table. According to this data water from the 2008 flood did not decant in this area.

Cross Section E

The first profile on the west is a shallow profile with a red soil overlying a vertic horizon. This is probably due to soil that was eroded from higher up from the western side and then settled on top of the vertic layer. The following profiles are Rensburg with a deep G in the middle and a shallower G toward the east. The next profile was outside the riverbed. The river bed is at this transect extend beyond the surveyed area. The bed in total consist of a deep swelling clay layer which will limit water loss and is suspected that decanting to the West is possible but limited with a flood as was experience in 2008.

Cross Section F

The first profile pit on the West was a Rensburg with a relatively shallow G horizon follow by Rensburg soil forms with deeper G horizons. The depth of the G horizons which is closer to the surface in the West than in the middle of the river bed, is indicative of water inflow from the west into the river that resulted in the prolonged wetness in the soil that cause the G horizon. The surveyed area did not cover the flooded area of 2008 but if it is expected that the shallow G horizon on the western side is the result of lateral movement of water from the West which would need a clay or impervious layer underneath to conserve the inflowing water. As a result it would probably not possible for major decanting in that direction.

FARM VOSSLPRUIT 326 KR Portion 5 & 7: Sylvania

Cross Section G

The profile on the West was a Rensburg soil form with a fairly shallow G horizon. This was followed by a structured (Shortland) soil with no signs of permanent wetness. This again indicates the presence of an island between the first Rensburg and the Arcadia with the Shortlands form in the middle. Towards the East the soils were deep Arcadia's in the middle. The Rensburg soil on the West again is indicative of water from the side which caused the wetness to form a G horizon so close to the surface. The lack of a G horizon in the middle of the river bed indicates that the permanent water table is quite deep and therefore the deeper G horizon. From this and previous observations it seems that there was a ridge on the western side that prevents water flowing directly into the river from the West and caused the water to pond on the western side of the ridge. The fact that the soil in the ponding area consist of swell clays little water will be able to decant on the western side.

Cross Section H

The soils in this transect are all relatively shallow Arcadias with Rensburg in the middle as normally can be expected. No indication of water flow from the West can be observed. The clay layer in the river bed is thick and will restrict water leaching from the river. No decanting was possible with the 2008 flood.

Cross Section J

The soils across this transect are Arcadia on the sides with Rensburg in the middle of the bed, as can be expected. No decanting took place in this area.

Cross Section K

Over the width of this transect the soils are deep clay soils with Arcadia on the sides and the Rensburg with the G horizon in the middle. Although the width that was surveyed did not cover the whole plane it can be expected that the sides would consist of soils from the Arcadia form and water loss would be limited and that no decanting during the 2008 flood took place.

Cross Section L

The width of the river bed consists of clay soils with Arcadia form on both sides of the river and Rensburg soil form with the G horizon in the middle. The Arcadia soils stretches wider than the surveyed area and it is expected that very little water could have decanted during the 2008 flood.

Cross Section M

The river bed is fairly narrow with deep/thick clay layer over the width of the river bed. On the sides the soil forms are Arcadia with Rensburg form in the middle of the flow path. The Arcadia soil stretches further than the surveyed area and decanting probably did not take place during the 2008 flood.

Cross Section N

The river bed consists of clay with the Arcadia from on the western side and Rensburg with the G horizon on the eastern side, again indicating the main flow area of the river. Due to the clay soil which extended further than that of the area survey, it is expected that no decanting took place during the 2008 flood.

HYDRAULIC CONDUCTIVITY STUDIES

The following profiles were used to sample for the determination of the hydraulic conductivity of soils from different horizons in the profile.

Profile 2

This profile was made inside the dam on Mr de Klerk's farm. The question was whether the top soil used to construct the dam wall may have reduced the thickness of the clay layer in the dam. The profile was made adjacent to a pond of free water still remaining in the dam.

The soil was classified as a Rensburg form consisting of a vertic A horizon follow by a G horizon. The latter indicating permanent water logged conditions. The G horizon can be up to 200 and even deeper. Underneath the G horizon the soil color change which may be part of the C horizon. This layer of soil is still clayey which contains calcium carbonate concretions.

This clay soil has a low hydraulic conductivity (8.3- 8.9 mm per hour) and seals the river from the adjacent areas to the river. This soil falls within the wetland area. This value is similar that was found by G E Blight in the Nylsvlei (Blight 2004).

It is interesting to note that even after several hours, no water accumulated in the pit although it was next to the free water in the dam. This indicated that the permeability of the soil was relatively slow.

Profile 2 (WP 161) Rensburg (de Klerk) In the Nyl river bed. Inside dam

Horizon	Depth (cm)	Description	
A	0-30	Black, vertic rich in organic matter with blocky structure	
B	30-120	G horizon, contain CaCO3 concretions	
C	120 +	Saprolite, grey color with CaCO3 concretions.	
Analytical data			
Horizon	Vertic A (0-30cm)	G horizon(30-200cm)	C saprolite 200 +
(Permeability mm/hour Hydraulic conductivity)	8.3	8.9	

The next profile, pit 3, was made beneath the dam wall. Here the soil was deeper indicated that the soil inside the dam was used to construct the dam wall, while beneath the dam the depth is an indication of the actual depth of the clay layer. Here again, although the B horizon indicated permanent hydromorphic conditions no water accumulated for several hours while the profile was open although it was made next to a pool of water. This again indicated a very low hydraulic conductivity of the clay layer. The vertic A horizon has a hydraulic conductivity of 9 mm/h while the G horizon has a conductivity of only 3.2 mm/h.

Profile 3 (WP 162) Rensburg (de Klerk) beneath dam wall

Horizon	Depth (cm)	Description	
A	0-30	Vertic A horizon dark brown to black, structured, moist, clay. Frequent roots.	
B	30-200	G horizon with CaCO3 concretions	
C	200+	Saprolite	
Analytical data			
Horizon	Vertic A	G horison	C Saprolite
Depth	0-30	30-200	200+
Permeability mm/hour	9	3.2	

Arcadia form:

This pit, profile 4 was made next to the river bed. The soil has a vertic A horizon follow by scapolite. No hydromorphic properties were observed in the C horizon. The Hydraulic conductivity (permeability) was low even in the C horizon.

Vertic soil is known for its swell and shrink properties. This form differs from the Rensburg form in that it has no hydromorphic properties. The profile is not very deep but the hydraulic conductivity is low and similar to the Rensburg soils.

Profile 4 (WP 163) Arcadia(Sylvania farm)
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Horizon	Depth (cm)	Description		
A	0-30	Vertic A, Black colour, moist, clay, crumby structure, frequent roots.		
C	30-250+	Saprolite friable. Grey colour		
Analytical data				
Horizon		Vertic A	C	
Depth		0-30		
Permeability mm/hour		7	6.4	

Profile pit 5 was made in the river bed. The profile properties were similar as those describe for the pits on Mr de Klerk's farm. The soil was classified as a Rensburg which has a vertic A horizon followed by a G horizon with signs of permanent wetness, the hydraulic conductivity was low, typical of swelling clay layers.

Profile 5 (WP 164) Rensburg (Sylvania farm)
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Horizon	Depth (cm)	Description		
A	0-30	Vertic A, Black moist, clay, crumby structure, frequent roots.		
B	30-200	G horizons with CaCO3 concretions (structure less), black-grey-green colour, moist, friable, clay, Roots frequent too few		
Analytical data				
Horizon		Orthic A	Apedal (structure less)B	C
Depth		0-30	30 -200 cm +	
Permeability		5.7	3.8	

CONCLUSIONS

From this survey it was obvious that in some transect that were investigated on the farms of Mr P de Klerk and Mr A Tayob, the presence of the G horizon in the different profiles over the width of the flood plain was not as expected. Normally it can be expected that if a water table is present in a flat plain the depth of the G horizons would occur more or less the same distance/depth from the surface and if there is some deviation it can be expected that the G horizon would be closest to the surface in the middle of the flood plain, which is the lowest point. The main abnormality is that the G horizon on the western side was closer to the surface than in the main river flow path, indicating water flow from the West that cause the permanent wetness to be closer to the surface in the profiles on the western side.

To verify the hypotheses that the river bed consist of a thick swelling clay layer that will restrict water from draining out of the river when free water is present, the hydraulic conductivity determined (3-8 mm/h) can be substituted in the Darcy equation for water movement and the flood Q or volume per unit time or surface can be calculated

$$Q=V/At= -K \nabla H/L$$

Where:

Q=flood

V= volume

A =surface area

T=time hour

∇H = Water head

L= thickness of the clay layer through which the water have to move

K= hydraulic conductivity mm/hour

Of importance is to realize that ∇H (water head) will depend on the depth of the water layer plus the thickness of the clay layer through which the water has to move.

From the survey results and test done it seems that water flowing through the larger extent of the clay layer would be minimal. The hypothesis is that water losses can be significant only when the river is flooded and decant to the surrounding areas along peripherals where soil permeability are higher and/ or clay layers are thinner.

Of importance to notice is that if the river overflows and the water rise above the level where the swelling clays end, it would decant to the surrounding area. From the flood line of the 2008 flood (as detected by Landsat satellite) that was used as an example to apply in this study, it become clear that decanting probably takes place where the clay layer is

overtopped. The important question that needs to be considered is to what extent does the flood exceed the clay layer perimeter, and for how long it was overtopped (logically once the water subsides the decanting will stop).

Figure 1 below indicates the area that may be expected to allow decanting of flood water to a significant extent. The area is associated with soils outside the riverbed which derived by the natural soil forming factors and probably mainly by the geology from the area which formed the red structured soils found during the survey.

With thicker clay layers and thinner free water layers these volumes will decline significantly. With these calculations it was assumed that the material beneath to soil or clay layer has a significantly higher hydraulic conductivity and water movement is only downwards. If lateral movement is to be considered then the factor L will increase and the hydraulic head $\nabla H/L$ will decline resulting a lower flood.

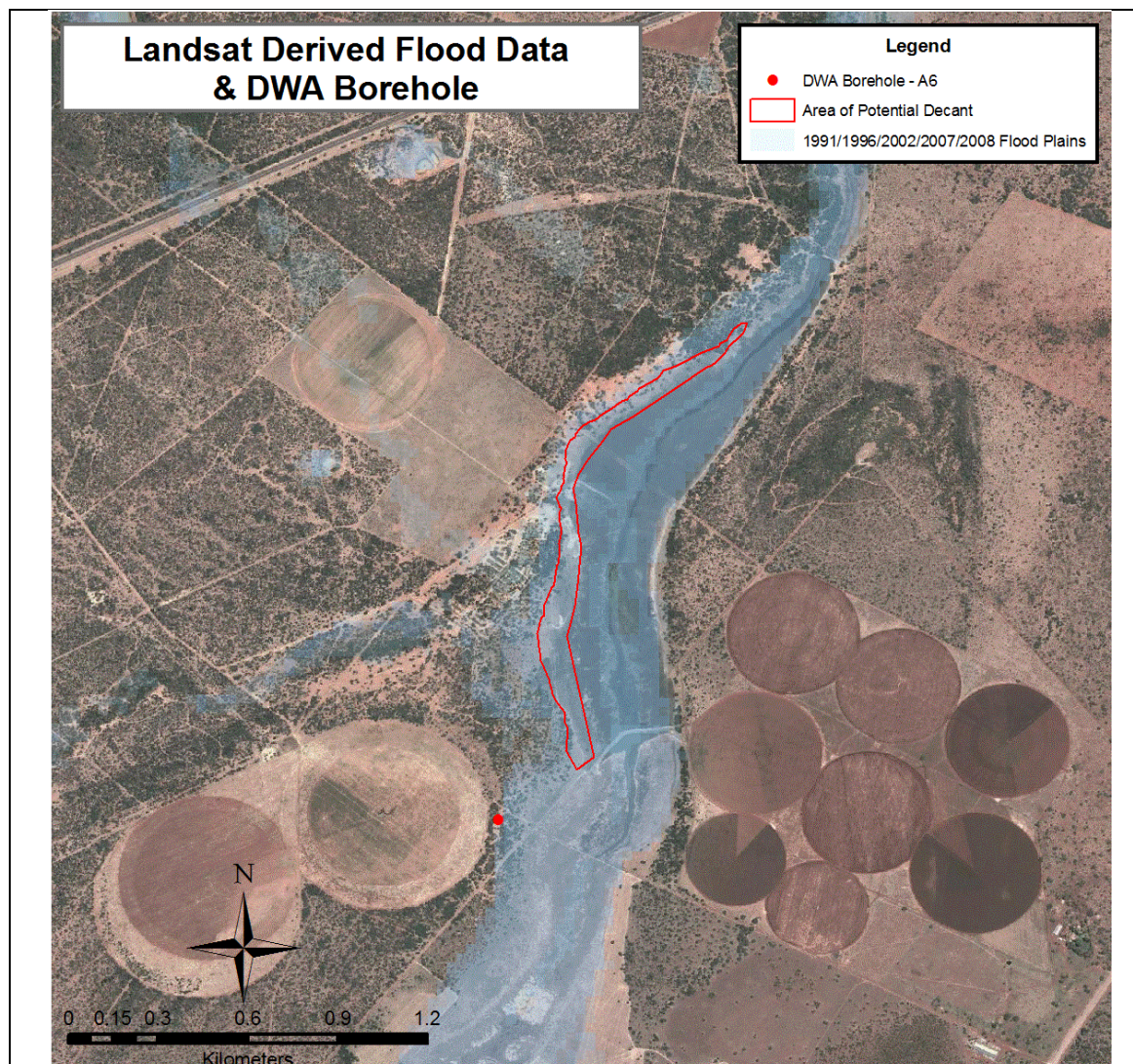


Figure 1: Area within which floods may decant to recharge aquifer depending depth and period of inundation (flood mask from Landsat flood images)

Based on the soil profiles from transects it seems that the recharge from the flood may takes place in a localised area due to combination of the flatter slope which allowed the flood line to extend further on the western periphery and an area where clay layers associated with the Nyl are also substantially thinner.

The period of inundation would be important to calculate the amount of water that would decant from peripheral areas to supplement the soil water next to the river and subsequently groundwater. Under circumstances normally seen in rivers with higher gradients it can be expected that a flood would subside quite significantly if the precipitation stops, however in the case of the Nyl it is has been determined from hydrological modeling and confirmed by observations that the inundation can last for periods longer than a month in lower-lying areas where vegetation traps water.

As a most conservative scenario it is assumed the area of potential ingress is some 4ha and $K = 15 \text{ mm/h}$ the below then the potential recharge over a month of inundation is given in Table 1 below. The scenario for a 1m vertic layer with a depth of inundation 25 cm is highlighted.

As a less conservative scenario it is assumed the area of potential ingress is some 4ha and $K = 8 \text{ mm/h}$ (as per tests) the below then the potential recharge over a month of inundation is given in Table 2 below. The scenario for a 1m vertic layer with a depth of inundation 25 cm is highlighted.

A realistic scenario is deemed to be fractions of what is presented in the table both in period as well as depth of inundation.

In this regard it was remarked by Mr de Klerk that when the dam on his property is full the borehole close to the dam delivers much more water than when the dam is empty. According to the profiles in the dam, the clay layer is still more than 2 meters thick and should not be able to leak much water. However, it was found that on the eastern side near the edge of the river a substantial amount of topsoil was removed and used to construct the wall. Especially at the edges where the clay layer become quite thin, most of it was probably removed and water may now move quite rapidly through the exposed underlying material which is much more porous that clays associated with wetland. This is the most probable explanation for Mr. de Klerk's observation.

Table 1: Most conservative scenario

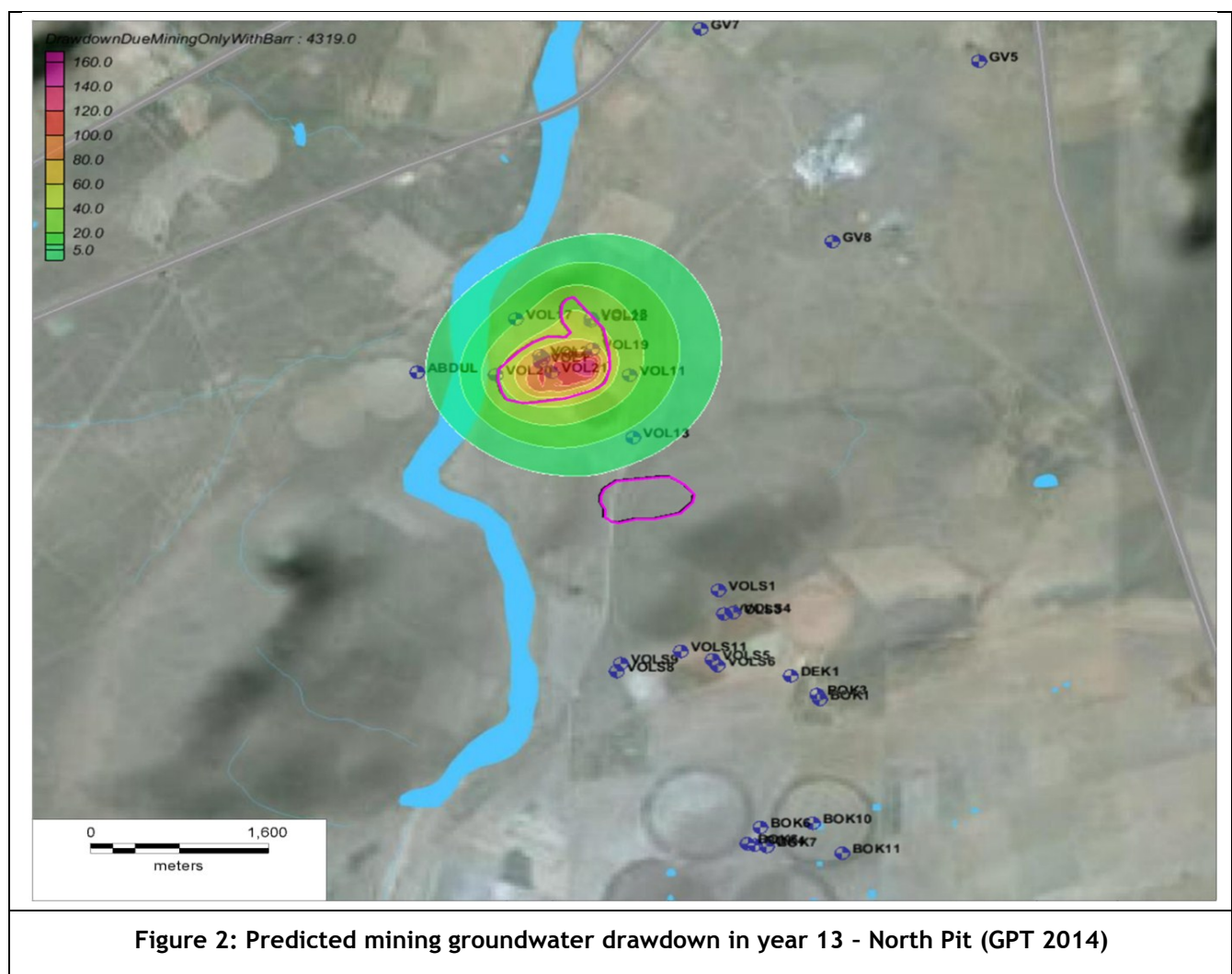
	Higher permeability clayey silt (15mm/h)														
	Water soil column (m)														
Thickness	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
0.1	669 600	1 339 200	2 008 800	2 678 400	3 348 000	4 017 600	4 687 200	5 356 800	6 026 400	6 696 000	7 365 600	8 035 200	8 704 800	9 374 400	10 044 000
0.2	334 800	669 600	1 004 400	1 339 200	1 674 000	2 008 800	2 343 600	2 678 400	3 013 200	3 348 000	3 682 800	4 017 600	4 352 400	4 687 200	5 022 000
0.3	223 200	446 400	669 600	892 800	1 116 000	1 339 200	1 562 400	1 785 600	2 008 800	2 232 000	2 455 200	2 678 400	2 901 600	3 124 800	3 348 000
0.4	167 400	334 800	502 200	669 600	837 000	1 004 400	1 171 800	1 339 200	1 506 600	1 674 000	1 841 400	2 008 800	2 176 200	2 343 600	2 511 000
0.5	133 920	267 840	401 760	535 680	669 600	803 520	937 440	1 071 360	1 205 280	1 339 200	1 473 120	1 607 040	1 740 960	1 874 880	2 008 800
0.6	111 600	223 200	334 800	446 400	558 000	669 600	781 200	892 800	1 004 400	1 116 000	1 227 600	1 339 200	1 450 800	1 562 400	1 674 000
0.7	95 657	191 314	286 971	382 629	478 286	573 943	669 600	765 257	860 914	956 571	1 052 229	1 147 886	1 243 543	1 339 200	1 434 857
0.8	83 700	167 400	251 100	334 800	418 500	502 200	585 900	669 600	753 300	837 000	920 700	1 004 400	1 088 100	1 171 800	1 255 500
0.9	74 400	148 800	223 200	297 600	372 000	446 400	520 800	595 200	669 600	744 000	818 400	892 800	967 200	1 041 600	1 116 000
1	66 960	133 920	200 880	267 840	334 800	401 760	468 720	535 680	602 640	669 600	736 560	803 520	870 480	937 440	1 004 400
1.1	60 873	121 745	182 618	243 491	304 364	365 236	426 109	486 982	547 855	608 727	669 600	730 473	791 345	852 218	913 091
1.2	55 800	111 600	167 400	223 200	279 000	334 800	390 600	446 400	502 200	558 000	613 800	669 600	725 400	781 200	837 000
1.3	51 508	103 015	154 523	206 031	257 538	309 046	360 554	412 062	463 569	515 077	566 585	618 092	669 600	721 108	772 615
1.4	47 829	95 657	143 486	191 314	239 143	286 971	334 800	382 629	430 457	478 286	526 114	573 943	621 771	669 600	717 429
1.5	44 640	89 280	133 920	178 560	223 200	267 840	312 480	357 120	401 760	446 400	491 040	535 680	580 320	624 960	669 600

