HYDROLOGY ANALYSIS: PROPOSED PHOTO VOLTAIC DEVELOPMENT: PORTION 1 OF THE FARM GROOTPOORT 168 LUCKHOFF: FREE-STATE

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1. INTRODUCTION

CWT Consulting was appointed by ***ENVIRONAMICS*** to perform a surface flow hydrologic study at the proposed site of the photo voltaic development on Portion 1 of the farm Grootpoort 168 near Luckhoff in the southern Free-State Province.

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

2. LOCATION

The location of the area is shown below.

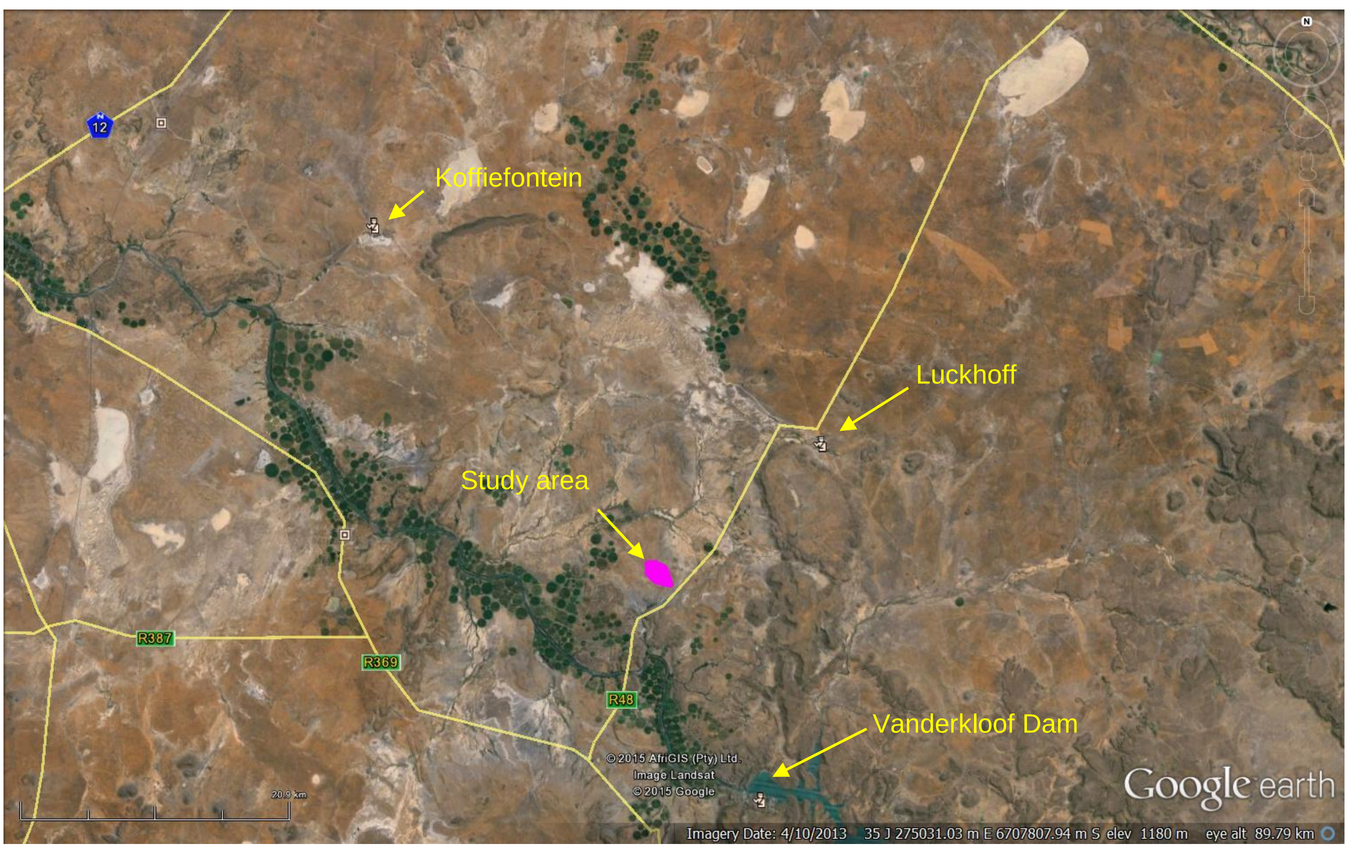

FIGURE 1

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.

