ATLANTIC RENEWABLE ENERGY PARTNERS (PTY) LIMITED

Storm Water, Erosion, and Wastewater Management Plan

On behalf of Humansrus Solar 3 (Pty) Ltd

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ABBREVIATIONS AND ACRONYMS

AEP	Atlantic Renewable Energy Partners
CSP	Concentrated Solar Power
EIA	Environmental Impact Assessment
MW	Megawatts
PV	Photovoltaic
SANRAL	South African National Roads Agency
SWMP	Storm Water, Erosion, and Wastewater Management Plan

1. INTRODUCTION

Humansus Solar 3 (Pty) Ltd appointed Atlantic Renewable Energy Partners (Pty) Ltd to prepare a Storm Water, Erosion, and Wastewater Management Plan (SWMP) for the proposed Humansrus Solar 3 (Pty) Ltd solar photovoltaic (PV) facility (hereinafter referred to as '**Humansrus 3**') in order to support the Environmental Impact Assessment (EIA) process. The purpose of this SWMP is to determine how precipitation will affect the proposed site and provide solutions that could mitigate any negative impacts expected to occur at the proposed site.

Humansrus 3 is proposed to have a contracted capacity totaling 75 MW and an estimated footprint of 216ha.Humansrus 3 is situated on the Farm Humansrus 147, 10km South-East of Copperton and 50km South-West of Prieska in the Northern Cape (as shown in Figure 1). The coordinates for the Humansrus 3 are provided in Table 1, below:

Table 1: Coordinates of Humansus 3

Latitude	Longitude
29°58'47.31"S	22°23'8.06"E

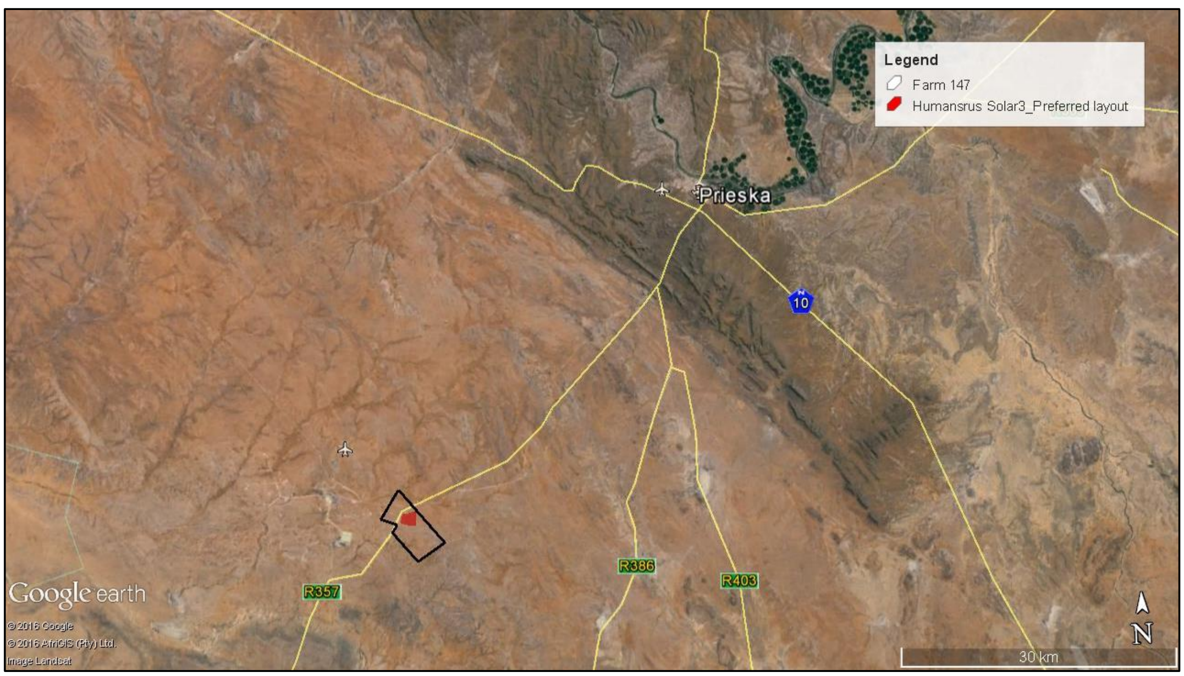


Figure 1: Google Map depicting the location of Humansrus 3 (Google Maps, 2016)

The scope of this report includes:

1. Determining the catchment area for Humansrus 3 using QuantumGIS™;
2. Using the South African National Roads Agency Limited (SANRAL) Drainage Manual (2006) in order to estimate flood peak for the catchment for a return period of 1:50 years;
3. Providing potential solutions in order to mitigate any negative impacts that could occur at the site during its project lifecycle.