Table 1: Less conservative scenario

	Lower permeability clay (8mm/h)														
	Water soil column (m)														
Thickness	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
0.1	357 120	714 240	1 071 360	1 428 480	1 785 600	2 142 720	2 499 840	2 856 960	3 214 080	3 571 200	3 928 320	4 285 440	4 642 560	4 999 680	5 356 800
0.2	178 560	357 120	535 680	714 240	892 800	1 071 360	1 249 920	1 428 480	1 607 040	1 785 600	1 964 160	2 142 720	2 321 280	2 499 840	2 678 400
0.3	119 040	238 080	357 120	476 160	595 200	714 240	833 280	952 320	1 071 360	1 190 400	1 309 440	1 428 480	1 547 520	1 666 560	1 785 600
0.4	89 280	178 560	267 840	357 120	446 400	535 680	624 960	714 240	803 520	892 800	982 080	1 071 360	1 160 640	1 249 920	1 339 200
0.5	71 424	142 848	214 272	285 696	357 120	428 544	499 968	571 392	642 816	714 240	785 664	857 088	928 512	999 936	1 071 360
0.6	59 520	119 040	178 560	238 080	297 600	357 120	416 640	476 160	535 680	595 200	654 720	714 240	773 760	833 280	892 800
0.7	51 017	102 034	153 051	204 069	255 086	306 103	357 120	408 137	459 154	510 171	561 189	612 206	663 223	714 240	765 257
0.8	44 640	89 280	133 920	178 560	223 200	267 840	312 480	357 120	401 760	446 400	491 040	535 680	580 320	624 960	669 600
0.9	39 680	79 360	119 040	158 720	198 400	238 080	277 760	317 440	357 120	396 800	436 480	476 160	515 840	555 520	595 200
1	35 712	71 424	107 136	142 848	178 560	214 272	249 984	285 696	321 408	357 120	392 832	428 544	464 256	499 968	535 680
1.1	32 465	64 931	97 396	129 862	162 327	194 793	227 258	259 724	292 189	324 655	357 120	389 585	422 051	454 516	486 982
1.2	29 760	59 520	89 280	119 040	148 800	178 560	208 320	238 080	267 840	297 600	327 360	357 120	386 880	416 640	446 400
1.3	27 471	54 942	82 412	109 883	137 354	164 825	192 295	219 766	247 237	274 708	302 178	329 649	357 120	384 591	412 062
1.4	25 509	51 017	76 526	102 034	127 543	153 051	178 560	204 069	229 577	255 086	280 594	306 103	331 611	357 120	382 629
1.5	23 808	47 616	71 424	95 232	119 040	142 848	166 656	190 464	214 272	238 080	261 888	285 696	309 504	333 312	357 120

From the soil profiling undertaken it is clear that flood water will mostly remain trapped on the clay layer and only peripherally decant during flood extremes. Dewatering below the clay layer may affect the volumes decanted from wetland margin to the extent that the mine dewatering will increase depth below ground of groundwater level.

When mining at the North Pit has reached final depth, drawdown of groundwater below the Nyl could be as much as 20 m (groundwater modeling GPT 2014), and compared to levels of around 10 m currently as a result of irrigation abstraction (groundwater measurements GPT 2013). The difference in volumes that will be lost from the flood event between current irrigation abstraction regime and future mining abstraction regime is not considered to be meaningful (figure 3).



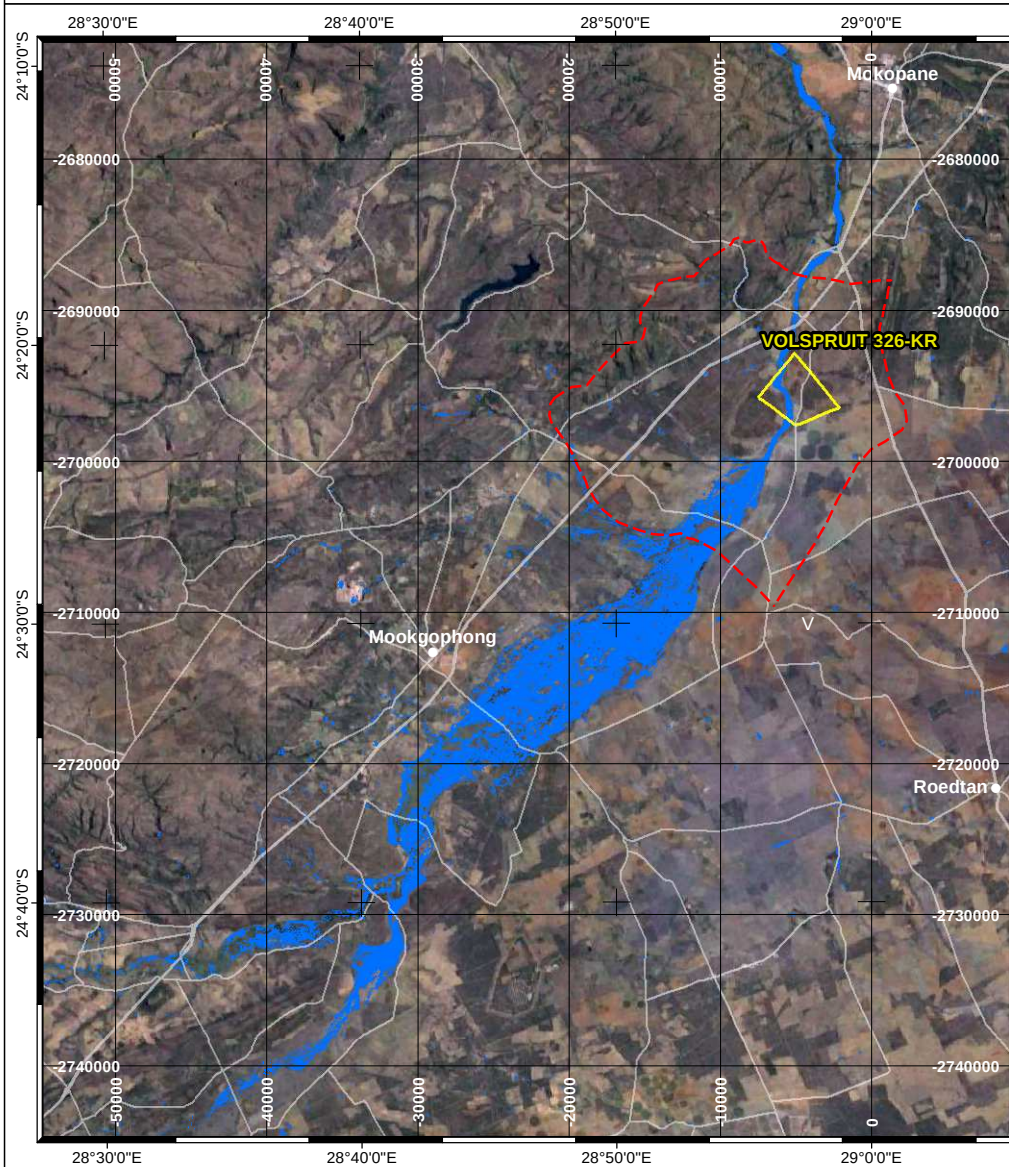
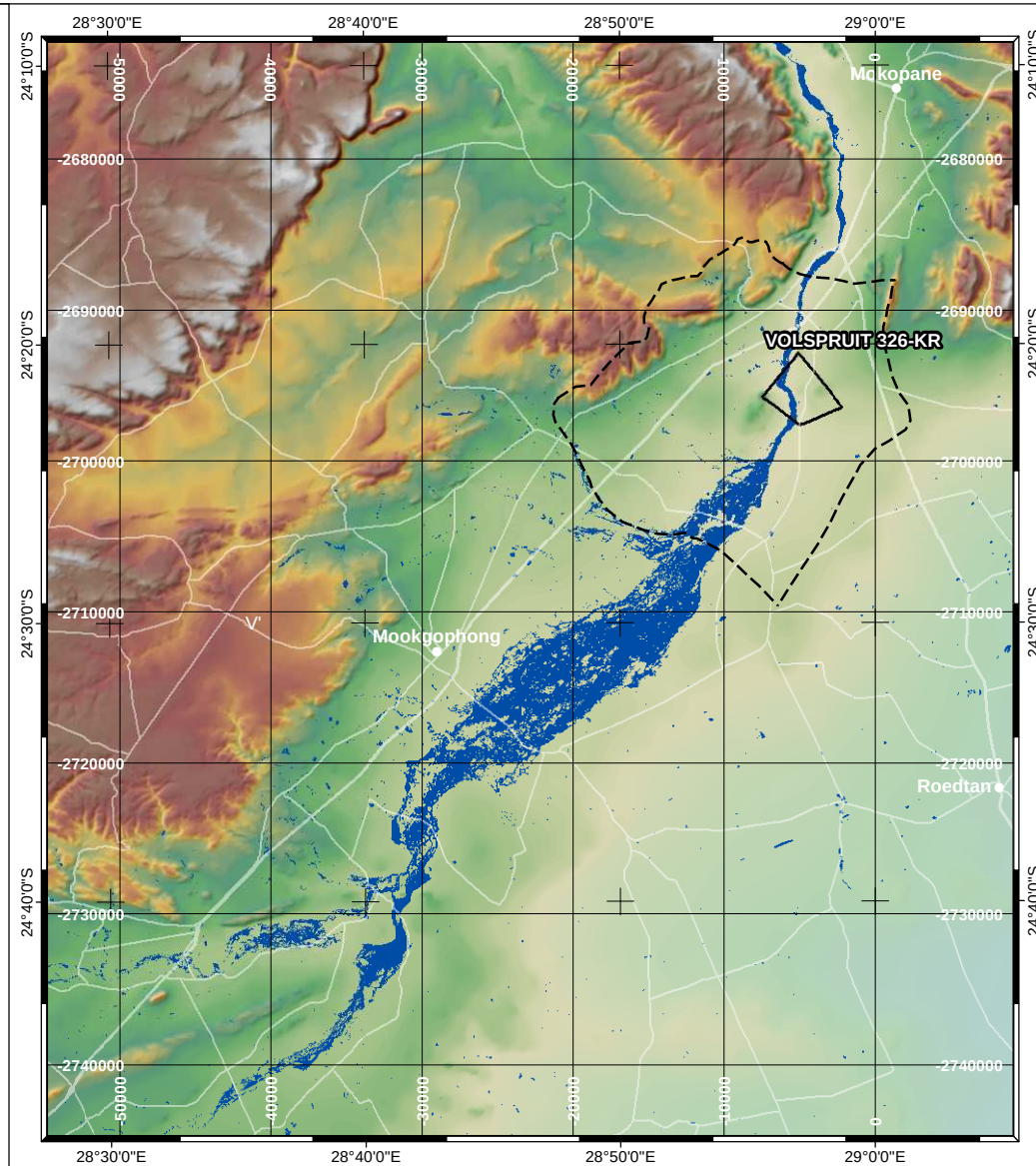
REFERENCES

Blight G. E. 2004. Water Balance for Soil Systems. Unsaturated Soil Juca, de Campos & Marinho (Eds) 1113-1124

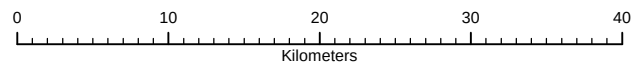
EScience and Associates 2013. Soils of the Nyl River Catchment: Literature review.

VOLSPRUIT SECTION

Greater Flooding Area with Groundwater Domain & 1 Feb 2008 Flood Overlay



Maps Scale - 1 : 500 000
 Projection - Transverse Mercator
 Datum - Hartebeeshoek 1994
 Reference Ellipsoid - WGS 1984
 Central Meridian - 29

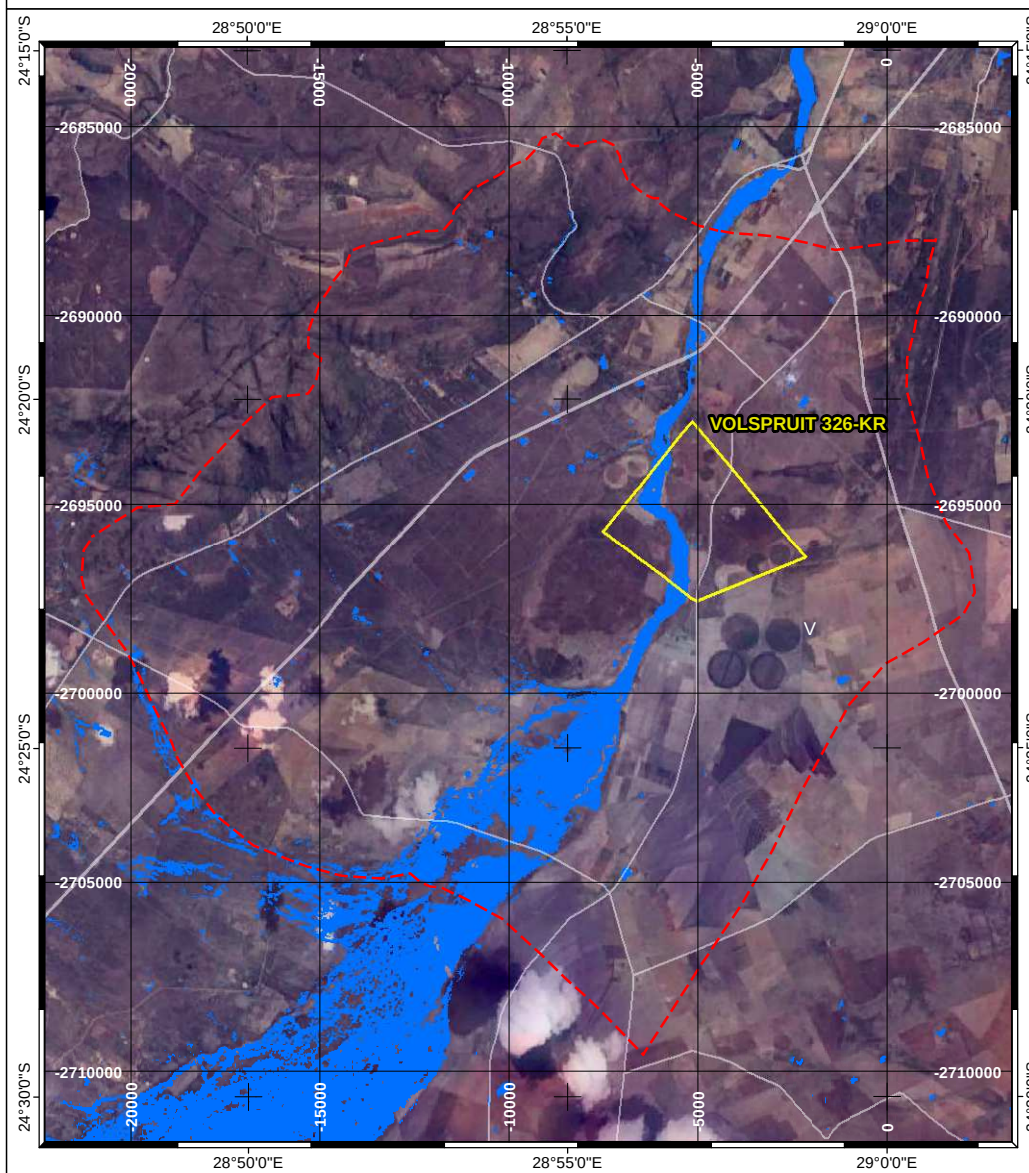
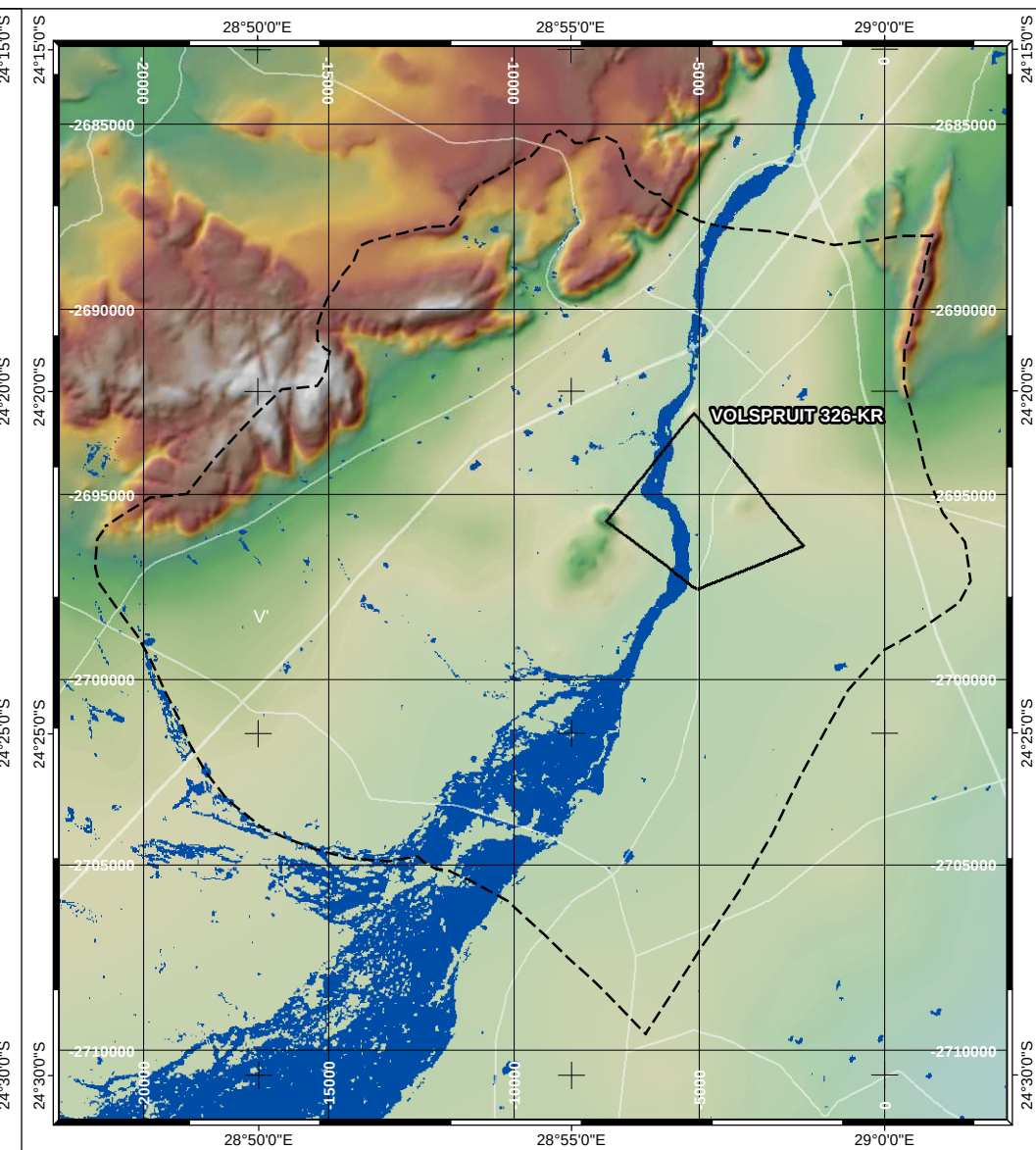


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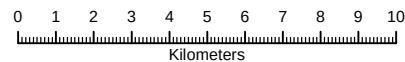
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Groundwater Domain & 1 Feb 2008 Flood Overlay

