HYDROLOGY ANALYSIS: PROPOSED PHOTO VOLTAIC DEVELOPMENT: MATJESSPRUIT 145: LEEUDORINGSTAD

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1. INTRODUCTION

CWT Consulting was appointed by ***SunEdison Energy Southern Africa Proprietary Limited*** to perform a surface flow hydrologic study at the proposed site of the photo voltaic development on a Portion of the farm Matjesspruit 145 HP near Leeudoringstad in the southern North-West Province.

The 1:2, 1:10, 1:20, 1:50 & 1:100 year flood peaks and flood volumes were determined.

The following should be noted:

1. The DWA Rivers Database was used and maps and Geographical Information Systems (GIS) were employed to ascertain which portions of the proposed development would have the greatest impact on the drainage areas and vice versa.
2. A map demarcating the local drainage area of the respective watercourses was included in the report, its respective catchment and other areas within a 500m radius of the study area. This demonstrates, from a holistic point of view the connectivity between the site and the surrounding regions, i.e. the hydrological zone of influence.
3. A map depicting demarcated water bodies together with a classification of delineated water bodies and their functionality has shown that there are no such water bodies near the study area.

The Vaal River is 2 600 m away and will not be influenced by this development because no dirty run-off or silt laden water will originate from the development.

4. An assessment of the potential impacts, based on a supplied methodology was done. The impacts will as described in the report although the scouring may take place with or with-out the proposed development.

5 An assessment to provide mitigations regarding project related impacts, including engineering services that could negatively affect demarcated water bodies was done. No mitigating measures are necessary. *It is also recommended that the vegetation cover should be increased with approved vegetation.*

6. The client will be supplied with geo-referenced GIS shape files of the riverine areas. All the AutoCad dwg and dxf files are attached.

2. LOCATION

The location of the area is shown below.