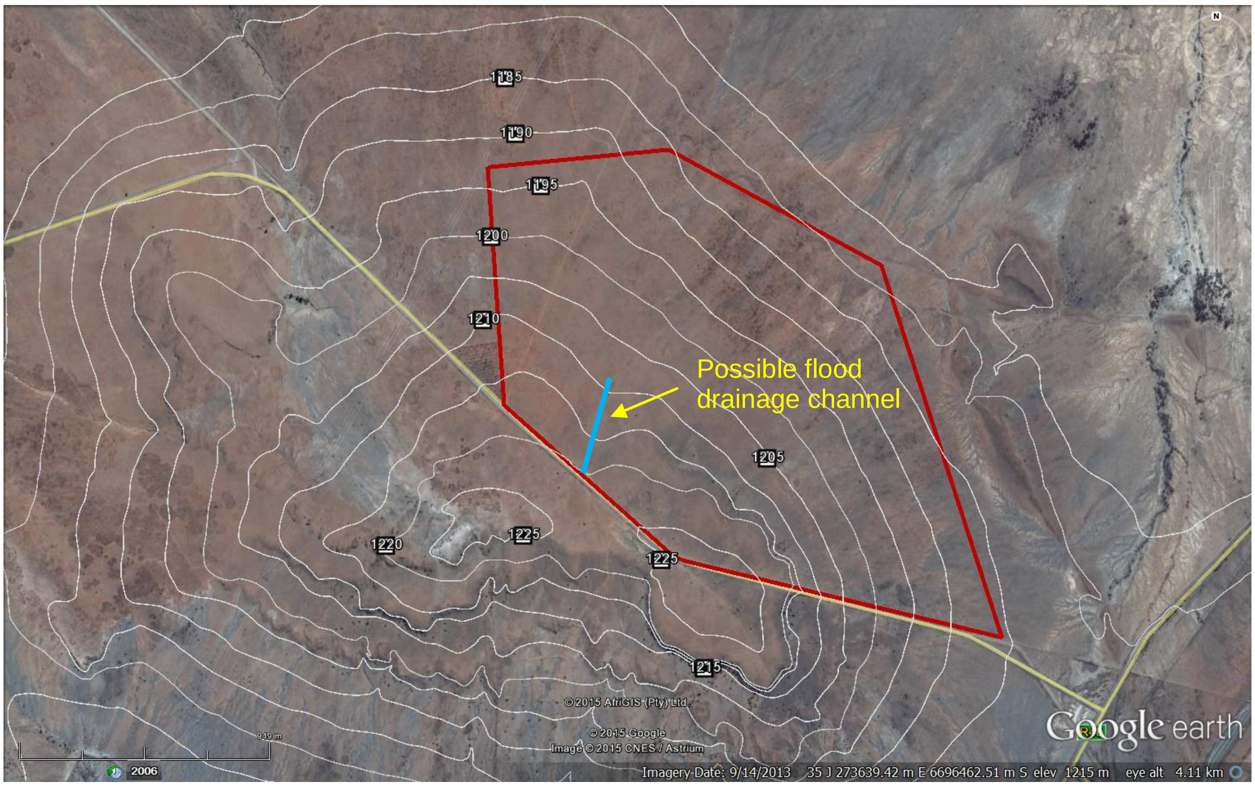

FIGURE 2

The contours slope from RL 1220 on the south-west border to RL 1180 on the north-eastern border. A possible flood drainage channel exists as indicated on Figure 2. However, the area draining to the possible channel is too small to yield a flood peak which may form a flood line situation.

No other prominent channel areas exist.

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

The catchment area draining into the possible flood channel is 0,175 km^2 and with a 1:100 year rainfall intensity of 98 mm/hour and a time of concentration of 21,4 minutes, the maximum flow from this small catchment will be 1,9 m^3/s.

The existing erosion channel on this site is shown below in Figure 3.