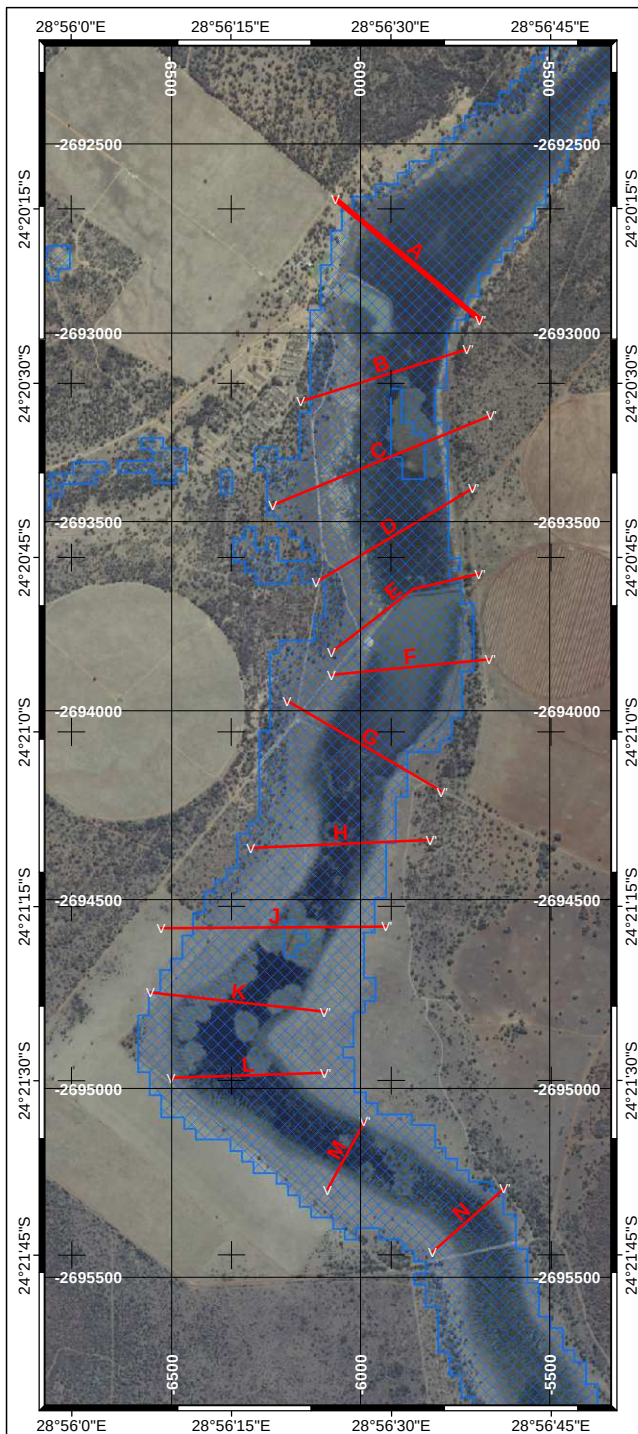


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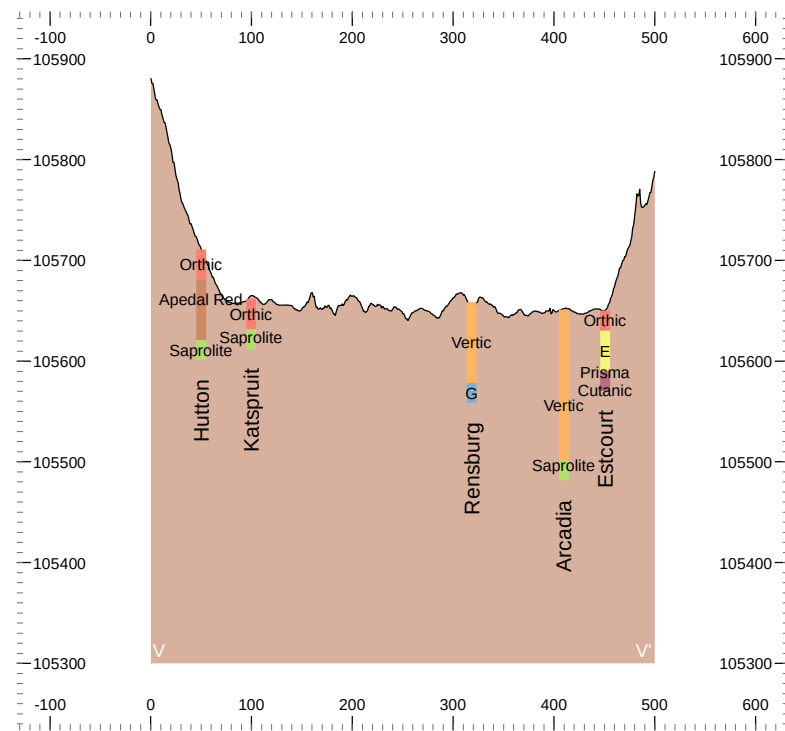


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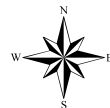
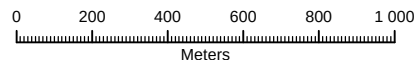
Cross Section A



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

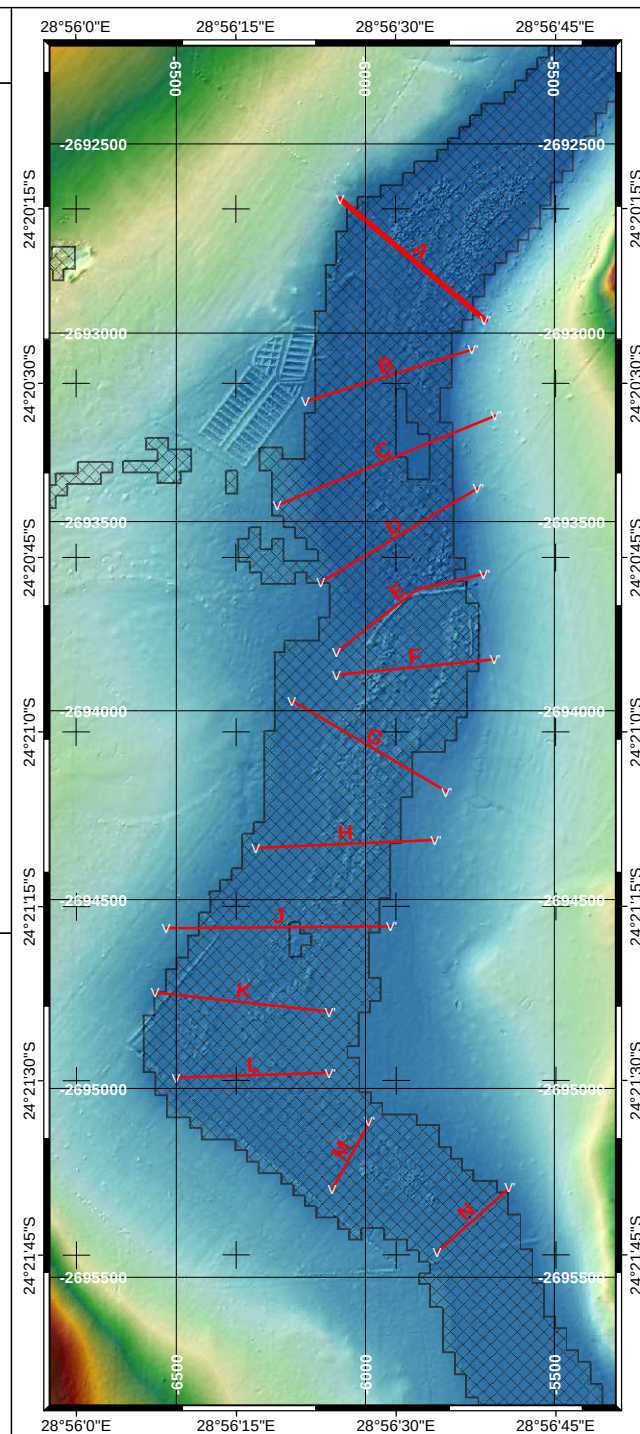
Soil Survey & 1 Feb 2008 Flood Overlay

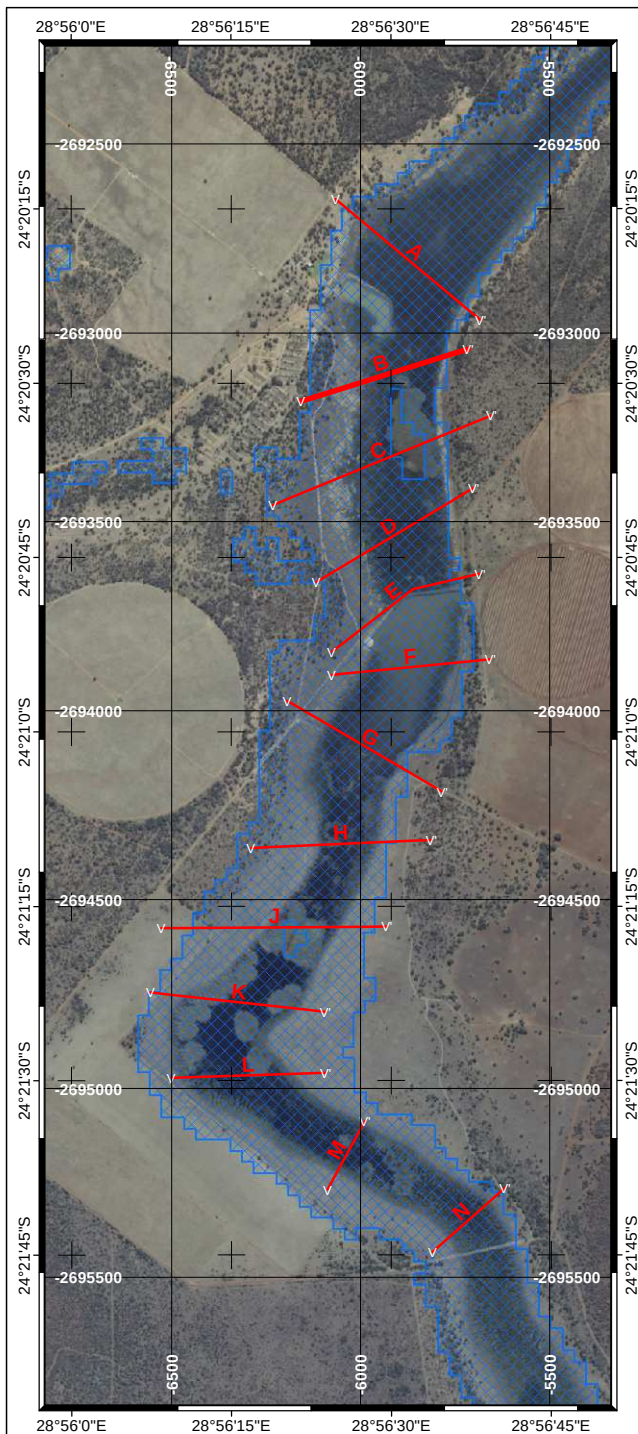


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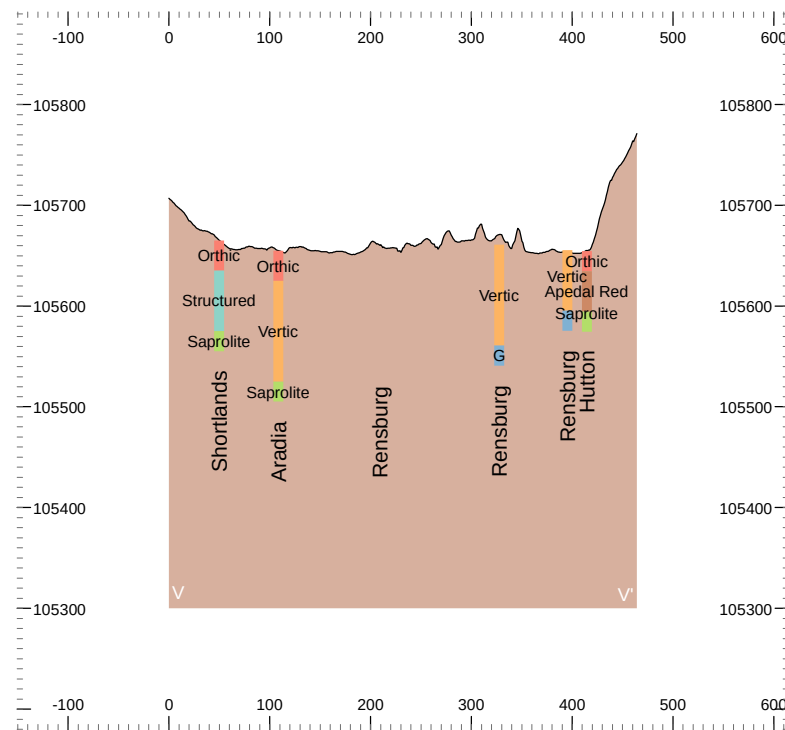
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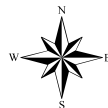
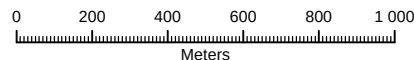
Cross Section B



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

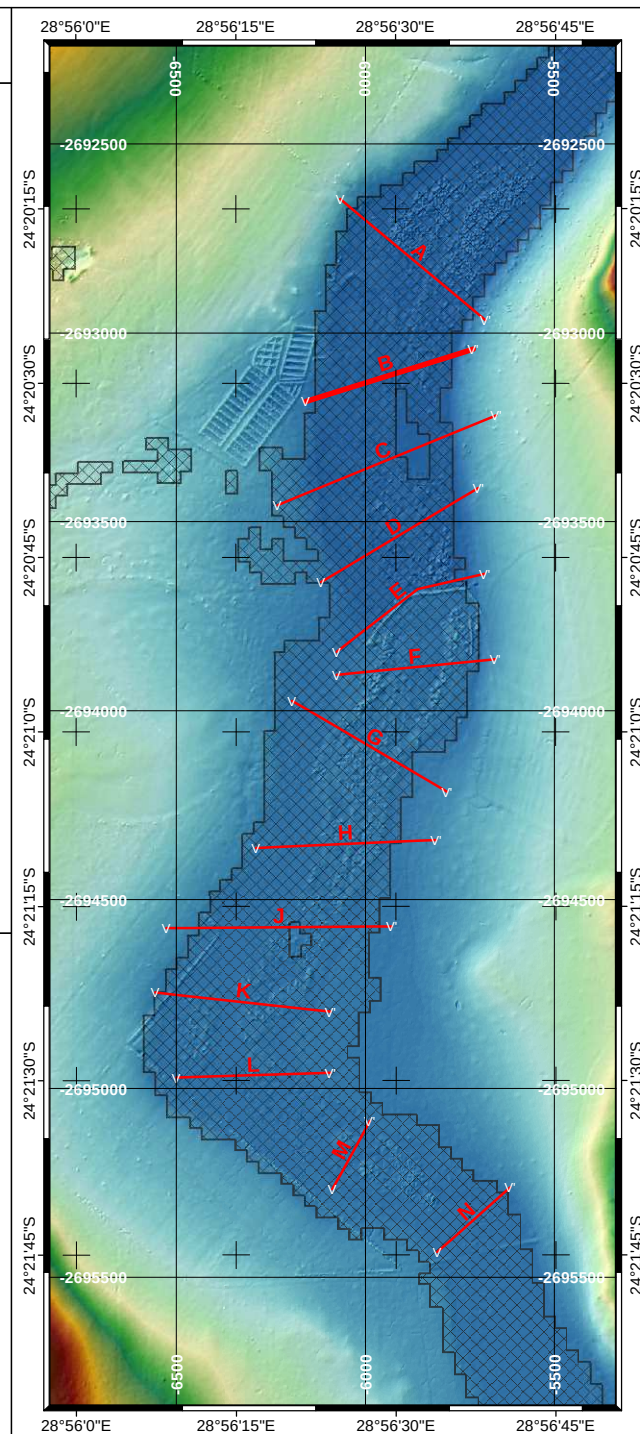
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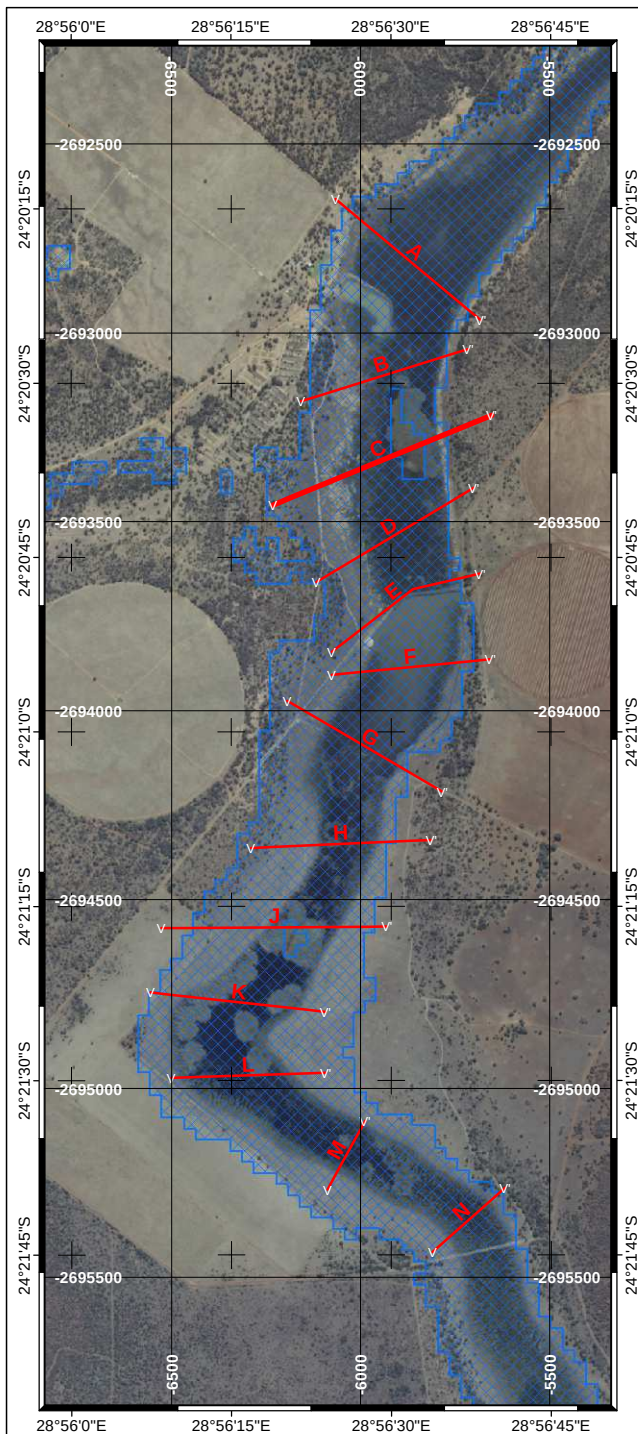


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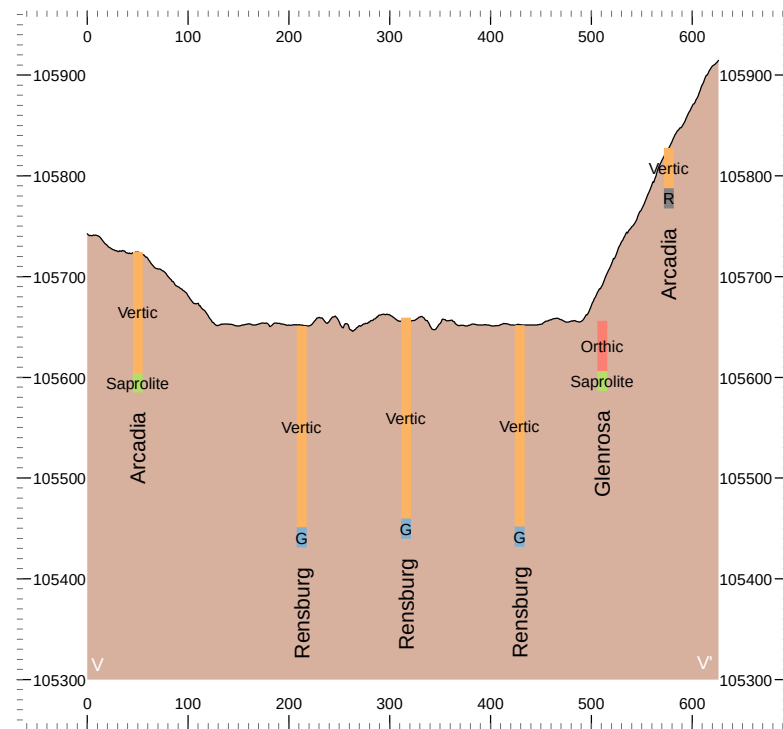
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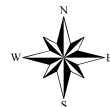
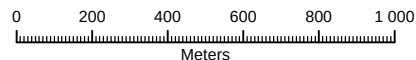
Cross Section C