2. PROJECT SITE CHARACTERISTICS

Humansrus 3 is situated near the town of Copperton in the central Karoo Region of the Northern Cape. The Karoo is a semi-desert natural region with sparse flora consisting mainly of shrubs and succulents. The region has a dry climate with low rainfall and cloudless skies; extremes of hot and cold temperatures are often common. Figure 2 depicts the sparse vegetation on which Humansrus 3 will be developed.

Economic activities in the surrounding area are primarily mining, renewable energy developments (PV, Concentrated Solar Power (CSP), and wind), and agriculture (particularly sheep farming).

Figure 2: View of the Humansrus 3 site taken from the R357 (Google Maps, 2016)

Humansrus 3 is proposed to have a maximum contracted capacity of 75MW and consist of the following elements:

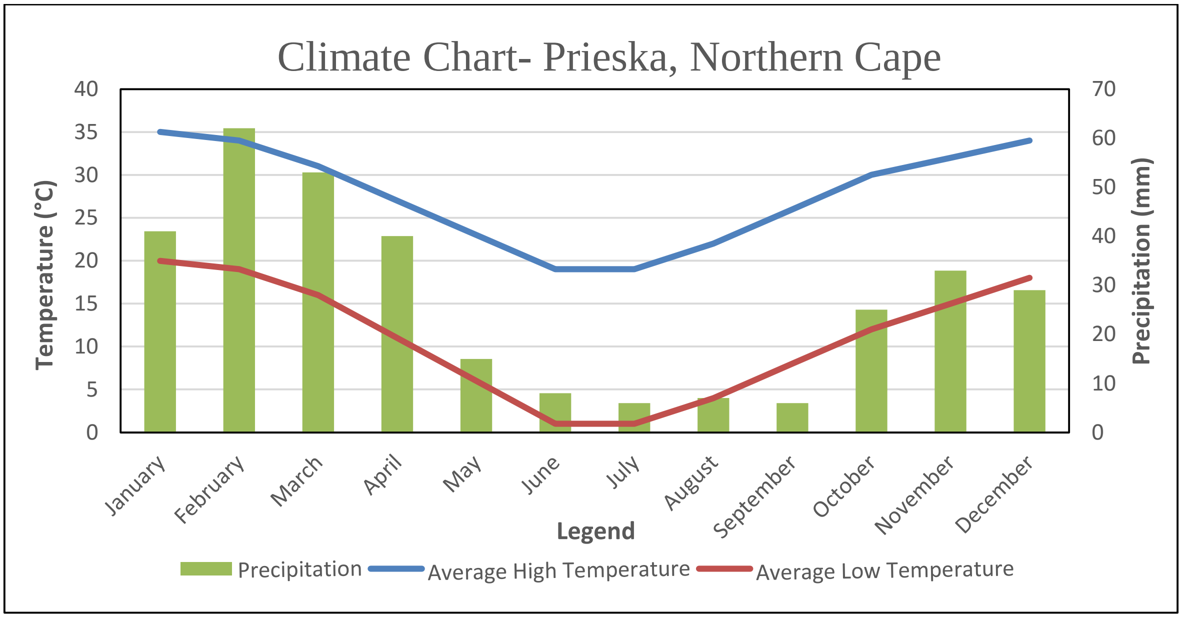
- PV panels;
- Mounting structures on which the solar modules will be connected;
- Inverters and a facility substation;
- Connection from the facility substation to Eskom's injection point (assumed to be Kronos MTS);
- Site offices and ablution facilities (both temporary and permanent depending of stage of

project development);

- Access roads and fencing; and
- Installation of cabling.

2.1 Climate Conditions in the Region

The region receives very little annual precipitation, with most of the rainfall typically occurring during the autumn months. Temperatures vary drastically throughout the year, with an annual average range of 16°C. Extreme high temperatures are experienced in the summer months when the mercury reach sits around 35°C, whereas the winter months often yield drastic low temperatures with an average temperature of 1°C during the middle of winter. Figure 3 shows average precipitation and temperature for the months of the year (Climate Data, 2016).



2.2 Figure 3: Climate conditions of Prieska, Northern Cape Topography of the Region

The region associated with Huamansrus 3 has a very mild gradient with an average range of 0-2% throughout the site, as can be seen in Figure 4. The site has a gentle concave shape with the drainage pattern having a general flow towards the North-West.

