Leopard Court Building, 1st Floor, South Wing
56 Jerome Street, Lynnwood Glen, Pretoria, South Africa
Tel: +27 (0) 12 348 1114 **Fax:** +27 (0) 12 348 1180 **Web:** www.gcs-sa.biz

Stormwater Management Plan for Block OI (West) at the Leeuwpan Coal Mine

Report

Version - 1

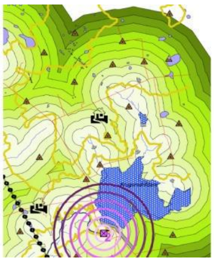
24 June 2019

Exxaro Leeuwpan Coal

GCS Project Number: 19-0545

Client Reference: PO4512331907

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Author	Roxane Schmidt		24 June 2019
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Director	Alkie Marais		24 June 2019

LIST OF ACRONYMS

Acronym	Description
BPG	**Best Practice Guidelines**
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
Exxaro	Exxaro Leeuwpan Coal
EIA	Environmental Impact Assessment
GCS	GCS Water and Environment (Pty) Ltd
GN704	General Notice 704
LoM	Life of Mine
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
m^3/d	Cubic meters per day
m^3	Cubic meters
NWA	National Water Act
SAWS	South African Weather Service
SoW	Scope of Work
SWMP	Stormwater Management Plan
WMA	Water Management Area
WR2012	South African Water Resources 2012 Study
WUL	Water Use Licence

EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was requested by Exxaro Leeuwpan Coal (Exxaro) to conduct an update on the stormwater management plan (SWMP) of pit area Block OI at the existing Leeuwpan Coal Mine within the Delmas Magisterial District in the Mpumalanga Province of South Africa.

The SWMP update was undertaken to fulfil the requirements of the existing Water Use Licence (WUL) for the Leeuwpan Coal Mine and to comply with the requirements of General Notice 704 (GN704) of the South African National Water Act, Act 36 of 1998 (NWA). Due to the increased capacity at the current processing plant, the proposed processing plant at Block OI is no longer required. This area will be mined out and form part of Block OI. The objective of the study was to achieve compliance by proposing a set of measures that will contribute to a sustainable solution of handling stormwater at Block OI and reduce the environmental impact.

A Mean Annual Precipitation (MAP) for the site was reported as 667 mm with a Mean Annual Evaporation (MAE) (Symons Pan) of 1677 mm. Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year.

Information was obtained and observed from the site visit was as follows:

- The current processing plant has been upgraded (increased capacity) and the proposed processing plant at Block OI is no longer required;
- The area where this processing plant was proposed will be mined out and form part of Block OI;
- There will be an approximate one (1) and a half year backfill delay with the Block OI progression;
- There are three (3) RWD located to the west of the workshop area. These RWDs receive pit water from all operational pits including Block OI; and
- There are wetlands and pans surrounding the area.

A phased approach was taken and the SWMP was extended over each phase. Proposed drainage measures for the site include a lined channel (to capture and transport clean water) and existing Suez Canal together with berms around the pit boundaries to divert clean water. Clean water from the clean water catchment are diverted around to ensure that this water does not mix with the dirty water areas.

Recommendations derived from this SWMP study include:

- The water level in the in-pit sumps need to be kept at a safe working water level.
- Water must be pumped from the in-pit sumps to the RWDs, where water can be reused.
- All drains should be cleaned regularly to prevent blockages from siltation and debris.
- Erosion protection measures should be implemented along the channel/ berms and at release points where clean water flows into the environment.

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1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was requested by Exxaro Leeuwpan Coal (Exxaro) to conduct an update on the stormwater management plan (SWMP) of pit area Block OI at the existing Leeuwpan Coal Mine within the Delmas Magisterial District in the Mpumalanga Province of South Africa (Figure 1.1).

The SWMP update was undertaken to fulfil the requirements of the existing Water Use Licence (WUL) for the Leeuwpan Coal Mine and to comply with the requirements of General Notice 704 (GN704) of the South African National Water Act, Act 36 of 1998 (NWA). Due to the increased capacity at the current processing plant, the proposed processing plant at Block OI is no longer required. This area will be mined out and form part of Block OI. The objective of the study was to achieve compliance by proposing a set of measures that will contribute to a sustainable solution of handling stormwater at Block OI and reduce the environmental impact.

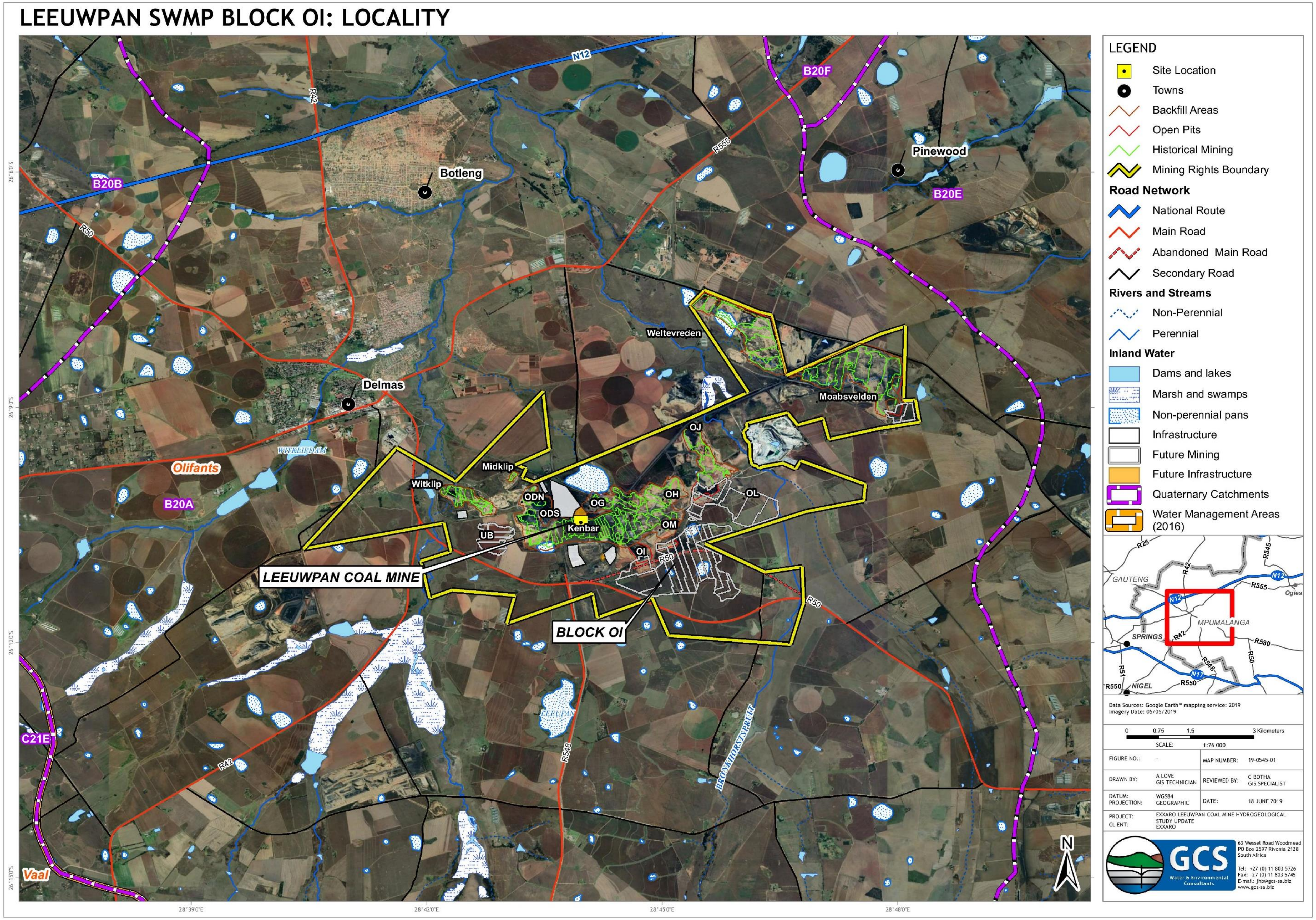


Figure 1.1: Leeuwpan SWMP study site locality.