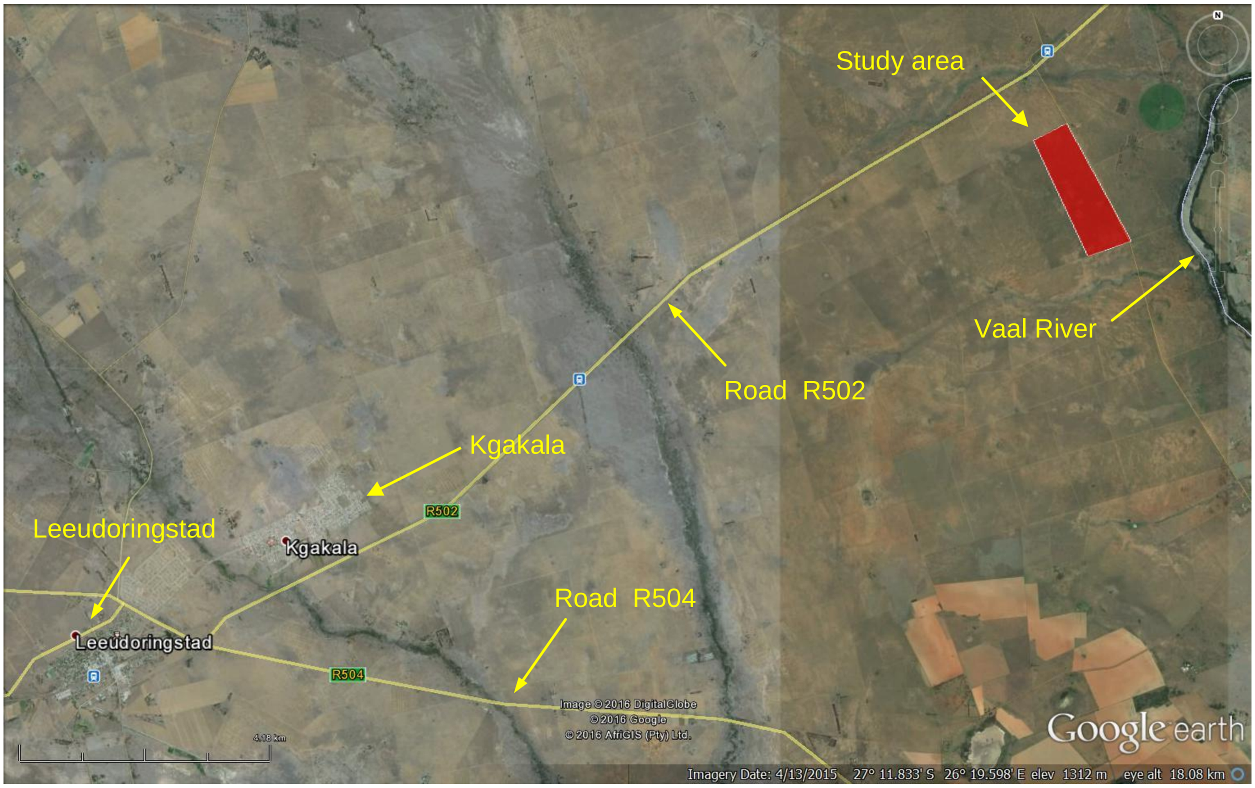

FIGURE 1

3. FLOOD LINE INTERFERENCE ON THE SITE

3.1 Analyse contour plan and surrounding area

The contours of the site and surrounding area are shown in Figure 2.