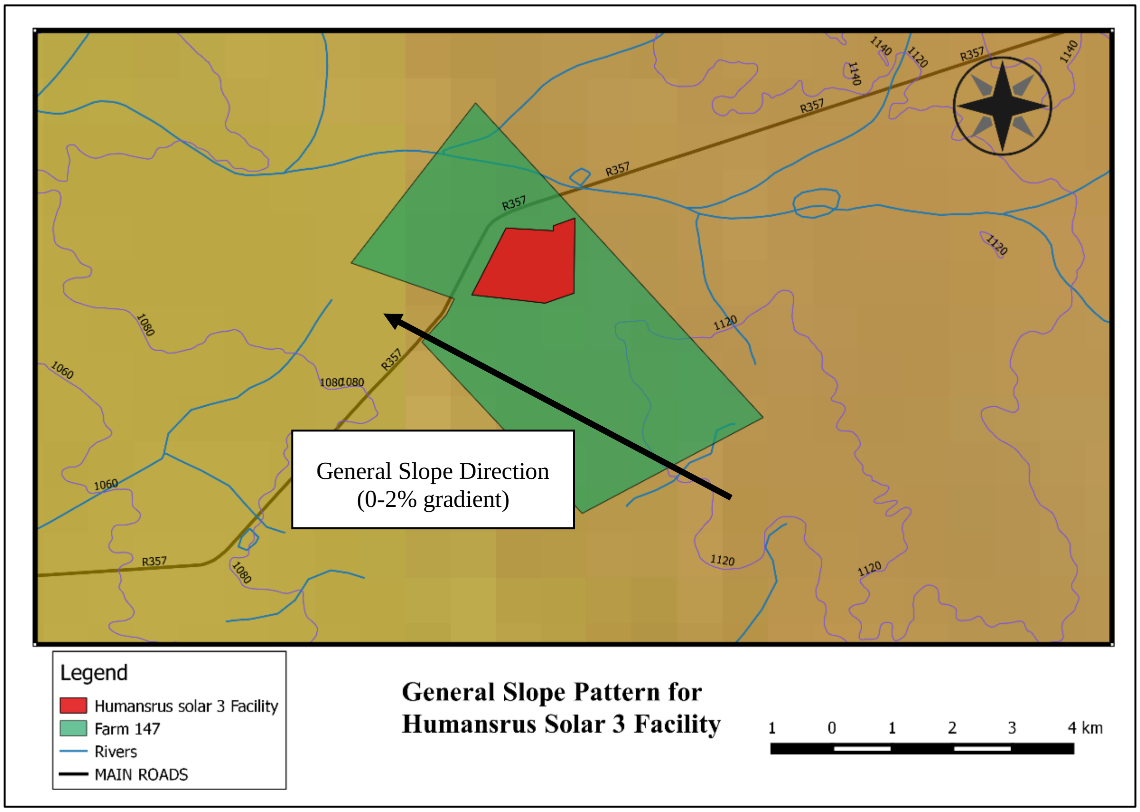


Figure 4: General slope pattern of the Humansrus 3 site

3. METHODOLOGY

In order to determine how precipitation will affect the proposed site, a method for calculating the flood peak was chosen. The characteristics of the project site have been compared with that of the SANRAL Drainage Manual (2006), and the following assumptions were made:

- The **Rational method** was used for the flood calculation;
- The recurrence period of **1:50 years** was chosen as this will reduce the risk of increased maintenance occurring during the operational phase of the project's life cycle;
- All potential solutions that were developed took both the Humansrus 3 facility, as well as the current environmental conditions, in to account.

This resulted in the following procedure being followed:

1. Catchments were determined according to the watercourses running through the site;
2. The area of these catchments and lengths of the watercourses were then calculated;
3. The gradient of the catchment was then determined through the '1085 method'.
4. The Rational method was then used in order to determine the flood peak; and
5. Potential solutions were developed in order to mitigate future risk occurring.

4. CALCULATIONS

In order to reduce the risk of damage to the facility over its lifecycle, a return period of **1:50 years** was chosen. The steps taken in order to determine this flood peak are described below.

4.1 Determine the size of the catchment

The catchments were measured using QuantumGIS™ software. There were two non-perennial river courses that ran through the site creating two catchments. Figure 5 shows the estimated catchments with their general run-off into their respective non-perennial river courses.