FIGURE 3

With Manning`s n = 0,025 and Q_{100} = 1,9 m^3/s the flow velocity in this erosion channel will be 0,66 m/s and the flow depth will be 1,3 m.

This means that the 1:100 year flood will be contained within the existing erosion channel and now flood lines will be formed.

4. HYDROLOGY

4.1 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: **200166 @ Kareepoort**

Mean annual precipitation (TR102): **388 mm**

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

STORM DURATION	**Return Period (RP)**					
	2	**5**	**10**	**20**	**50**	**100**
1 day	43 mm	60 mm	73 mm	86 mm	106 mm	122 mm
2 days	55 mm	78 mm	96 mm	115 mm	144 mm	168 mm
3 days	60 mm	85 mm	104 mm	124 mm	154 mm	179 mm
7 days	75 mm	111 mm	139 mm	169 mm	214 mm	252 mm

Table 1

4.2 Catchment characteristics

The catchment area is shown in Figure 4.

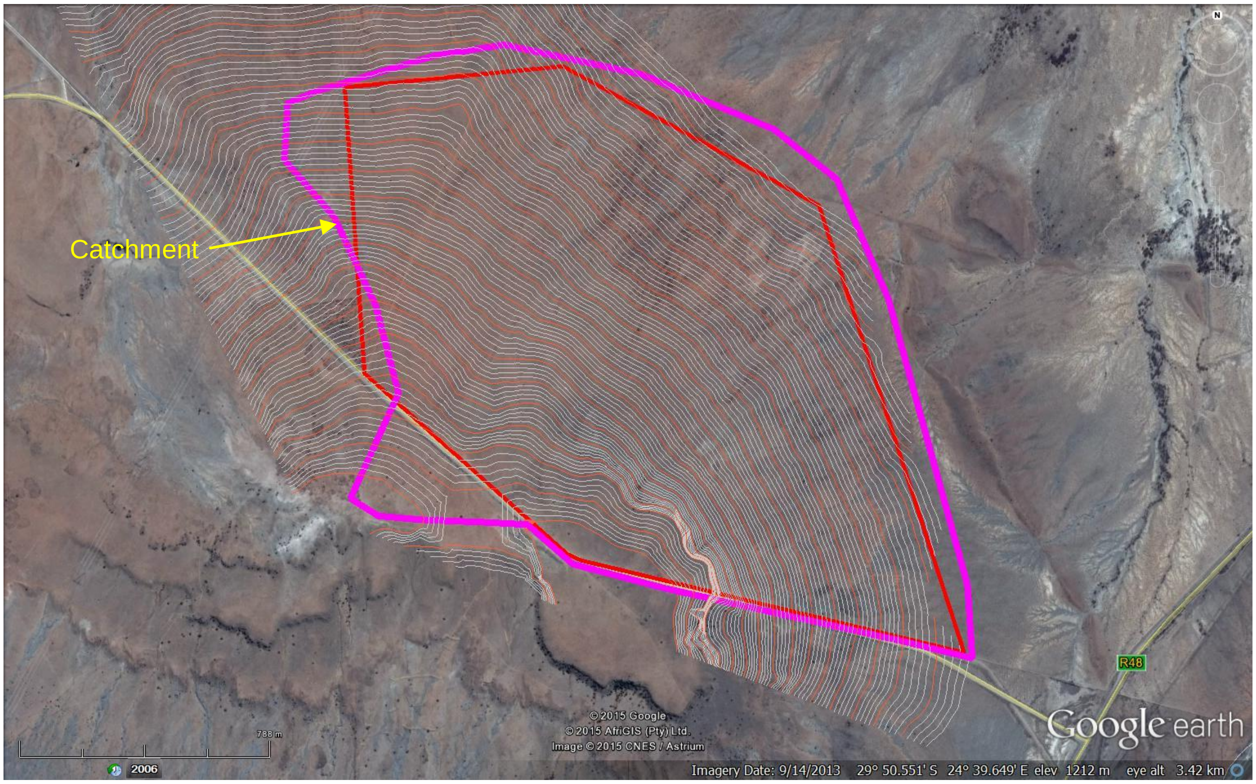

Figure 4

Characteristics

Area of catchment:	2,683	km²
Length of longest watercourse:	1,72	km
Flow of water	Overland Flow	
Equal area height difference:	27,5	m
Average slope	0,01599	m/m
Time of concentration	1,16	hour

4.3 Flood Peak Calculations

4.3.1 Time of concentration

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.

