LICHTENBURG 1 PHOTOVOLTAIC FACILITY AND ASSOCIATED INFRASTRUCTURE

CONCEPTUAL STORMWATER MANAGEMENT PLAN

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1. INTRODUCTION

Knight Piésold Consulting was appointed by ABO Wind Lichtenburg 1 PV (Pty) Ltd to investigate and compile a conceptual Stormwater Management Plan for the proposal of a photovoltaic (PV) energy facility and associated infrastructure. Portion 06 of the Farm Zamenkomst No.04 has been identified as the preferred site suitable for the development of a commercial PV facility, which is capable of generating 100MW. The total area of the project site is approximately 428ha.

This report should be viewed as a localised high-level study and not as a detailed design report. The objective is purely to demonstrate that stormwater from the new development could be managed and controlled in an optimised and non-destructive manner. The purpose of this study is to prepare a conceptual Stormwater Management Plan (SMP) to support the Environmental Impact Assessment Process of the proposed Lichtenburg 1 PV facility.

The SMP includes the following:

- Determining the catchment area of the project site;
- Defining the topography, slope gradients and rainfall intensities;
- Estimating expected floods for the catchment;
- Confirming of existing drainage patterns and streams;
- Proposing drainage elements such as side drains, outlets and other mitigation measures to accommodate the resultant stormwater flows.

2. DEFINITIONS AND ASSUMPTIONS

The following assumptions are made on stormwater calculations and are deemed to be adequate for a conceptual investigative report:

- The Rational Method is used for flood calculations, which is widely accepted to be very accurate for areas of this size and
- The recurrence period applied is a 1:50 year design flood.
- There are no watercourses that will affect planning and the design of the solar facility.

3. EXISTING SITE CONDITIONS

3.1. Location

The site is situated approximately 12km to the north of the town of Lichtenburg, and 5.5km south-east of Bakerville, situated in the North West Province of South Africa, see *Figure 3.1*. The site falls within ward 16 of the Ditsobotla Local Municipality. A formal gravel access road currently provides access from the regional road (R505) to the property. This gravel road then becomes a formal 2-wheel track, leading up to a gate used to access the project site.

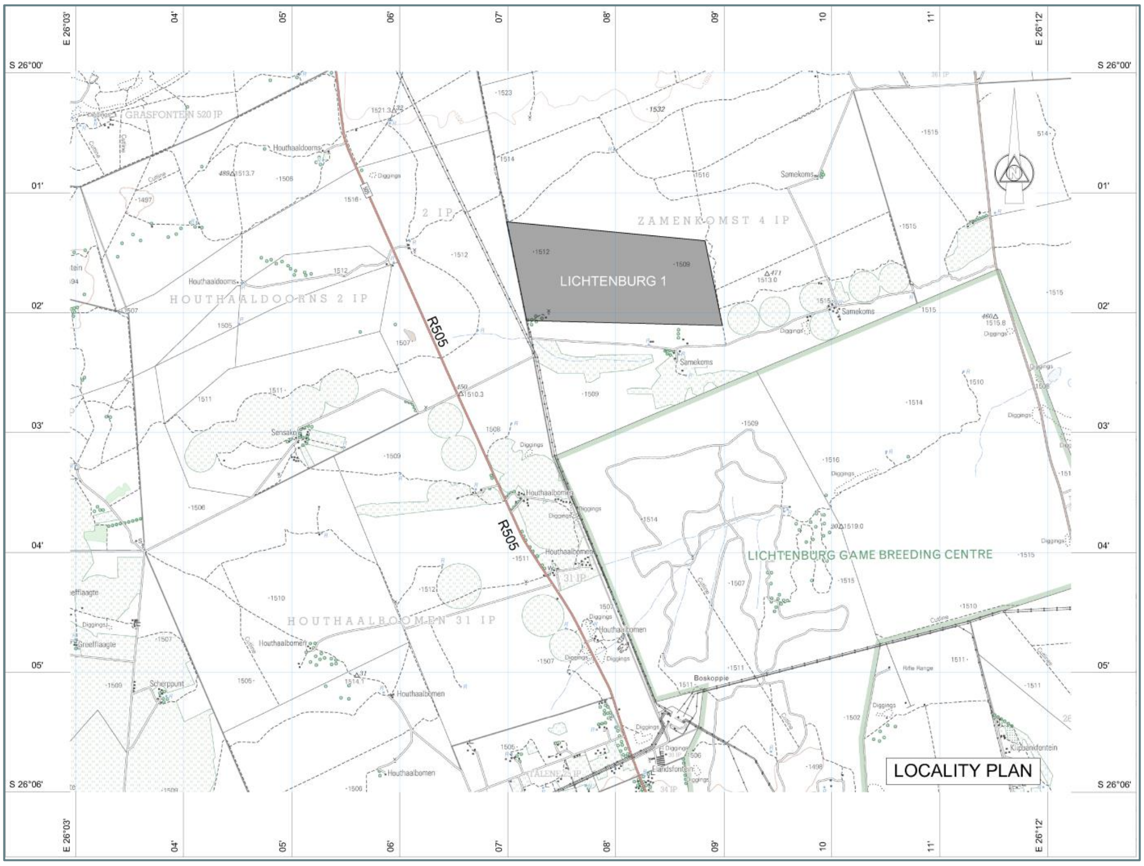

Figure 3.1: Locality Plan

3.2. Topography, Geomorphology and Vegetation (Drainage Characteristics)

The North West Province is situated in the central-northern extent of South Africa and is characterised by altitudes ranging between 900 and 1 800m above mean sea level (AMSL). This makes it one of the provinces with the most gradual slopes within the country. Lichtenburg 1 is situated at elevations of between 1 509m AMSL and 1 518m AMSL, the elevation gain/loss being a mere 9m. The project site can therefore be described as being flat with an average slope of

0.3% and a maximum slope of 1.4%. The northern portion of the project site is the flattest, becoming slightly more undulating to the south, with a slight south to south-west inclination. The property is characterised by open grassland and shrub lands, and is largely being used for livestock farming.

3.2.1. Drainage Patterns and Runoff Characteristics

The approximate total drainage area of the site is in excess of 428 hectares. A relatively small sized depression appears to be present in the south western corner of the project site. Although the site does not reflect evidence of any watercourses, the drainage pattern slopes in a south to south westerly direction, see *Figure 3.2.* The slope gradient for the longest drainage path length within the catchment area is 0.5%.