2 SCOPE OF WORK

The scope of work in order to meet the study objectives is summarised as follows:

1. Information Sourcing/ Literature Review
    - Acquisition and assessment of existing literature; and
    - Legislative and policy frameworks relating to the relevant surface water resource management and WUL;
    - A site visit to visually assess the site in order to establish existing conditions at Block OI; and
    - Collection of relevant information necessary to complete the SWMP.
2. Confirmation of Baseline Hydrology
    - Review of previously investigated hydrology (GCS, 2018).
3. Conceptual Stormwater Management Plan (SWMP)
    - Delineation of clean and dirty water catchments at Block OI;
    - Determination of stormwater flows and volumes for the 1:50 and the 1:100-year return period event for the clean and dirty water catchments;
    - Placement of berms, channels and pumping to Pollution Control Dams (PCD) / return water dams (RWD) as required on-site in line with GN704 of the NWA; and
    - Mapping of water diversion berms, drainage channels and conveyances for stormwater infrastructure at Block OI.
4. Reporting:
    - A summary report describing all the findings of the hydrological assessment of the project area.

3 METHODOLOGY

3.1 Information sourcing / Literature review:

Review of previous hydrological reports for the site and the existing WUL, national legislation and guideline documents that govern water use and management in South Africa. The Department of Water Affairs (now Department of Water and Sanitation (DWS)) Best Practice Guidelines (BPGs), SWMP (DWA, 2006a) was reviewed and adhered to with regards to opencast pits. A site visit was undertaken to visually assess factors that are likely to influence runoff and stormwater on-site at Block OI.

3.2 Confirmation of Baseline Hydrology

Previously investigated hydrology (GCS, 2018) will be confirmed and summarised. If required, baseline hydrology was updated using climate data will be obtained from the South African Weather Service (SAWS) and/or databases of WR2012 (WRC, 2015).

3.3 Conceptual Storm Water Management Plan

The existing SWMP of Leeuwpan Coal Mine at Block OI was reviewed and conceptually updated with the proposed expansion with adherence to the NWA. Catchment delineation was undertaken using topographical survey data.

The plan was generated using PCSWMM software in order to separate areas of clean and dirty water and to contain dirty water on site. Recommendations on how to achieve an efficient and legally-compliant conceptual SWMP were made in writing and visually, using a series of recommended channels, berms and sumps, if necessary.

4 LEGISLATIVE AND POLICY FRAMEWORKS

4.1 The National Water Act (Act No. 36 of 1998)

The National Water Act (NWA), Act 36 of 1998 is the principal legal instrument relating to water resource management in South Africa. As guardian and trustee of the nation's water resources, the Government (specifically the DWS) must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons and in accordance with its constitutional mandate.

Legislation guiding the required SWMP was adopted from the GN704 of the South African NWA, Act 36 of 1998. The GN704 states that clean and dirty water must be separated and dirty water runoff must be stored in a PCD, where reasonable precautions are taken to prevent leaks or seepage.

4.2 Best Practice Guidelines

DWA BPGs G1: Storm Water Management (NWA, 1998 (Act No 36 of 1998), 1999)

The South African DWS (formerly the department of Water Affairs – DWA) Best Practice Guidelines G1: Storm Water Management (DWA, 2006a) states the following general principles:

- Keep clean water clean;
    - Route all clean water in a natural watercourse,
    - Limit the dirty water areas to the smallest area possible,
    - Ensure that the dirty water is kept separate and ensure the dirty water system has a
    - low risk of spillage.
- Collect and contain dirty water;
    - Dirty water should be diverted, collected and contained separate from the clean water system,
    - Containment of dirty water should minimise the impact on the clean water resources.
- Sustainability over mine life cycle;
    - Stormwater measure should to sustainable over the life of mine and over differently
    - hydrological cycles.
    - Consideration of regulations and stakeholders;
    - Consideration and incorporation of stakeholders and regulatory agencies should be taken into account according to the statutory requirements.

These principles were adopted as guidelines when designing the conceptual SWMP in Section 7.

5 SITE INVESTIGATION

A site visit was undertaken on the 11th June 2019 to gain an understanding of the Block OI and surrounding areas and to visually assess the site topography. Relevant areas of the mine (general surroundings and infrastructure) were visited (see Photograph 5.1 to Photograph 5.4).

The following information was obtained and observed:

- The current processing plant has been upgraded (increased capacity) and the proposed processing plant at Block OI is no longer required;
- The area where this processing plant was proposed will be mined out and form part of Block OI;
- There will be an approximate one (1) and a half year backfill delay with the Block OI progression;
- There are three (3) RWD located to the west of the workshop area. These RWDs receive pit water from all operational pits including Block OI pit; and
- There are wetlands and pans surrounding the area.

Photograph 5.1: A view of the new RWD.


Photograph 5.2: A view of the current operations (11/06/2019) in Block OI box cut.


Photograph 5.3: A view of the two pit sumps in Block OI box cut.

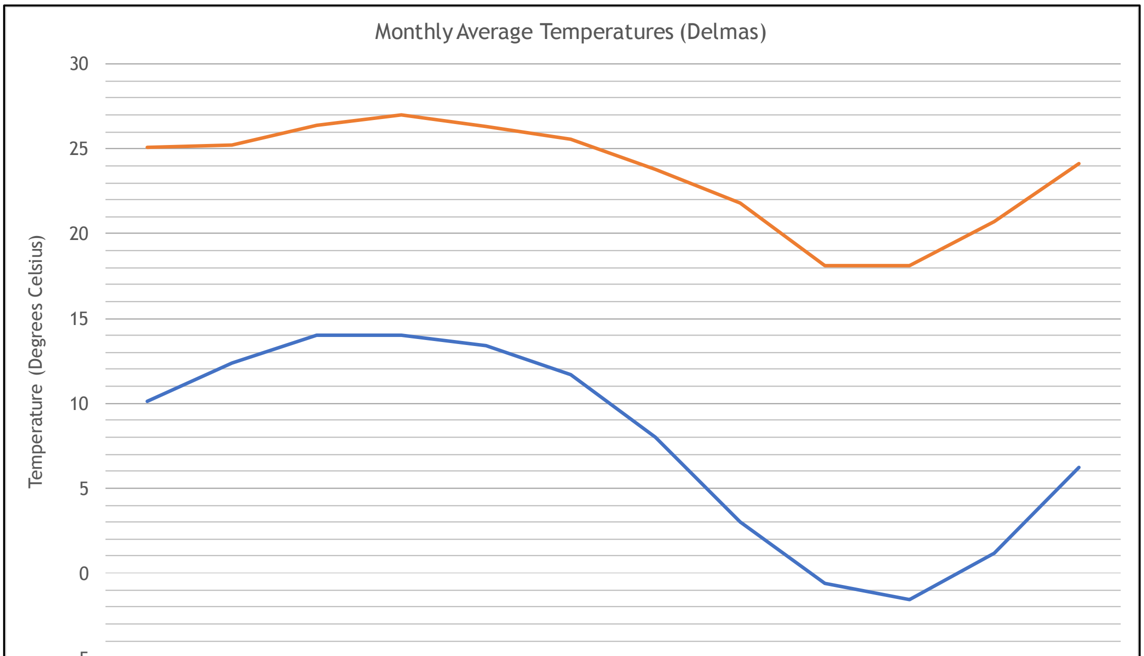
Photograph 5.4: A view of the area where the future Block OI box cut (west) will be located.