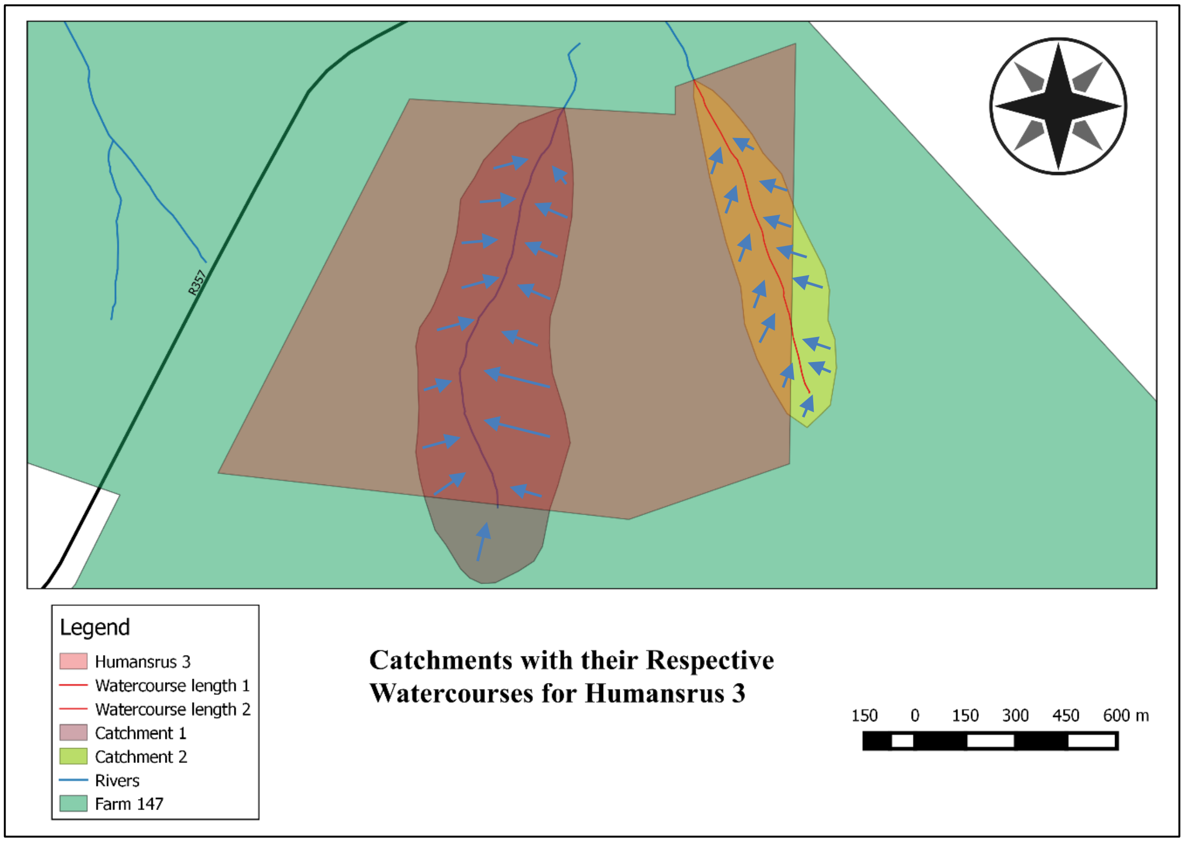


Figure 5: Catchments and Watercourses for Humansrus Solar 3

Table 2 illustrates the area and length measurements for both the catchments and their respective watercourses. The data calculated was then used in the following equations in order to determine the flood peaks.

Table 2: Sizing of Catchments and Watercourses

Catchment	Area (km^2)	Length of watercourse (km)
1	0.549	1.446
2	0.236	1.113

4.2 Calculating the Peak Flow

The Rational method was used in order to determine the peak flow for the catchment area. This method was used due to the size of each catchment being less than 15km^2. This application is based on the following assumptions (adapted from SANRAL, 2006):

- The rainfall has a uniform area distribution across the catchment area;
- The rainfall has a uniform time distribution equal to at least the time of concentration (T_c);
- Peak discharge occurs when the total catchment contributes to the flow at the end of T_c;
- The runoff coefficient (C) remains constant throughout the duration of the storm;
- The return period of the peak flow (T) is the same as that of the rainfall intensity.

The rational method is governed by Equation 1 (SANRAL, 2006),

Equation 1: Rational Method

$$Q = \frac{C.i.A}{3,6}$$

Where,

Q	= Peak flow (m^3/s)
C	= Run-off coefficient (dimensionless)
i	= Average rainfall intensity over catchment (mm/hr)
A	= Effective area of catchment (km^2)
3,6	= Conversion factor

4.2.1 Run-off Coefficient (C)

The run-off coefficient is a dimensionless value based on the most significant factors affecting the rainfall-run-off relationship. Figure 6 and Equation 2 were used in order to calculate the coefficient.