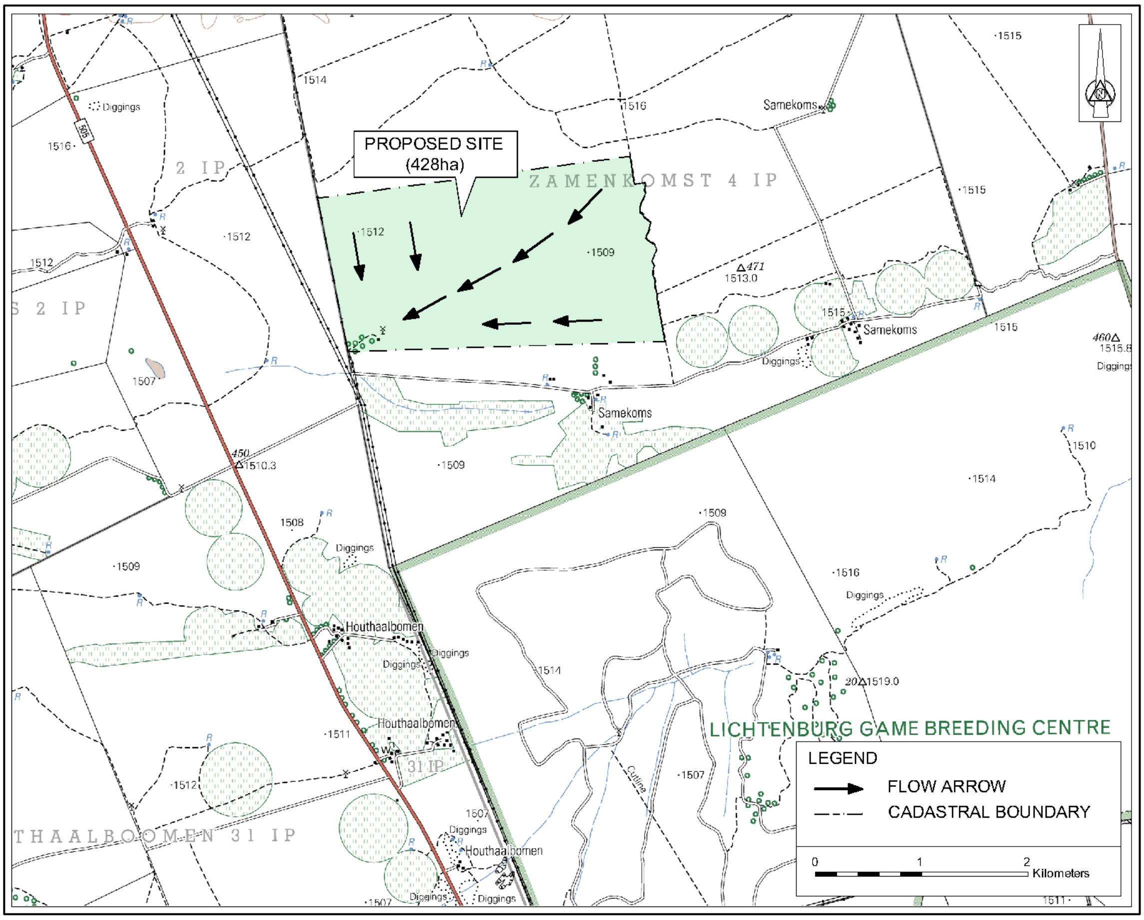

Figure 3.2: Drainage Pattern of Existing Site

It should be noted that, in the absence of detailed topographical survey information, 1:10 000 orthographical maps together with spot height data taken on site were used to establish the drainage patterns. The greater catchment area is 1 050ha, see *Figure 3.3* below. The sparse vegetation, together with the flat gradient and semi-permeable soils yield very low runoff coefficients.