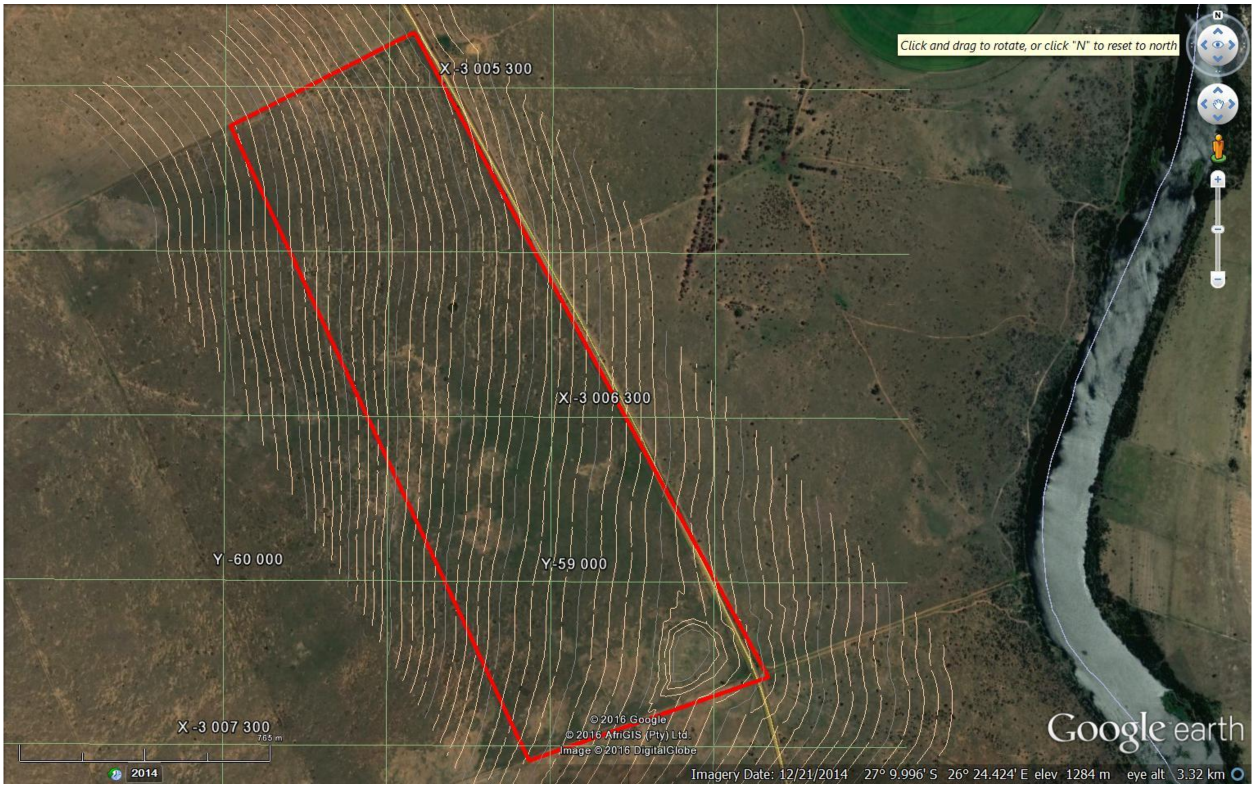

FIGURE 2

The contours slope from RL1291 m on the North-Western border to RL1272,5 m on the South-Eastern border.

No possible flood drainage channel exists as indicated on Figure 2.

However, an area exists in the south-eastern corner of the property where rainwater will accumulate after a rainstorm.

3.2 Determine whether flood line(s) will occur/not occur (see par 4.1)

Existing conditions will cause an accumulation of flood water in the South-Eastern corner of the property after a rainstorm.

A proposed pipe line as detailed on the plans in **Addendum B** will drain the flood water and distribute it in such a manner that erosion will be eliminated.

4. HYDROLOGY

4.1.1 Rainfall Data

Catchment MAP (ex HRU quaternary): Less than 600 mm

The rainfall data in the table below are derived from three sources. The modified recalibrated Hershfield equation is used for durations up to four hours.

The daily rainfall is from the Department of Water Affair's publication TR102 adjusted so that TR102 MAP = catchment MAP. Where the equation values exceed the 1-day rainfall, they are reduced to equal to the 1-day rainfall.

Weather Bureau station: **399241 @ LEEUKOP**

Mean annual precipitation (TR102): **520 mm**

Precipitations in ***mm*** associated with various storm durations are given in the Table1.

The time of concentration ($\mathbf{t_c}$) for this site is 1,73 hour.

The length of the design rainstorm is $4t_c$ = 6,92 hour

Return Period (yr)	Storm Duration	Precipitation	Average precipitation	Run-off Coefficient
2	6,92 hour	21 mm	12 mm/hour	57 %
5	6,92 hour	28 mm	16 mm/hour	58 %
10	6,92 hour	36 mm	21 mm/hour	59 %
20	6,92 hour	44 mm	25 mm/hour	60 %
50	6,92 hour	57 mm	33 mm/hour	62 %
100	6,92 hour	71 mm	41 mm/hour	62 %

Table 1

4.1.2 Evaporation Data

This site is within the **C24J Quaternary Catchment** and the mean annual s-pan evaporation is 1 800* mm. This information is available from the Water Research Commission (WRC) Report TT 382/08.

4.2 Catchment characteristics

The catchment area is shown in Figure 3.