Rural (C_1)					Urban (C_2)	
Component	Classification	Mean annual rainfall (mm)			Use	Factor
		< 600	600 - 900	> 900		
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 - 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30	*Industry*	
Vegetation (C_v)					- Light industry	0,50 – 0,80
	Thick bush and plantation	0,03	0,04	0,05	- Heavy industry	0,60 – 0,90
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Figure 6: Table of significant variables used to calculate C (SANRAL, 2006)

Equation 2: Run-off Coefficient:

$$C = Ft(C_s + C_P + C_V)$$

Where,

Ft = 0.95 (Coefficient factor for 1:50 year return period)

The run-off coefficient was calculated to be **0.238**. The specific values used are listed in Appendix 1.

4.2.2 Rainfall Intensity (i)

In order to determine what the largest peak discharge for a given return period (1:50 years) will be, the storm rainfall should have a duration equal to that of the time required for the whole catchment to contribute to run-off, defined as the time of concentration (T_C). T_C, for a defined watercourse where channel flow occurs, is governed by Equation 3:

Equation 3: Time of Concentration:

$$T_C = \left(\frac{0.87L^2}{1000S_{av}}\right)^{0.385}$$

Where,

T_C = Time of concentration (hours)
L = Length of longest watercourse (km)
S_{av} = average slope (m/m)

S_{av} was calculated using the '1085 Method'. This calculation is expressed in Equation 4:

Equation 4: 1085 Method:

$$S_{av} = \frac{H_{0.85L} - H_{0.1L}}{(1000)(0.75L)}$$

Where,

$H_{0.1L}$ = Elevation at 10% length of the watercourse (m)
$H_{0.85L}$ = Elevation at 85% length of the watercourse (m)
L = Length of the longest watercourse (km)

The time of concentration for watercourse 1 and 2 was calculated to be **0.516hrs** and **0.395hrs** respectively.

Therefore, the rainfall intensity (*i*) for the region was determined using Equation 5:

Equation 5: Rainfall Intensity:

$$i = (regional\ factor) * (MAP\ factor) * (frequency\ factor)$$

Where,

$$Regional\ factor\ (inland) = \frac{217.8}{(1 + 4.164 * t)^{0.8832}}$$

$$MAP\ factor = \frac{18.79 + 0.17 * MAP}{100}$$

$$frequency\ factor = 1.3\ @\ 1{:}50\ year\ return\ period$$

Where,

i = Rainfall intensity (mm/hr)
t = Storm duration
MAP = Mean annual precipitation (mm/yr)

The rainfall intensity for catchment 1 and 2 was calculated to be **24.05mm/hr** and **28.03mm/hr** respectively.

4.2.3 Effective Catchment Area (A)

The effective catchment was calculated using QuantumGIS™ Software and is shown in Table 2.

4.3 Finding of Results

By using Equation 1, the following results for the peak flow were obtained, as shown in Table 3. There is a low peak flow for watercourse 1 and 2 in Humansrus 3, which is due to the very flat gradient and the lack of annual rainfall in the area. However, in order to reduce unforeseen risk of damage to the facility, preventative measures are provided in the following section.

Table 3: Peak Flow for the Watercourses

Watercourses	Peak Flow (m^3/s)
1	0.87
2	1.02

5. PROPOSED PREVENTATIVE MEASURES

The following measures have been proposed in order to reduce the risk of damage occurring to the facility and the environment.

5.1 Preventative Storm Water Measures

These measures are proposed in order to reduce the disruption of vegetation and watercourses within the region where Humansrus 3 will be located.

5.1.1 Watercourse 1 and 2

As far as reasonably possible, the two watercourses running through the Humansrus 3 site must not be altered or filled in. Disruption of these watercourses will cause the drainage channels to divert elsewhere and could potentially result in flooding or waterlogged regions developing.

5.1.2 Removal of Vegetation

Disruption of all existing contours and vegetation must be kept to a minimum. Where these disruptions have to occur, provisions must be made in order to guide the rainwater away from the facility, or to increase vegetation further up slope in order to decrease run-off.

