LETSOLO
WATER AND ENVIRONMENTAL SERVICES
"Engineered Solutions for Environmental Quandary"

HALFGEWONNEN SOLAR PV FACILITY

HYDROLOGICAL IMPACT ASSESSMENT

Ref No.: LWES 1039

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0. EXECUTIVE SUMMARY

Letsolo Water and Environmental Services cc, hereafter referred to as Letsolo, was appointed to compile a Hydrological Impact Assessment Report for the proposed Halfgewonnen Solar PV Facility. The proposed site falls within the farm Halfgewonnen 190IS, located in the magisterial district of Bethal, Mpumalanga Province.

0.1. Area of Influence

The area of influence in hydrological terms was assessed for 3 tiers as follows:

- Tier 1 - Olifants Water Management Area
- Tier 2 - B11A Department of Water and Sanitation (DWS) Quaternary Catchment Area
- Tier 3 - Site Delineated Catchment Areas (Catchments 1,2 and 3)
- Tier 4 - Affected surface water resources (Olifants River)

0.2. Impact Assessment

As part of the hydrological assessment, potential impacts where identified. The impact identification assessment methodology is in line with international best practices and the requirements are stipulated in Regulation 982 of 4 December 2014 promulgated in terms of Section 24 of National Environmental Management Act, 107 of 1998 (NEMA).

0.3. Water Quality Monitoring

Surface water samples were collected for this assessment and should be collected monthly with a report summarizing the findings. Key surface water monitoring points were selected and monitored in February 2021. Additional samples were collected far upstream (approximately 5km) of the site and far downstream (also approximately 5km) of the site for regional water quality. The following once off water quality samples were collected:

- In-stream water quality samples
  - Olifants upstream
  - SH12-Tributary of Olifants
  - SH2 Olifants at Overlooked Colliery
  - Olifants downstream

0.4. Increase in runoff

Hydrological calculations were used to simulate runoff for two conditions: the pre- and post-development conditions. Solar panels themselves do not have a significant effect on the peak flows and runoff volumes. However, if the ground cover under the panels is gravel or bare ground, owing to design decisions or lack of maintenance, the peak discharge may increase significantly with storm-water management control measures needed.

The proposed Solar PV panels are impervious, the rainwater that drains from the panels will appear as runoff over the downgradient cells. The runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts (almost doubled).

A simple practice that can be implemented is a buffer strip at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the panels and associated infrastructure were installed. Alternatively, a detention basin can be installed.

0.5. **Salt balance**

Because there is no immediate/site interlink between the Olifants River at SH2 and the Leeufonteinspruit, the salt balance assessment was based on the monitoring points located along the Leeufonteinspruit river which is the receiving river system. The findings are as follows ::

- SH8, which is located downstream of the confluence of SH 6 and SH7, contributes 71% of the salt loads. Followed by SH 7 at 21% and SH6 at 8%.
- TDS contributes 64% of loads followed by Sulphates (21%), then Sodium and Chlorides at 8% and 7%, respectively.

GLOSSARY

Catchment: In relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

Clean water: Water that complies with a negotiated standard.

Dirty water: Water that does not comply with a negotiated standard.

Groundwater: Water that occurs in the voids of saturated rock and soil material beneath the ground surface is referred to as groundwater and the body within which the groundwater is found is referred to as an aquifer.

Mitigation: Measures taken to reduce adverse impacts on the environment.

Passive management system: A management system that does not require external energy inputs (such as electrical power) or continuous operator attention for its continued successful operation.

Pollution: Pollution (in relation to a water resource) means the direct or indirect alteration of physical, chemical or biological properties of a water resource so as to make it –

(a) Less fit for any beneficial purpose for which it may reasonably be expected to be used; or
(b) Harmful or potentially harmful.

Rehabilitation: Return of disturbed land to a stable, productive and self-sustaining condition after taking into account beneficial uses of the site and surrounding land.

Runoff: Surface runoff is defined as the water that finds its way into a surface stream channel without infiltration into the soil and may include overland flow, return flow, interflow and base flow.

Watercourse: Watercourse means –

a) a river or spring;
b) a natural channel in which water flows regularly or intermittently;
c) a wetland, lake or dam into which, or from which, water flows; and
d) any collection of water which the Minister (the Department of Water and Sanitation) may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its beds and banks. (National Water Act, 1998 (Act 36 of 1998)).

Water system: includes any dam, any other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of water.

LIST OF ABBREVIATIONS

MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NEMA	National Environmental Management Act, 107 of 1998
NWA	National Water Act, 36 of 1998
SWMP	Storm Water Management Plan

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1. INTRODUCTION

Letsolo Water and Environmental Services cc, hereafter referred to as Letsolo, was appointed to compile a Hydrological Impact Assessment Report for the proposed Halfgewonnen Solar PV Facility. The proposed site falls within the mining right area of Halfgewonnen Colliery on the farm Halfgewonnen 190IS, located in the magisterial district of Bethal, Mpumalanga Province.

Dreamworks Haven Investments Pty Ltd (the Applicant) proposes to develop the Solar PV Facility as part of the Department of Mineral Resources and Energy (DMRE) Renewable Energy Independent Power Producer Procurement Programme (REIPPP), and the facility will also be able to sell electricity to surrounding consumers.

The goal of this study is to determine the hydrological effects of the proposed facility and examine whether storm-water management is needed to control runoff volumes and rates during storm events. The assessed measures related to the change in hydrological patterns includes potential flooding and erosion control.

1.1. Purpose of this study

The Hydrological Assessment is required to predict and quantify the potential impacts on surface water resources as well as to recommend reasonable mitigation measures. The content of this report ensures that:

- Effect is given to the objectives of the National Water Act, 1998 (Act 36 of 1998) (NWA) and National Environmental Management Act, 1998 (Act 107 of 1998) (NEMA).
- Systems are in place to enable effective management of potential impacts on the water resources.
- Surface water monitoring requirements and parameters are assessed and prescribed.

1.2. Date and season of the site investigation

The site visit was conducted in February 2021. The site investigation made allowance for the following:

- Observe and take note of the pre development status quo.
- Identify areas that may be hydrologically affected;
- Logging of areas of interest for mapping purposes;
- Identification of nearby streams; and
- Characterisation of tributaries in terms of their perennial or non-perennial nature.

1.3. Site Location

The proposed Halfgewonnen Solar PV facility will be located approximately.

28 km north of Bethal in the Mpumalanga Province. The study area covers Portions 7, 8, Remaining extent of Portion 9 and 16 of the farm Halfgewonnen 191 IS.