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

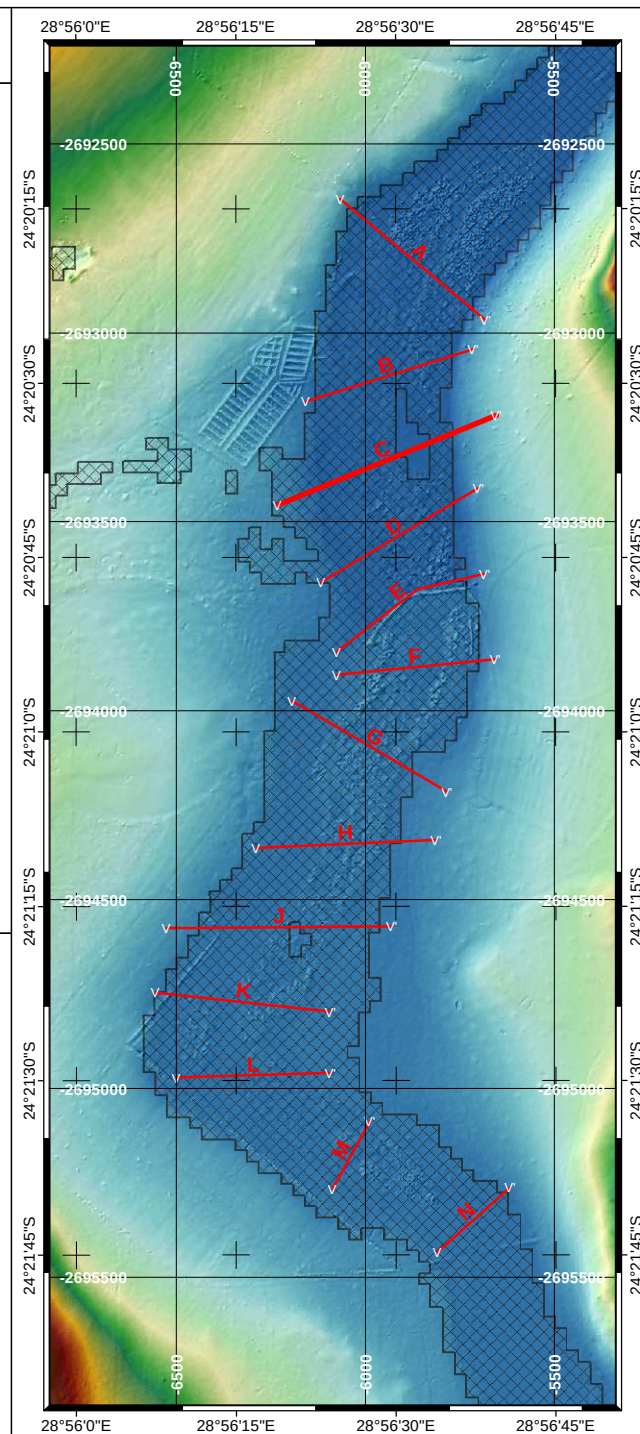
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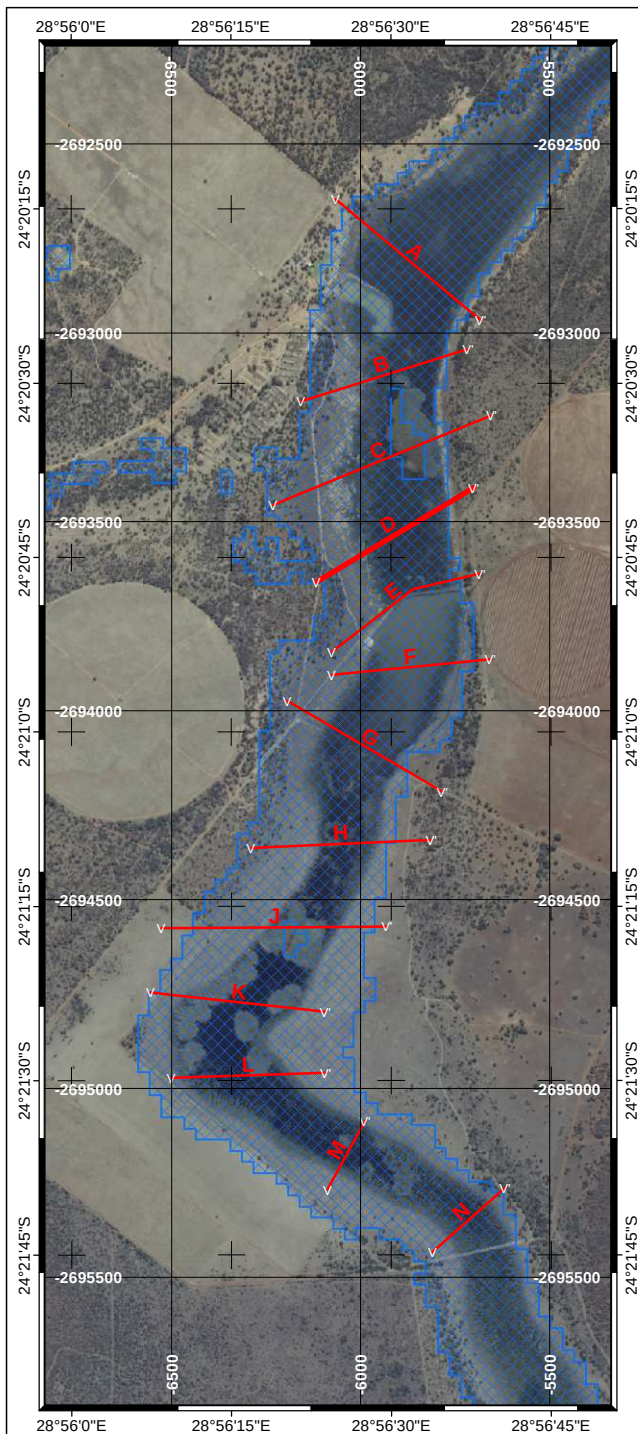


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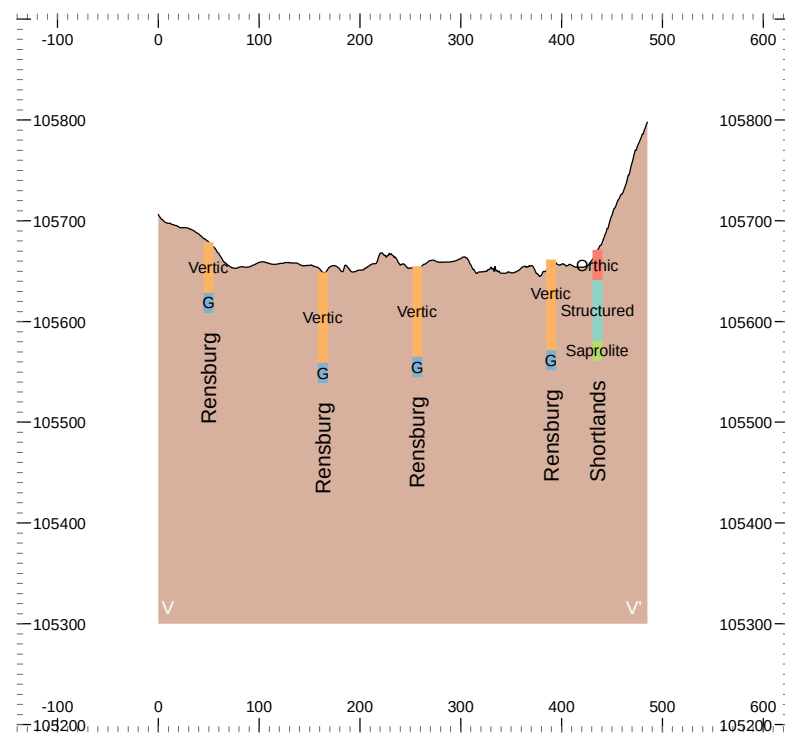
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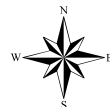
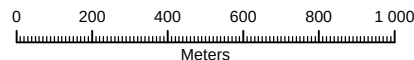
Cross Section D



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

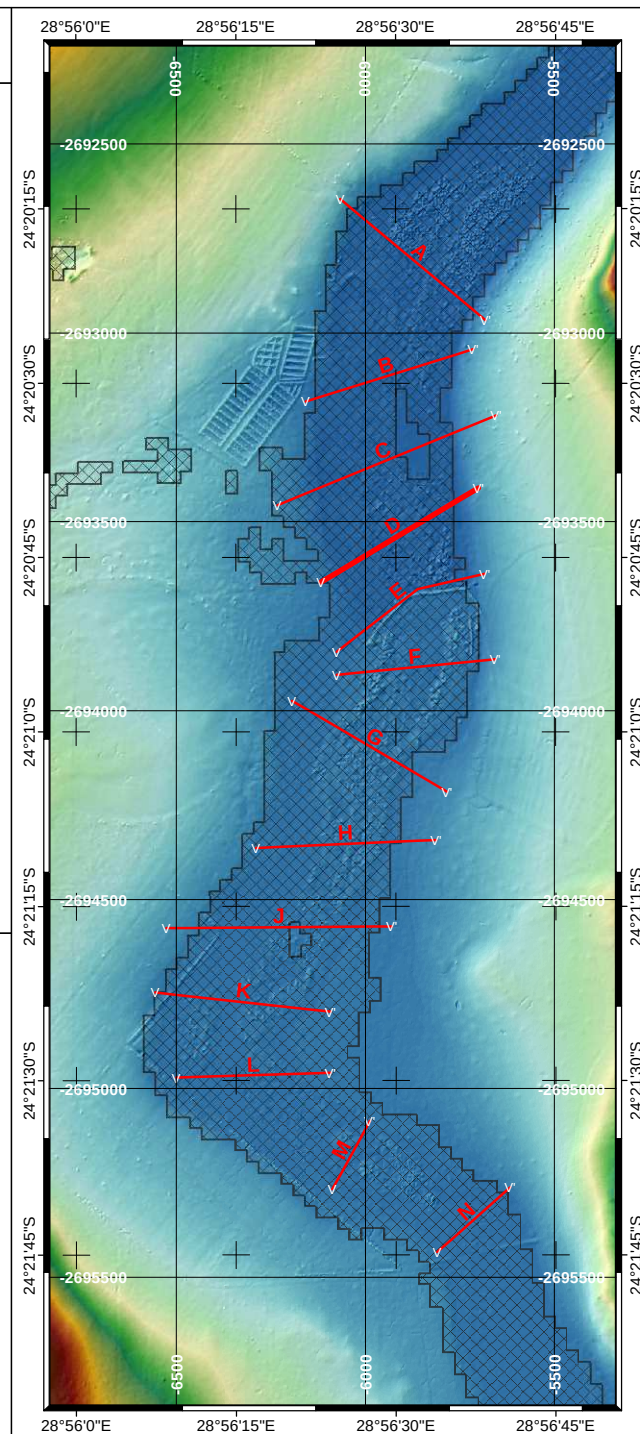
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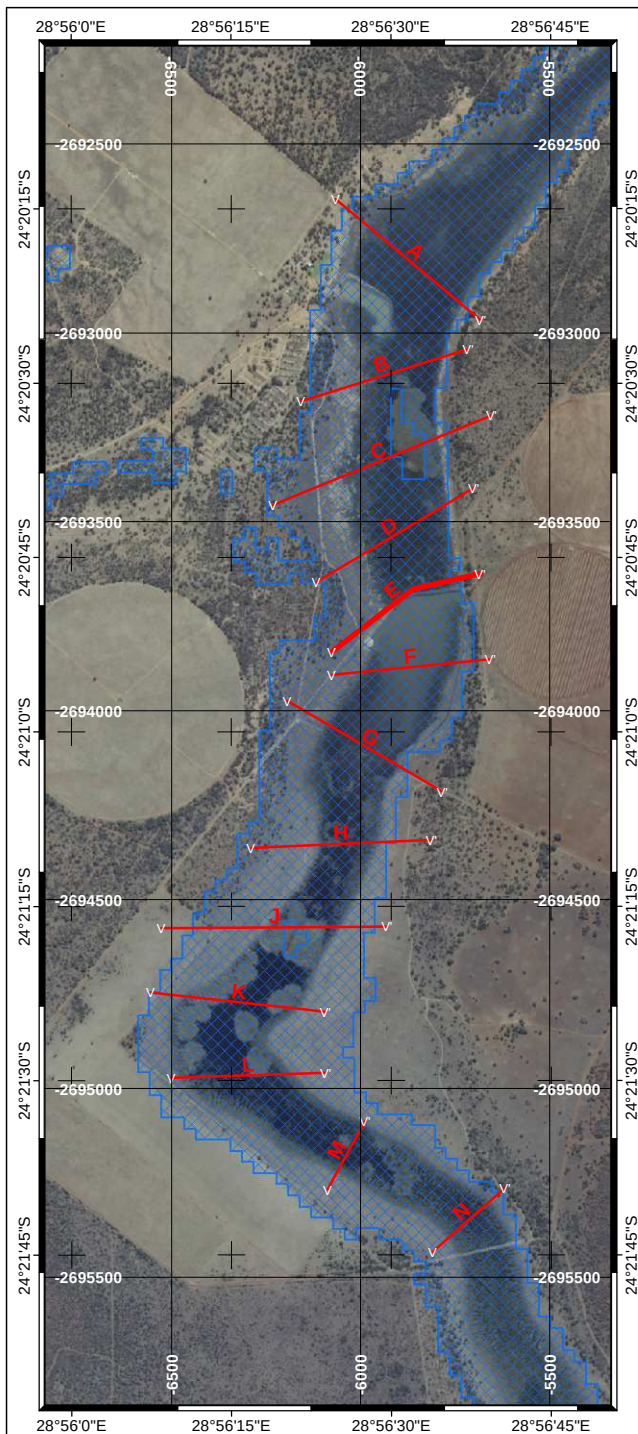


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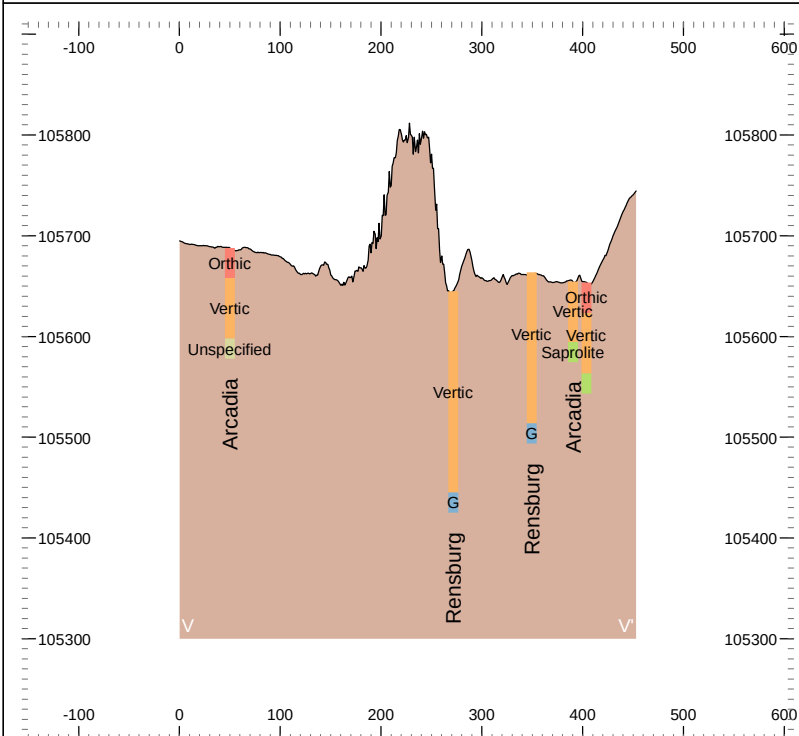
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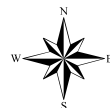
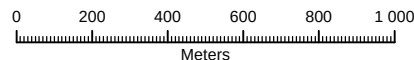
Cross Section E



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

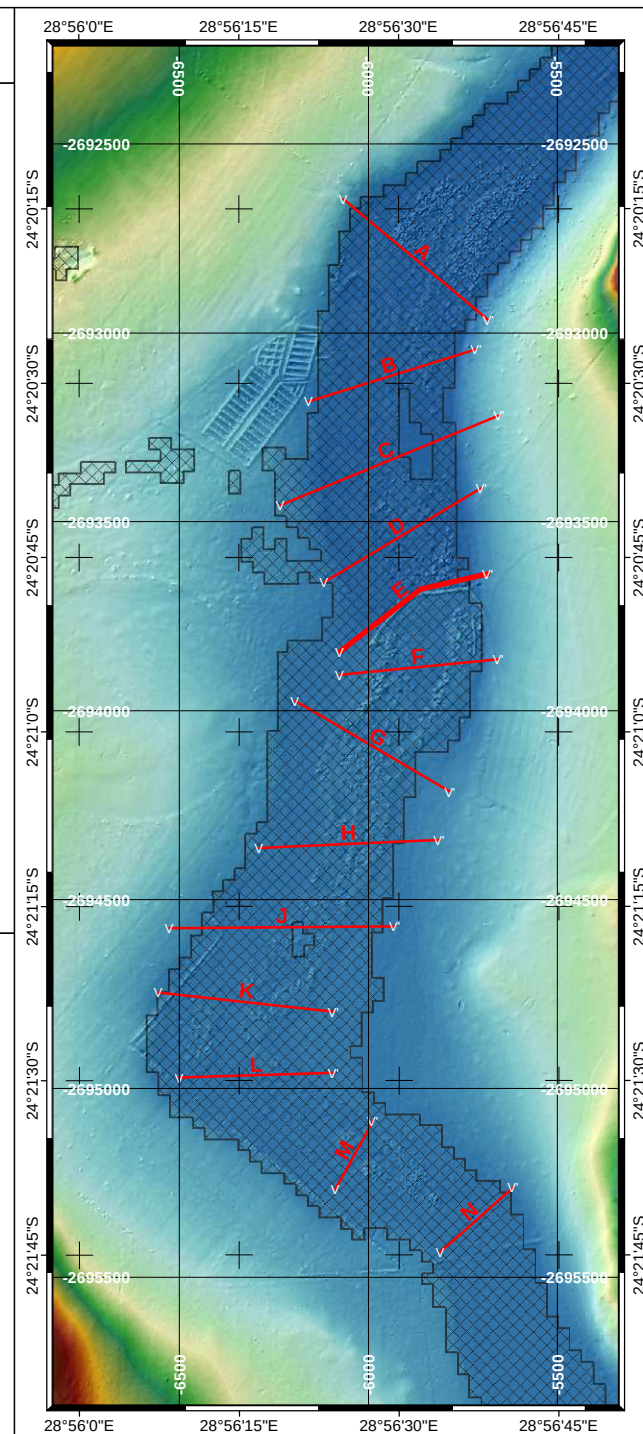
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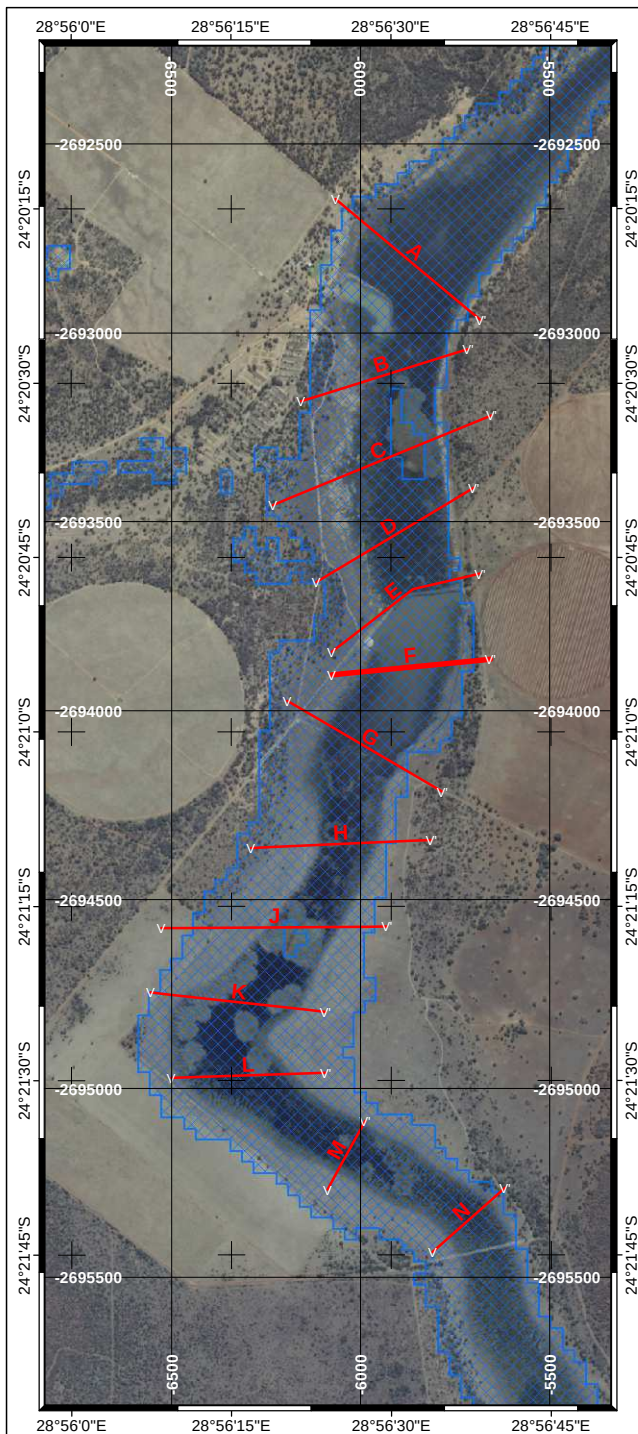


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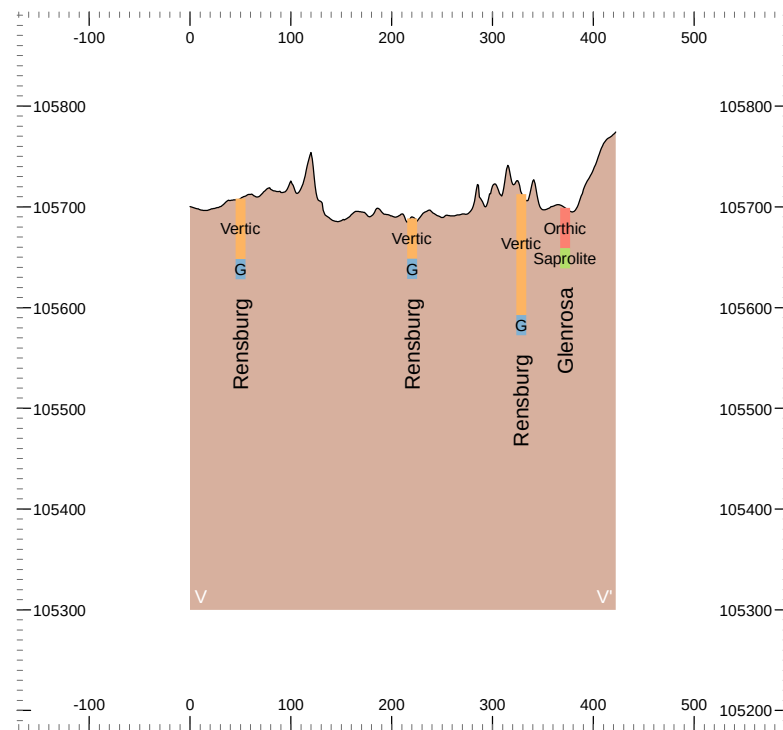
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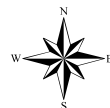
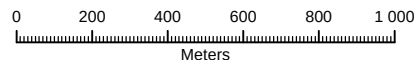
Cross Section F