5.2 Applied Storm Water Measures

With vegetation and watercourses inevitably being disrupted due to the construction of the facility, the following measures are proposed:

5.2.1 Access road

The site access road, that is to be constructed off the R357, is to be designed with road drainage systems in order to prevent excessive surface run-off. The following procedures can be implemented in order to reduce this:

- Kerbs: concrete structures used in order to divert run-off along a channel. Figure 7 shows cross section details of some typical kerbs.
- Berms: small ridges placed on top of an embankment to prevent erosion by run-off down the side of the embankment.

The outlets placed in kerbs and berms must be placed correctly in order to ensure satisfactory operation of drainage systems.

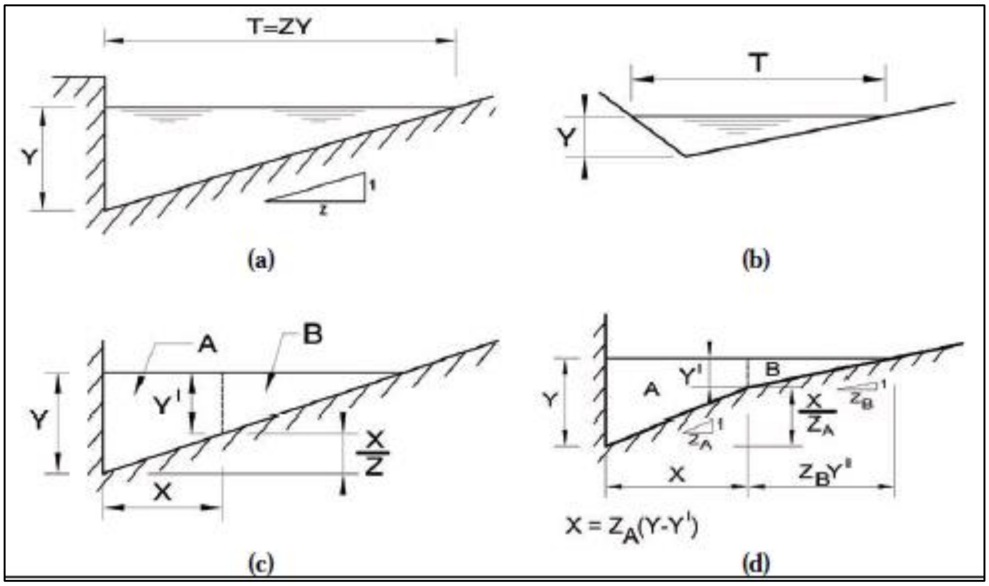


Figure 7: Cross section of typical kerbs (SANRAL, 2006)

5.2.2 Discharge Channels

Discharge channels are open waterways with longitudinal slopes of less than 10%. These channels must be implemented in order to redirect water away from the facility and towards the natural drainage lines that would have originally received the water from the area. Figure 8 shows a stepped channel, this channel design is used to dissipate energy as the water flows downhill.

Figure 8: Stepped energy dissipater channel (SANRAL, 2006)

5.3 Erosion Protection Measures

With disruption of the regions natural drainage lines, there is potential of localised erosion occurring to the facility. Therefore, the following preventative measures have been developed.

5.3.1 Topography

The vegetation and natural topography must be disturbed as little as possible throughout the site. Where large excavation has occurred, retaining walls must be sufficiently implemented.

5.3.2 Implementation of Gabions

Gabions must be implemented when localised erosion could occur. The gabions can be placed as either the lining of channels for protection against scour or as reinforcement along the edges of banks. Figure 9 and 10 provide erosion protection examples.

Figure 9: Gabions protection on walls of channel

Figure 10: Gabions used for bank stabalisers

5.4 Wastewater Management

During the lifecycle of the facility, the production of wastewater will occur predominately during the construction phase. Chemicals used could potentially cause short-term deterioration to the surface water quality and nearby watercourses. It is proposed that all contractors provide detailed method statements as to how these risks of pollution can be mitigated. These method statements must all comply with the Environmental Management Plan.

5.4.1 Wash Water runoff

During the operational phase of the project lifecycle, cleaning of the panels is likely to cause nominal additional run-off. According to a previous study completed (namely Humansrus 1 Pty (Ltd)), the cleaning of the panels is estimated to occur twice a year, for a duration of around two weeks, resulting in ±3 l/m^2 of wash water used. However, due to the size and topography of this site, the low water volumes would cause minimal risk of erosion to the facility. The wash water used must also be chemical free so no pollution of ground water will occur.

Other water-free contenders can be used in order to provide for a more environmentally friendly solution. Figure 10 shows a machine developed by Eccopia which does a daily brush sweep of the panels over a defined time interval.