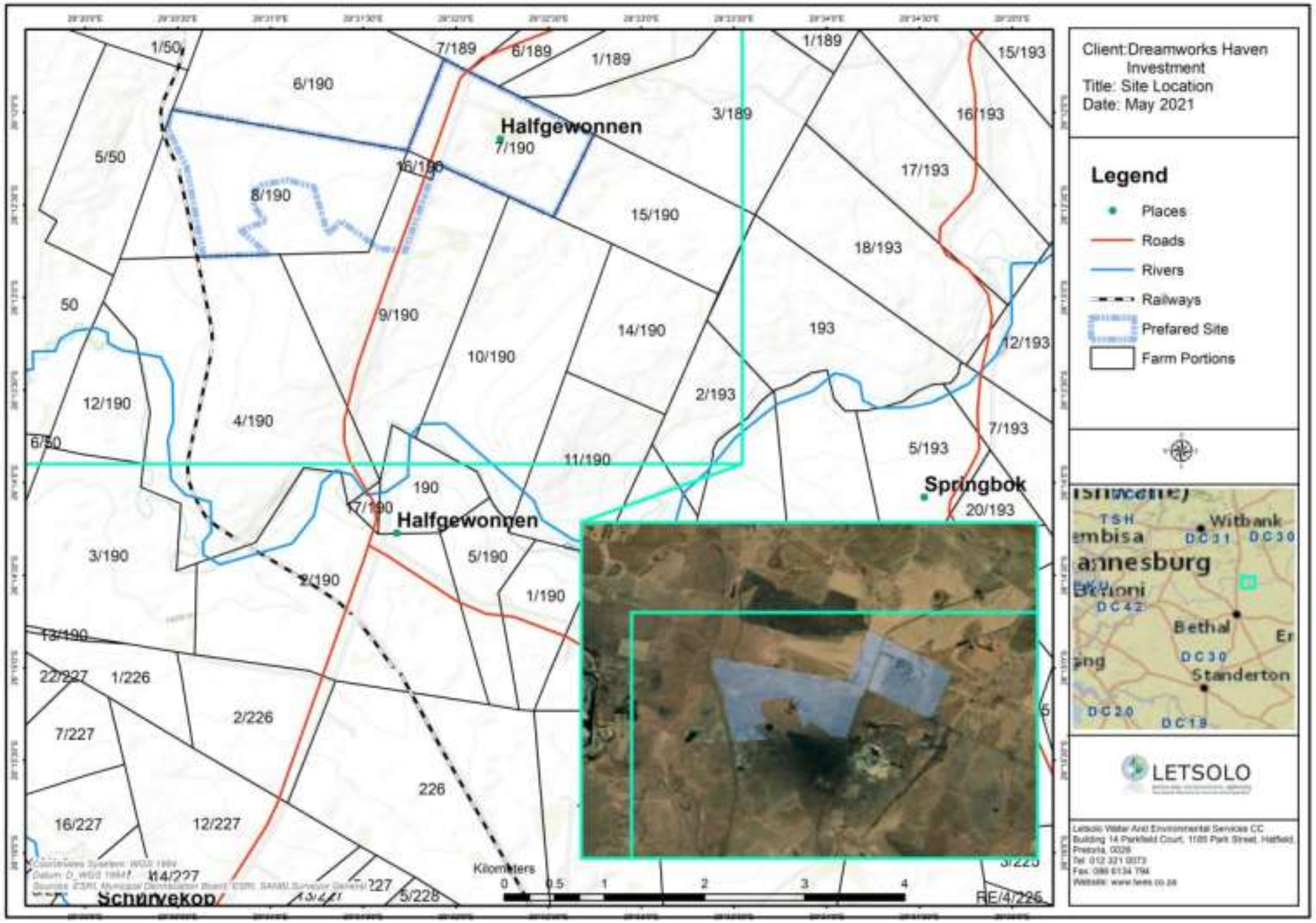

Figure 1-1: Site Location Map

1.4. Specialist Expertise

(a) Details of the specialist who prepared the report.

Details of the specialist who prepared this report are summarised as follows:

Surname	: Phalane
First Names	: Ishmael Letsolo
Specialty	: Hydrology
Entity	: Letsolo Water and Environmental Services
NQF Level 5	: Baccalaureus Technologiae: Civil Engineering
Professional Registration	: Engineering Council of South Africa Reg No. 201480763
	: Water Institute of South Africa
	: Institute of Directors of South Africa

(b) The expertise of the specialist to compile a specialist report including a curriculum vitae can be summarised as follows.

Mr Phalane has more than 19 years' experience in the field of Hydrological Engineering (Hydraulics, Water Quality and Quantity). Over the years Mr Phalane gained valuable experience in the implementation of the National Water Act, 1998 (Act 36 of 1998), National Water Resource Strategy, implementation of the General Authorizations as well as Water Use License Authorizations.

Mr Phalane has extensive experience in Hydrological Impact Assessment for Environmental Impact Assessments (EIA's), Environmental Management Program Reports (EMPR's), Site Management Plans, Water Balance Calculations, Mine Closure Applications and Water Conservation/Demand Management Principles.

Mr Phalane was appointed as a Technical Manager by the Department of Water and Sanitation (DWS) during the Revision of Government Notice 704 (GN704) for the period starting on the 10th of January 2013 and ending on the 31st of December 2013.

Mr Phalane was also part of the technical team assessing the Water Use License Applications on behalf of the Department of Water and Sanitation (Letsema Backlog Project). Specifically, to review Storm Water Management Plans (SWMP), Hydrological Impact Assessment Reports (HIAR), Water Quality Management Reports (WQMR), Integrated Water and Waste Management Plans (IWWMP) and Section 27 Water Use Motivations. Mr Phalane also compiled the Record of Recommendation to be considered and approved by the Director General (DWS), on behalf of the Regional Director (DWS) (01 April 2013 – 31 March 2014).

Mr Phalane was part of the negotiation team during the transfer of Sand-Vet Government Water Scheme to Sand Vet Water User Association in 2001. In the field of Civil Engineering

Mr Phalane gained valuable experience in calculation and analysis of hydrological data and liaison with different organizations in the private, governmental and international sectors, through negotiations with Irrigation Boards. He is practical and has the ability to, logically and strategically, resolve a problem and to work under pressure of a deadline.

As a director, Mr Phalane is involved in strategic decision making in line with the company's vision, mission and values to ensure long term sustainability of the company during the recession time and beyond by being competitive, by developing staff as well as personal development in top management.

1.5. Declaration of Independence:

I, Ishmael Phalane, act as the independent specialist in the environmental impact assessment processes for the proposed Halfgewonnen Solar PV Project. I will perform the work relating to the applications in an objective manner, even if this results in views and findings that are not favourable to the applicant.

I declare that there are no circumstances that may compromise my objectivity in performing such work. I have expertise in conducting the Hydrological Impact Assessment specialist study and report relevant to the environmental authorisation applications. I confirm that I have knowledge of the relevant environmental Acts, Regulations and Guidelines that have relevance to the proposed activity and my field of expertise and will comply with the requirements therein.

I undertake to disclose to the applicant, environmental assessment practitioner and the competent authority all material information in my possession that reasonably has, or may have, the potential of influencing any decision to be taken with respect to the application by the competent authority; and

the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;

All particulars furnished by me in this report are true and correct. I realise that a false declaration is an offence in terms of the National Environmental Management Act, 107 of 1998 (NEMA) and is punishable in terms of the Act.