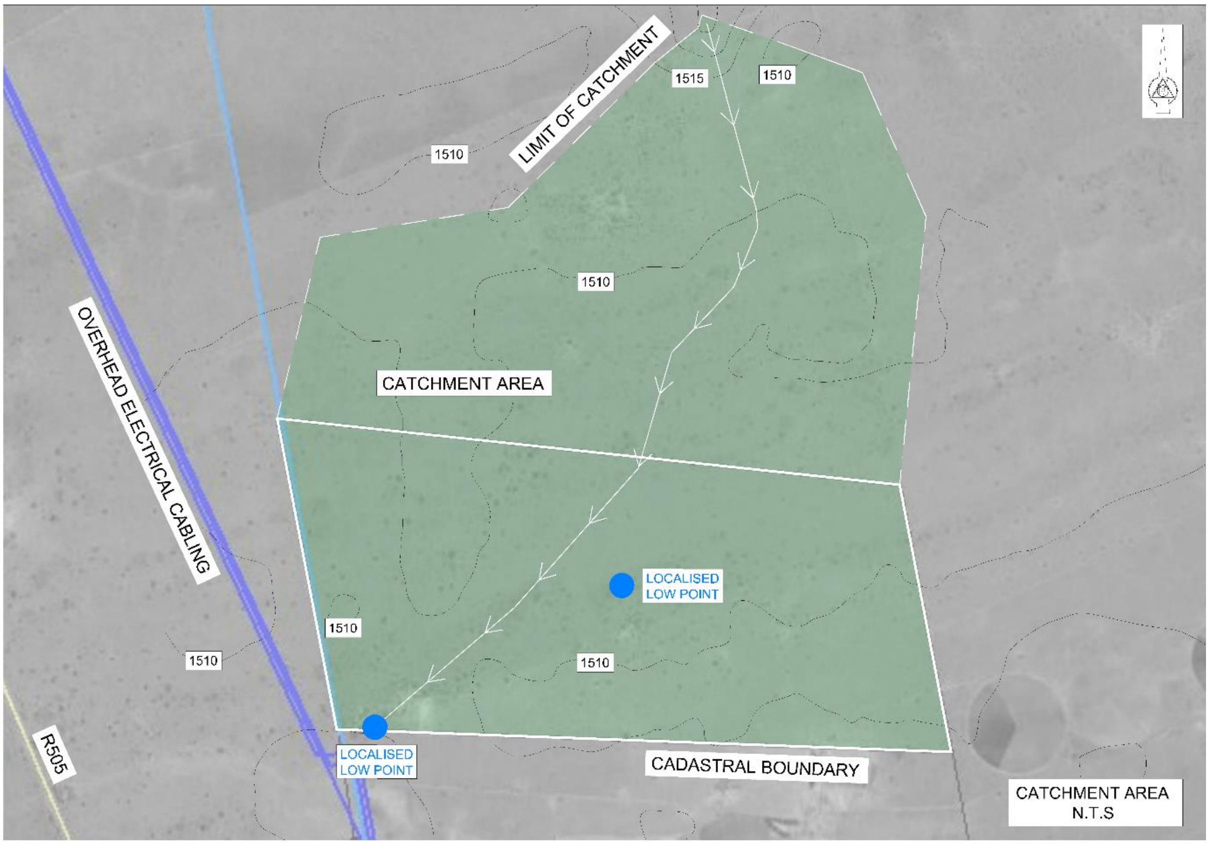

Figure 3.3: Catchment Areas

3.3. Geology and Soils

The site overlies dolomites and associated marine sedimentary rocks and comprises mainly dolomite and chert. The dominant soil forming processes have been rock weathering and the formation of orthic topsoil horizons, as well as common clay illuviation, all giving rise to lithocutanic horizons. The soil forms that represent these processes are Glenrosa and Mispah, which tend to be reddish-brown in colour, and are weakly structured soils. Surface rock may be present, and hillcrest areas within this land type are characterised by rock, Mispah soils and occasionally shallow Hutton form soils. The site is generally viewed as permeable and the ingress of rainwater into the soils happens relatively quickly.

3.4. Climate and Hydrology

Lichtenburg 1 is located within the Lower Vaal Water Management Area (WMA). Minimal usable surface runoff is generated within the WMA as a result of the low rainfall, flat topography, and sandy soil conditions.

Lichtenburg is typically hot in summer and mild-to-cold in winter. It experiences summer rainfall in the form of thunderstorms with a mean annual average precipitation of 601mm; see *Figure 3.4* for a graph indicating the average monthly rainfall figures. At an average temperature of 21.7°C, January is the hottest month of the year, and June the coldest at 9.9°C; see *Figure 3.5* for average monthly temperatures. The information was gathered from the weather station at the Lichtenburg Municipality.