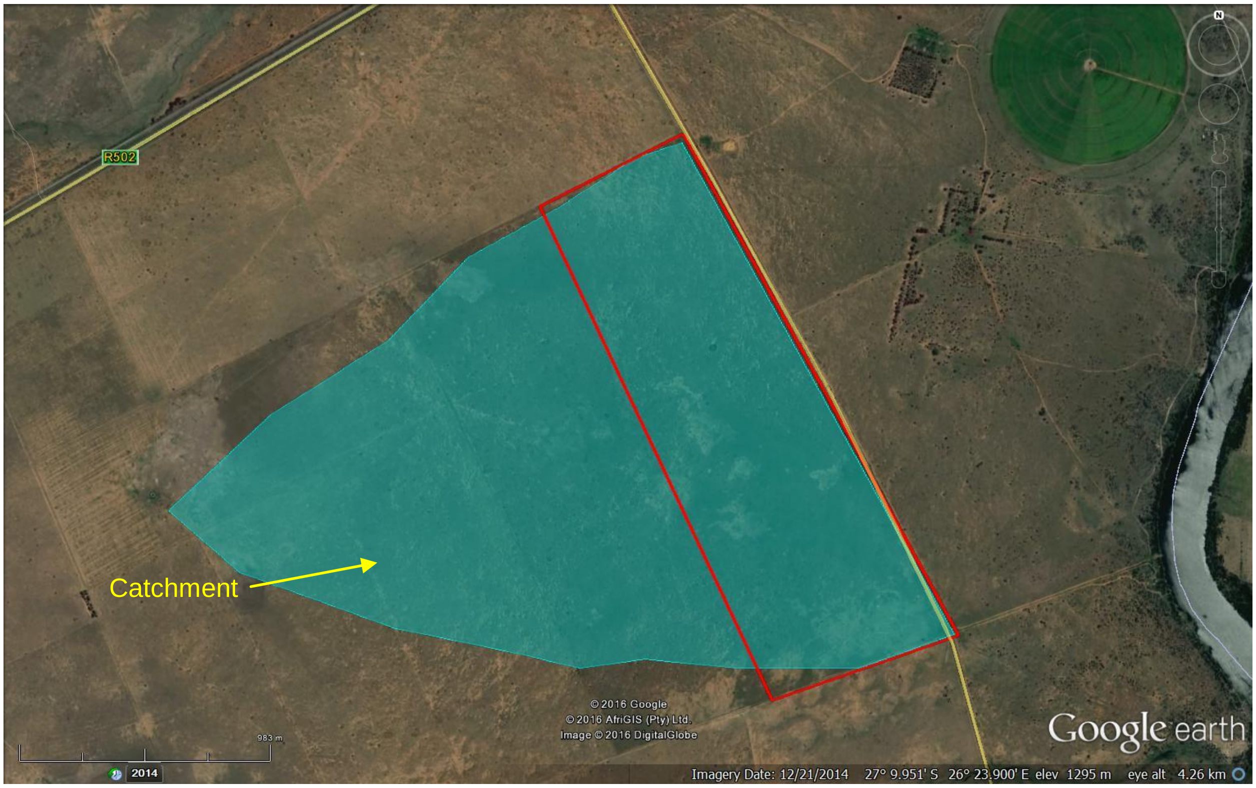

Figure 3

Characteristics

Area of catchment:	3,622	km²
Length of longest watercourse:	3,12	km
Flow of water	Overland Flow	
Equal area height difference:	30	m
Average slope	0,00962	m/m
Time of concentration	1,73	hour

4.3 Flood Peak Calculations

4.3.1 Time of concentration and volume of the hydrograph

The catchment area has no defined stream section and therefore ***sheet-flow or overland flow*** will be the flow pattern during a rainstorm. The time of concentration was determined with the Kerby formula.

Time of concentration: t_c = 1,73 hour

The volume of the hydrograph is 0,5 x 4t_c x Q_T m^3/s with

T = Return period, t_c in ***seconds.***

4.3.2 Methods used to calculate the Flood Peaks

Various different methods were used to calculate the flood hydrology for the catchment as this increases the accuracy of the final flood peak calculation.

All the methods used take the following into account:

All factors relating to storm water run-off.

- Evaporation during rain storm (Please read **Addendum A**)
- Wind during rainstorm (Please read **Addendum A**)
- Depth of rainstorm (Please read **Addendum A**)
- Infiltration (Please read **Addendum A**)
- Flow roughness of area. (Please read **Addendum A**)

The following methods were considered:

1. Rational method as implemented by the Department of Water Affairs.
2. Alternative Rational method
3. Standard Design Flood (SDF) method as developed at Pretoria University.
4. Unit Hydrograph method.
5. Ten Noort & Stephenson algorithms as developed at Wits University.
6. Herbst algorithm developed by the Department of Water Affairs.
7. The HRU algorithm.

Due to the small size of the catchment only the first three methods are deemed to be applicable.

Results of the calculations

The results are listed below. The flows indicated are in cubic meter per second.

Details of the calculations ***(of all 7 methods)*** are shown in **Addendum A**.