Name of the specialist: Ishmael Phalane

Name of company: Letsolo Water and Environmental Services cc

Date: 06 July 2021

2. LEGAL FRAMEWORK

This section contains the national requirements related only to Hydrological specialist field.

2.1. South African Legal Framework

For this Hydrological Assessment, the Acts of relevance are The National Water Act, 1998 (Act 36 of 1998) (NWA) as well as The National Environmental Management Act (NEMA, Act No. 107 of 1998).

The NWA provides for the protection, usage, development, conservation, management and control of the country's water resources in an integrated manner. The Act provides the legal basis, upon which to develop tools and means to give effect to the protection of water resources.

NEMA provides a set of environmental management principles that apply throughout South Africa for activities that may significantly affect the environment.

3. SCOPE OF WORK

The Scope of work for the Hydrological Assessment Report allows for the following:

- To evaluate the physical hydrological conditions for DWS Quaternary Catchment B11A and its larger surrounding areas;
- To evaluate the physical hydrological conditions for delineated site-specific catchment areas;
- To propose management and mitigating measures that will ensure that the natural environment is preserved and protected as far as possible;
- Determine the current status of any surface water resources which are in the affected area or may be affected by the activities in terms of existing resource objectives, inclusive of water quality and in-stream flow;
- Water Quality Monitoring;
- Water and Salt Balance Calculations.

4. METHODOLOGY

The following sub-sections provide a description of the methodologies used for:

- Field investigation.
- Hydrological calculations.
- Catchment delineation
- Impact Assessment.
- Water and Salt Balance.
- Surface Water Quality Monitoring.
- Floodline Delineation.

4.1. Methodology for field investigations

The site visit was conducted on 16 and 17 February 2021 to gain a general understanding of site conditions and the hydrology of the study area. General weather conditions during the site visits were as follows:

Warm; partly cloudy; Dry on 16 February 2021 but precipitation with mild wind blowing on 17 February 2021.

4.2. Methodology for flood calculations

Flood calculation methods were applied for the calculation of peak flows and volume as well as to determine if the proposed development will require stormwater management facilities to manage the change in hydrological yield. The common Hydrological Method applied was the Rational Method. This method is highly dependent of field observations data. To determine the flood volumes following the rational method the following needs were considered:

- Run-off coefficient;
- Slope;
- Vegetation; and
- Permeability.

The Rational method was selected as the most reliable method for site specific flood calculations, based on the size of the catchment as well as the reliability of input data. The Rational method is based on a simplified representation of the law of conservation of mass. Rainfall intensity is an important input in the calculations, because uniform aerial and time distributions of rainfall must be assumed.

The 1085 method was used to calculate the slope for overland flow pathway. This method (10% and 85% of the hydraulic length) determines the height difference which is refers to the difference between elevation height at 10% and 85% of the length of the watercourse. Since there is no defined watercourse at the infrastructure area, this length was determined by measuring the length from the centroid of the study are to the lowest point (point of discharge). This height difference is then divided by the length of the watercourse to determine the 1085 slope.

4.3. Methodology for Catchment Delineation

Geographical Information System Software Package, Global Mapper Version 18, was used to delineate catchments. This was achieved by producing Digital Elevation Maps (DEM) form topographical survey data. DEMs are mainly used in water resources projects to identify drainage features such as ridges, valley bottoms, channel networks, surface drainage patterns, and to quantify sub catchment and channel properties such as size, length, and slope.

The accuracy of this topographic information is a function both of the quality and resolution of the DEM, and of the DEM processing algorithms used to extract this information. Watershed delineation is one of the most performed activities in hydrologic analyses. DEM for the study area provided good terrain representation from which watersheds were derived automatically using GIS technology.

With Global Mapper, Terrain processing uses DEM to satisfy the surface drainage pattern. Once preprocessed, the DEM and its derivatives were used for efficient watershed delineation and stream network generation.

4.4. Methodology for Impact Rating

An aspect and impact matrix were used to assist in identifying potential interactions between environmental and social receptors and proposed project activities. Where interactions were deemed likely, the interactions were further rated to determine if impacts could potentially be created which should be further investigated. The matrix made provision for the identification of potential interactions starting from the construction to the post closure phase of the project (either positive or negative).
To ensure consistency, Similar Impact Rating Definitions were applied for current and future activities.

4.4.1. Impact Rating Definitions

Likelihood, duration, extent, magnitude, sensitivity and significant ratings should be based on the following scoring scheme:

Table 4-1: Likelihood:

1 = Unlikely	**2 = Possible**	**3 = Likely**	**4 = Definite Likelihood**
Low probability of occurrence with the implementation of management measures	Possible that impact may occur from time to time	Distinct possibility that impacts will occur if not managed and monitored	Impacts will occur even with the implementation of management measures

Table 4-2: Duration:

1 = Short term	**2 = Medium Term**	**3 = Long Term**	**4 = Permanent**
Possible to immediately or within a short period of time mitigate / immediate or fairly quick progress with management implementation <3 yrs	Impacts reversible	Impacts will only cease after the operational life +/- 5 yrs	Long term, or irreplaceable

Table 4-3: Extent:

1 = Localised	2 = Confined to site	3 = Wider area of Influence	4 = National / International
Localised to specific area of activities	Confined to the site	The extent of the impacts will affect the wider area of Influence	Importance of the impact is of provincial or national importance

Table 4-4: Magnitude:

1 = Low	2 = Minor	3 = Moderate	4 = High
Minor deterioration Nuisance Will not cause any hydrological change to the value or function of the receptor	Moderate deterioration of a water resource a	Reversible although substantial and notable deterioration of a water resource but does not fundamentally affect its overall viability	Mainly irreversible Causes a significant change in hydrological patterns affecting the viability, value and function of the receptors.

Table 4-5: Sensitivity:

1 = Low	2 = Moderate Low	3 = Moderate	4 = High
Areas already subjected to significant degradation Non-sensitive receptor	Partially degraded area Sensitive receptors present Small number of vulnerable communities present	Regionally designated sites. Moderately sensitive receptor with regard to the impact type	Nationally or internationally designated sites. High sensitivity with regard to the impact type High dependency on water resource.

Table 4-6: Significance

		Likelihood + duration + extent + sensitivity			
		Low (+ / -) ≤4	Minor (+/ -) 5 – 8	Moderate (+ / -) 9 – 12	High (+ / -) 13 – 16
Magnitude	Low (1)	Not significant	Not significant	Minor	Moderate
	Minor (2)	Not significant	Minor	Minor	Moderate
	Moderate (3)	Minor	Moderate	Moderate	High
	High (4)	Moderate	High	High	High

4.5. Methodology for Water and Salt Balance

Natural water flows within the catchment were calculated and interpolated to quantify site specific quantities using excel spreadsheet. Once all the water volume data was assessed and confirmed, by the mathematical equations, water quality was then introduced to the spreadsheet calculations. Water quality data was sorted for each unit with water quality monitoring data.

It is important to note that with Salt loads calculations, the monitoring point with the poorest water quality data may not necessarily reflect the worst salt loads. Another determining factor is the volumes concerned.