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

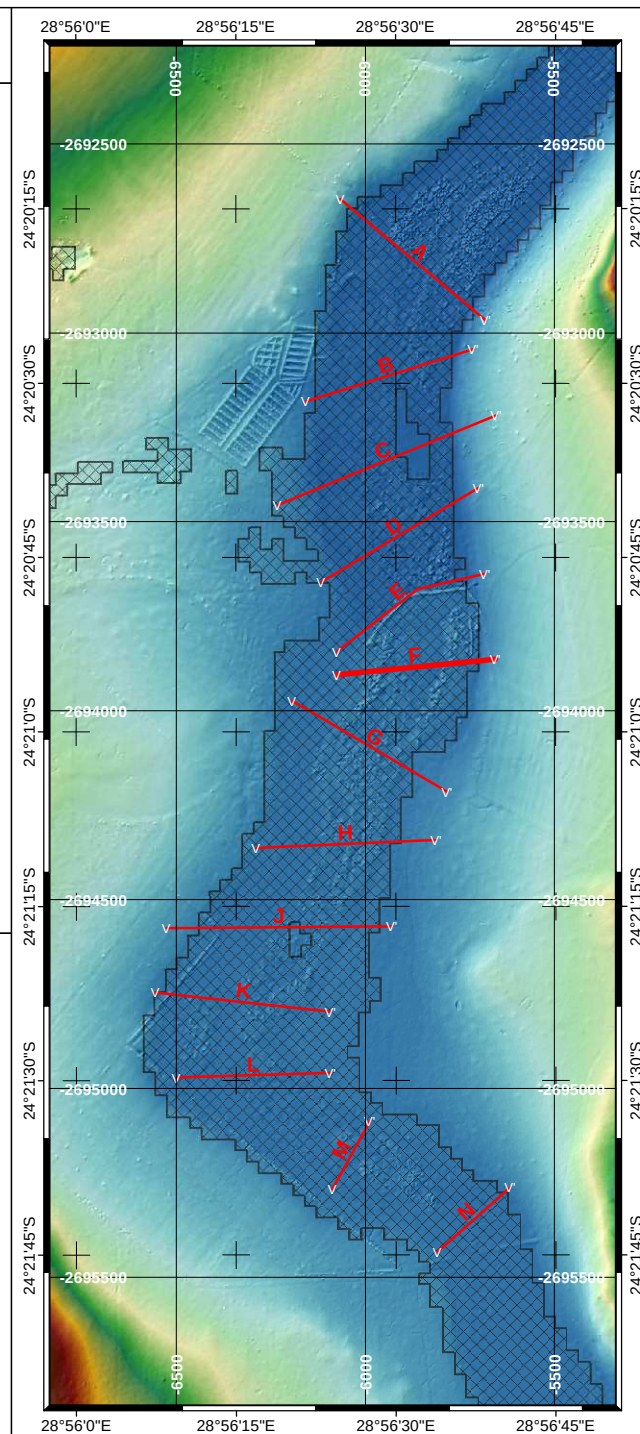
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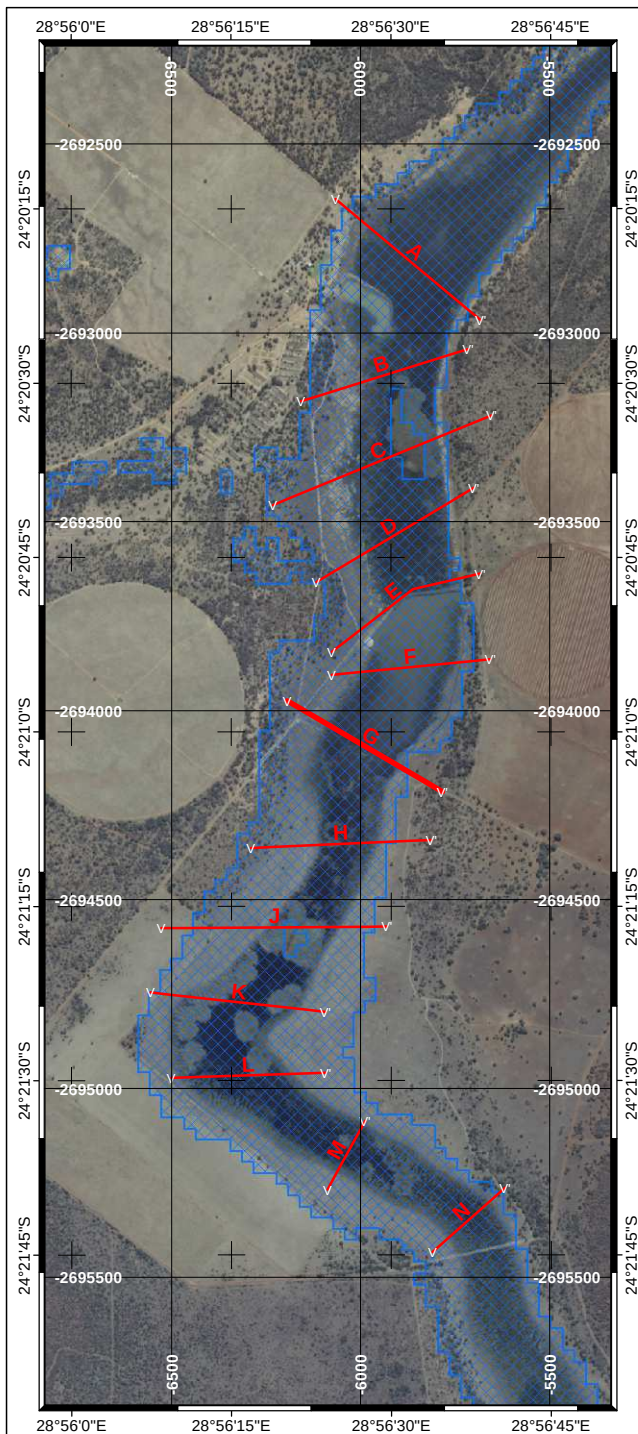


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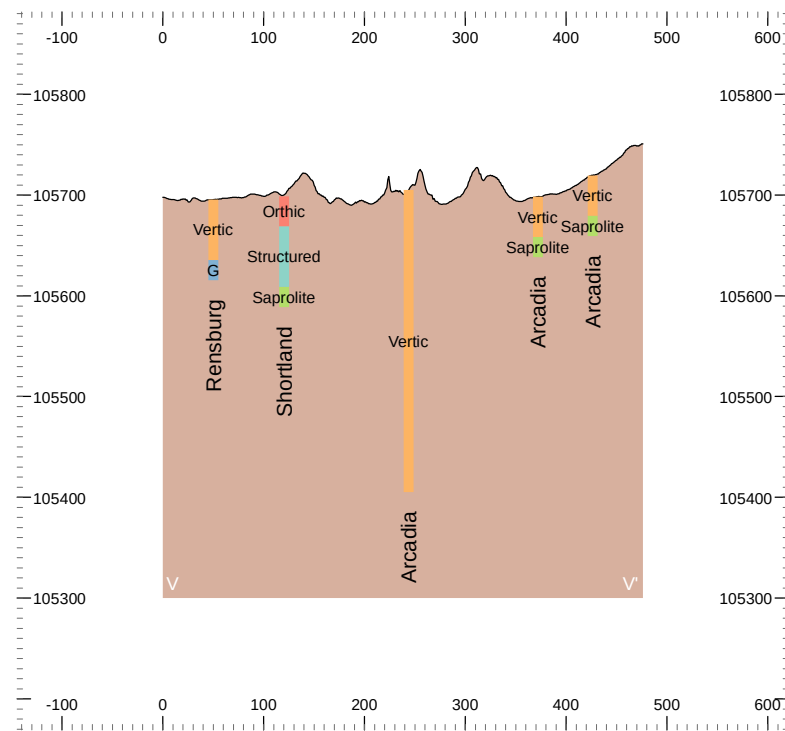
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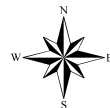
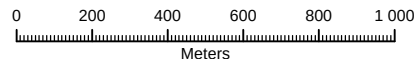
Cross Section G



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

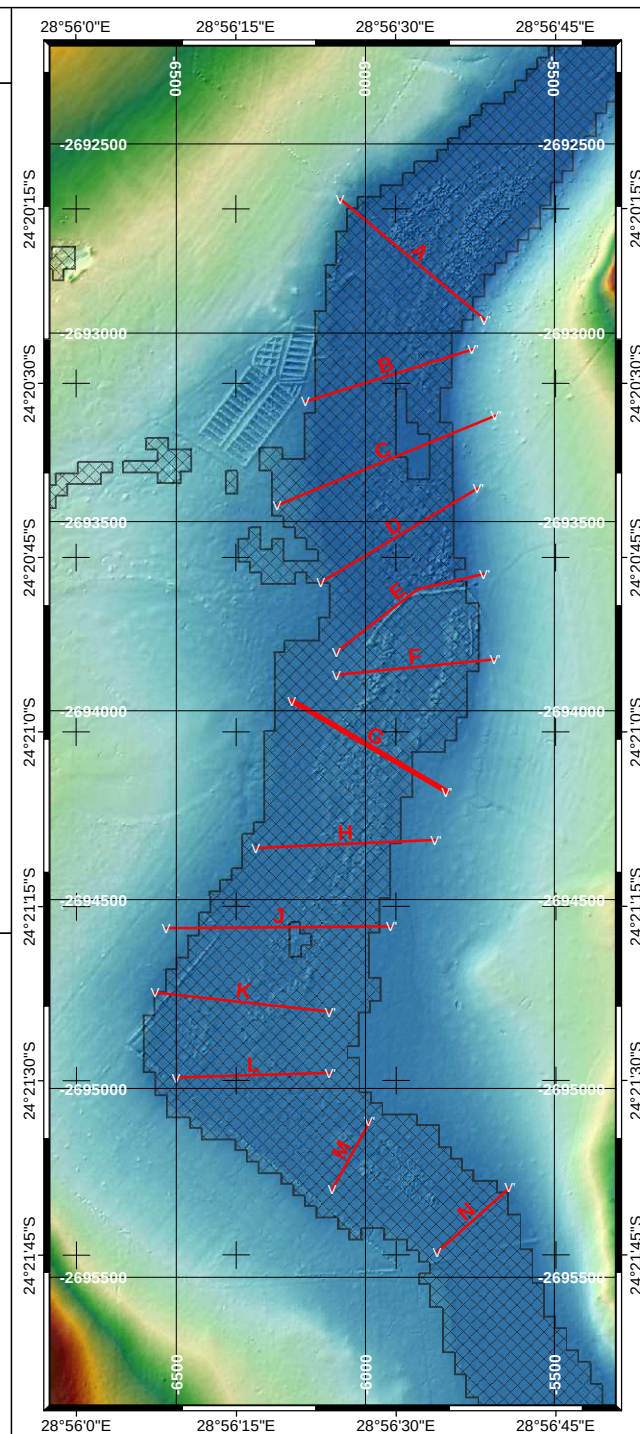
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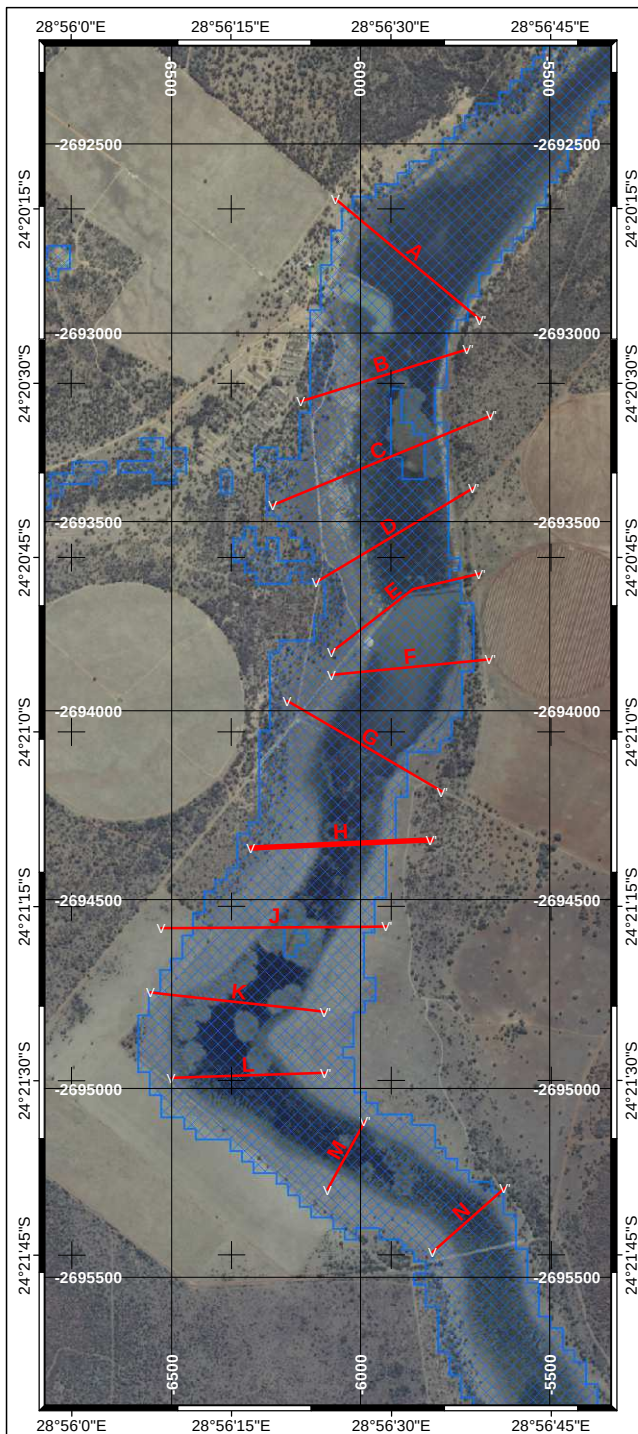


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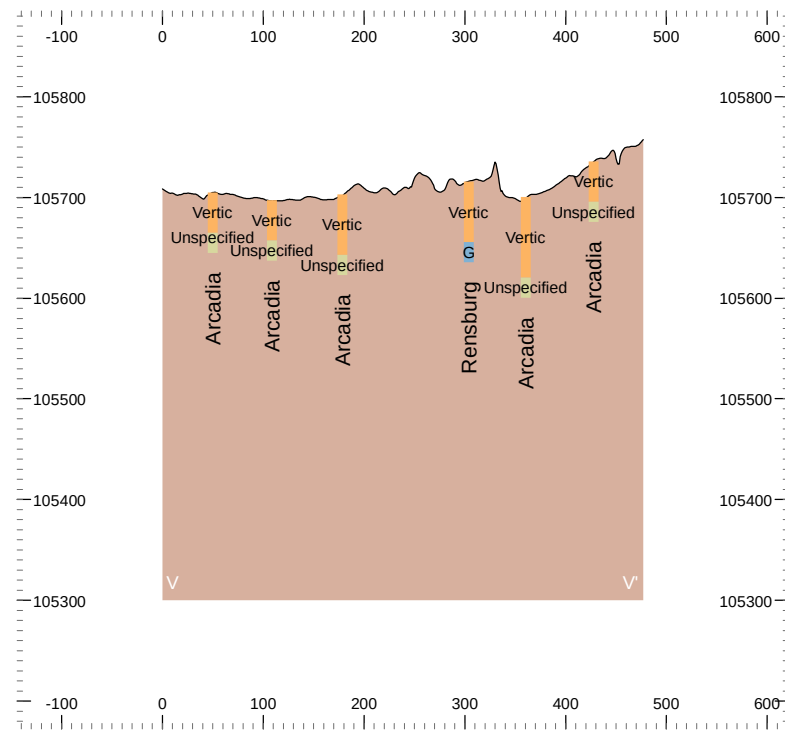
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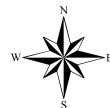
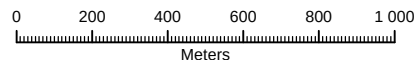


Cross Section H



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

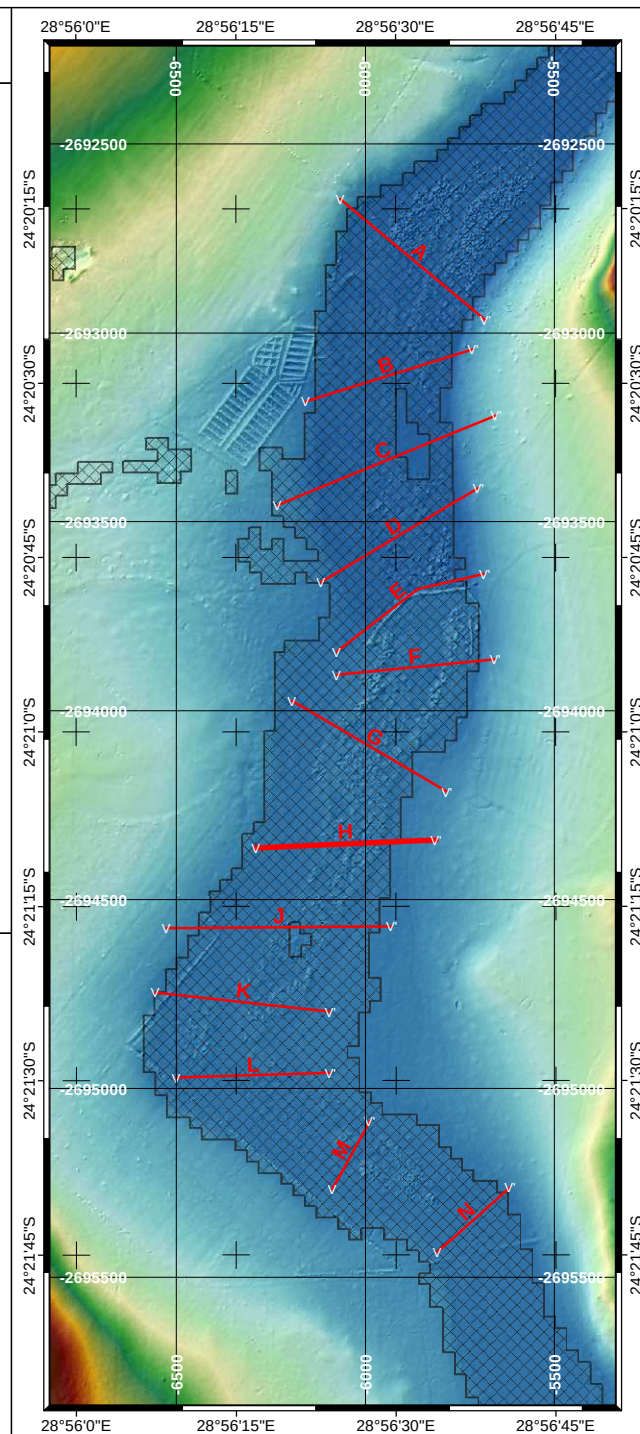
VOLSPRUIT SECTION Soil Survey & 1 Feb 2008 Flood Overlay

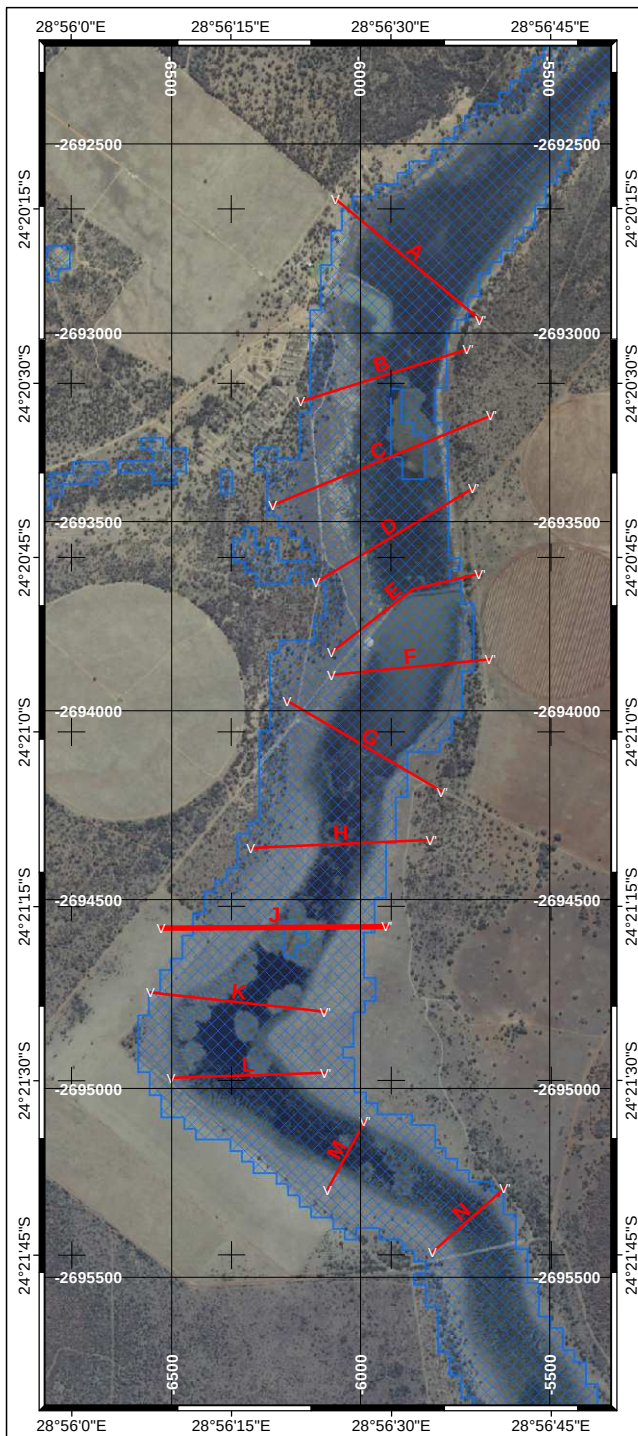


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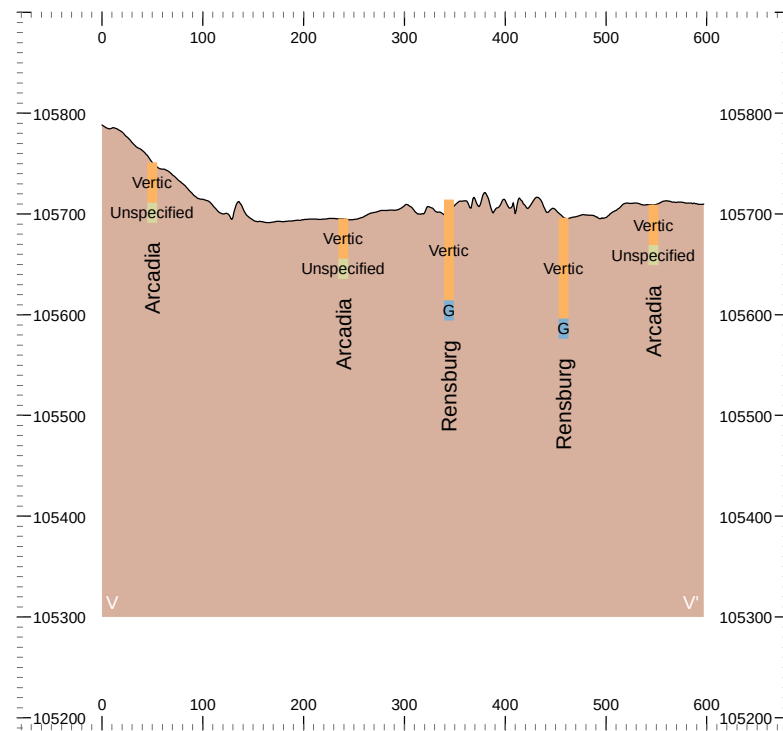
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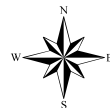
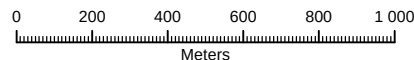
Cross Section J