Return Period Year	Rational method DWA	Rational method alternative	SDF method
1:2	7	10	4
1:5	9	18	14
1:10	12	23	23
1:20	15	30	33
1:50	20	38	49
1:100	25	44	62

Table 2

The flood peaks were calculated by applying the following algorithm:

$$Q_T = [RMDWA + RMA + SDF] / 3$$

With:

Q_T = Flood peak for return period T

T = Return Period

RMDWA = Rational method DWA

RMA = Rational method alternative application

SDF = SDF method

5 Recommended Flood Peaks and Volumes

The recommended total flood peaks in **m^3/s** and the flood volumes in **m^3** at the site are listed in Table 3 below. The typical length of the storm hydrograph is $4t_c$.

Return Period Year	Flood peak m^3/s	Flood volume m^3
1:2	7	87 192
1:5	14	170 232
1:10	19	240 816
1:20	26	323 856
1:50	36	444 264
1:100	44	543 912

Table 3

6. ACCUMULATION OF STORMWATER IN THE SOUTH-EASTERN CORNER.

An area in the South-Eastern corner of the property exists where flood water will accumulate due to the road levels – see **Figure 2 & 4.**

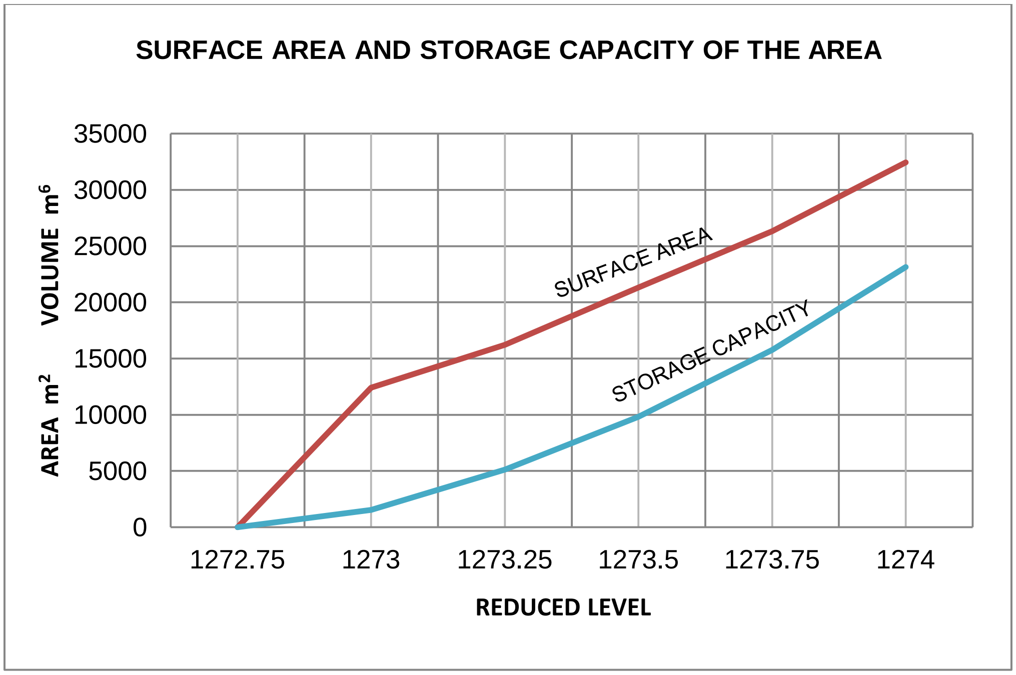

Figure 4

The total inflows after rainstorms for various return periods are listed in Table 4.

To prevent any accumulation of rainwater in this area a pipeline structure was designed to eliminate any damming of rainwater in this area. See **Addendum B.**

Return Period Year	Flood volume inflow m^3
1:2	4360
1:5	8512
1:10	12041
1:20	16193
1:50	22213
1:100	27196

Table 4

7. ASSESS IMPACT FLOODING EROSION & DEPOSITION OF SILT

7.1 EROSION AND DEPOSITION OF SILT

The soil type at the site can be seen in figure 4. The soil can be classified as a sandy loam type and the grass cover is such that 10% of the soil is not covered by grass.