The same basic principles for the water balance are applicable to the salt balance, i.e. the conservation of mass across a system:

Total salt load in = Total salt load out

where:

Salt load (kg/day) = Flow (m^3/annum) x Salt concentration (mg/l)

The mg/l was converted to kg/m^3.

4.6. Methodology for Water Quality Monitoring

Internationally recognized Water Quality Monitoring methodology was applied for the study area. It is especially important to ensure that each sample bottle is correctly identifiable, filled accordingly and does not leak.

4.6.1. **Sampling Methods and Guidelines**

Samples were collected and preserved on site to ensure that the samples are maintained in a condition representative of their in-situ state. The sampling and sample preservation was undertaken according to the following guidelines: -

- SABS ISO 5667-2: 1991 Guidance on sampling techniques; and
- SABS ISO 5667-3: 1994 Guidance on the preservation and handling of samples.

4.6.2. **Sample bottling and labelling**

All samples were collected utilizing sterilized bottles. Before a sample can be collected, a prescribed sampling bottle was labeled in correspondence with the monitoring point from which sampling will take place. The bottle was then rinsed at least three times with water to be sampled, before it is filled. Sampling date and time was also recorded on each sample bottle

4.6.3. **Sample collection, field measurements, storage and transportation measurements**

After samples have been collected, sampling bottles were stored in a cooler box at a temperature below 4^0C and then transported to the Laboratory within 48 hours of sampling for screening.

The location of points were digitised using a handheld GPS for the location (x:y) as well as elevation (z).

The following field parameters were recorded on site; pH; electrical conductivity (EC), total dissolved solids (TDS) and temperature.

4.6.4. **Instruments**

Field instruments that were used are as follows:

- Bailer to collect the sample,
- Cooler box for preserving samples
- GPS and Camera

4.6.5. **Analyses**

Quaternary catchment B11A activities were considered for the selection of water quality parameters. The main activities in the catchment are coal mining, power generation and diversified farming (beans, potatoes, and maize). To determine if there are impacts from these catchment activities, physical and chemical water quality parameters were monitored. During the operational phase, the desired water parameters of concern will be physical parameters. Detailed chemical (same as the ones analysed in this report) and biological parameters like E-Coliforms and F-Coliforms could be considered if on-site water sources like boreholes will be considered. The parameters monitored are as follows:

- Physical parameters

- pH - Value at 25°C
- Electrical Conductivity in mS/m at 25°C
- Total Dissolved Solids at 180°C *

- Chemical and metals
  - Total Alkalinity as $CaCO_3$
  - Chloride as Cl
  - Sulphate as SO_4
  - Nitrate (NO_3)
  - Ammonium (NH_4)
  - Ammonia (NH_3)
  - Ortho Phosphate as P
  - Fluoride as F
  - Calcium as Ca
  - Magnesium as Mg
  - Sodium as Na
  - Potassium as K
  - Aluminium as Al
  - Iron as Fe
  - Manganese as Mn
  - Zinc as Zn
  - Total Hardness as $CaCO_3$ *

4.7. Methodology for Floodline Delineation

The public domain and internationally accepted software package HEC-RAS developed by the US Army Corps of Engineers was used to hydraulically model Olifants river system. The system consists of three components i.e. flow data, geometric data and simulation options.

The procedure involved the following:

- Estimation of the catchment area;
- Flood Peaks analysis was undertaken to determine the 1:100 year recurrence interval flood peaks for the effective catchment;
- The flood peaks and cross sections derived from contours of the study area were used as inputs to the HEC RAs backwater programme to determine the surface water elevations for the 1:100 year floods peaks; and
- The Floodlines were plotted on a layout map.

5. STATUS QUO

5.1. Climate

As indicated in Table 5-1 below, four meteorological stations are available within quaternary catchment B11A. Due to the close proximity to site, station B1E004 (Rietfontein) was selected as a reliable station for historic data.

Table 5-1: Meteorological stations

Station No	Place	Latitude	Longitude
B1E001	Witbank @ Witbank Dam	-25.88806	29.29973
B1E002	Rondevalley	-25.92556	29.69141
B1E003	Rondebosch @ Middelburg Dam	-25.77557	29.54557
B1E004	Rietfontein	-26.35775	29.21639

5.1.1. Rainfall data

Mean Annual Precipitation (MAP) is representative of the average rainfall that occurs over an area during any given year. This rainfall is obtained by taking the total rainfall received over time at a specific point including any extreme periods and/or events and averaging it. According to the rainfall data available the average annual rainfall for the study area is 718.1mm.

5.1.2. Evaporation data

As in the case of rainfall and runoff it is also necessary to analyze the Mean Annual Evaporation (MAE). Data for Evaporation is measured at dams and mostly stations that are operated by DWS; these stations provide such data. Gross annual evaporation 'A' pan evaporation for the study area is 1934.7mm/a. Table 5.2 below provides details on the Rainfall and Evaporation data for the study area.

Table 5-2: Rainfall and Evaporation Data (REF – DWS Hydrological Information System)

Month	Rainfall (mm)	Evaporation (mm)
October	97.6	198.4
November	122.3	202.4
December	134.4	204.6
January	108.7	207.1
February	81.5	178.3
March	80.9	165.6
April	38	135.7
May	11.1	122.1
June	8.7	91.5
July	2.2	105.1
August	9	141.1
September	23.7	182.8
Annual	**718.1**	**1934.7**

6. SENSITIVITIES

The area of influence in hydrological terms was assessed for 3tiers as follows:

- Tier 1 - Olifants Water Management Area;
- Tier 2 - B11A DWS Quaternary Catchment Area ;
- Tier 3 - Site Delineated Catchment Areas.

6.1. Water Management Area

The proposed solar PV facility falls within the Olifants Water Management Area 2 (WMA 2). The WMA 2 lies in the north-eastern part of South Africa (*National Water Resources Strategy*, 2016). The Water Management Area hosts four (4) major rivers, namely the Elands, Wilge, Steelport and Olifants. The proposed site falls within the Olifants River Basin.

6.2. Quaternary Catchment Area

A catchment or water shed is derived from the topographical landscape. It is sectioned by a water divide, a high land separating two or more water systems. A quaternary catchment is the land and water surface area that contributes to the discharge at the system outlet. The PV facility falls in the B11A quaternary drainage region. Based on the data collected at Meteorological station B1E004, The quaternary catchment B11A has the Mean Annual Runoff (MAR) is 38.9 mm and the MAP is 718.1 mm.

6.3. Site Delineated Catchments

The site delineated catchments layer is a multiple polygon layer that defines hydrologically accurate drainage areas of how stormwater is routed through the study area and discharged to the receiving water resource. A catchment can either be discrete (draining to a single discharge point) or distributed (draining via multiple discharges, and/or non-concentrated or sheet flow discharge). For the study area, the three delineated catchments are discrete catchments.

Delineation of these catchment boundaries was achieved using survey data as well as regional spatial datasets, primary drainages were linked to the receiving waters (Olifants River) to which they drain. These primary drainages were then subdivided into smaller secondary sub-drainage areas. Finally, these sub-drainage areas are divided into manageably sized catchments.