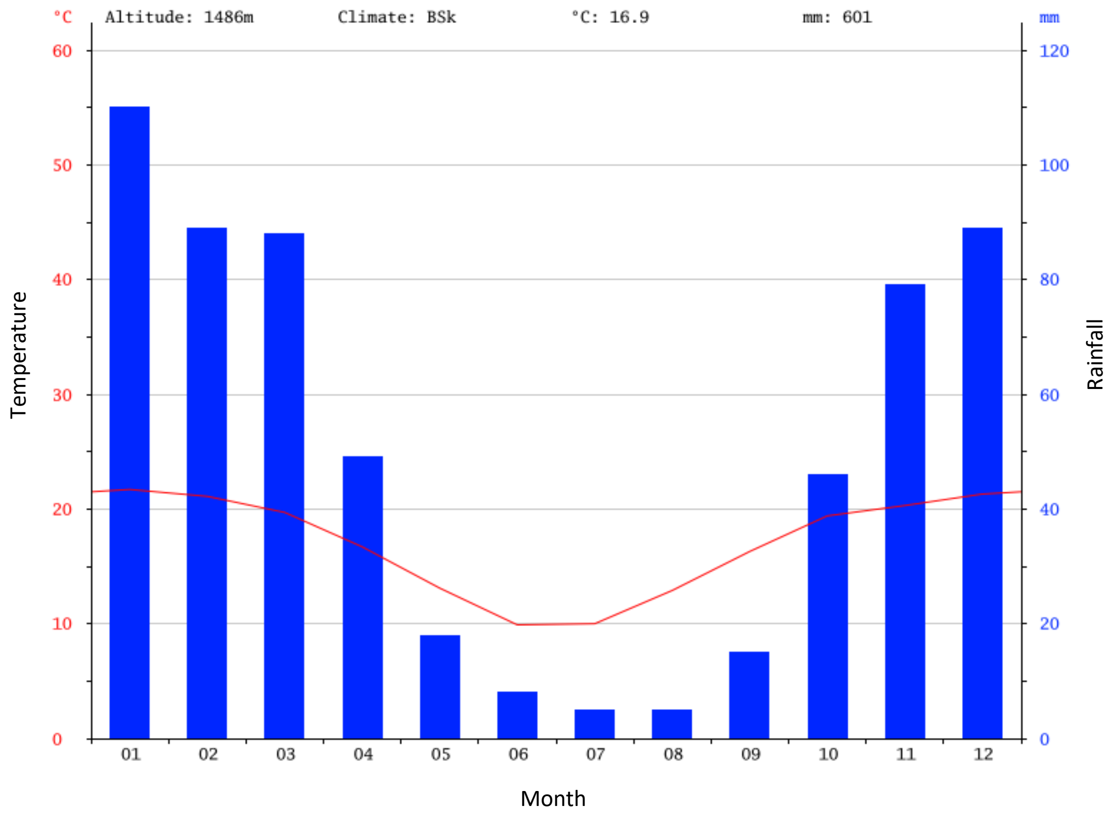

Figure 3.4: Monthly Rainfall for Lichtenburg

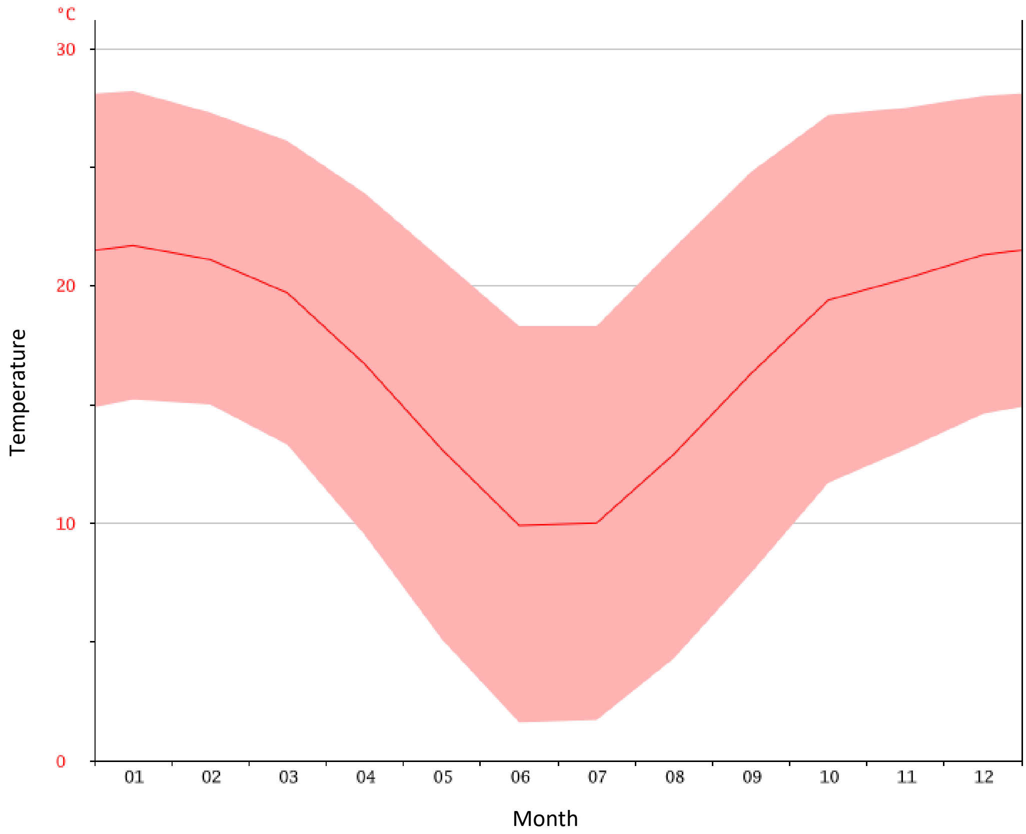

Figure 3.5: Average Monthly Temperatures for Lichtenburg

4. STORMWATER CALCULATIONS

As mentioned before, the calculations to determine the run off volumes and intensities of the site are based on the Rational Method with a return period of 1:50 years.

4.1. Runoff Coefficient

4.1.1. Pre-development

The pre-development runoff coefficient was calculated by making allowance for the rock outcrop observed on site during the visual inspection; 5% was therefore allowed for impermeable soil. The site mainly consists of grasslands with a portion of the site consisting of light bush and cultivated land, see run-off coefficient percentages listed in *Table 4.1* below.

Table 4.1: Pre-development Runoff Coefficient Percentages

Permeability	% Applied	Vegetation	% Applied
Very	0	Thick bush & Forest	0
Permeable	50	Light Bush & Cultivated Land	30
Semi-Permeable	45	Grasslands	70
Impermeable	5	Bare	0
TOTAL	*100*	*TOTAL*	*100*

The calculated runoff coefficient based on the above for the pre-development phase is 0.307; refer *Annexure A* for further detail calculations in this regard.

4.1.2. Post-development

The post-development runoff coefficient takes the installation of the panels into account, as well as the vegetation alterations that may occur post construction. An area of 280ha (approximately 65% of the total project site) is required for the development of Lichtenburg 1 PV. Even though the PV panels are impermeable, they will be mounted on bases that only cover a small surface area. A small percentage of the run-off coefficient was thus allowed for hardened surface.

During the construction phase, vegetation will be lost and this may not fully recover due to the shade that will be created by the panels post construction. A further allowance was made by amending the vegetation area when calculating the post-development peak runoff flows by allowing for 20% bare areas or no vegetation. These percentage figures are reflected in *Table 4.2* below.

Table 4.2: Post-development Runoff Coefficient Percentages

Permeability	% Applied	Vegetation	% Applied
Very	0	Thick bush & Forest	0
Permeable	45	Light Bush & Cultivated Land	30
Semi-Permeable	45	Grasslands	50
Impermeable	10	Bare	20
TOTAL	*100*	*TOTAL*	*100*

The calculated runoff coefficient based on the above for post-development phase is 0.332; refer *Annexure B* for further detail calculations in this regard.

4.2. Time of Concentration

The following formula was used to calculate the time of concentration, which is the time it takes for surface water at the furthest point on the site to reach the lowest area:

$$Tc = \left(\frac{0.87 \times L^{2}}{1000.S}\right)0.385$$

Where Tc = Time of Concentration (hours), L = Length of waterway (km), S = average slope.

4.3. Point Intensity

Point Intensity is based on standard time of concentration, and information was extracted from rain fall intensity depth graphs for the area.

4.4. Runoff

4.4.1. PV Area

The runoff distribution of the respective catchment areas will be dictated by the layout of the larger PV area, as well as the internal roads and channels. Each PV area which is a combination of smaller blocks should preferably be orientated in such a way to minimise the impact on natural drainage patterns. A typical PV panel configuration (subject to the final site development plan) is indicated in the *Figure 4.1,* with the resultant drainage pattern in *Figure 4.2* as follows:

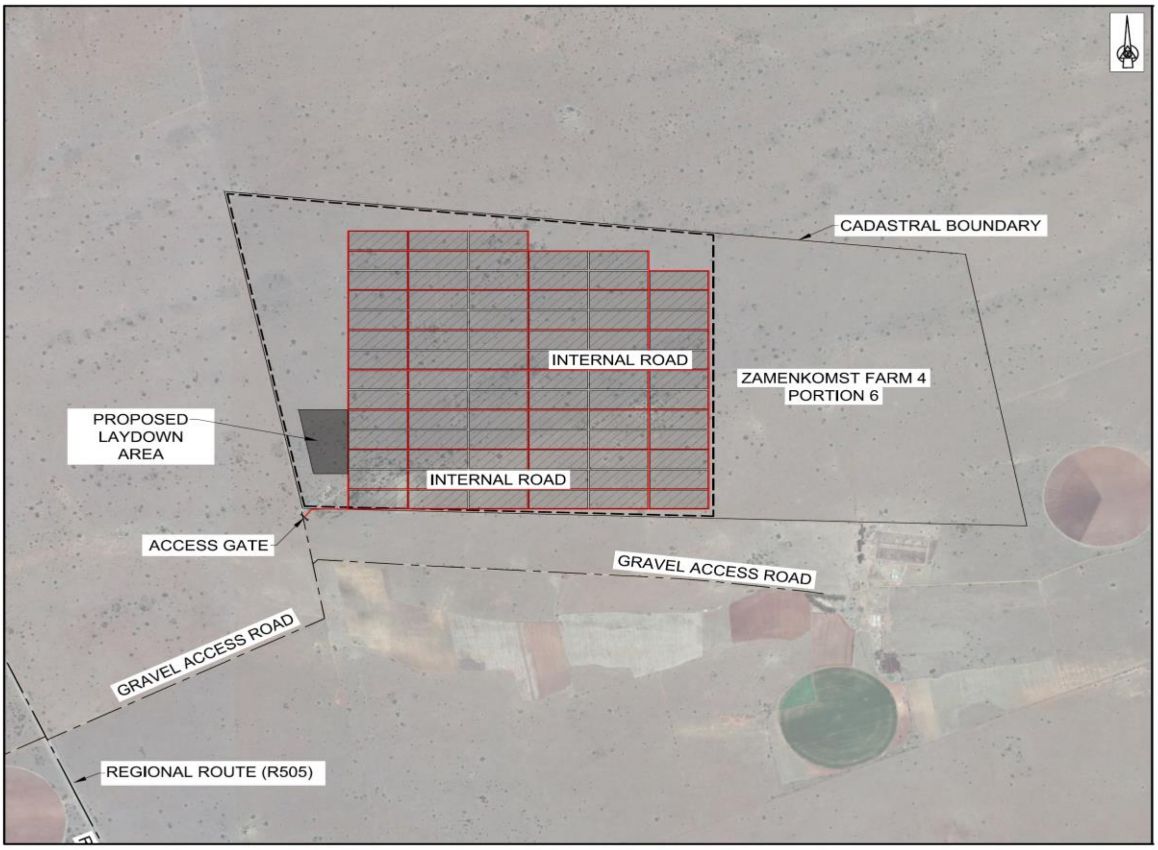

Figure 4.1: Conceptual Layout of PV Panels

Figure 4.2: Drainage pattern for conceptual layout of PV panels

Other than two localised low spots within the layout (see Figure 3.3) there are no waterbodies or places of ponding visible on the proposed site. Water could possibly pond at these two identified spots during extended heavy periods of rain and this should be considered during the final detailed design.

The 1:50 year flood occurrence for pre and post-development runoff for the catchment area is shown below:

Catchment Area = 10.0 km2

Pre-Development C = 0.307

Post-Development C = 0.332

TC = 1.33 hours

Intensity = 62.9 mm/hr

Rational Method Pre-Development Q = $\frac{\mathrm{CIA}}{3.6} =$ **43.01 m³/s**

Rational Method Post-Development Q = $\frac{\mathrm{CIA}}{3.6} =$ **46.59 m³/s**

4.4.2. Access Roads

As mentioned previously, the access road intersects with the R505 (see Figure 4.3) and this road does have sufficient drainage. It is recommended that the first 200m of the access road be upgraded to a hardened (bitumen) surface, to prevent damage to the road edge. This upgrade should allow for sufficient drainage, however the remainder of the access road will remain gravel and provision must be made for drainage thereof.

The run-off across the gravel road is viewed to be very limited. The flow velocity and depth at the various outlets will have to be confirmed during the detailed design stage. The average velocity is in the order of 1.0 m/s for the gentle slopes on this site (0.3% to 1.4% max). Such flows will not cause any serious erosion, but appropriate measures should be implemented at outlets and points of concentration caused by drainage channels. This will reduce the risk of erosion damage.

Frequent nominal drainage measures, typically piped culverts and/or mitre drains cut by a grader, must be provided at intervals between 200m to 300m as dictated by the site conditions and must be taken care of in the detail design. These could also be in-situ formed drifts where the road alignment is close to the natural ground level.

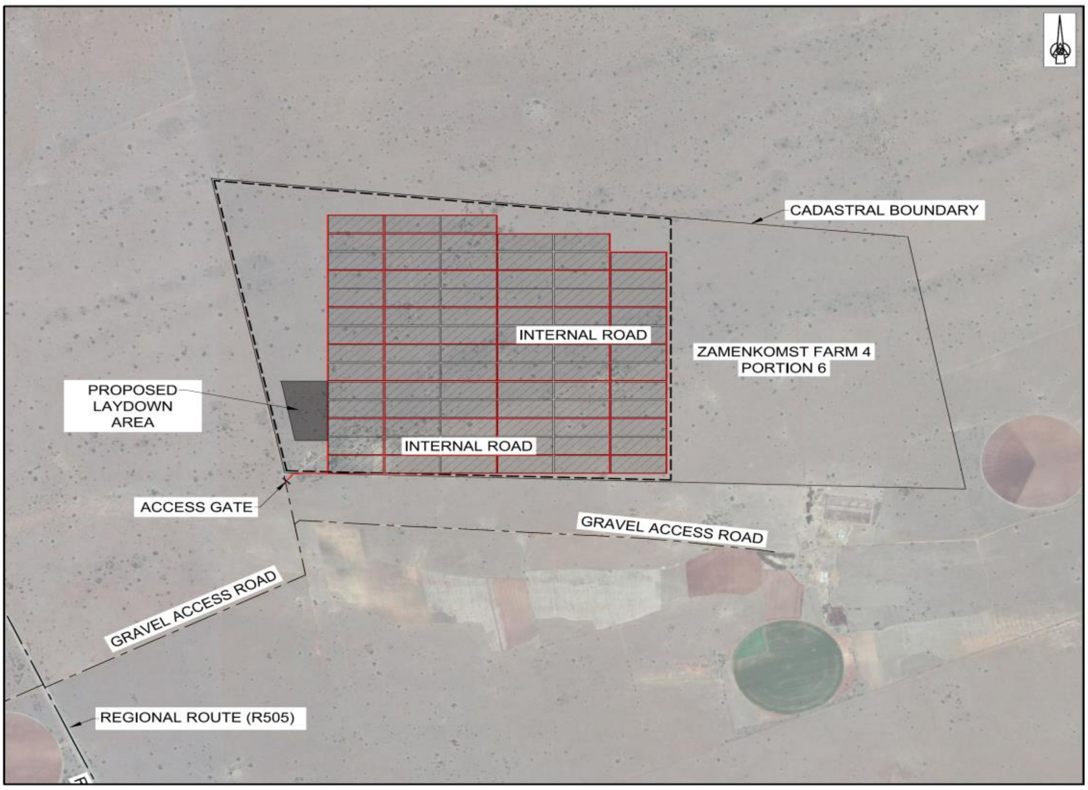

Figure 4.3: Access Roads

5. PROPOSALS FOR STORMWATER MANAGEMENT

The existing drainage patterns and characteristics should be preserved as far as possible. It is therefore suggested that the existing contours and vegetation be retained and that the internal roads are designed and constructed to minimum standards. The runoff calculations indicate that an additional 3.58 m^3/s or roughly a 8% increase in peak runoff will have to be accommodated when designing the stormwater management measures.