6 BASELINE HYDROLOGY

6.1 General Climate

The mine site is located ~8.6 km south east of Delmas in the Mpumalanga Province of South Africa. This site is situated in Quaternary Catchment B20A, Water Management Area (WMA) 4 (Olifants). The Köppen-Geiger classification of the study site is Cwb (Kottek, et al., 2006). This indicates a warm temperate climate with dry winters and warm summers. The vegetation biome that dominates this area is Moist Highveld Grassland (Kruger, 2004). Surrounding land use is agricultural and mining activity.

The mine site is located in a temperate climatic zone of South Africa, which is characterised by warm summers and dry cold winters. Figure 6.1 shows that the area experiences - on average - lowest temperatures in July and is warmest during January (Climate-Data.org, 2012). The monthly average minimum and maximum temperatures recorded in the town of Delmas are 7.7°C and 23.6°C, respectively.



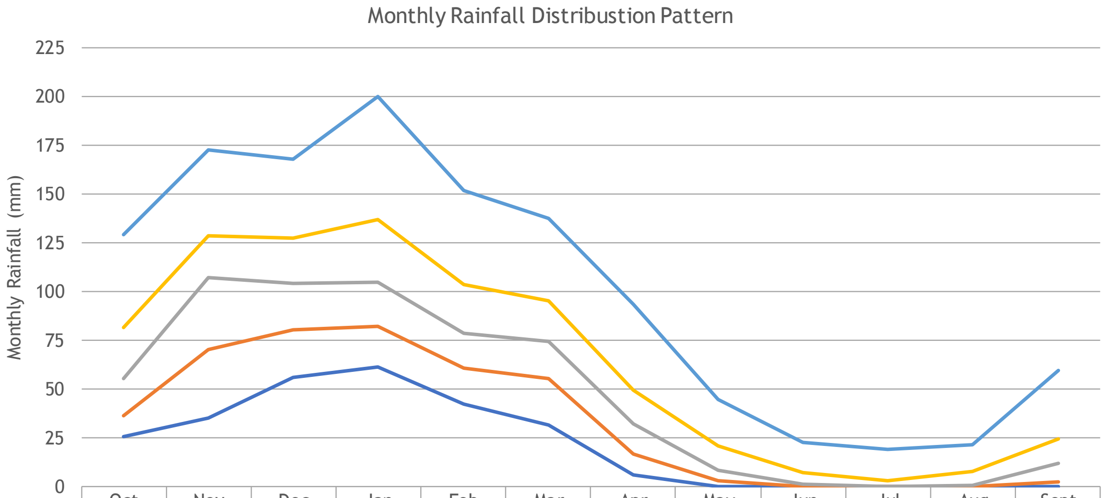
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Min	10.1	12.4	14	14	13.4	11.7	8	3	-0.6	-1.6	1.2	6.2
Max	25.1	25.2	26.4	27	26.3	25.6	23.8	21.8	18.1	18.1	20.7	24.1

Figure 6.1: Average minimum and maximum temperatures at Delmas (source: (Climate-Data.org, 2012)).

6.2 Rainfall and Evaporation

A Mean Annual Precipitation (MAP) for the site was reported as 667 mm with a monthly rainfall distribution presented in Figure 6.2.

Mean Annual Evaporation (MAE) (Symons Pan) of 1677 mm and are reported for the site (Bailey & Pitman, 2015). Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year.

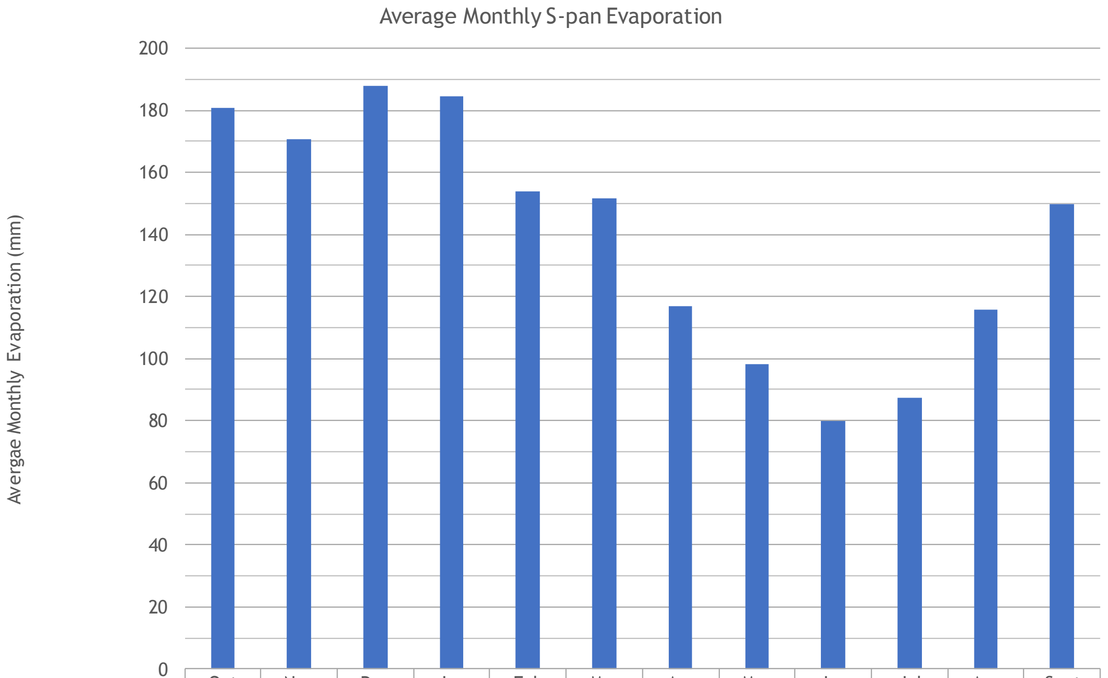


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
E10	25.4	35.3	56.2	61.0	42.2	31.7	5.8	0.0	0.0	0.0	0.0	0.0
E30	36.1	70.1	80.4	82.0	60.9	55.5	17.0	2.8	0.0	0.0	0.0	2.5
E50	55.2	107.0	104.0	104.8	78.7	74.3	32.1	8.4	1.2	0.0	0.9	11.9
E70	81.7	128.7	127.4	137.2	103.7	95.3	49.1	21.0	7.2	2.9	7.8	24.6
E90	128.9	172.5	168.2	200.1	151.9	137.5	93.3	44.9	22.8	18.9	21.3	59.3