6.4. Hydrological Calculations

The hydrological characteristics of the delineated catchments are summarised as in Table 6-1 below.

Table 6-1: Site delineated catchments

Description	Surface area (Km^2)	Hydraulic Length (km)	Change in Height (m)	1:50 Years Peak Flow (m^3/s)	1:50 Years Peak Flow (m^3/s)
Catchment 1	80.4	18.71	118	256.89	327.48
Catchment 2	453	55.381	170	549.26	700.19

The proposed solar PV Facility is in Catchment 1 and 2. The hydrological characteristics of Catchment 1 are summarised as follows:

Catchment characteristics:

- Area of catchment = 80.4 km^2
- Length of longest watercourse = 18.71 km
- 1085 height difference = 118 m
- Average slope = 0.0084 m/m

Drainage basin characteristics:

- Mean annual daily max rain = 58 mm
- Days on which thunder was heard = 20 days
- Basin mean annual precipitation = 630 mm
- Basin mean annual evaporation = 1600 mm
- Basin evaporation index MAE/MAP = 2.54

Peak Flow

- 1 in 50 years = 256.89m^3/s
- 1 in 100 = 327.48m^3/s

The hydrological characteristics of Catchment 2 are summarised as follows:

Catchment characteristics:

- Area of catchment = 453 km^2
- Length of longest watercourse = 55.381 km
- 1085 height difference = 170 m
- Average slope = 0.0041 m/m

Drainage basin characteristics:

- Mean annual daily max rain = 58 mm
- Days on which thunder was heard = 20 days
- Basin mean annual precipitation = 630 mm
- Basin mean annual evaporation = 1600 mm
- Basin evaporation index MAE/MAP = 2.54

Peak Flow

- 1 in 50 years = 549.26 m^3/s
- 1 in 100 years = 700.19 m^3/s

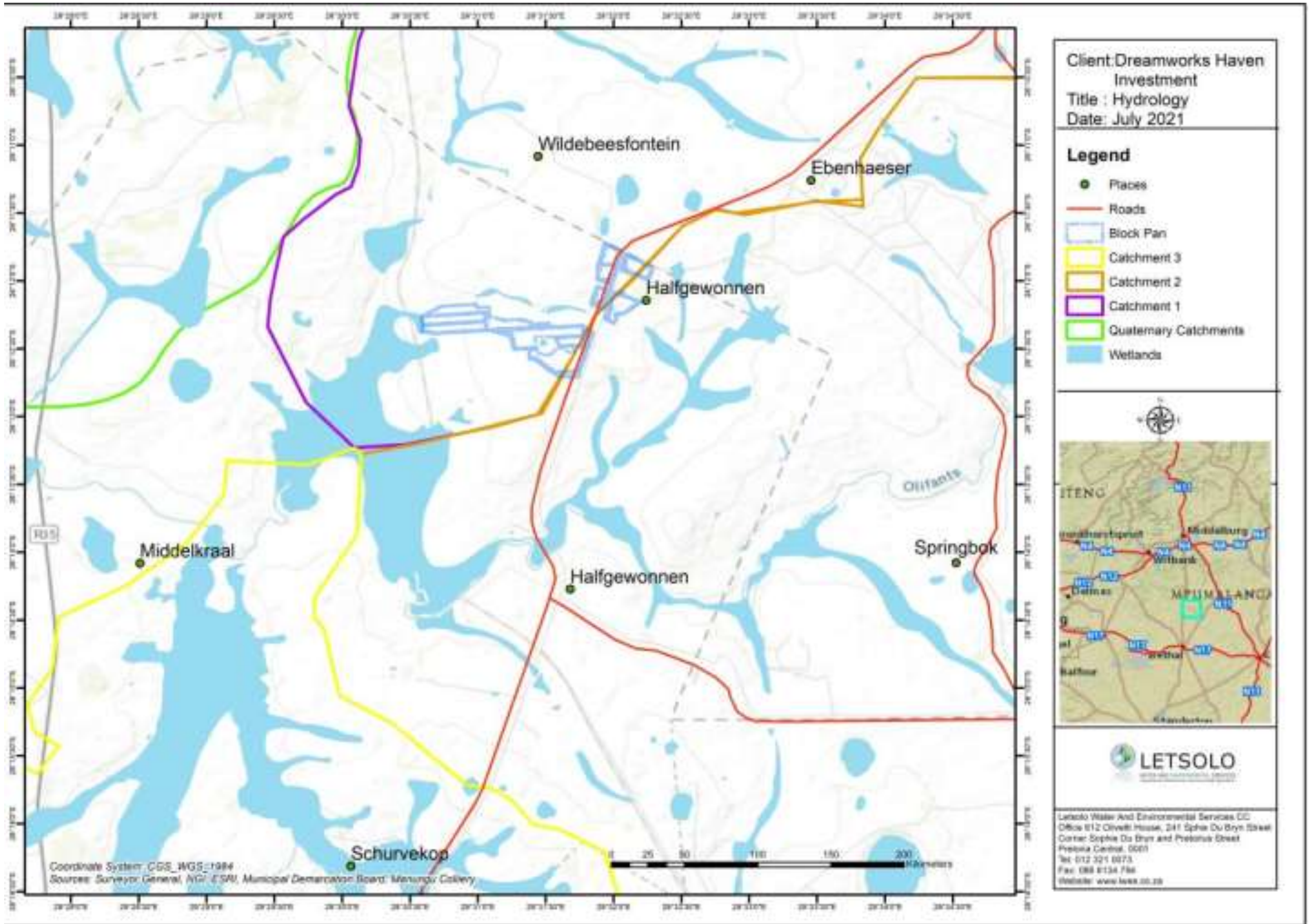

Figure 6-1: DWS Quaternary Catchments and Site Delineated Catchment

7. STORM WATER MANAGEMENT PLAN

Storm-water management practices are generally implemented to reverse the effects of land-cover changes that cause increases in volumes and rates of runoff. This is a concern posed for new types of land-cover change such as the solar PV Facility. Because solar farms require considerable surface area, it is necessary to understand the design of solar farms and their potential effect on erosion rates and storm runoff, especially the impact on offsite properties and receiving streams.

The solar panels are impervious to rain water; however, they are mounted on metal rods and placed over pervious land. In some cases, the area below the panel is paved or covered with gravel. Service roads are generally located between rows of panels.

The issue posed is whether these rows of impervious panels will change the runoff characteristics of the site, specifically increase runoff volumes or peak discharge rates. If the increases are hydrologically significant, storm-water management facilities will be needed.

Additionally, it is possible that the velocity of water draining from the edge of the panels is sufficient to cause erosion of the soil below the panels, especially where the maintenance roadways are bare ground.

7.1. *Flood Calculations*

7.1.1. Storm Magnitude

The effect of storm magnitude was investigated by calculating the 50- and 100-years storm events. The runoff from the panelled watershed condition increased compared to the pre panelled condition. This increase represents increase in flood volume. The peak discharge and the time to peak did not change significantly.