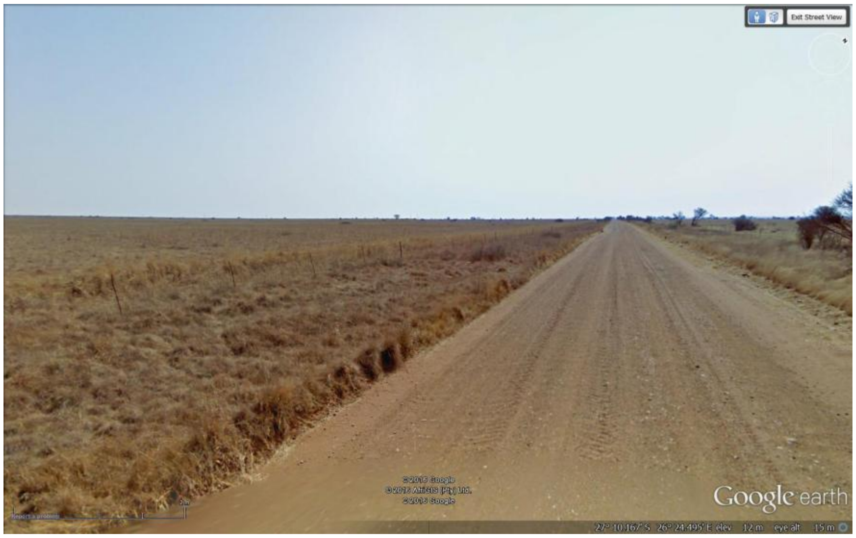

Figure 5

The flow depths and velocities during the various storm return periods were determined. (Table 4.)

Return Period	Flow Depth mm	Actual Flow Velocity m/s	Flow Velocity to start erosion m/s	Flow Velocity to start silting m/s
1:2	18	0,184	0,46	0,05
1:5	27	0,242	0,47	0,06
1:10	32	0,271	0,47	0,06
1:20	39	0,307	0,48	0,07
1:50	48	0,347	0,49	0,08
1:100	54	0,374	0,49	0,09

Table 5

The flow depths and velocities of the storm water over the area for these conditions to cause erosion/deposition of silt were determined and summarized in **Table 5.**

The following conclusions can be made From **Table 5** and **Figure 5**:

Return period 1:2 year

No erosion and no silting will occur.

Return period 1:5 year

No erosion and no silting will occur.

Return period 1:10 year

No erosion and no silting will occur.

Return period 1:20 year

No erosion and no silting will occur.

Return period 1:50 year

Minimum erosion and no silting will occur.

Return period 1:100 year

Minimum erosion and no silting will occur.

8. Drag Forces on the legs of the PV stands

Water flowing past a partly or wholly immersed body (legs of PV stands in this case) exerts a force on the body, the component of which in the direction of the flow is known as the *drag force*. The drag force exerted by the flood water on the legs of the PV stands is a function of the depth of flow, the flow velocity raised to the power of two as well as the density of water (**r=1000 kg/m^3**). Furthermore a coefficient of drag must also be used for the calculation of the drag. For this case this coefficient ($\mathbf{C_{DRAG}}$) is 2,2. The width of a leg was taken as 120 mm which includes debris around the leg.