E10 E30 E50 E70 E90

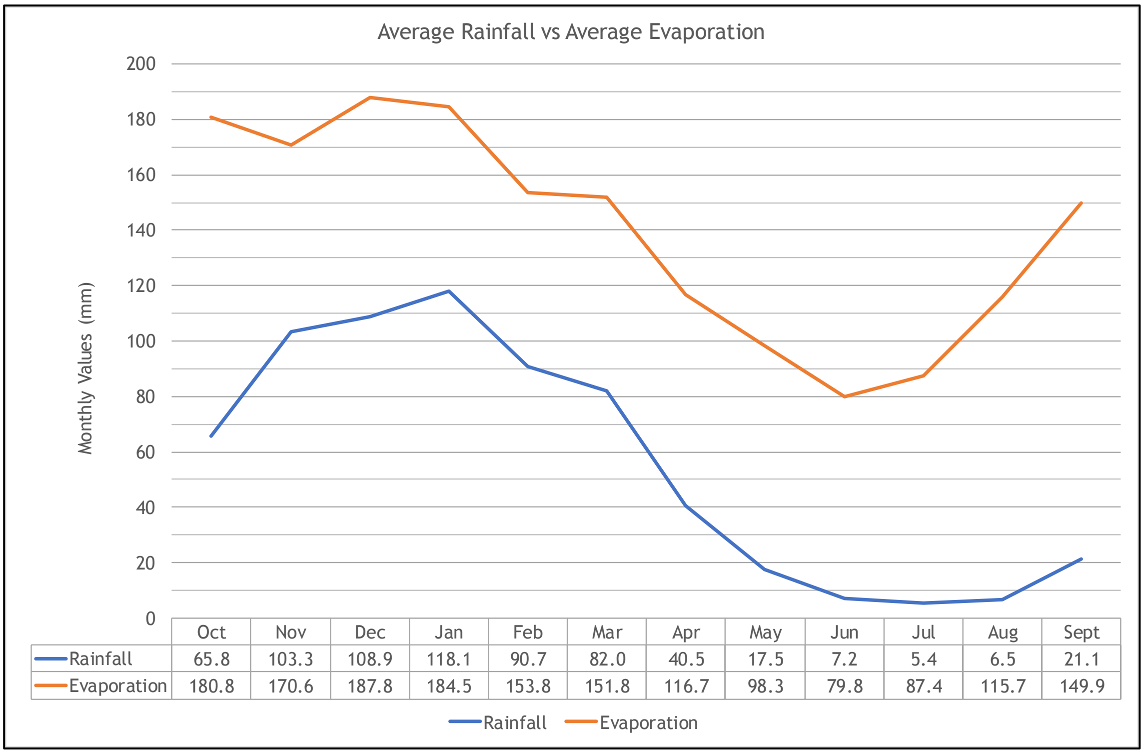
Note: E30 represents value that is likely to be exceeded in 30% of years

Figure 6.2: Monthly rainfall distribution for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
S-pan Evaporation	180.8	170.6	187.8	184.5	153.8	151.8	116.7	98.3	79.8	87.4	115.7	149.9

Figure 6.3: Average monthly evaporation for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Rainfall	65.8	103.3	108.9	118.1	90.7	82.0	40.5	17.5	7.2	5.4	6.5	21.1
Evaporation	180.8	170.6	187.8	184.5	153.8	151.8	116.7	98.3	79.8	87.4	115.7	149.9

Figure 6.4: Mean monthly rainfall and evaporation for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015).

6.3 Catchment Runoff

Total runoff from natural (unmodified) catchments in this area is simulated in WR2012 as being equivalent to 30.5 mm/yr over the surface area (WRC, 2015). This represents approximately 4.6 % of the MAP. WR2012 simulated natural runoff for Quaternary Catchment B20A is distributed and shown in Figure 6.5.

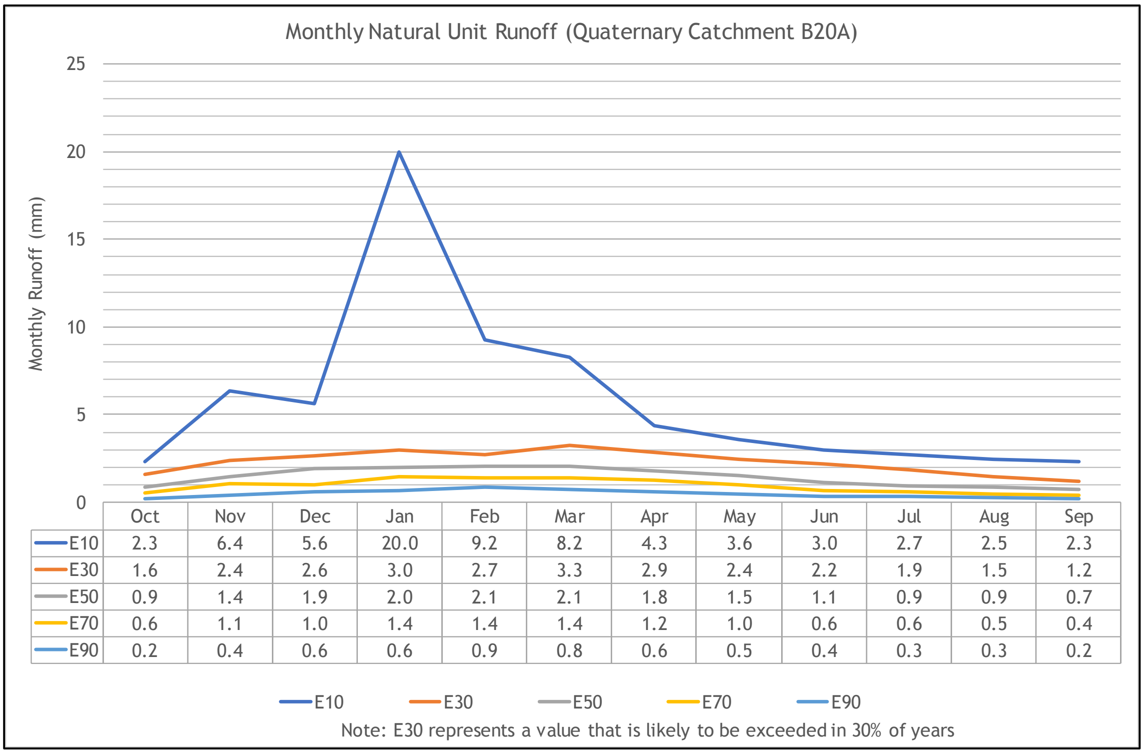


Figure 6.5: Monthly natural unit runoff distribution for Quaternary Catchment B20A (WRC, 2015).

6.4 Catchment Delineation

The site is situated across six (6) sub-catchments, that flow into the Bronkhorstspruit system. The delineated clean water catchments on site are presented in Table 6.1 and catchment details are presented in Table 6.1.

Table 6.1: Identified sub-catchment areas.

Sub-catchment Area (natural conditions)	River	Area (km^2)
Bronkhorstspruit 1 Sub-catchment	Bronkhorstspruit	84.9
Bronkhorstspruit 2 Sub-catchment	Bronkhorstspruit	15.3
Tributary 1 Sub-catchment	Tributary 1	43.7
Tributary 2 Sub-catchment	Tributary 2	30.5
Tributary 3 Sub-catchment	Tributary 3	162.2
Tributary 4 Sub-catchment	Tributary 4	10.6

6.5 Rainfall Depth and Design Storm Events

The design rainfall depths for the facility were calculated using the Design Rainfall software for South Africa (Schulze & Smithers, 2002). The design rainfall depths for the overall site for 1:2-year, 1:5-year, 1:10-year, 1:20-year, 1:50-year and 1:100-year return periods can be seen in Table 6.2.

Table 6.2: Design rainfall depths for the mine.