Drainage structures would include smaller diameter pipes (encased in concrete because of the low fill anticipated) or preferably gravel or concrete drifts. These drifts should have cut-off walls on the down-stream side as a minimum requirement.

5.1. Side Drains

Open drains will be provided along the proposed internal roads or between PV panels. These drains would be gravel drains with concrete or edge beam protection at road crossings where required.

5.2. Berms

Berms are proposed to prevent external stormwater from entering the PV area and for directing flow to suitable areas of release, see *Figure 5.1* for typical berm details. Cut off drains are proposed on the northern property boundary to reduce runoff from the larger catchment area (see Fig 3.3).

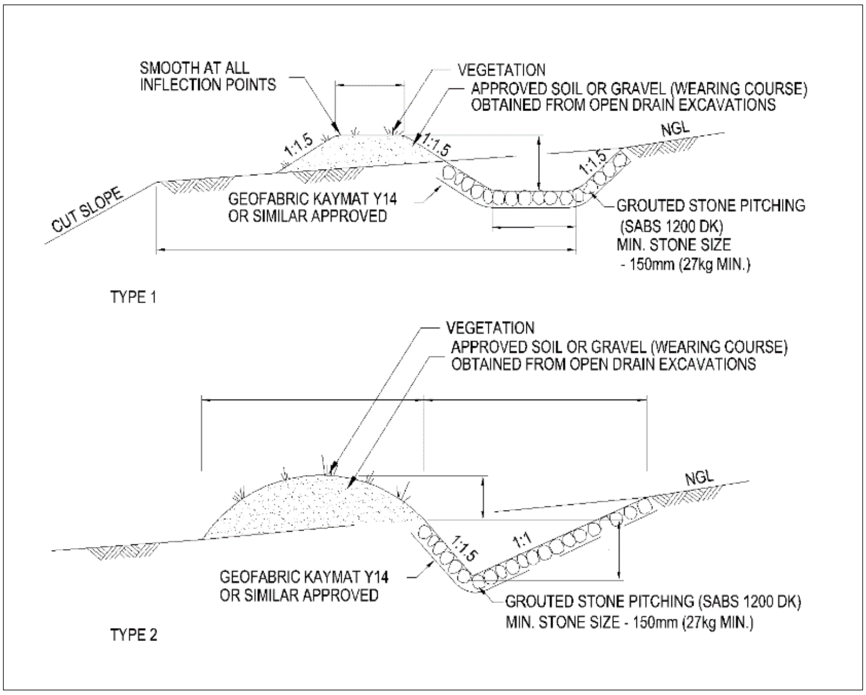

Figure 5.1: Typical Berm Detail

5.3. Outlets

All culverts on the access roads must be provided with concrete outlets with erosion protection. Side drain outlets should be terminated with suitable erosion protection to reduce the velocity and the flow depth.

6. EROSION PROTECTION MEASURES

The volume and velocity of the stormwater runoff must be thoroughly evaluated during the detailed design phase. The following erosion protection measures should be considered:

- Side drains, see *Figure 6.1 and 6.2*
- Inlet and outlet structures, see *Figure 6.3 and 6.4*