With: r = 0,3 L = 1,72 km h = 27,5 m s = 0,01599 m/m.

Time of concentration: $t_c = 0{,}604(rL/s^{0{,}5})^{0{,}467}$ = **69,6 minutes**.

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.

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.

Results of the calculations

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

Details of the calculations are shown in **Addendum 1**.

Return Period Year	Rational method DWA	Rational method alternative	SDF method	Unit Hydrograph Method	Ten Noort & Stephenson algorithm	Herbst algorithm	HRU algorithm
1:2	4,3	4,8	1,4	4,0	2	-	-
1:5	6,2	8,7	6,5	7,0	3	17	-
1:10	8,3	12,1	11,4	10,4	4	23,8	11,8
1:20	10,9	15,8	16,9	14,7	5,5	32,1	16
1:50	14,9	20,9	25,3	22,5	8,7	38,6	22,2
1:100	19,3	25,4	32,4	31,4	12,2	45	28

Table 2

The flood peaks were calculated by applying the following algorithm:

$$\mathbf{Q_T = [\,RMDWA + RMA + SDF + 0{,}2TNS + UH\,] / 5}$$

With:

Q_T = Flood peak for return period T

T = Return Period

RMDWA = Rational method DWA

RMA = Rational method alternative application

SDF = SDF method

UH = Unit Hydrograph method

TNS = Ten Noort & Stephenson algorithms

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	3	15 062
1:5	5,8	29 121
1:10	8,6	43 179
1:20	11,9	59 748
1:50	17,1	85 856
1:100	22,2	111 462

Table 3

6. ASSESS IMPACT FLOODING EROSION & DEPOSITION OF SILT

6.1 EROSION AND DEPOSITION OF SILT

The soil type at the site can be seen in figure 3. The soil can be classified as a sandy loam type and the grass cover is sparse with 50% soil not covered by grass.

For the purpose of this analysis the site was divided into 5 areas where similar flow velocities can be expected. See Figure 5.