Figure 11: Ecoppia's E4 cleaning panels (Pickerel, 2015)

5.4.2 Sewage Disposal

All sewage generated on site will be disposed of adequately. During the construction phase, temporary ablution facilities (chemical toilets) will be used for all workers on site. ‘Honeysucker’ trucks will be used, on a regular basis, to transport collected sewage to a nearby waste water treatment works.

The operational phase of the project will require a more permanent means of sewage disposal. Connection to the sewage network could prove difficult due to the remote locality of the facility. Septic tank systems (conservancy tanks) would provide for an adequate long term solution. It is recommended that the tanks be equipped with a float switch controlled alert system so that no overspill occurs during operation.

5.5 Impeding, Diverting and Changing Characteristics of the Watercourses

The proposed layout of Humansrus 3 should be developed to avoid, where practical, as many watercourses within the site. Where impeding of these watercourses has occurred, all development must ensure that the flows are not disrupted and that erosion protection is placed appropriately.

Figure 12 shows a potential site layout of the facility with watercourse 1 and 2 running directly through the site. However, with annual run-off in the region being very low and water beds being predominately dry throughout the year, the implementation of the PV facility across the two watercourses will cause little impact to the natural drainage patterns of the region. Nevertheless, by crossing these watercourses, the 32m buffer area will be impeded. Therefore, the following measures are recommended in order to mitigate any risk of damage occurring to both the facility and surrounding environment.

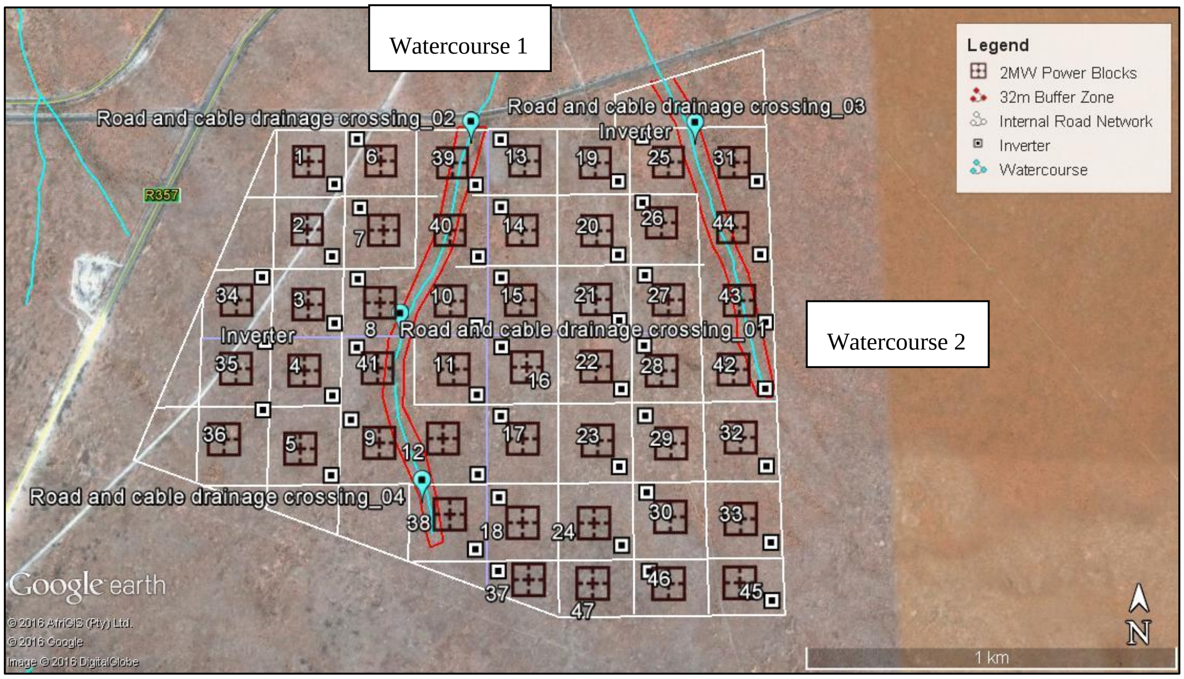


Figure 12: Potential Site Layout

5.5.1 Water Use License Application (WULA)

If the 32m buffer zone for the watercourses is impeded, a WULA will be required. This application will need to be issued from the Department of Water and Sanitation (DWS) in terms of the National Water Act 36 of 1998 Section 21. These applications are subdivided as follows:

(a) Taking water from a water resource;

(c) Impeding or diverting the flow of water in a watercourse; and

(i) Altering the bed, banks, course or characteristics of a watercourse.