Duration	Return Period (Years)					
	2	5	10	20	50	100
5 m	10.4	14.3	17.3	20.6	25.3	29.4
10 m	15.1	20.9	25.3	30.0	36.9	42.9
15 m	18.9	26.1	31.5	37.4	46.1	53.5
30 m	23.9	33.0	39.9	47.4	58.3	67.7
45 m	27.4	37.9	45.8	54.4	66.9	77.7
1 h	30.3	41.8	50.5	60.0	73.8	85.7
1.5 h	34.7	48.0	58.0	68.9	84.7	98.4
2 h	38.3	52.9	63.9	75.9	93.4	108.5
4 h	44.9	61.9	74.9	88.9	109.4	127.1
6 h	49.2	67.9	82.1	97.5	120.0	139.4
8 h	52.5	72.6	87.7	104.1	128.2	148.8
10 h	55.3	76.3	92.3	109.6	134.8	156.6
12 h	57.6	79.6	96.2	114.2	140.6	163.2
16 h	61.5	85.0	102.7	122.0	150.1	174.3
20 h	64.7	89.4	108.1	128.3	157.9	183.4
24 h	67.5	93.2	112.7	133.8	164.6	191.2
1 d	58.5	80.7	97.6	115.9	142.6	165.6
2 d	70.4	97.3	117.6	139.6	171.8	199.5
3 d	78.5	108.5	131.1	155.7	191.6	222.5
4 d	86.1	118.9	143.7	170.7	210.0	243.9
5 d	92.5	127.7	154.4	183.3	225.5	261.9
6 d	98.0	135.3	163.6	194.3	239.0	277.6
7 d	102.9	142.2	171.9	204.1	251.1	291.6

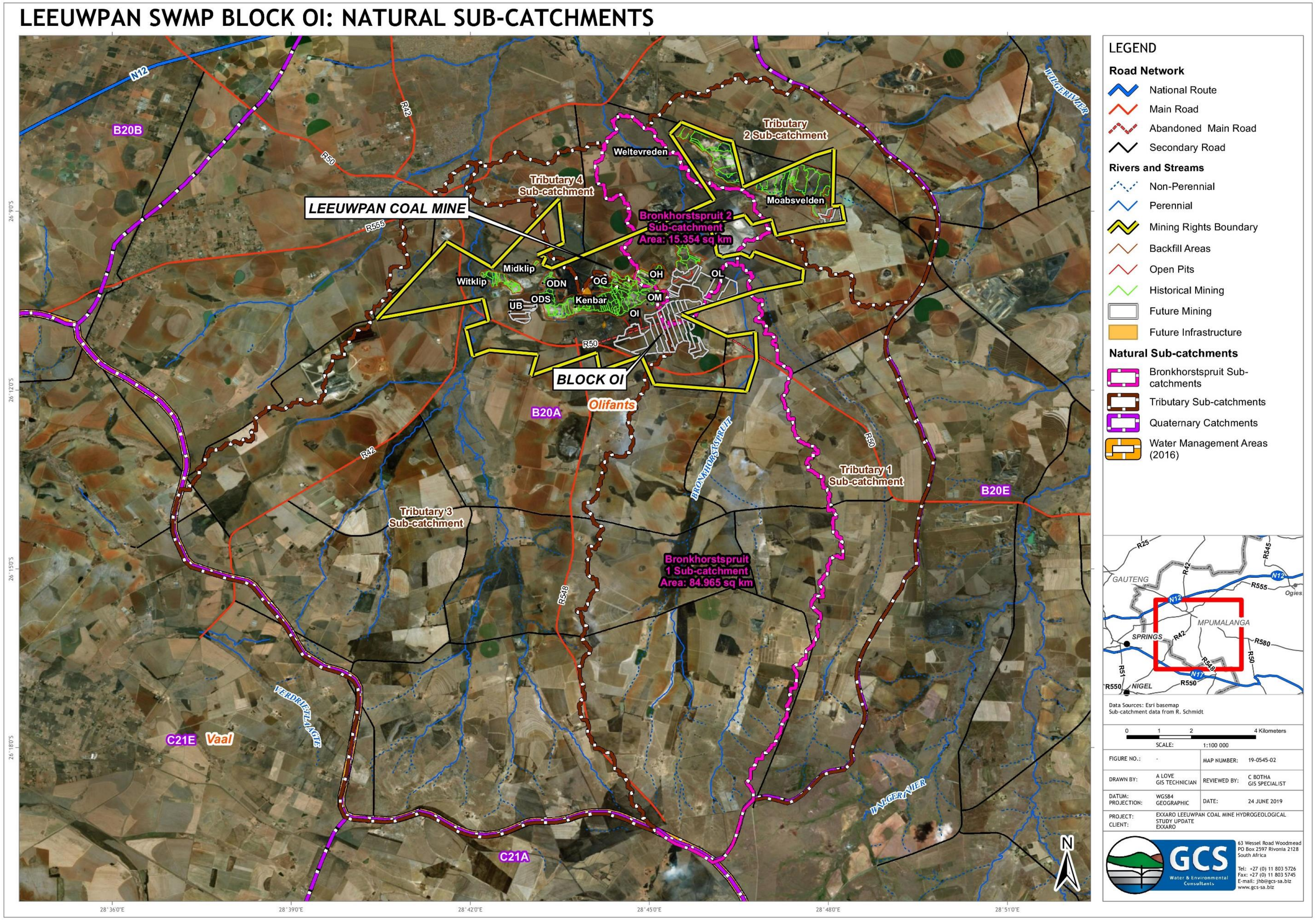


Figure 6.6: Leeuwpan up-stream natural catchments.

7 CONCEPTUAL STORMWATER MANAGEMENT PLAN

7.1 Assumptions and Limitations

The assumptions for the Block OI SWMP are as follows:

- GCS split Block OI into three (3) phases according to the life of mine (LoM) scheduling received by Exxaro (Drawing Number- 0136657600):
  - Phase 1 – 2019-2022
  - Phase 2 – 2023-2026
  - Phase 3 - 2027-2030
- Major berms (diversion berms as indicated) that divert upstream clean catchments will be placed along the contours to ensure minimum cut/fill is required.
- Smaller berms should be placed around the pit bounders (where indicated) to ensure no clean water enters into Block OI.

The limitations to the Block OI SWMP are as follows:

- GCS has no information on how the pits will be rehabilitated. In this SWMP it is assumed that the pit areas remain a dirty water area and runoff for these areas need to be captured and reused as it cannot be released.

7.2 Peak Flow Volumes

Peak storm rainfall depths were used to estimate the magnitude and frequency of flood events in the delineated site catchments and surrounding clean water catchments. The peak flood runoff volumes were determined using the Rational Method and SCS Method (US Department of Agriculture, Soil Conservation Service, 1972) and (Schulze, et al., 2004)) as described in the SANRAL Drainage Manual (SANRAL, 2013). Peak flow results are presented in Table 7.1 for each phase. The SCS peak flood runoff volumes were used in PCSWMM software (Chiwater, 2017) to size all channels.

Table 7.1: Estimated peak flow results.

Summary Section	1:2 year		1:5 year		1:10 year		1:20 year		1:50 year		1:100 year	
	RM3 (m^3/s)	SCS (m^3/s)	RM3 (m^3/s)	SCS (m^3/s)	RM3 (m^3/s)	SCS (m^3/s)	RM3 (m^3/s)	SCS (m^3/s)	RM3 (m^3/s)	SCS (m^3/s)	RM3 (m^3/s)	SCS (m^3/s)
Phase 1												
Suez Channel Catchment 1	11.3	21.9	16.7	39.0	21.4	53.2	27.0	69.6	35.0	94.5	42.8	116.9
Suez Channel Catchment 2	1.2	1.5	1.8	2.7	2.3	3.6	2.8	4.7	3.7	6.4	4.5	8.0
Phase 1 Catchment 1	0.6	2.5	0.8	4.4	1.1	6.0	1.3	7.8	1.8	2.0	2.1	13.1
Phase 2												
Phase 2 Catchment 1	0.9	1.1	1.3	2.0	1.6	2.7	2.1	3.5	2.7	4.8	3.3	5.9
Phase 2 Catchment 2	0.1	0.2	0.1	0.4	0.2	0.5	0.2	0.7	0.3	0.9	0.4	1.2
Phase 3												
Phase 3 Catchment 1	0.9	0.6	1.3	1.1	1.7	1.4	2.2	1.9	2.8	2.6	3.5	3.2
Phase 3 Catchment 2	0.6	0.5	0.9	0.9	1.2	1.2	1.5	1.6	1.9	2.1	2.3	2.7
Phase 3 Catchment 3	0.6	0.5	1.0	0.9	1.2	1.3	1.5	1.7	2.0	2.3	2.5	2.8
Phase 3 Catchment 4	1.0	0.6	1.4	1.1	1.8	1.6	2.3	2.0	2.9	2.8	3.6	3.4

7.3 Berm Locations and Sizing

A phased approach was taken and the SWMP was extended over each phase. Proposed drainage measures for the site include a lined channel (to capture and transport clean water) and existing Suez Canal together with berms around the pit boundaries to divert clean water, are presented in Figure 7.1 to Figure 7.3.