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

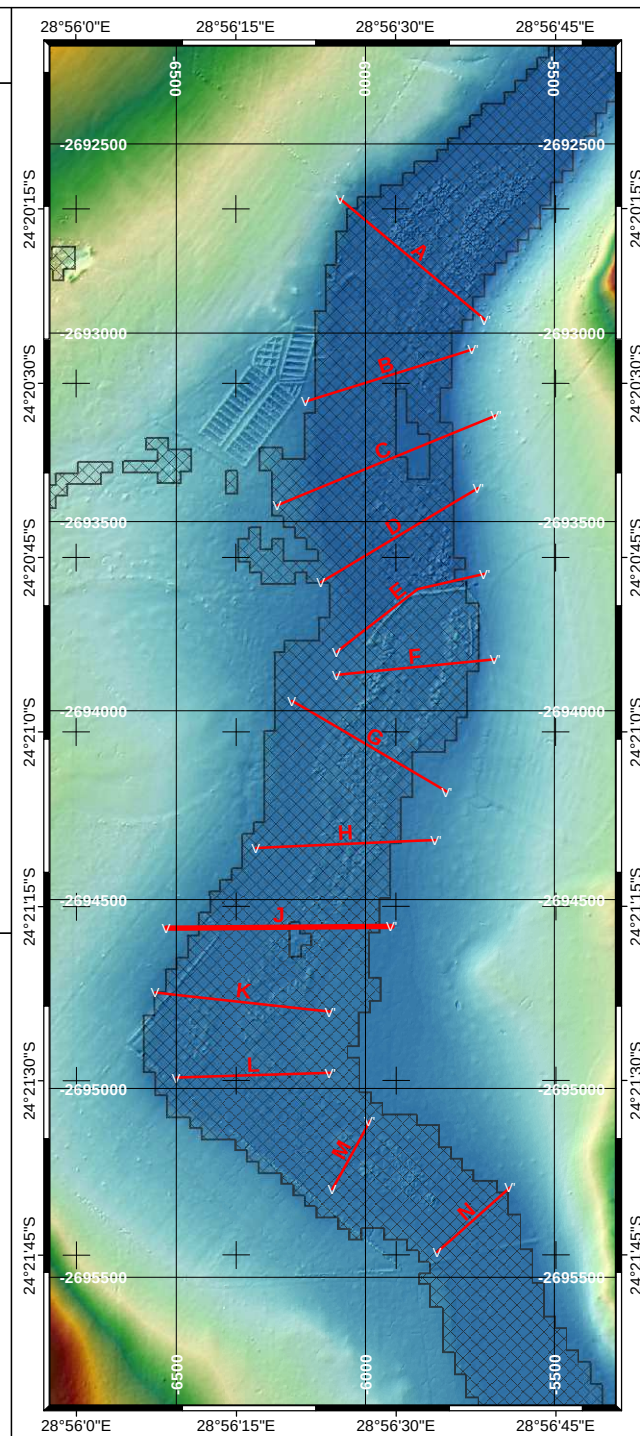
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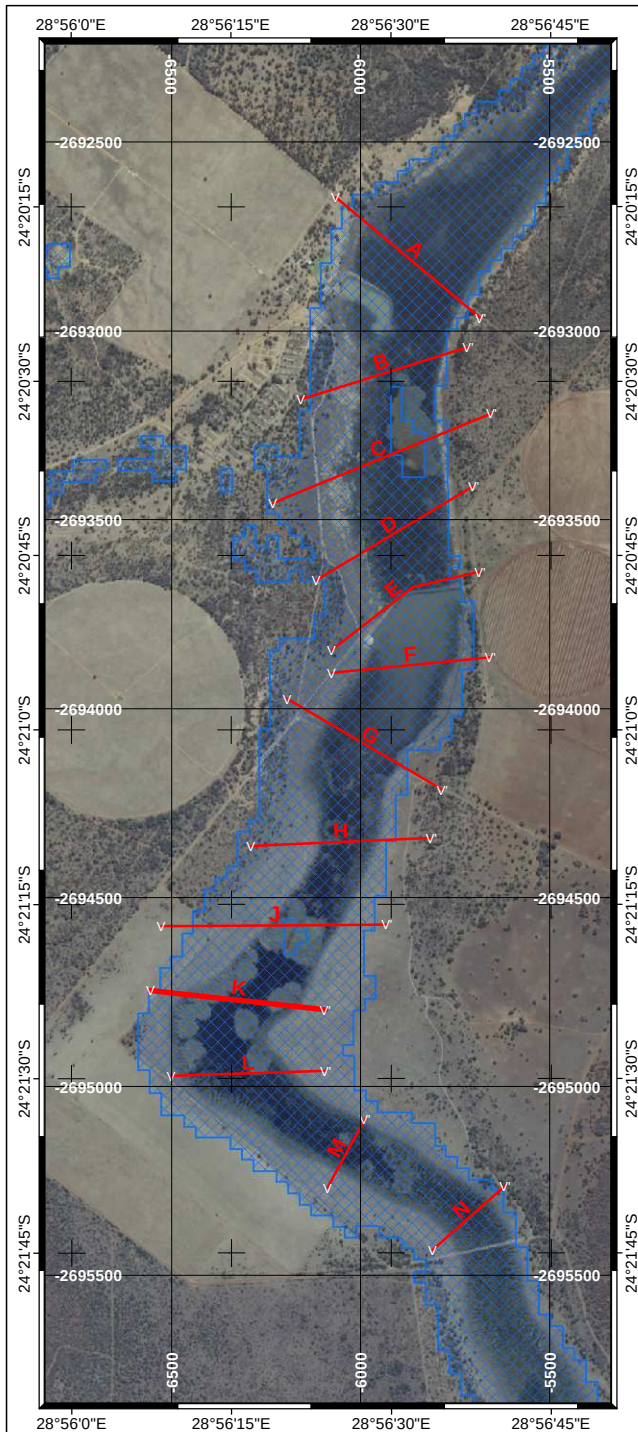


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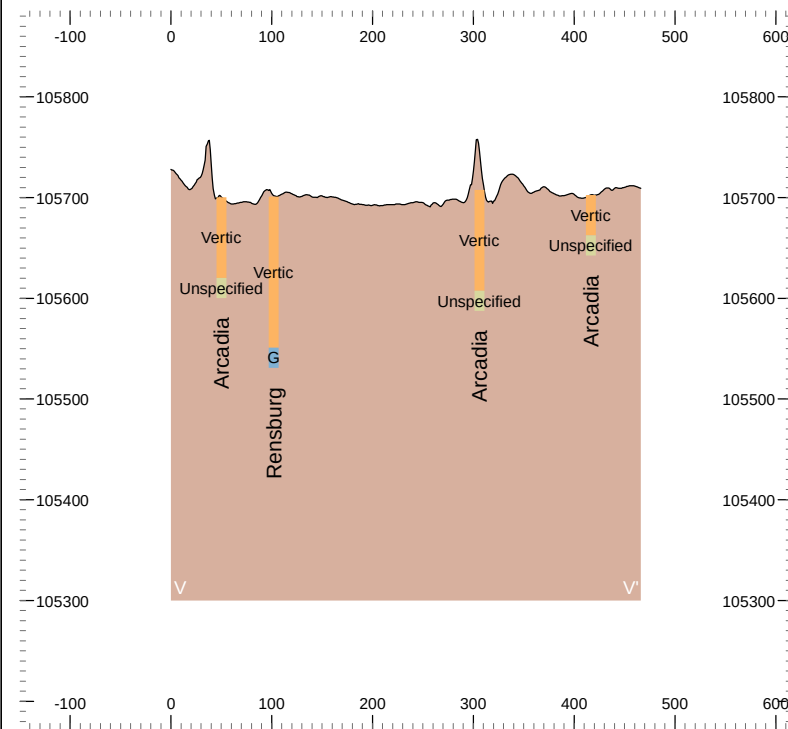
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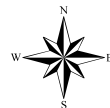
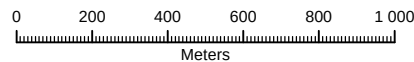


Cross Section K



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

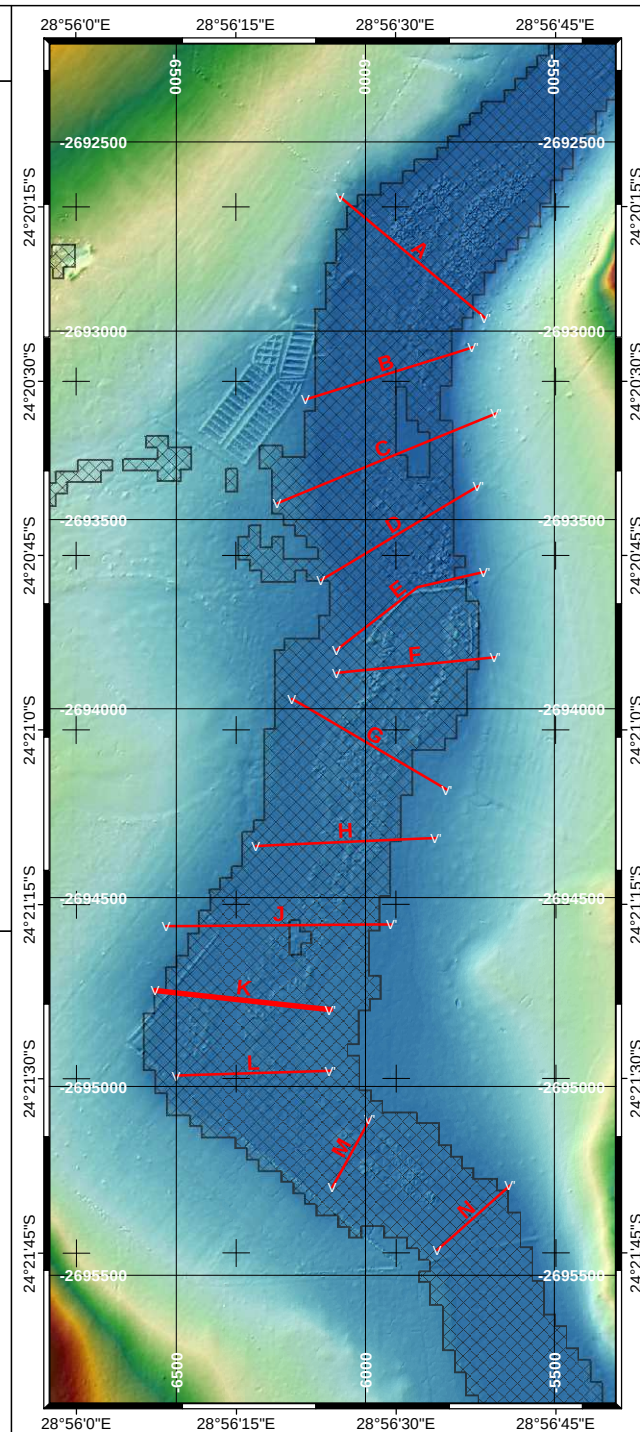
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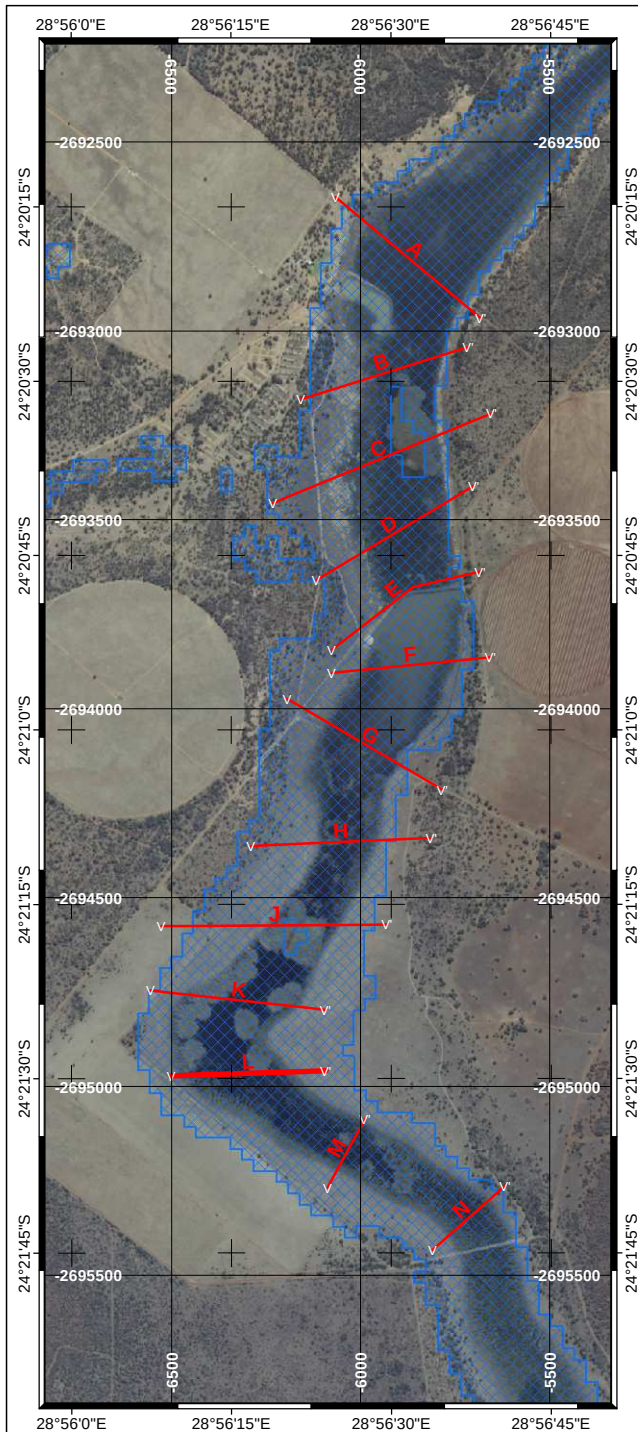


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 Central Meridian - 29

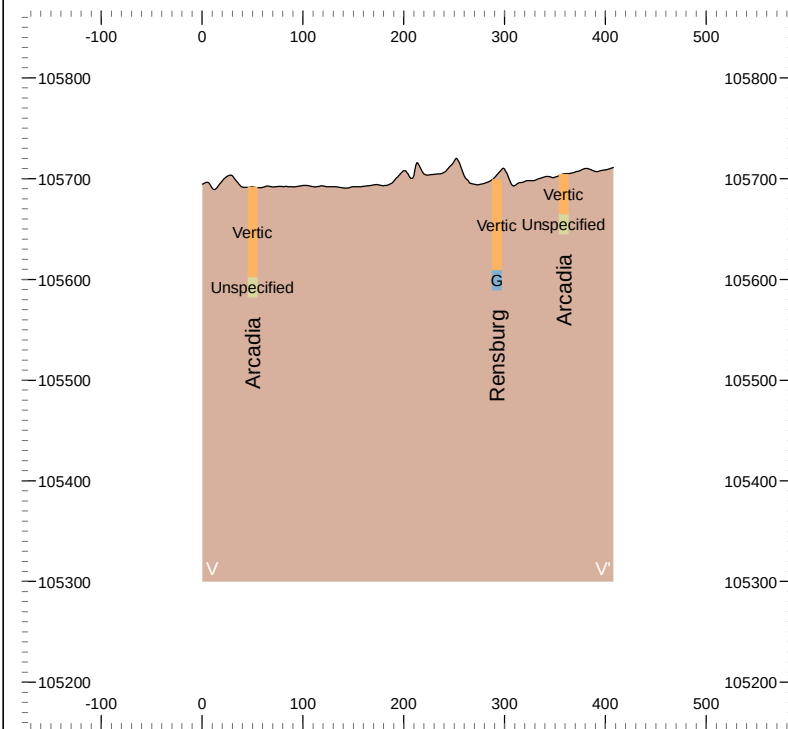
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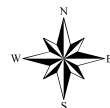
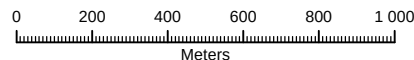
Cross Section L



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

VOLSPRUIT SECTION

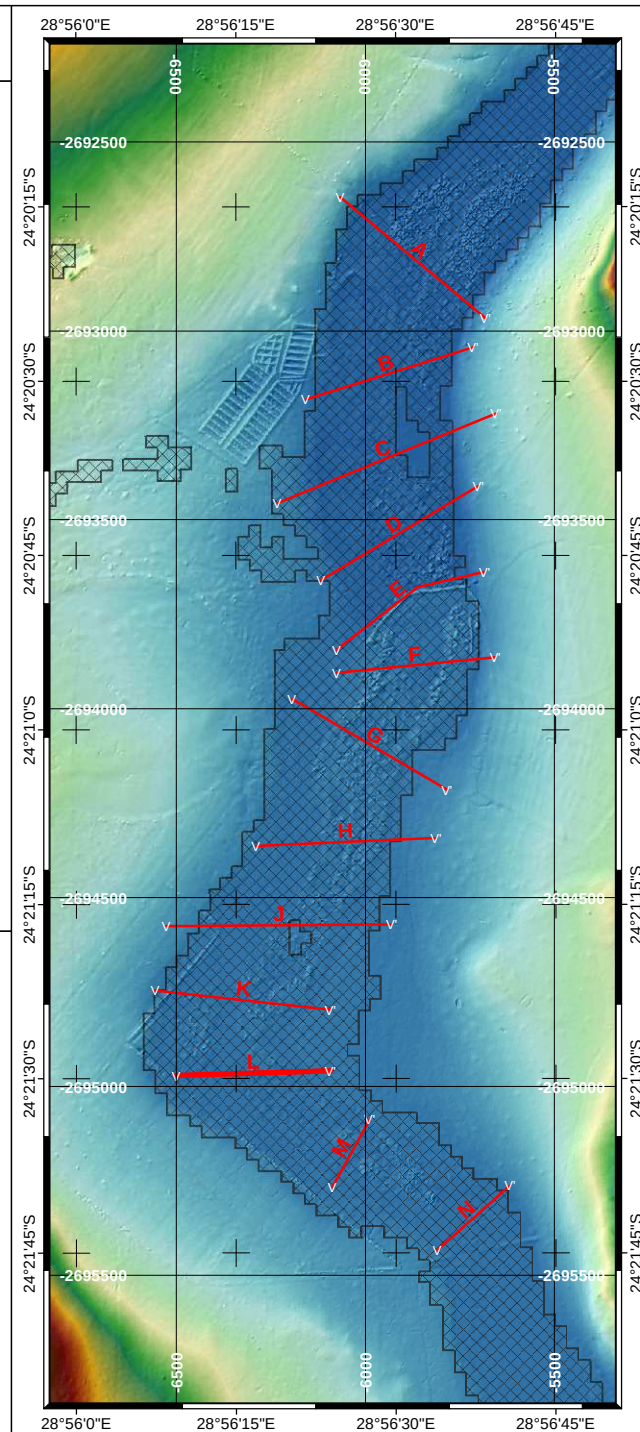
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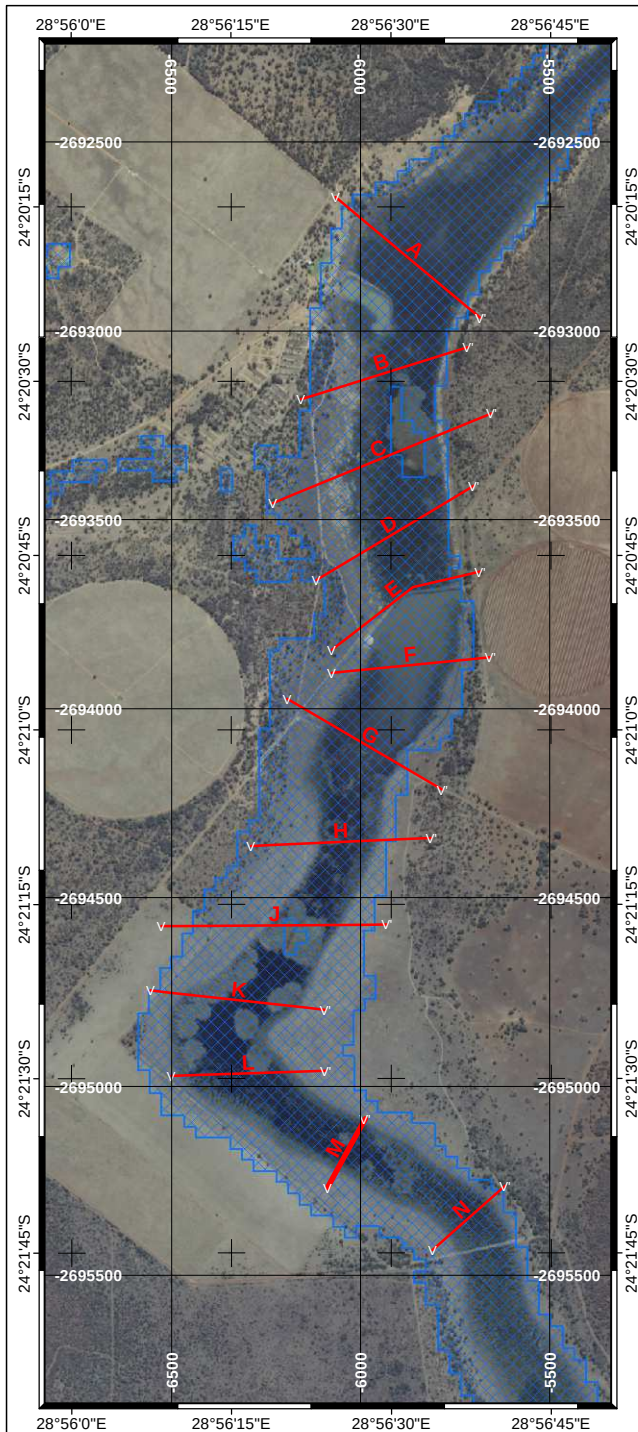