5.5.2 Installation of the Internal Road Network

The internal road network must be designed in order to avoid crossing of the watercourses as much as possible. However, where crossing of this watercourse will occur, the following method is proposed for construction.

1. Remove all plants growing within the construction footprint;
2. Excavate topsoil and store separately;
3. Excavate the strip footings for the foundations of the cut-off walls;
4. Cast concrete walls and place gabion mattresses;
5. Build road layer; and
6. Replace topsoil and plants.

In the event of rainfall occurring during construction within the watercourse, civil works within the watercourse will be stopped and temporary erosion protection measures put in place.

5.5.3 Installation of Solar PV Array

The installation of all of PV array must adhere with materials that are able to withstand the local climate constraints of the region. The following method for installation of PV array within the watercourses on site is recommended:

1. Establish internal road network prior to the civil works in all watercourses and restrict vehicle access to these roads;
2. Demarcate the construction footprint in watercourses and prevent access by workers to areas outside of the construction footprint in these areas;
3. Undertake work during a dry season of the watercourses;
4. Remove plants growing within the construction footprint;
5. Excavate topsoil and store separately;
6. Install foundation posts in areas where subsurface areas are hard, or
7. Install poles with a length of 170 – 240 mm and a width of 50 – 60 mm with a percussion hammer;
8. Assemble mechanical structure on top of poles;
9. Mount and electrically connect PV modules on top of the tracking platforms; and
10. Replace topsoil and plants.

In the event of rainfall occurring during construction within the watercourse, civil works within the watercourse will be stopped and temporary erosion protection measures put in place.

5.5.4 Internal Reticulation and Trenching

Where solar PV array is constructed within the watercourses, trenches will need to traverse these features for installation of cabling. Therefore, it is proposed that the followed method be followed for installation of all reticulation:

1. Remove plants growing within the construction footprint;
2. Excavate topsoil and store separately;
3. Excavate subsurface material;
4. Install electrical cabling in trenches;
5. Replace excavated material; and
6. Replace topsoil and rescued plants.

In the event of rainfall occurring during construction within the watercourse, civil works within the watercourse will be stopped and temporary erosion protection measures put in place.

5.5.5 Installation of Inverters, Laydown area and housing facilities

All inverters, the Laydown area, and housing facilities within the site are recommended to be developed outside of the prescribed 32m buffer area of the watercourses.

7. CONCLUSION AND RECOMMENDATIONS

The study found that both of the peak flows for Humansrus 3 were below 1.1m^3/s. These low values are due to the flat topography and lack of annual rainfall in the region. Therefore, it can be concluded that Humansrus 3 will have a low risk of flooding occurring during its project lifecycle.

However, the following recommendations are proposed in order to further reduce this risk and to also mitigate potential negative impacts from occurring on the surrounding region.

- Preventative measures are to be implemented in order to disrupt the environment as little as possible.
- All access roads require proper drainage systems in place in order to channel water away to a culvert.
- All excavations and drainage channels must be adequately protected against potential erosion.
- Mitigation measures must be provided by all personnel that negatively affect the quality of the ground water.
- Wash water used must be chemical free or water-free options must be implemented (if feasible).
- All sewage created on site must be contained and eventually removed from site.
- All development within the watercourses must be constructed in a manner that will not disrupt the natural drainage pattern of the surrounding area.

8. REFERENCES

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APPENDIX 1- Excel sheet

Rational method				
Description	**Symbol**	**Value of watercourse**		**Unit**
		1	**2**	
Constants				
Return Period	-	1:50	2:50	Years
Coefficient factor	-	0.95	0.95	m/m
at 10% of watercourse	0.1L	1094	1095	m
at 85% of watercourse	0.85L	1105	1105	m
Length of watercourse	L	1.446	1.113	km
Area of catchment	A	0.549	0.549	km2
Frequency factor	-	1.3	1.3	-
Mean Annual Precipitation	MAP	27.08	27.08	mm/yr
Calculations				
Peak flow	Q	0.87	1.02	m3/s
Run-off coefficient	C	0.24	0.24	-
Surface Slope	Cs	0.06	0.06	-
Permeability	Cp	0.12	0.12	-
Vegetation	Cv	0.07	0.07	-
Time of Concentration	Tc	0.52	0.40	hours
Average Slope	Sav	0.01	0.01	m/m
Rainfall Intensity	*i*	24.05	28.03	mm/hr
Regional factor	Rf(inland)	79.09	92.17	-
MAP factor	MAP	0.23	0.23	mm/hr