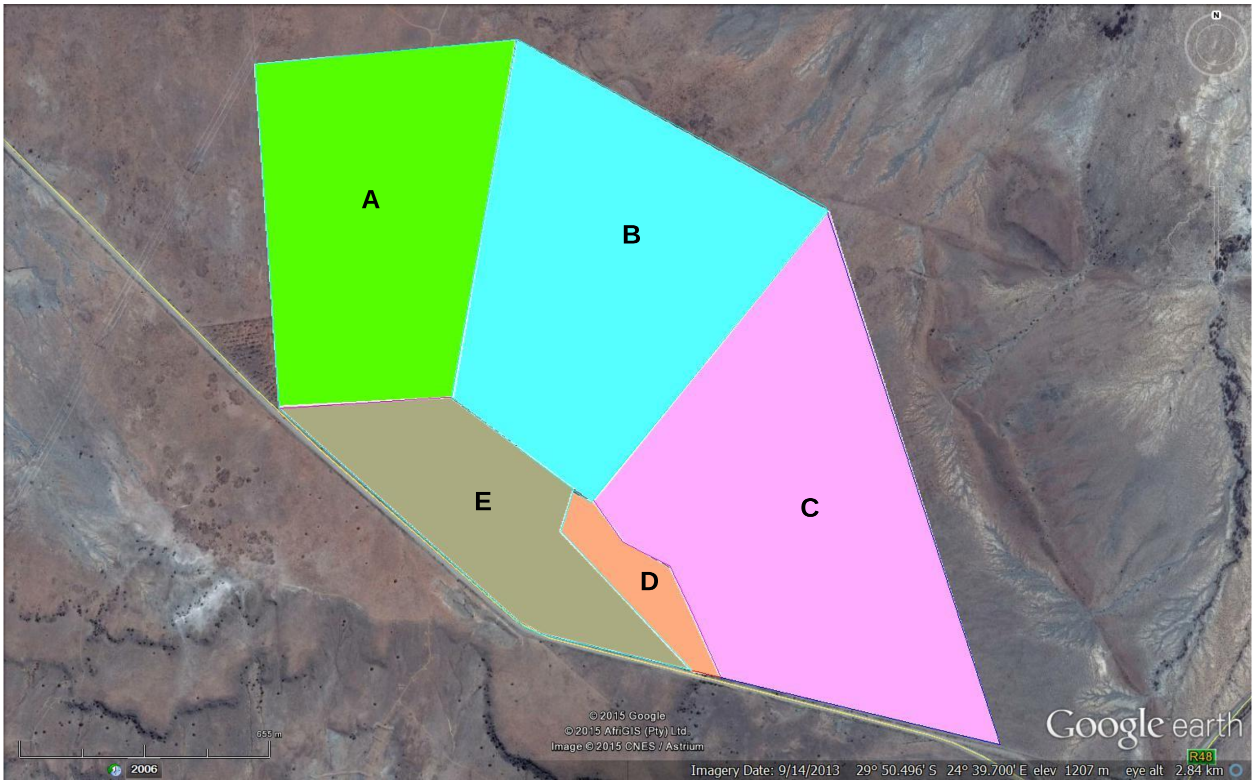

Figure 5

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

Area with the same velocity	A	B	C	D	E
Return Period	Existing Conditions Sheet Flow velocity in m/s				
1:2	0,23	0,22	0,19	0,30	0,14
1:5	0,3	0,29	0,25	0,40	0,22
1:10	0,36	0,34	0,3	0,47	0,26
1:20	0,4	0,38	0,33	0,53	0,29
1:50	0,47	0,45	0,44	0,62	0,33
1:100	0,53	0,51	0,5	0,70	0,39

Table 4

The minimum flow velocity of the storm water over the area for these conditions to cause erosion were determined and summarized in Table 5.

Area with the same velocity	A	B	C	D	E
Return Period	Minimum sheet flow velocity to start scour (m/s)				
1:2	0,48	0,48	0,46	0,47	0,47
1:5	0,49	0,49	0,47	0,48	0,48
1:10	0,51	0,51	0,48	0,49	0,48
1:20	0,52	0,52	0,49	0,5	0,49
1:50	0,53	0,53	0,5	0,51	0,5
1:100	0,54	0,54	0,51	0,52	0,5

Table 5

The flow velocity to cause deposition of silt for this site was determined – see Table 6

Return Period	Mean flow velocity m/s	Velocity to start silting m/s
1:2	0,237	0,03
1:5	0,309	0,04
1:10	0,361	0,04
1:20	0.411	0,05
1:50	0,476	0,06
1:100	0,528	0,06

Table 6

From **Tables 4, 5 and 6** and **Figure 5** the following conclusions can be made:

Area A

Erosion may occur for rainfall intensities above the 1: 50 year return period. Minimal silting is expected.

Area B

Erosion may occur for the 1:100 year rainfall intensity.

Minimal silting is expected.

Area C

Erosion may occur for the 1:100 year rainfall intensity.

Minimal silting is expected.

Area D

Erosion will occur for the 1:2 year up to the 1:20 year rainfall intensity. ***Excessive scouring*** will occur for bigger floods. Minimal silting is expected.

Area E

No erosion is expected. No silting is expected.

7. 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 (**C_{DRAG}**) is 2,2. The width of a leg was taken as 120 mm which includes debris around the leg.

The equation to calculate the drag force is:

F_{DRAG} = 0,5 (C_{DRAG} x r x Velocity^2 x Area perpendicular to the flow direction)

The drag forces for the 1:100 year flood on the PV stands are as follows:

AREA	Maximum flow velocity m/s	Maximum hydraulic depth m	Flow area immersed m^2	Drag force on four legs Kg
A	0,53	0,031	0.004	**4.6**
B	0,51	0,023	0.003	**3.2**
C	0,5	0,019	0.002	**2.5**
D	0,7	0,022	0.003	**5.7**
E	0,39	0,037	0.004	**3.0**

Table 7

The biggest expected drag force will be in Area D because of the flow depth and the flow velocity.

Conclusion

The PV stands can be erected provided the foundations of the stands are designed to withstand the forces shown on Table 7.

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2 October 2015