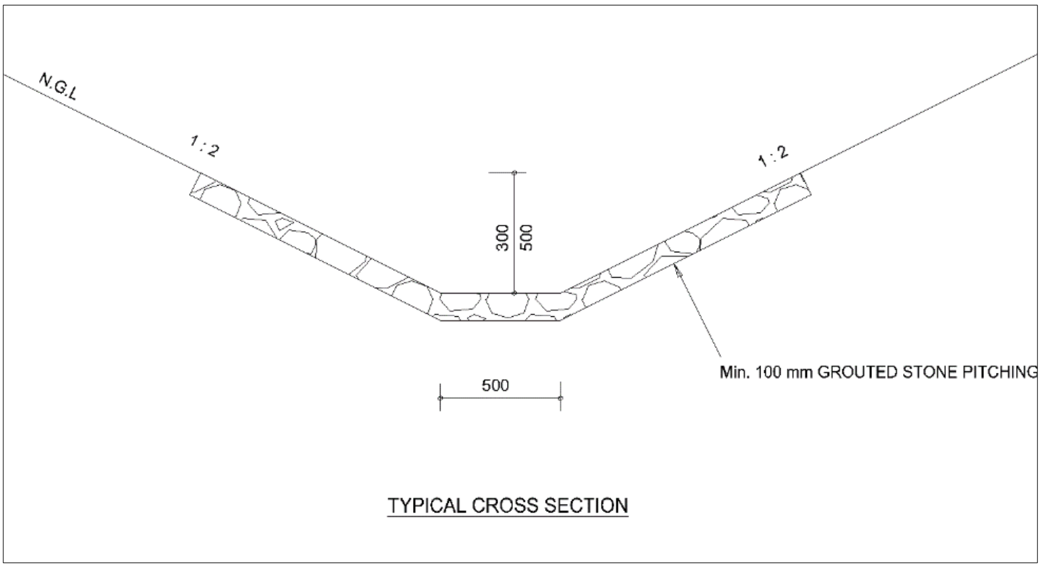

Figure 6.1: Typical Stone Pitched Side Drain

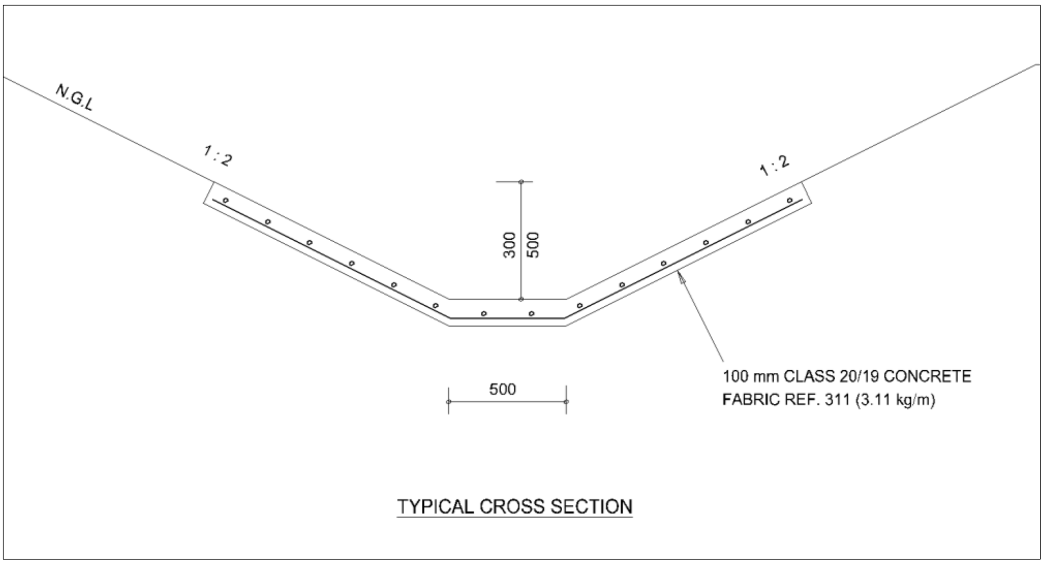

Figure 6.2: Typical Concrete Lined Side Drain

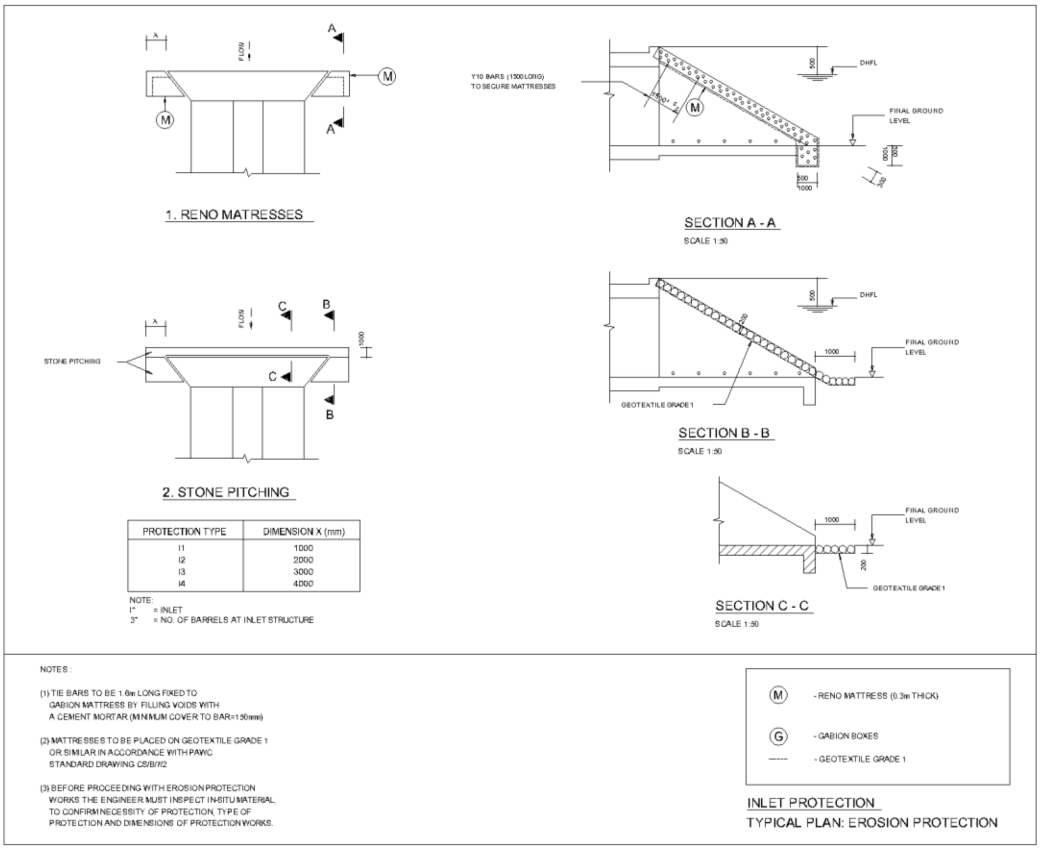

Figure 6.3: Typical inlet erosion protection measures

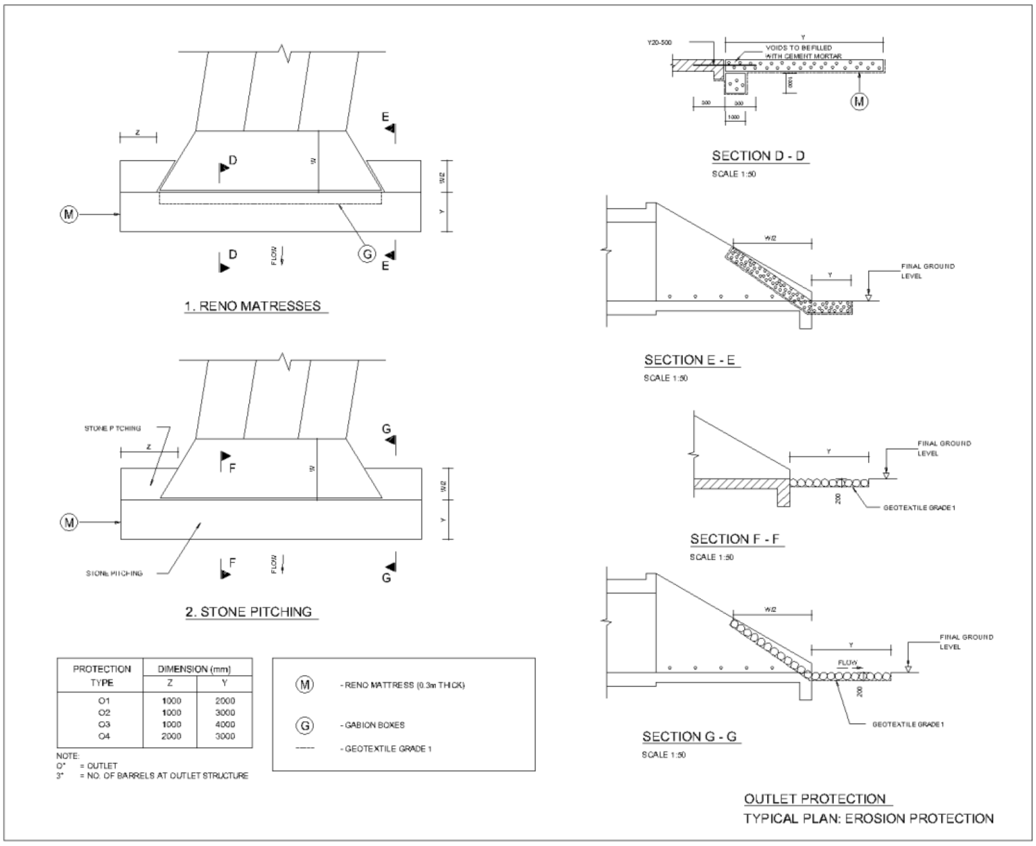

Figure 6.4: Typical outlet erosion protection measures

It is envisaged that in combination with the above the following are also likely to be required:

- Stone masonry walls to reduce the flow velocity in steeper areas;
- Side Drain Outlets with stone pitching to prevent erosion; and
- Temporary berms and straw bales during construction in the vicinity of identified streams to reduce flow and sediment transport during this phase.