7.1.2. Ground slope

The natural slope for pre and post development phase is 0.07595m/m. The angle of the solar panels would influence the velocity of flows from the panels. As the ground slope was increased, the velocity of flow over the ground surface would be closer to that on the panels. This could cause an overall increase in discharge rates. The ground slope was changed from 1 to 5%, with all other conditions remaining the same as the base conditions.

7.1.3. Storm Duration

To assess the effect of storm duration, analyses were made for 50 and 100-year return periods, with the results compared with those for the 24-h rainfall events. The longer storm duration could produce a different ratio of increase in runoff between the pre panelled and panelled conditions. When comparing the pre panelled to the panelled condition, the increase in the runoff volume was almost doubled regardless of the return period. The peak discharge and the time-to-peak did not differ significantly between the two conditions.

7.1.4. Ground Cover

The ground cover under the panels was assumed to be a native grass that received little maintenance. For some solar farms, the area beneath the panel is covered in gravel or partially paved because the panels prevent the grass from receiving sunlight.

Thus, it was necessary to determine whether these alternative ground-cover conditions would affect the runoff characteristics. This was accomplished by changing the Manning's n for the ground beneath the panels.

7.1.5. Pre-development hydrological calculations

The pre-development hydrological characteristics for the solar farm area are summarised as follows:

Area of catchment	= 3.4 km²
Dolomitic area	= 0.0 %
Length of longest watercourse	= 0.79 km
Flow of water	= Overland flow
Height difference	= 60.0 m
Value of r for over land flow	= Moderate grass (r=0,4)
Rainfall region	= Inland
Average slope	= 0.07595 m/m
Time of concentration	= 38.6 min
Run-off factor	
Combined - C	= 0.462
Peak Flow (1:50 years)	= 51.68m³/s
Peak Flow (1 in 100 years)	=66.78m³/s

Please refer to Table 7-1 for details.

Table 7-1: Pre-development flood calculations

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:2	0.64	29.4	99.6	45.4	0.75	34.7	14.86
1:5	0.64	40.0	99.4	61.8	0.80	37.0	21.56
1:10	0.64	50.6	99.3	78.0	0.85	39.3	28.94
1:20	0.64	62.5	99.1	96.2	0.90	41.6	37.77
1:50	0.64	81.2	98.8	124.7	0.95	43.9	51.68
1:100	0.64	100.0	98.6	153.0	1.00	46.2	66.78

7.1.6. Post-development hydrological calculations

The post-development hydrological characteristics for the solar farm area are summarised as follows:

Area of catchment = 3.4 km²
Mean annual rainfall (MAR) = 718.00 mm
Length of longest watercourse = 0.79 km
Flow of water = Overland flow
Height difference = 60.0 m
Value of r for over land flow = Paved area (r=0,02)
Rainfall region = Inland
Average slope = 0.07595 m/m
Time of concentration = 9.5 min
Run-off factor
Combined - C = 0.590
Peak Flow (1:50 years) = 137.33m³/s
Peak Flow (1 in 100 years) = 169.66m³/s

Please refer to Table 7-2 for details.

Table 7-2: Post development hydrological calculations

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:2	0.16	14.6	99.2	91.3	0.75	56.3	48.53
1:5	0.16	19.9	98.8	123.9	0.80	56.8	66.51
1:10	0.16	25.2	98.5	156.3	0.85	57.4	84.73
1:20	0.16	31.1	98.2	192.4	0.90	57.9	105.23
1:50	0.16	40.5	97.7	248.7	0.95	58.5	137.33
1:100	0.16	49.8	97.1	304.4	1.00	59.0	169.66

7.1.7. **Findings**

The panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. Some of the runoff infiltrates. If the grass cover of a solar farm is not maintained, it can deteriorate either because of a lack of sunlight or maintenance vehicle traffic. In this case, the runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts (see calculations in Table 7-3 below).

Table 7-3: Pre and Post Development comparison

Return Period	Tc (Hours)	Peak flow (m3/s)
1: 50 Pre-development	0.64	51.68
1: 50 Post-development	0.64	137.33

Return Period	Tc (Hours)	Peak flow (m3/s)
1:100 Pre-development	0.16	66.78
1: 100 Post-development	0.16	169.66

In addition, if gravel or pavement is placed underneath the panels, this can also contribute to a significant increase in the hydrologic response.

7.1.8. **Detention basin**

If bare ground is foreseen to be a problem or gravel is to be placed under the panels to prevent erosion, it is necessary to counteract the excess runoff using some form of storm-water management.

A simple practice that can be implemented is a buffer strip in a form of a contour berm at 10m height difference. These can be constructed from the infrastructure area to the downgradient end of the PV facility. This buffer will assist to maintain vegetation to control soil erosion and physical water quality parameters. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed.

Alternatively, a detention basin can be installed.

8. PRE-DEVELOPMENT SALT BALANCE

8.1. *Salt Balance (SB)*

The key requirements for the SB are average water quality of selected variables and the Mean Annual Runoff (MAR). 3 in stream monitoring points were selected for the calculations of salt loads. The selected points are summarized in the Table 8-1 and Figure 8-1 below.

Table 8-1: Surface water quality points considered for calculations.

Monitoring Point Identity	Description	Longitude	Latitude
SH 6	Tributary of Leeufonteinspruit north of block 8.	260 12' 15.88"	290 30' 31.87"
SH 7	Leeufonteinspruit upstream of block 8.	260 12' 00.57"	290 30' 17.67"
SH 8	Leeufonteinspruit downstream of block 8.	260 12' 44.85"	290 30' 00.86"

8.2. *Average Water Quality*

Historical water quality data is for a period commencing on January 2018 and ending in June 2019 (see Table 8-2). Average monthly data for the 18 months period was calculated and used for the SB. The selected variables for the salt load calculations are Total Dissolved Solids, Chloride, Sulphate and Sodium.

Table 8-2: Average Water Quality Data (Jan 2018 to June 2019)

Average Data (January 2018 to July 2019)				
Analyte Name (mg/l)	Total Dissolved Solids	Chloride as Cl	Sulphate as SO_4	Sodium as Na
Sh 6	81	13	21	14
Sh 7	132	22	21	24
Sh 8	240	21	91	27

8.3. *Mean Annual Runoff*

Letsolo Water adopts a holistic approach and methodology whereby WR2005 quaternary catchment runoff data is downscaled to site specific runoff data by making use of area and volume relationships as well as a rainfall reduction factor. The formula assumes uniform catchment characteristics as far as possible. A rainfall reduction factor which compares quaternary catchment rainfall (according to WR2005) with site specific rainfall (according to DRUP) is applied to quaternary catchment runoff (according to WR2005) to ultimately obtain site specific runoff (thus also according to WR2005 data).

The Mean Annual Runoff (MAR) calculations are dependent on the surface area. Runoff figures were analysed statistically in a similar manner as rainfall. The MAR for the study area was sourced from the Water Research Commission database (WR2005). As presented in Table 8-3 below, the MAR was calculated based on the catchment surface area as well as the Catchment MAR of 38.9mm per annum.