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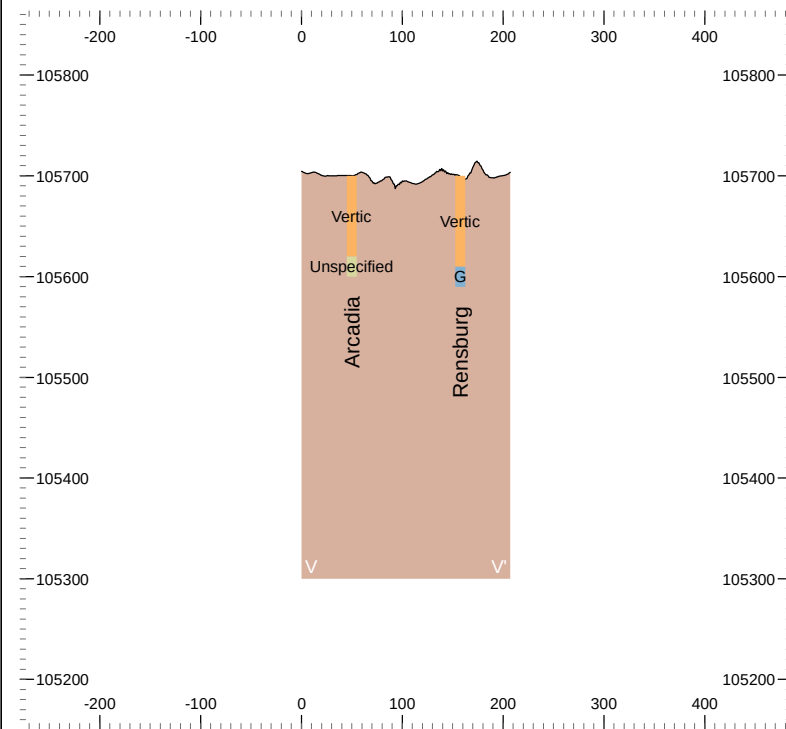
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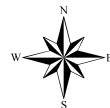
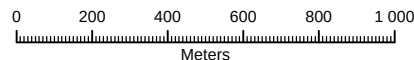


Cross Section M



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

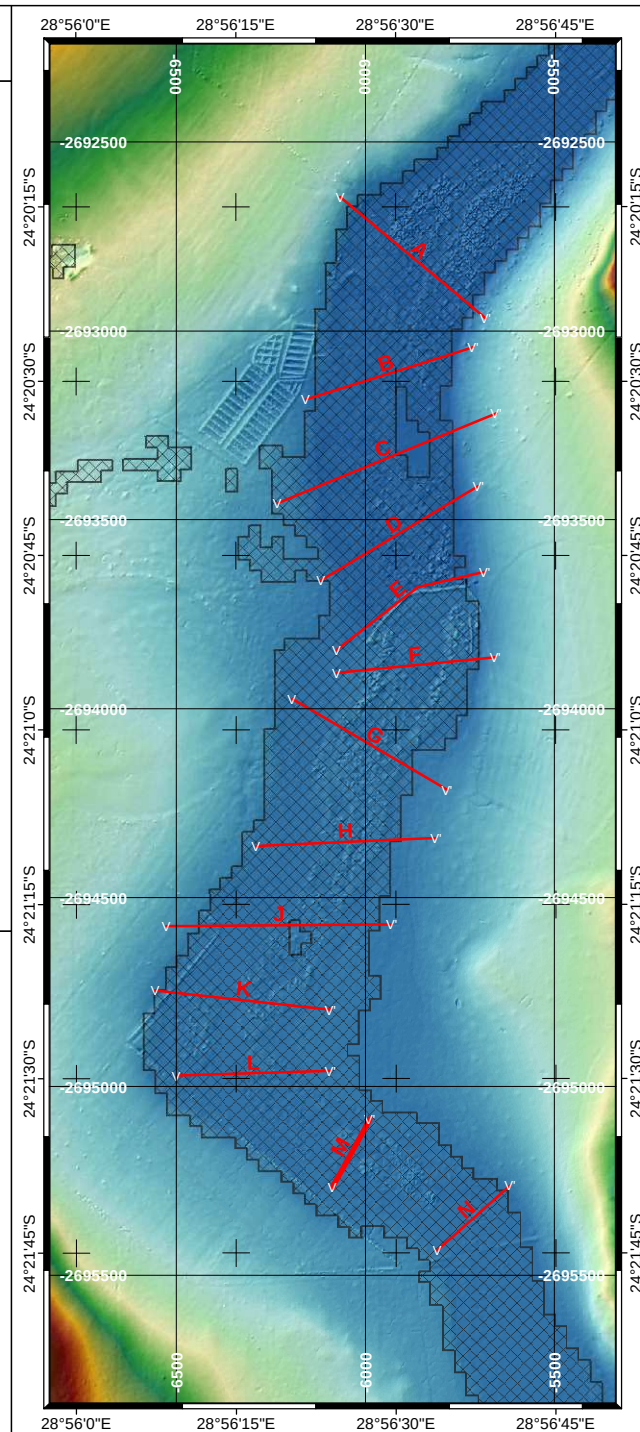
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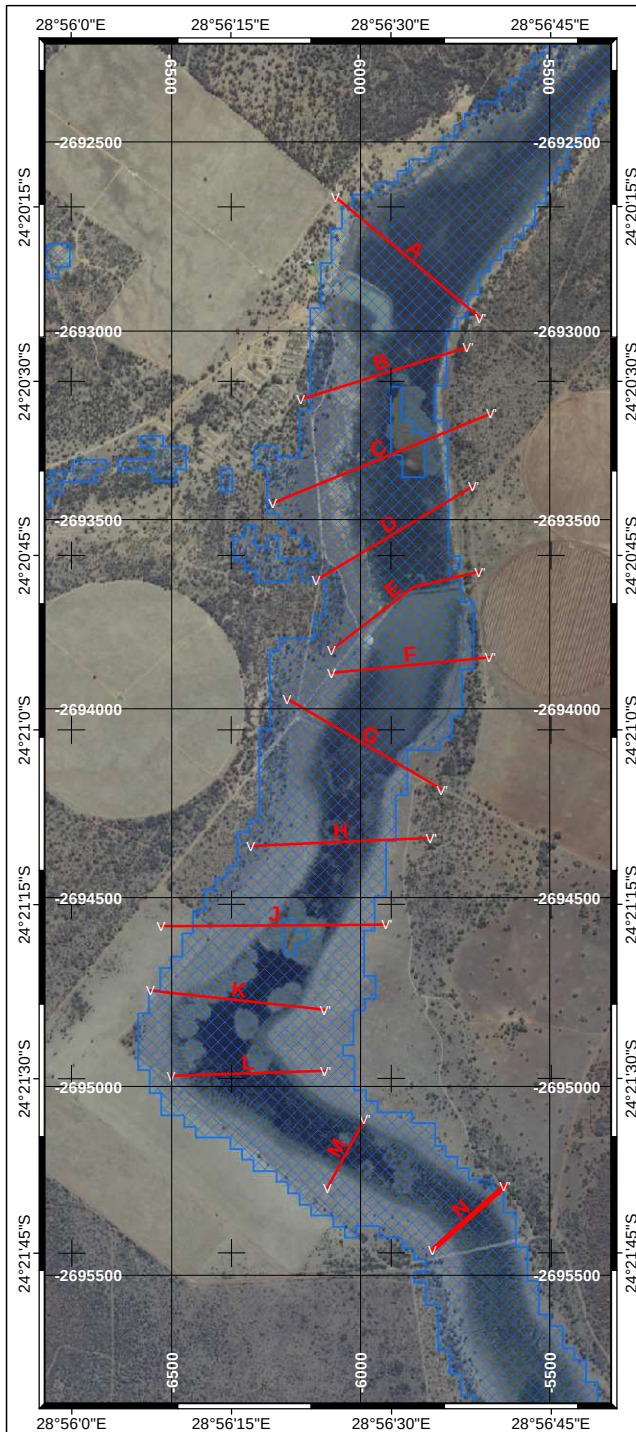


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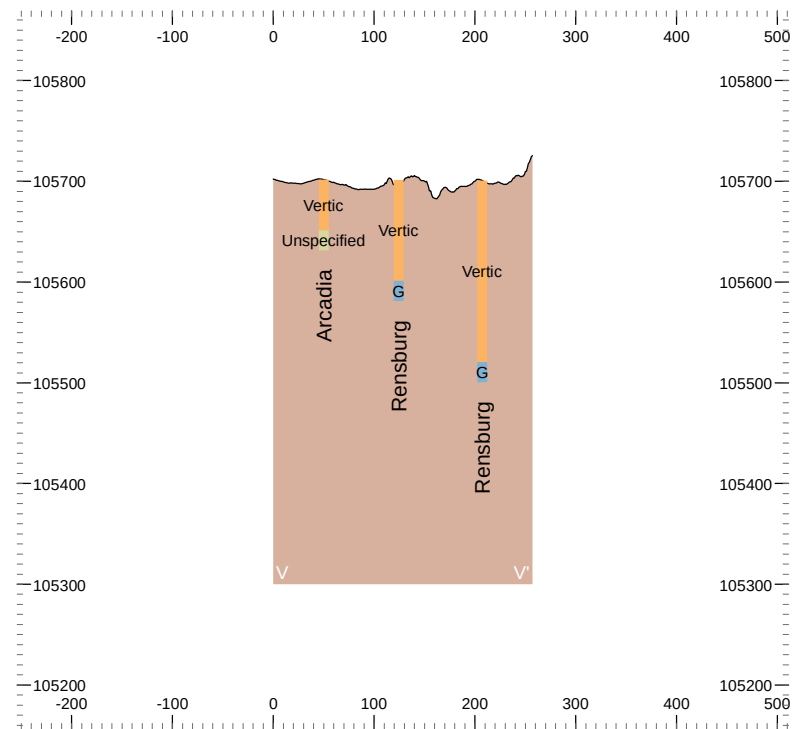
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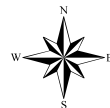
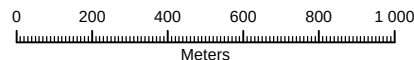


Cross Section N



Profile Scale - 1 : 7 500
 Vertical exaggeration - 100x X(m) from start / Y(cm) above MSL
 Note: Elevation model is not true ground height. Vegetation was included during photogrametrical elevation extraction by mine contractor.

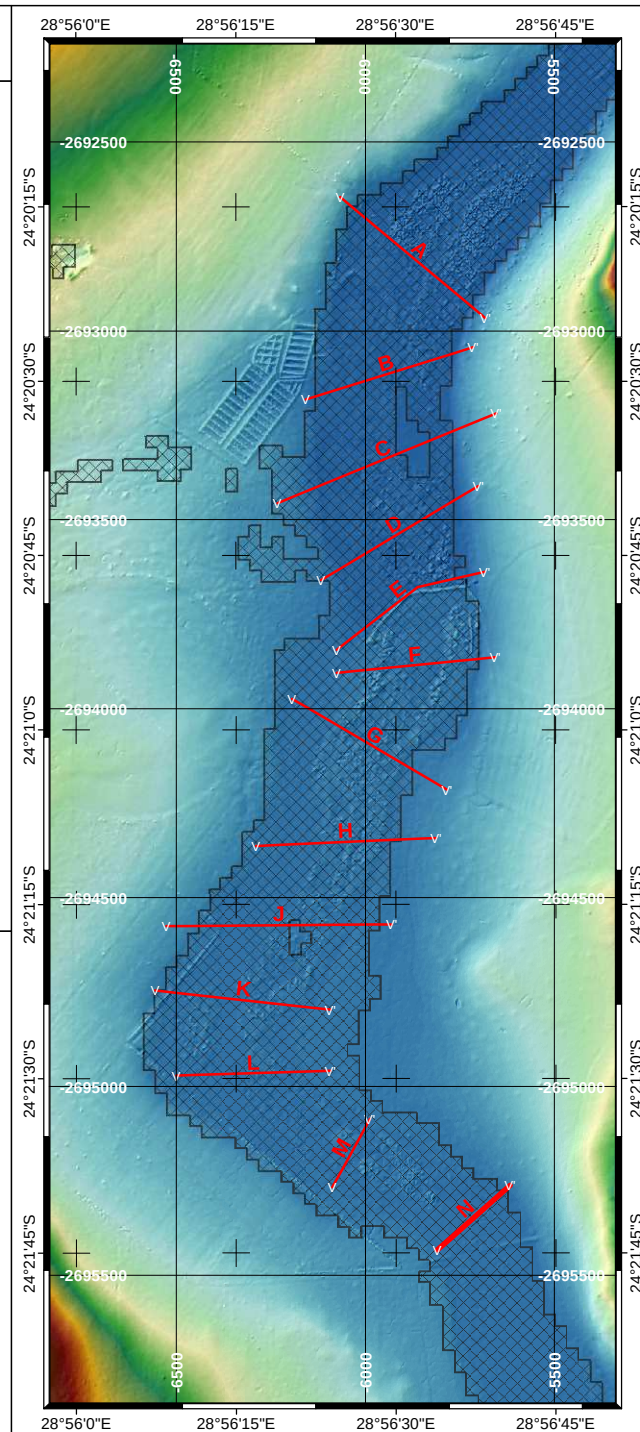
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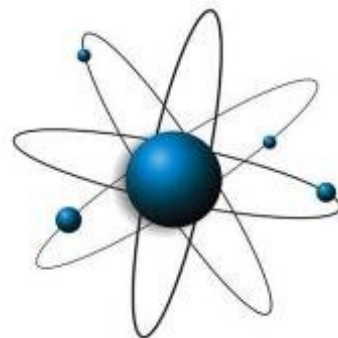


Maps Scale - 1 : 20 000
 Projection - Transverse Mercator
 Datum - Hartbeeshoek 1994
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REPORT ON SOILS OF THE NYL RIVER CATCHMENT: LITERATURE REVIEW

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SOILS OF THE NYL RIVER CATCHMENT: LITERATURE REVIEW

PROPOSED ESTABLISHMENT OF AN OPEN CAST PGM MINING OPERATION

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1. INTRODUCTION AND PURPOSE

Sylvania Resources proposes to establish a Platinum Group Metals (PGM's) mine near Mokopane in the Limpopo Province. The mine will consist of two open cast operations. The site is a Greenfields site currently under agricultural use. This literature review compiled by EScience Associates (ESA) consists of literature pertaining to the characteristics of the soils in the Nyl river catchment. The purpose this document will serve is to inform interested and affected parties of the current literature pertaining to soils with the Nyl river catchment. This document will further go to supply information for the creation of hydrological models that will help inform the greater Environmental Impact Assessment.

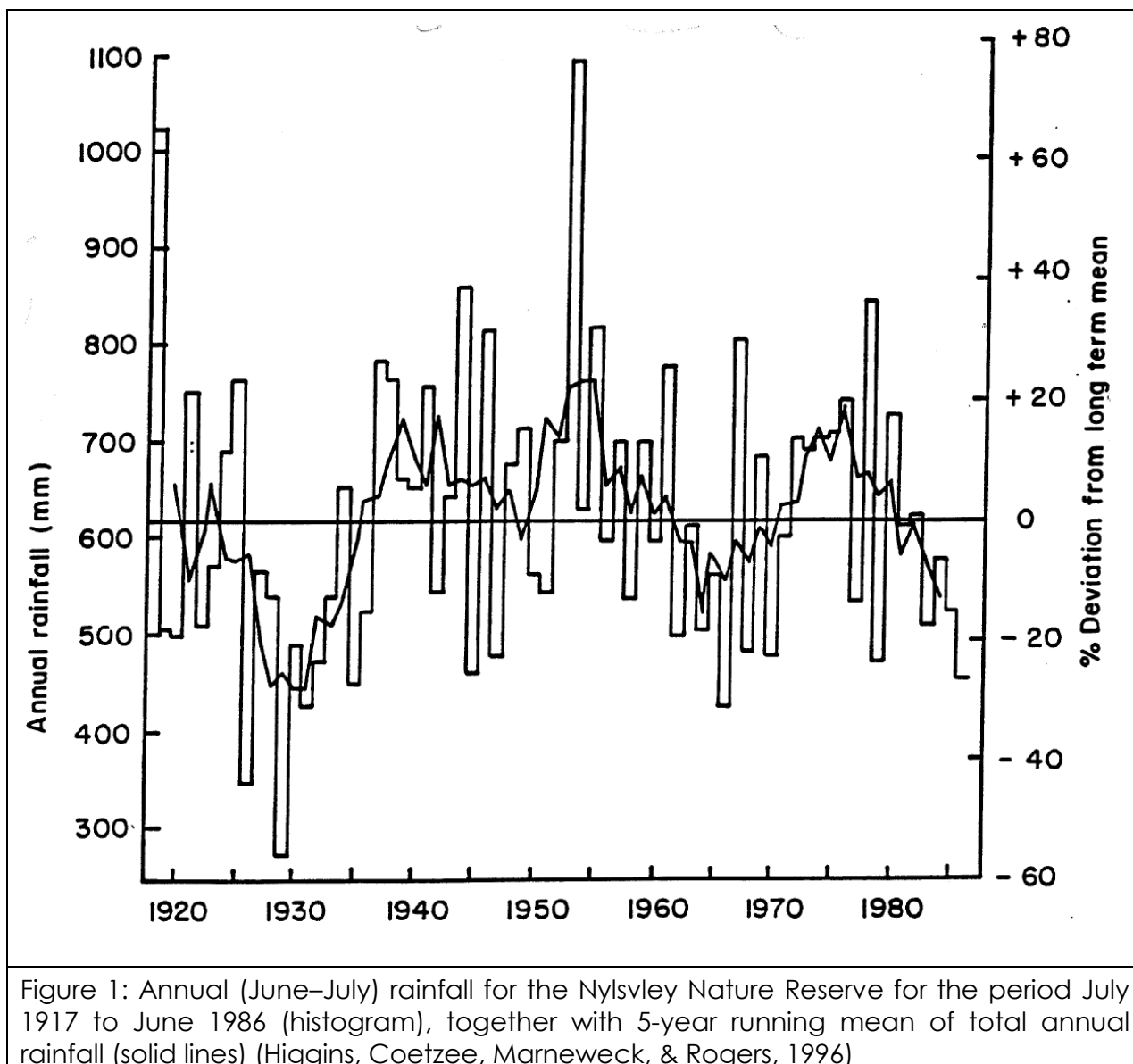
2. PHYSICAL CHARACTERISTICS OF THE NYL RIVER CATCHMENT

In order to understand the way soils currently influence the hydrological dynamics of the Nyl River, it is important to first understand the different forces that lead to their formation. The climate, biology, geology and geomorphology of the catchment have collectively played a role in the formation of the catchments current stratigraphic profile. It is important to note that these components do not act independently and are intrinsically connected as part of the greater system. This chapter will briefly discuss the literature pertaining to each of these components.

2.1 CLIMATE

The climate of the area is characterised by cool dry winters and warm wet summers. About 60% of summer rainfall events are attributed to localized intense thunderstorms spanning only a few kilometres in diameter while the other 40% of rainfall events are gentle downpours spanning various durations. The mean annual rainfall within the catchment is 623mm with a mean temperature of 19° C (Higgins, Coetzee, Marneweck, & Rogers, 1996).

As is evident in Figure 1 below, there is a high variation from the rainfall averages year on year, this, along with the fact that evaporation in the catchment nearly always exceeds rainfall, leads to periodic flooding events preceded by long periods of low or no flow. This therefore makes the Nyl an ephemeral river.