Clean water from the clean water catchment is diverted around to ensure that this water does not mix with the dirty water areas. All upstream clean water catchment of Block OI are diverted using a system of berms and released into the environment. During Phase 3 the upstream catchment 'Phase 3 Catchment 2' (Figure 7.3) has a small portion that cannot be diverted around with the berm that follows the 1586 m contour. This area's runoff will have to be captured in the pit and reused within the process.

Erosion protection measures should be implemented along the channel/ berms and at release points where clean water flows into the environment. This is to reduce flow velocities into the environment and to ensure that no erosion takes place.

PCSWMM software was used to establish a network of stormwater drainage channels and berms which route stormwater from catchment inlets through junctions to the outlets/release points. Sizing of drainage channel in PCSWMM was based on the South African SCS method. A 24-hour storm duration of a 1:50-year return periods was used as input to create a flood hydrograph for each sub-catchment. Results of the proposed channel size and calculated peak flow is summarised in Table 7.2. The channel was sized according to the 1:50-year storm event. It was assumed that the Suez Canal has enough capacity to divert the Suez Canal Catchment 2.

Table 7.2: Summary of drainage channel result.

Drain Name	Roughness	Cross-Section	Depth (m)	Bottom width (m)	Side slopes (h/w)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)
C_1	0.015	TRAPEZOIDAL	1.5	1.5	1:1.5	8.50	2.7

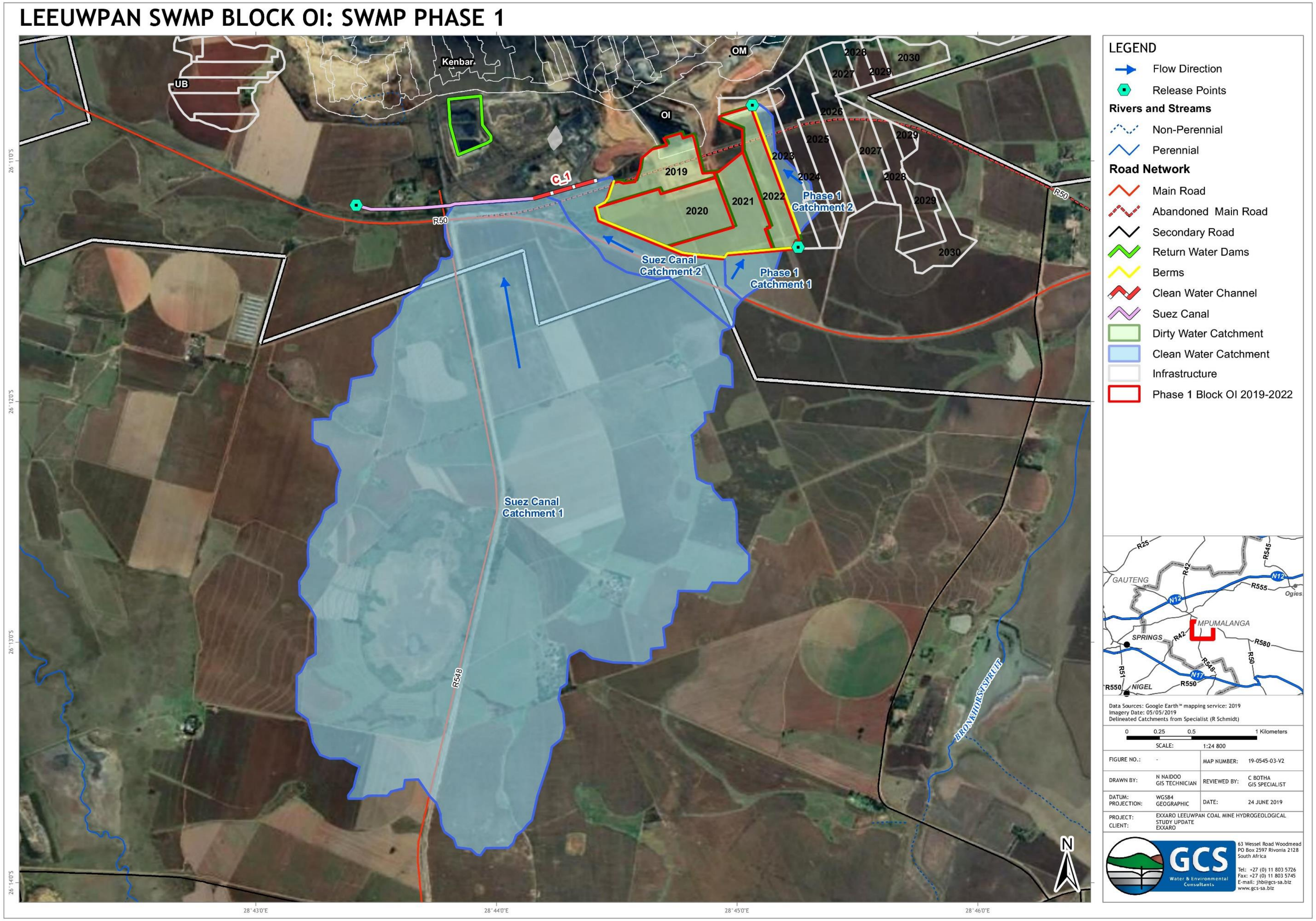


Figure 7.1: Leeuwpan Block OI SWMP Phase 1.