Table 8-3: Effective Catchment areas and MAR Calculations

Description	Area (m^2)	Mean Annual Runoff (mm/a)	Mean Annual Runoff (m^3/a)
Effective area at SH 6	2690834	38.9	104673
Effective area at SH 7	4748096	38.9	184701
Effective area at SH 8	8294940	38.9	322673

8.4. *Salt Load findings*

Because there is no interlink between the Olifants River at SH2 and the Leeufonteinspruit, two separate systems were assessed, and the findings are as follows (Table 8-3, Figures 8-2 and 8-3 :

- Leeufonteinsprui
  - SH8, which is located downstream of the confluence of SH 6 and SH7, contributes 71% of the salt loads. Followed by SH 7 at 21% and SH6 at 8%.
  - TDS contributes 64% of loads followed by Sulphates (21%), then Sodium and Chlorides at 8% and 7%, respectively.

Table 8-4: Salt loads calculations

Monitoring Point	MAR (m3/a)	Total Dissolved Solids	Chlorides as Cl	Sulphate as SO_4	Sodium as Na	Total Salts (kg/a)	Total Salts (kg/month)
SH 6	104673	8528	1353	2212	1486	13579	754
SH 7	184701	24381	3990	3849	4360	36579	2032
SH 8	322673	77543	6632	29496	8634	122305	6795
	Leeufonteinspruit Salt Loads	110452	11974	35557	14480	172463	9581

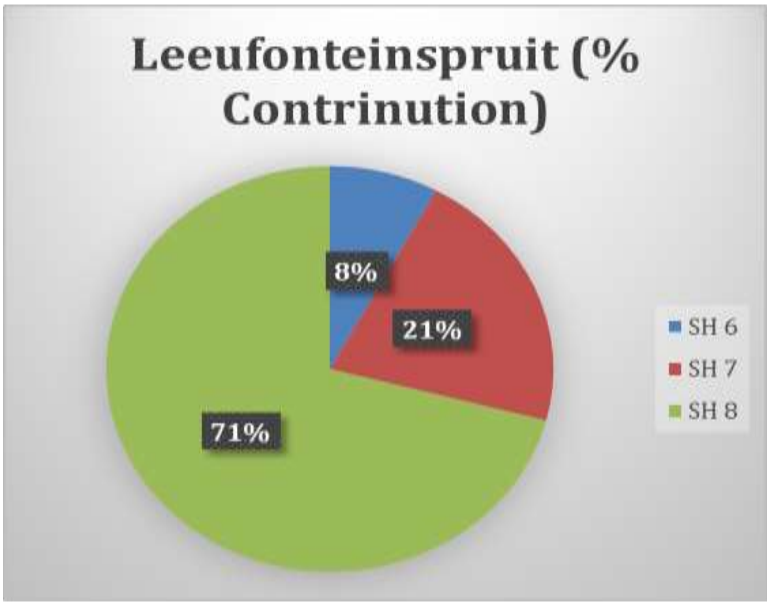

Figure 8-1: Salt loads at monitoring points

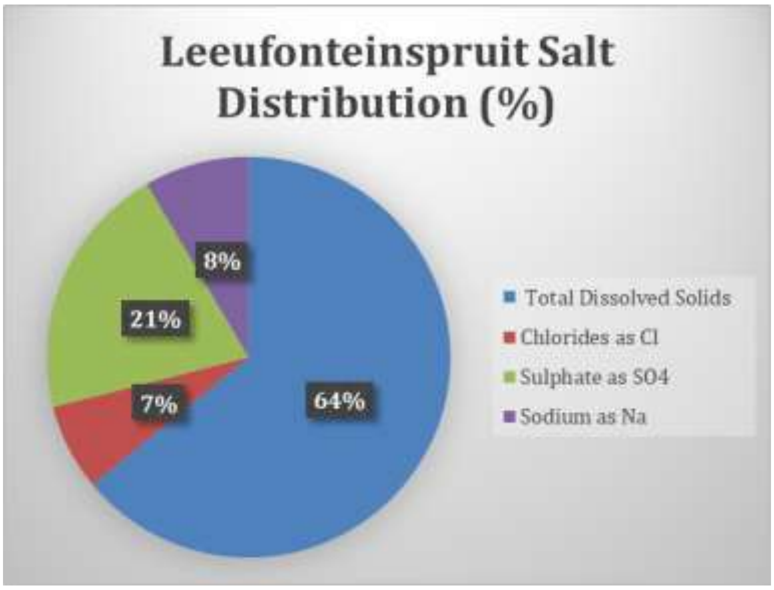

Figure 8-2: Salt Distribution (%)

9. FEBRUARY 2021 WATER QUALITY MONITORING

Besides catchment cumulative impacts, surface water quality is dependent on natural factors (geological, topographical, meteorological, hydrological, and biological) in the drainage basin and varies with seasonal differences in runoff volumes and weather conditions. It is always advisable to consider historic water quality changes as opposed to once off water quality results.

Key monitoring points were selected and monitored in February 2021 (See **Figure 9-1** and **Table 9-1** below for selected points). Additional samples were collected far upstream (approximately 5km) of the site and far downstream (also approximately 5km) of the site for regional water quality. The following once off water quality samples were collected:

- In-stream water quality samples
    - Olifants upstream
    - SH12-Tributary of Olifants
    - SH2 Olifants at Overlooked Colliery
    - Olifants downstream

Table 9-1: Once off monitoring points

Olifants Upstream

Tributary of Olifants

SH2 at Olifants

Olifants Downstream

9.1. *Field parameters for once off samples*

When samples were collected, in-situ physical parameters were also recorded. The advantage of recording physical parameters on site is that should there be any high concentrations for certain indicators; one is still able to conduct field investigations immediately.

Table 9-2: Field Parameters

Monitoring ID	Field Observations				
	Colour	pH	EC (mS/cm)	TDS (ppt)	Temp (˚C)
		5.0 - 9.7	170	1200	-
Olifants upstream	*Light Brown*	*7.73*	*65*	*300*	*21.2*
SH12-Tributary of Olifants	Light Brown	7.76	174	930	20.9
SH2 Olifants @overlooked	Light Brown	7.9	168	700	20.9
Olifants downstream	Light Brown	8.01	63	320	21.2

9.2. *Regional Water Quality*

As stated previously, Regional water quality is affected by a wide range of natural and human influences. The most important of the natural influences for surface water are hydrological and climatic since these affect the quantity and the quality of water available. High water flow was observed at monitoring points on the day of monitoring due to the heavy rains experienced prior to the date of site visit.