2.2 BIOLOGY

Surrounding the floodplain is broad-leafed savanna which is generally described as nutrient poor. The floodplain therefore attracts wildlife from these surrounding areas due to its richness in nutrients. The floodplain provides habitat for a large number (over 100 species) of waterfowl. Over 50% of them breed on the floodplain and at least 23 species are on the South African Red Data List. The floodplains seasonally inundated grasslands provide ideal habitat for large antelope and has viable populations of the endangered Roan (*Hippotragus equinox*) and rare Tsessebe (*Damaliscus lunatus*). (Higgins, Coetzee, Marneweck, & Rogers, 1996). The Nyl is also home to many fish, amphibian and plant species. (Vlock, Cook, Greenfield, Hoare, Victor, & Van Vuren, 2006)

2.3 GEOLOGY

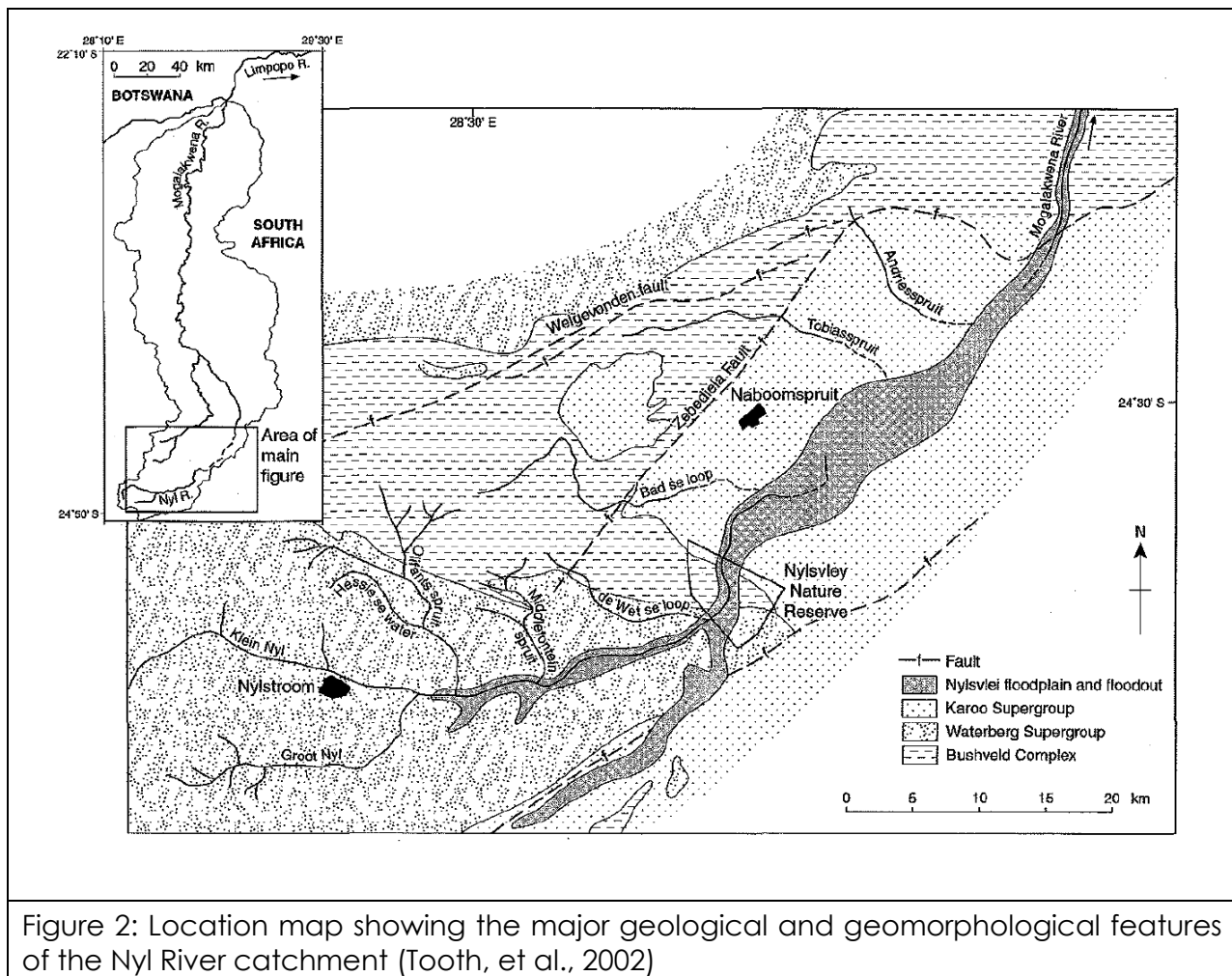
The geological profile of the catchment mainly consists of sandstones with some clays (Blight, 2004). The sandstones of the Waterberg group are generally found in the upper reaches of the floodplain and are highly permeable and therefore have high infiltration rates (Higgins, Coetzee, Marneweck, & Rogers, 1996). The Waterberg group however

also consists of some greywacke, mudstones and siltstones (Robery, Thompson, Nomnganga, & Moyo, 2011). The middle reaches of the floodplain consist of felsites of the Rooiberg group and are relatively impermeable but, due to the presence of joints and fractures, do allow for water infiltration and storage. Basalts of the Karoo sequence form the lower reaches and are also areas where ground water is stored and transmitted. About 15m of alluvium overlay most of the Nyl River valley, this alluvium is mainly constituted of Waterberg sandstone (Higgins, Coetzee, Marneweck, & Rogers, 1996).

Reasons for this deep sedimentation are disputed, the original hypothesis was that the Zebidelia fault runs through the Nyl river valley and the that the movement associated with this fault has created a basin which has been filled by sediment from the Nyl river (Tooth, et al., 2002). This hypothesis has however recently been disputed by (McCarthy, et al., 2011). McCarthy et al 2011 proposes that instead of tectonic forces, the deep sedimentation of the Nyl has been due the obstruction of the lower reaches by coarse-grained sediment being delivered by steep tributaries. This in turn has caused back ponding and therefore gradient reduction in the higher reaches. Whatever the reason for the deep sedimentation, it has created a situation where the river flows up to 35m above the bedrock which creates an unusual hydrological situation (McCarthy, et al., 2011).

2.4 GEOMORHOLOGY

The main feature of the catchment is an extensive floodplain that is unusually flat in its topographic nature. The Waterberg mountain range borders the floodplain to the north-west and the Springbok Flats border the floodplain to the south-east (Blight, 2004). Below is Figure 2, a map showing the major geological and geomorphological features of the catchment.



2.5 SOIL TYPE AND CHEMISTRY

“On Nylsvelei Nature Reserve alone, 17 soil forms (classified according to the South African National Soil Classification System, Macvicar *et al.*, 1977; Haskins and Kruger, 2014) and, within them, 34 soil series have been identified and mapped (Harmse, 1977; Haskins and Kruger, 2014). On a broader scale Scholes and Walker (1993) divided the soils into 9 major soil groups as follows (Haskins and Kruger, 2014):

- shallow soils derived from felsite
- deeper soils derived from felsite
- alluvium
- sodium-affected duplex soils
- vertisols derived from basalt
- shallow sandy soils derived from sandstone
- deeper sandy soils derived from sandstone
- deep sandy soils enriched with nutrients
- sandy soils with alluvial horizon

At an even broader level three mapping units occur (Haskins and Kruger, 2014):

- Black and red montmorillonitic clays - red clays contain less calcium carbonate, lower phosphorus and have higher percentages of iron and aluminium oxides than black clays. Black clays are confined to the shallow, poorly drained depressions of the floodplain. (Gary Marneweck, Wetlands consultant, Strategic Environmental Focus, Pretoria)
- Lithosols of the scattered sandstone outcrops (Maroelakop and Stemmerskop)
- Savanna soils of red, yellow and grey ferrisallitic sands (upland situation) and loams of the bottomlands. “

3. HYDROLOGY AND HYDRAULICS

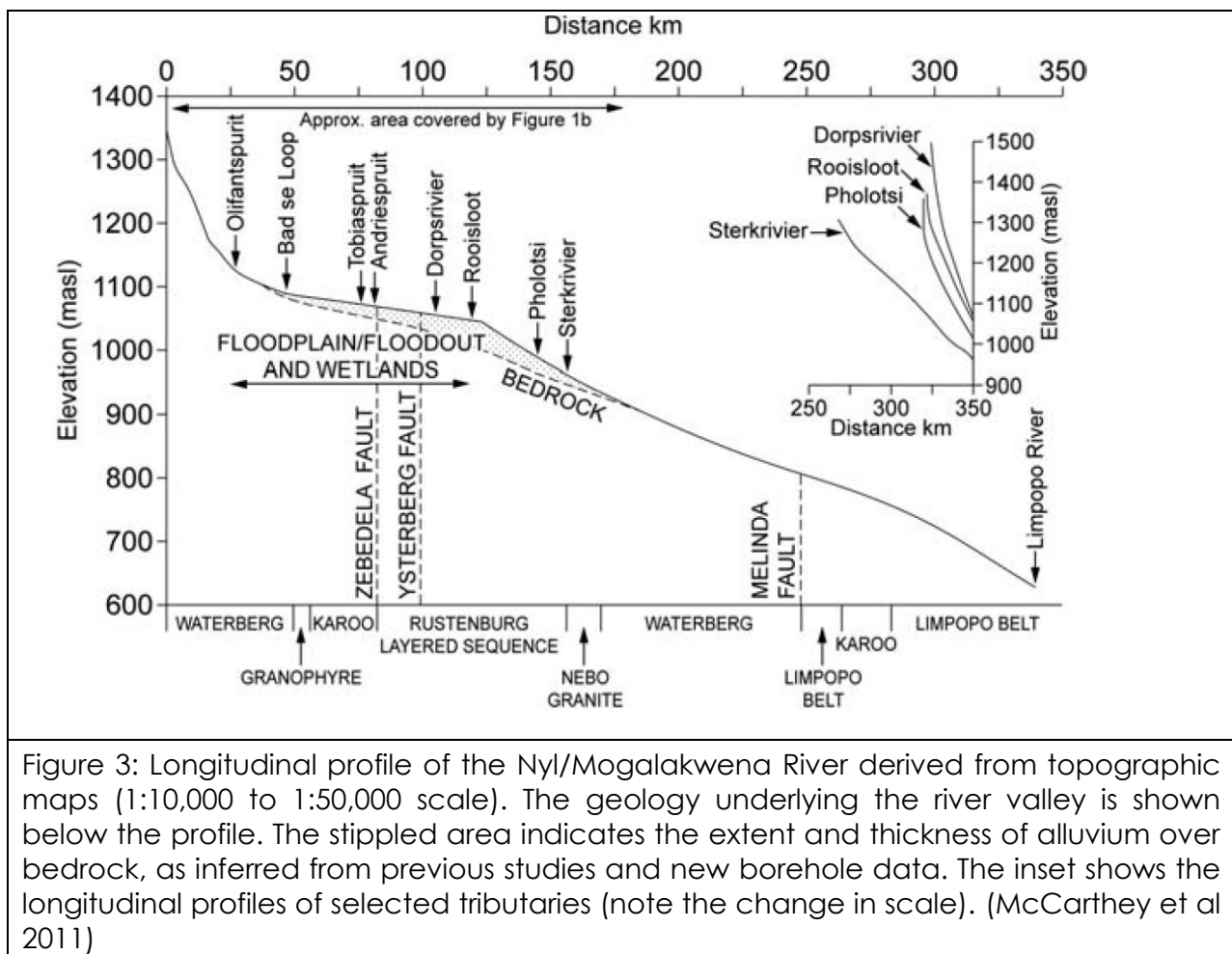
3.1.1 PRIOR MPRDA APPLICATION REF NO LP30/5/1/2/2/10016MR

The upper reaches of the Nyl River, around Nylstroom (Figure 2), are associated with moderate to low gradient tributaries which generally disappear before they actually meet with the main river channel. These tributaries mostly deposit fine grained sediment on the margins of the wetland (Tooth, et al., 2002). The upper to middle reaches of the Nyl are characterised by extremely low gradient and deep sediment. This is where the floodplain lies and this region is also characterised by ponding, back flooding, and shallow lakes.

Further down this section, seen in Figure 2 just east of Naboomspruit (now Mokopane), the channel disappears completely and the water either moves through the substrate or as sheetflow overland but only during a flood. Along this section several tributaries join the Nyl, these, as with the tributaries in the upper reaches, also disappear and deposit material onto the edge of the floodplain. When the channel reappears it is then referred to as the Mogalakwena river . This is where steep tributaries join the channel and deposit coarse grained material that has, as McCarthy et al 2011 suggested, led to the blocking of the channel and therefore the formation of the sediment that Nyl river floodplain. Past this point the gradient begins to steepen and eventually the river flows on or close to the bedrock, this is clear in the longitudinal profile, Figure 3, below (McCarthy, et al., 2011).

3.1.2 SOILS OF THE FLOODPLAIN

Specific stratigraphic profiles of the entire floodplain are lacking, however (Tooth, et al., 2002), (McCarthy, et al., 2011) and (Blight, 2004) have conducted various studies of sections of the floodplain at various depths. (Tooth, et al., 2002) and (McCarthy, et al., 2011) agree that the sediment typically consists of gravelly sand above the bedrock then slowly degrades to less coarse sand and finally to fine sand, silt and clay towards the surface. This is however a huge generalisation as the stratigraphic profile non homogeneous throughout the catchment as is evident in Figure 4 . One section that is however homogeneous is a deep layer of clay directly under the floodplain wetland, evident in Figure 4 below . This layer has a very low hydraulic conductivity and is therefore where the water ponds and form shallow lakes.



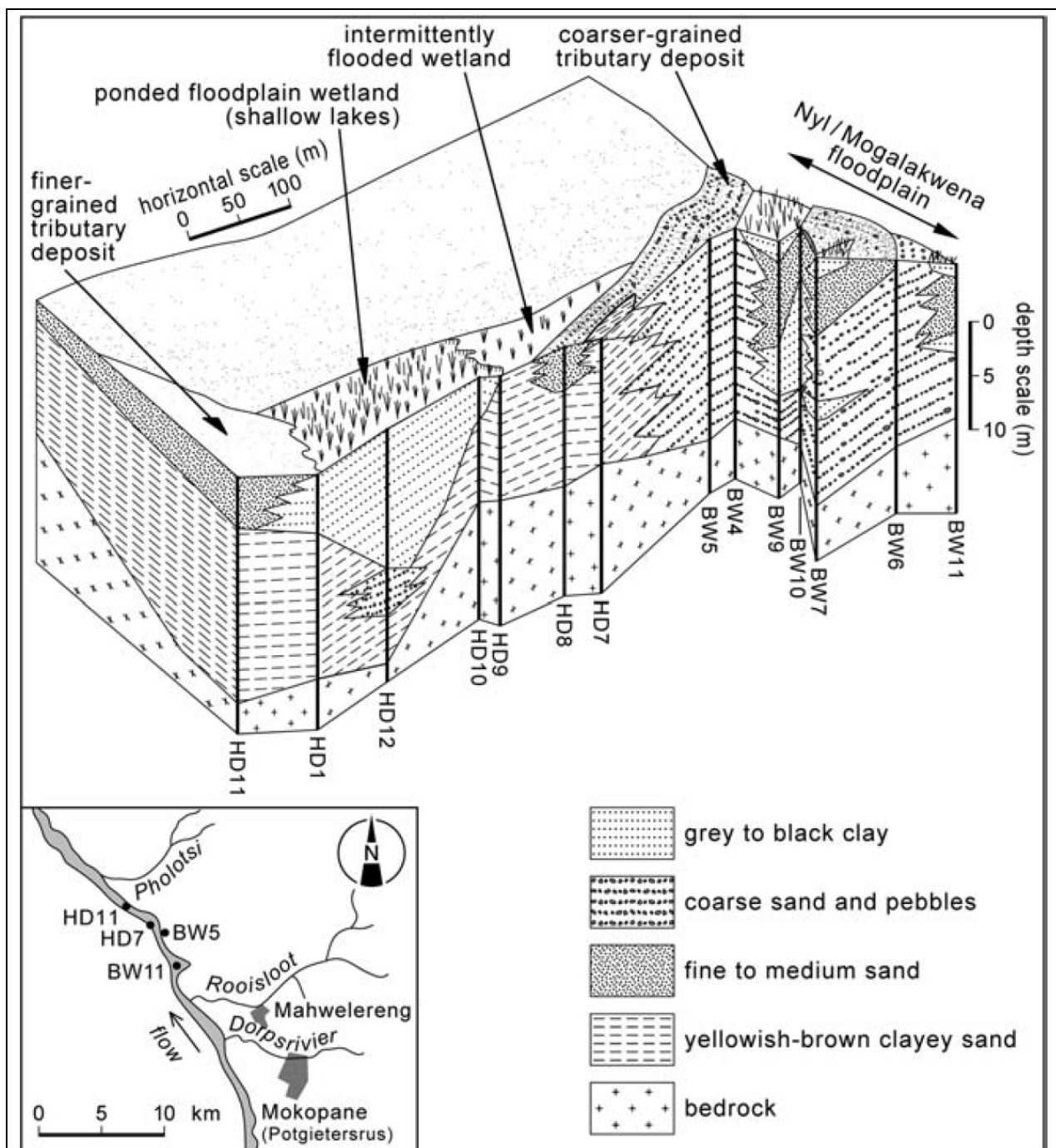


Figure 4: Fence diagram illustrating the stratigraphy of the alluvial fill in the Nyl/Mogalakwena valley between the Pholotsi and Rooisloot confluences. The inset shows the location of selected boreholes and the major tributaries. (McCarthy et al 2011)

The Nyls River floodplain can be seen outlined in Figure 5 below shows typical soil profiles of the Nyls floodplain. Please note that distance 0 is the edge of the floodplain and distance 100 is in the channel. It is evident from Figure 5 that the closer one gets to the channel, the deeper the clay layer. This agrees with the findings of (McCarthy, et al., 2011).

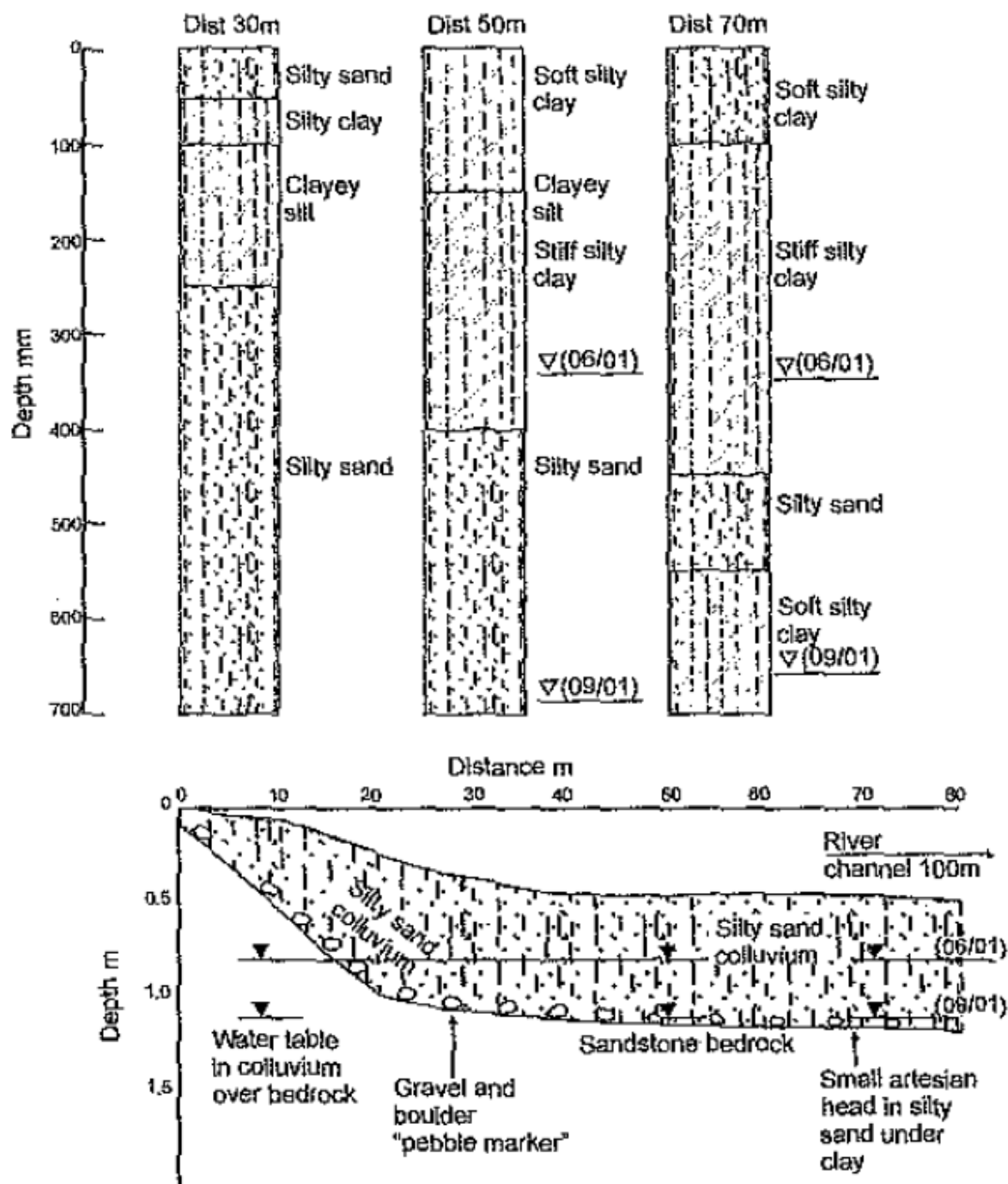


Figure 5: Transverse profile of test site at Nylsvley with three typical soil profiles. (Blight, 2004)

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