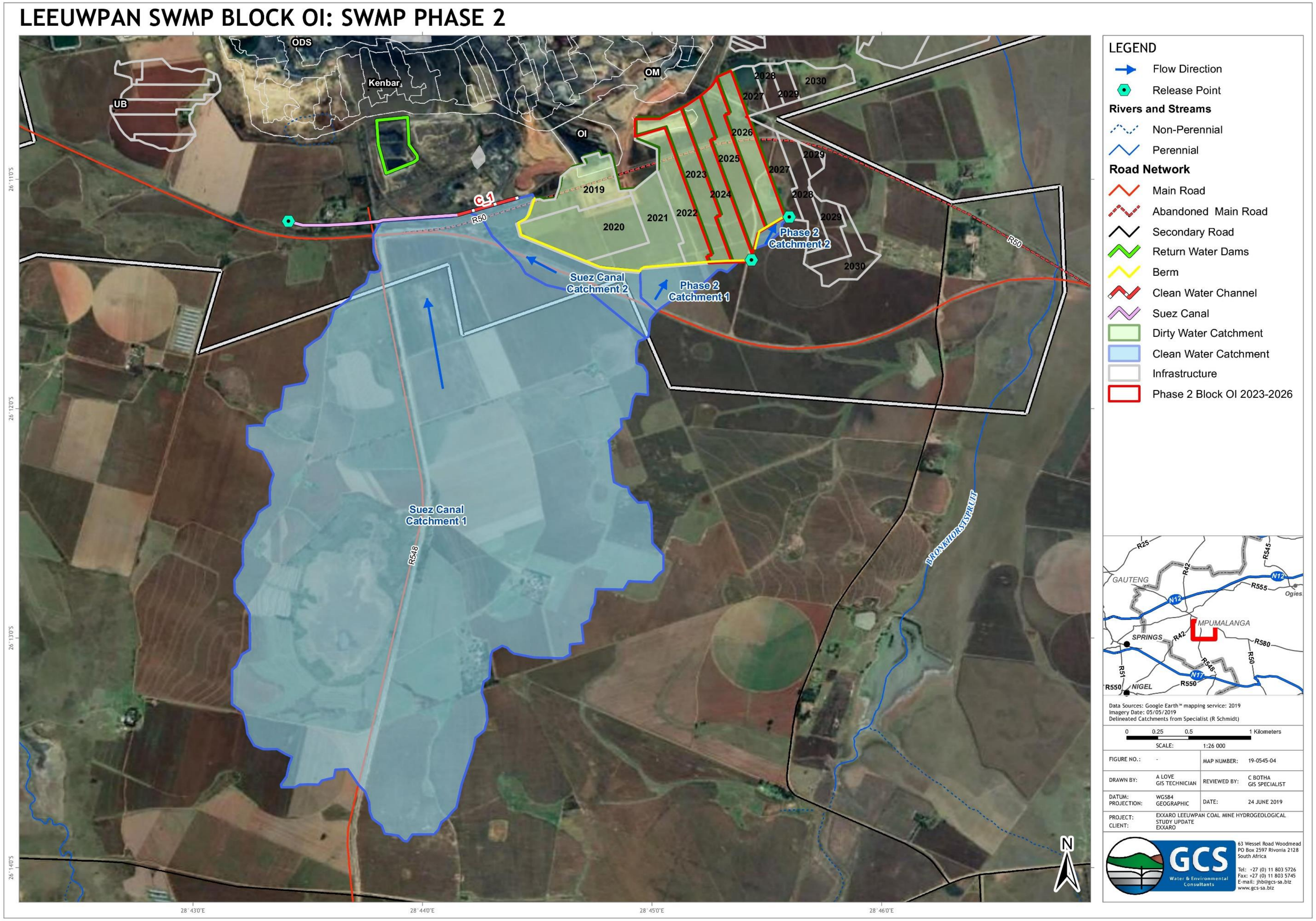


Figure 7.2: Leeuwpan Block OI SWMP Phase 2.

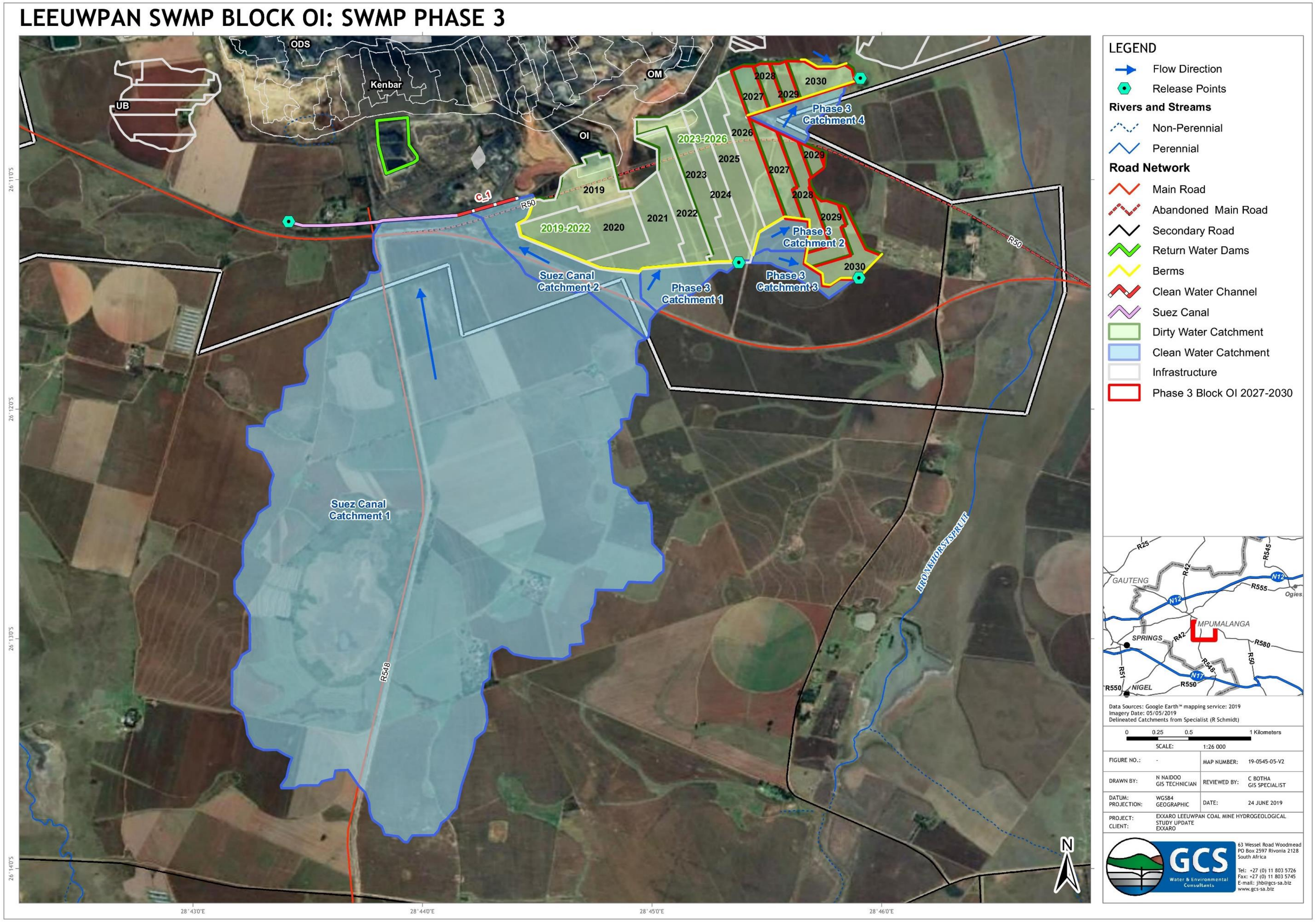


Figure 7.3: Leeuwpan Block OI SWMP Phase 3.

7.4 Water Volumes from Block OI

In line with regulations, water that is considered dirty must be contained (Section 4). Dirty water from groundwater inflow and surface water runoff in Block OI is captured in a in-pit sump and pumped to the RWDs. Table 7.3 and Table 7.4 summarises the total inflow volume (surface and groundwater) at the sump during a 1:2-year and 1:50-year flood event (surface water) and annual average groundwater inflow.

Table 7.3: Surface water runoff for the1:2-year and 1:50-year flood events.

Years	1:2-year Surface Water Runoff (m^3)	1:50-year Surface Water Runoff (m^3)
2019	10 300	27 700
2020	16 700	45 300
2021	12 800	35 000
2022	9 900	27 000
2023	11 200	30 900
2024	10 300	28 000
2025	10 500	28 700
2026	10 200	27 800
2027	9 700	26 500
2028	8 600	23 300
2029	8 700	23 700
2030	10 800	29 500

Table 7.4: Average groundwater inflow for each year.

Years	Average Groundwater Inflow (m^3/d)
2019	-
2020	360
2021	433
2022	476
2023	620
2024	643
2025	651
2026	715
2027	738
2028	790
2029	834
2030	809

8 CONCLUSIONS

The following describes the conclusions derived from the SWMP.

- The conceptual SWMP layout was based on a 24-hour 1:50-year return period using the SCS-SA method in PCSWMM to create a flood hydrograph for each sub-catchment.
- Proposed longitudinal drainage (channels) measures for the site includes a lined drainage trapezoidal channel. This channel is linked to the excising Suez Canal.
- Discharge points were carefully considered as concentration of storm peak flow should be prevented to avoid erosion.