Table 9-3: In-stream Water Quality Results

Description	Unit of measurement	Olifants upstream	SH12-Tributary of Olifants	SH2 Olifants @overlooked	Olifants downstream
Sampled date		**16-Feb-21**	**15-Feb-21**	**16-Feb-21**	**16-Feb-21**
pH - Value at 25°C	pH	7.86	7.59	7.8	7.96
Electrical Conductivity in mS/m at 25°C	mS/m	37.6	146	46.8	39.7
Total Dissolved Solids at 180°C *	mg/l	270	1098	324	264
Total Alkalinity as CaCO3	mg CaCO3/l	119	91.3	128	124
Chloride as Cl	mg/l	23.1	1.55	23.2	19.9
Sulphate as SO4	mg/l	46.4	627	74.1	55.4
Nitrate (NO3)	mg/l	0.349	0.219	0.498	0.299
Ammonium (NH4)	mg/l	0.116	0.032	0.049	0.03
Ammonia (NH3)	mg/l	<0.005	<0.005	<0.005	<0.005
Ortho Phosphate as P	mg/l	<0.005	<0.005	<0.005	<0.005
Fluoride as F	mg/l	0.429	<0.263	0.818	0.542
Calcium as Ca	mg/l	23	143	30.4	25.4
Magnesium as Mg	mg/l	14.8	80.7	19.3	15.9
Sodium as Na	mg/l	28.1	49.6	35.4	27.2
Potassium as K	mg/l	11.3	10.3	7.07	9.07
Aluminium as Al	mg/l	0.169	<0.002	0.107	0.145
Iron as Fe	mg/l	0.839	<0.004	0.47	0.359
Manganese as Mn	mg/l	0.02	3.86	0.006	<0.001
Zinc as Zn	mg/l	0.013	0.004	<0.002	<0.002
Suspended Solids at 105°C *	mg CaCO3/l	118	689	155	129
Total Hardness as CaCO3 *	mg/l	72	16	70	53
Temp	°C	21.6	20.8	20.6	20.9

10. POTENTIAL IMPACTS

It is important to determine the environmental and hydrologic effects of the proposed Solar PV Facility. Various sensitivity analyses were conducted including changing the storm duration and volume, soil type, ground slope, panel angle, and ground cover to determine the effect that each of these factors would have on the volumes and peak discharge rates of the runoff.

The addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly but not enough to require storm-water management facilities. However, when the land-cover type was changed under the panels, the hydrologic response changed significantly. When gravel or pavement was placed under the panels, with the spacer section left as patchy grass or bare ground, the volume of the runoff increased significantly and the peak discharge increased.

The potential for erosion of the soil at the base of the solar panels was also studied. It was determined that the kinetic energy of the water draining from the solar panel could be as much as 10 times greater than that of rainfall. Thus, because the energy of the water draining from the panels is much higher, it is very possible that soil below the base of the solar panel could erode owing to the concentrated flow of water off the panel, especially if there is bare ground in the spacer section of the cell. If necessary, erosion control methods should be used.

10.1.1. **Negative Impact**

The identified potential impacts are as follows:

- Erosion/sediment transport: Vegetation protects the surface by restricting the movement of sediments. As vegetation is removed, soil is loosened and this result in a higher potential for sediment transport during storm events.

Table 10-1: Erosion

Impact Component	**Impact 1**	**Significance prior to Mitigation**	**Significance with Mitigation**
Activity	Site preparation and vegetation clearance		
Risk/ Impact	Vegetation clearance for infrastructure can directly impact on sediment transport. Loose particles are erodible.		
Project Phase (during which impact will be applicable) CO = construction, OP = operational, CL = Closure and post-closure Nature of Impact	CO, OP, CL Negative		
Type of Impact	Direct: clearance will directly lead to impact		
	Define Significance Categories	Significance Prior to Mitigation	Significance With Mitigation
Likelihood/ probability	Possible	4	1
Duration	Short Term	2	1
Extent	Site	3	3
Receptor Sensitivity	Moderate	2	2
Magnitude	Moderate	4	2
Impact Significance	Moderate	Moderate 12	Minor 6
Mitigating and Monitoring Requirements			
Required Management Measures	The necessary flood attenuation and erosion control structures have to be put in place		
Required Monitoring (if any)	A maintenance schedule for the vegetation recovery and potential new erosion gullies at steep areas.		
Responsibility for implementation	Environmental Officer and Mine Manager		
Impact Finding			
Impact Finding	Impact can be managed through Erosion Control Measures management programs.		

11. MONITORING AND REPORTING REQUIREMENTS

11.1. Data management and reporting

Effective water quality and water quantity data management is the key to providing consistent, accurate, and defensible data and data products.

11.1.1. Monthly

Surface water samples must be collected monthly. A report summarizing the findings must be produced monthly.

11.1.2. Quarterly

The quarterly report must be produced to summarize the 3 months observations and analysis. This report will be submitted to the authorities to indicate compliance or challenges in relation to water quality changes.

11.1.3. Annually

The annual report must be produced to summarise the 12 months data and must consist of all the active environmental components.

11.1.4. Water Quality Parameters

Based on the nature of the activities, the variables indicated in Table 11-1 below, must be considered as the minimum requirement for water quality analyses.

Table 11-1: Analytical Parameter Schedule Summary

Analyses		Unit
Physio-Chemical Parameters		
- pH	pH	pH unit
- Electrical Conductivity	EC	mS/m
- Total Dissolved Solids	TDS	mg/L
- Total Alkalinity	T-Alk	mg $CaCO_3$/L
Note/s: - mS/m - milli Siemens per metre - mg/L - milli grams per Litre - mg $CaCO_3$/L - milli grams calcium carbonate per Litre		

12. CONCLUSION

This study investigated the hydrologic effects of the proposed project, assessed whether storm-water management might be needed, and if the velocity of the runoff from the panels could be sufficient to cause erosion of the soil below the panels.

Rainwater that drains from the upper panel onto the ground will flow over the land under the panels on the downgradient strip. Depending on the land cover, infiltration losses would be expected as the runoff flows to the bottom of the slope. Runoff in the form of sheet flow without the addition of the solar panels served as the pre panelled condition. The panelled condition assumed a downgradient series of cells with one solar panel per ground cell.

The panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. The runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts (almost doubled).

A simple practice that can be implemented is a buffer strip at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed. Alternatively, a detention basin can be installed.

Because there is no immediate/site interlink between the Olifants River at SH2 and the Leeufonteinspruit, the salt balance assessment was based on the monitoring points located along the Leeufonteinspruit river which is the receiving river system. The findings are as follows ::

- SH8, which is located downstream of the confluence of SH 6 and SH7, contributes 71% of the salt loads. Followed by SH 7 at 21% and SH6 at 8%.
- TDS contributes 64% of loads followed by Sulphates (21%), then Sodium and Chlorides at 8% and 7%, respectively.

13. RECOMMENDATIONS:

13.1. General Recommendations

Reasonable measures as recommended in this report must be implemented in order to reduce the impact on surface water resources. In view of the above conclusions, the following recommendations are made:

- Earth berms should be used for contouring at the buffer strips ;
- Vegetation stripping must be limited to the minimum area required;

- After the operational phase, the topography of all disturbed areas must be rehabilitated, in such a manner that it blends with the surrounding natural area. This will reduce soil erosion and improve natural re-vegetation;

13.2. Erosion control

It is recommended that erosion and silt management be considered carefully and monitored regularly.

14. REFERENCES

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