During the construction phase special attention must be given to stormwater so that construction activities do not result in any water ponding, especially in the vicinity of the roads and structures.

7. WASTE WATER MANAGEMENT

After the installation of the panels, the cleaning (washing) of the solar panels is likely to generate small amounts of additional runoff. This process is estimated to occur twice a year, and add approximately 3l/m² of additional runoff to the site, over a period of approximately 2 weeks. This runoff would however be spread throughout the site, and due to the low localised water volumes would cause minimal, if any, erosion on the site and may even help as a form of dust control. The methods used for washing the panels determine the mitigation measures to be applied. This could be in the form of phasing the washing of panels or optimising the methods used. The overall effect on the site is expected to be very low, provided the cleaning water is free from detergents and includes only approved bio-degradable substances.

Rain will also aid in keeping the PV panels clean. The solar module surfaces are installed at a relatively large incline with gaps between modules. This does not allow significant water build up on the modules while also reducing the energy generated by the falling rain droplets.

On large structures or buildings appropriate guttering could be used around the building to avoid water erosion where roof water would be flowing off the roof. Wherever practically possible, stormwater run-off from the gutter/roofs will be captured and stored in rainwater tanks. If this water cannot be captured, water will be channelled into energy dissipating structures to spread the water and slow it down to reduce risk of erosion. Such a structure could be constructed from precast concrete or loosely packed rock or perforated bags filled with stone. There is a large amount of loose rock available on site that can be used for this purpose.

8. CONCLUSIONS AND RECOMMENDATIONS

The additional stormwater runoff generated from the new facility post-development is almost negligible compared to pre-development. It is therefore envisaged to do limited stormwater management to reduce the impact of the proposed development on the environment.

By implementing earth drains, lined drains and limited erosion protection structures, the stormwater on the site, between the PV panels and for the adjacent access roads could easily be accommodated safely and in a non-destructive way. The development of the site will also be done in accordance with the existing slopes. The contours will be followed closely in order to minimise impacts on the existing drainage patterns.

9. REFERENCES

- Various Municipal Management of Urban Stormwater Impacts Policies
- The Georgia Stormwater Management Manual
- The South African National Roads Agency Limited. (2006). Drainage Manual Fully Revised 5th Edition
- Adamson P.T. (1983). Technical Report TR 102. Southern African Storm Rainfall
- Savannah environmental: Lichtenburg 1, North West Province, Scoping report, August 2018

10. ANNEXURES

Annexure A: Pre-Development Runoff Calculations

Flood Frequency Analysis: Rational Method

Project	= LICHTENBURG PV1
Analysed by	= RdV
Name of river	= N/A
Description of site	= PORTION 6 OF THE FARM ZAMENKOMST NO. 04 : PRE-DEVELOPED
Date	= 2018/09/25
Area of catchment	= 10.0 km²
Dolomitic area	= 20.0 %
Mean annual rainfall (MAR)	= 586.00 mm
Length of longest watercourse	= 4.0 km
Flow of water	= Overland flow
Height difference	= 22.0 m
Value of r for over land flow	= Clean soil (r=0,1)
Rainfall region	= Inland
Area distribution	= Rural: 100 %, Urban: 0 %, Lakes: 0 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	0	Houses	0	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	0	Light industry	0	Streets	0
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	0	Very permeable	0	Thick bush & forests	0
Flat area	80	Permeable	50	Light bush & cultivated land	30
Hilly	20	Semi-permeable	45	Grasslands	70
Steep areas	0	Impermeable	5	Bare	0

Average slope	= 0.0055 m/m
Time of concentration	= 1.33 h
Run-off factor	
Rural - C1	= 0.307
Urban - C2	= 0.000
Lakes - C3	= 0.000
Combined - C	= 0.259

Rural run-off coefficient C1 above includes dolomitic factors where applicable.
The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	1.33	65.3	98.7	48.5	0.90	23.3	31.47
1:50	1.33	84.9	98.3	62.9	0.95	24.6	43.01
1:100	1.33	104.5	97.9	77.0	1.00	25.9	55.50

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.1.0

Annexure B: Post-Development Runoff Calculations

Flood Frequency Analysis: Rational Method

Project	= LICHTENBURG PV1
Analysed by	= RdV
Name of river	= N/A
Description of site	= PORTION 6 OF THE FARM ZAMENKOMST NO. 04 : POST DEVELOPED
Date	= 2018/09/25
Area of catchment	= 10.0 km²
Dolomitic area	= 20.0 %
Mean annual rainfall (MAR)	= 586.00 mm
Length of longest watercourse	= 4.0 km
Flow of water	= Overland flow
Height difference	= 22.0 m
Value of r for over land flow	= Clean soil (r=0,1)
Rainfall region	= Inland
Area distribution	= Rural: 100 %, Urban: 0 %, Lakes: 0 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	0	Houses	0	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	0	Light industry	0	Streets	0
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	0	Very permeable	0	Thick bush & forests	0
Flat area	80	Permeable	45	Light bush & cultivated land	30
Hilly	20	Semi-permeable	45	Grasslands	50
Steep areas	0	Impermeable	10	Bare	20

Average slope	= 0.0055 m/m
Time of concentration	= 1.33 h
Run-off factor	
Rural - C1	= 0.332
Urban - C2	= 0.000
Lakes - C3	= 0.000
Combined - C	= 0.281

Rural run-off coefficient C1 above includes dolomitic factors where applicable.
The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	1.33	65.3	98.7	48.5	0.90	25.3	34.09
1:50	1.33	84.9	98.3	62.9	0.95	26.7	46.59
1:100	1.33	104.5	97.9	77.0	1.00	28.1	60.11

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.1.0