The horizontal drag forces on the PV stands are as follows:

Return Period	Maximum flow velocity m/s	Maximum hydraulic depth m	Flow area immersed m^2	Drag force on four legs Kg
1:2	0,184	0,018	0,0144	**0,5**
1:5	0,242	0,027	0,0216	**1,4**
1:10	0,271	0,032	0,0256	**2,1**
1:20	0,307	0,039	0,0312	**3,2**
1:50	0,347	0,048	0,0384	**5,1**
1:100	0,374	0,054	0,0432	**6,6**

Table 6

9. Conclusion

1. The PV stands can be erected provided the foundations of the stands are designed to withstand the forces shown on **Table 6.**

2. The runoff emanating from the project area eventually drains to the streams and rivers shown in the **Figure 6.**

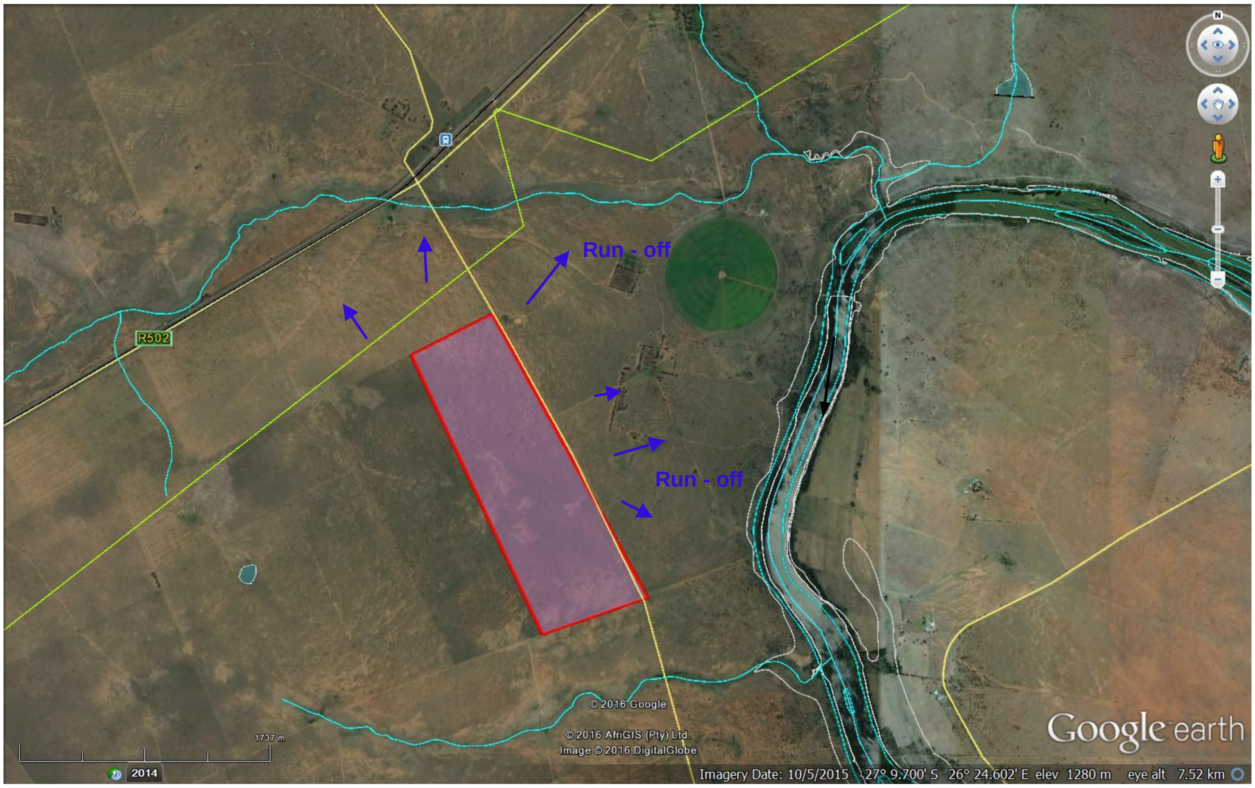

Figure 6

10. REFERENCES

1. ***Water Research Commission (WRC) Report TT 382/08.***
2. ***Department of Water Affair's publication TR102***
3. ***Hydrological Research Unit Report No. 1/72***

4. ***PlanetGIS Geographic Information System (GIS) software suite***
5. ***National Road Commission: Drainage Handbook.***

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28 June 2016