9 RECOMMENDATIONS

Recommendations derived from this SWMP study include:

- The water level in the in-pit sumps need to be kept at a safe working water level.
- Water must be pumped from the in-pit sumps to the RWDs, where water can be reused.
- All drains should be cleaned regularly to prevent blockages from siltation and debris.
- Erosion protection measures should be implemented along the channel/ berms and at release points where clean water flows into the environment.

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APPENDIX A: CALCULATION OF THE PEAK FLOWS USING RATIONAL METHOD

RATIONAL METHOD 3							
Description of catchment		Suez Channel Catchment 1					
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	10.02	km^2		Rainfall region		B2A	
Longest watercourse (L)	5.407	km		**Area distribution factors**			
Average slope (S_{av})	0.0042	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	20	0.08	1.60	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	0	0.26	0.00	Light industry		0.6	0
Total	100	0.54	14.40	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
2.718 hours	2.002		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.284	0.284	0.284	0.284	0.284	0.284	
Adjusted for dolomitic areas, C_{1D}	0.284	0.284	0.284	0.284	0.284	0.284	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.213	0.2272	0.2414	0.2556	0.270	0.284	
Combined run - off coefficient, C_T	0.213	0.2272	0.2414	0.2556	0.270	0.284	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	38.3	52.9	63.9	75.9	93.4	108.5	
Point Intensity (mm/h), P_{it}	19.13	26.43	31.92	37.92	46.66	54.21	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	19.13	26.43	31.92	37.92	46.66	54.21	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	11.34	16.71	21.45	26.98	35.04	42.85	

RATIONAL METHOD 3

Description of catchment	Suez Channel Catchment 2						
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	0.411	km^2		Rainfall region	B2A		
Longest watercourse (L)	1.5	km		**Area distribution factors**			
Average slope (S_{av})	0.0105	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	C_s	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	C_p	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	C_v	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
1.205 hours	0.524		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	24.2	33.5	40.5	48.1	59.1	68.6	
Point Intensity (mm/h), P_{it}	46.27	63.90	77.26	91.78	112.89	131.09	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	46.27	63.90	77.26	91.78	112.89	131.09	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	1.20	1.76	2.26	2.85	3.70	4.52	

RATIONAL METHOD 3

Description of catchment	Phase 1 Catchment 1						
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	0.1049	km^2		Rainfall region	B2A		
Longest watercourse (L)	0.34	km		**Area distribution factors**			
Average slope (S_{av})	0.0078	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavys,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavys,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.645 hours	0.187		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	16.0	22.2	26.8	31.8	39.1	45.5	
Point Intensity (mm/h), P_{it}	85.73	118.58	143.43	170.13	209.39	243.31	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	85.73	118.58	143.43	170.13	209.39	243.31	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.57	0.83	1.07	1.35	1.75	2.14	

RATIONAL METHOD 3

Description of catchment	Phase 2 Catchment 1		
River detail			
Calculated by	Roxane Schmidt	Date	20/06/2019

Physical characteristics

Size of catchment (A)	0.1488	km^2	Rainfall region	B2A	
Longest watercourse (L)	0.34	km	**Area distribution factors**		
Average slope (S_{av})	0.0118	m/m	Rural (α)	Urban (β)	Lakes (γ)
Dolomite area (D%)	0	%	1	0	0
Mean annual rainfall(MAR)	667	mm			

Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0

Time of concentration (TC)

Overland flow:

$$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$

0.587 hours

Defined watercourse:

$$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$$

0.160 hours

Use Defined watercourse

Run-off coefficient

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	

Rainfall

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	14.7	20.4	24.6	29.2	36.0	41.8	
Point Intensity (mm/h), P_{it}	92.05	127.36	154.17	182.85	224.89	261.45	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	92.05	127.36	154.17	182.85	224.89	261.45	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.86	1.27	1.64	2.05	2.67	3.26	

RATIONAL METHOD 3

Description of catchment		Phase 2 Catchment 2					
River detail							
Calculated by	Roxane Schmidt				Date	20/06/2019	
Physical characteristics							
Size of catchment (A)	0.02362	km^2		Rainfall region		B2A	
Longest watercourse (L)	0.15	km		**Area distribution factors**			
Average slope (S_{av})	0.0138	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0

Time of concentration (TC)

Overland flow:

$$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$

0.386 hours

Defined watercourse:

$$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$$

0.080 hours

Use Defined watercourse

Run-off coefficient

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	

Rainfall

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	10.0	13.7	16.6	19.8	24.3	28.3	
Point Intensity (mm/h), P_{it}	62.51	85.96	103.99	123.82	152.07	176.72	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	62.51	85.96	103.99	123.82	152.07	176.72	

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.09	0.14	0.18	0.22	0.29	0.35	

RATIONAL METHOD 3							
Description of catchment	Phase 3 Catchment 1						
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	0.1489	km^2		Rainfall region	B2A		
Longest watercourse (L)	0.3	km		**Area distribution factors**			
Average slope (S_{av})	0.0133	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.538 hours	0.138		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	13.5	18.7	22.6	26.8	33.0	38.3	
Point Intensity (mm/h), P_{it}	97.60	134.85	163.22	193.75	238.22	276.92	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	97.60	134.85	163.22	193.75	238.22	276.92	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.91	1.35	1.73	2.18	2.83	3.46	

RATIONAL METHOD 3

Description of catchment	Phase 3 Catchment 2		
River detail			
Calculated by	Roxane Schmidt	Date	20/06/2019

Physical characteristics

Size of catchment (A)	0.0888	km^2	Rainfall region		B2A
Longest watercourse (L)	0.4	km	**Area distribution factors**		
Average slope (S_{av})	0.0138	m/m	Rural (α)	Urban (β)	Lakes (γ)
Dolomite area (D%)	0	%	1	0	0
Mean annual rainfall(MAR)	667	mm			

Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0

Time of concentration (TC)

Overland flow		Defined watercourse		
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$		$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$		Use Defined watercourse
0.610	hours	0.170	hours	

Run-off coefficient

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	

Rainfall

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	15.3	21.1	25.6	30.3	37.3	43.4	
Point Intensity (mm/h), P_{it}	110.38	152.75	184.88	219.24	269.70	313.53	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	110.38	152.75	184.88	219.24	269.70	313.53	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.62	0.91	1.17	1.47	1.91	2.34	

RATIONAL METHOD 3

Description of catchment	Phase 3 Catchment 3						
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	0.0954	km^2		Rainfall region	B2A		
Longest watercourse (L)	0.38	km		**Area distribution factors**			
Average slope (S_{av})	0.0138	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavys,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavys,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegetation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.596 hours	0.164		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	14.9	20.7	25.0	29.7	36.5	42.4	
Point Intensity (mm/h), P_{it}	107.98	149.43	180.89	214.52	263.84	306.74	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	107.98	149.43	180.89	214.52	263.84	306.74	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.65	0.96	1.23	1.55	2.01	2.45	

RATIONAL METHOD 3

Description of catchment		Phase 3 Catchment 4					
River detail							
Calculated by	Roxane Schmidt			Date	20/06/2019		
Physical characteristics							
Size of catchment (A)	0.1298	km^2		Rainfall region	B2A		
Longest watercourse (L)	0.46	km		**Area distribution factors**			
Average slope (S_{av})	0.0138	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	667	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	100.00	0.03	3.00	**Lawns**			
Flat areas (3 - 10%)	0.00	0.08	0.00	Sandy,flat<2%		0.08	0
Hilly (10 - 30%)	0.00	0.16	0.00	Sandy,steep>7%		0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%		0.15	0
Total	100.00	0.53	3.00	Heavy s,steep>7%		0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	0	0.04	0.00	Houses		0.5	0
Permeable	10	0.08	0.80	Flats		0.6	0
Semi-permeable	80	0.16	12.80	Industry			
Impermeable	10	0.26	2.60	Light industry		0.6	0
Total	100	0.54	16.20	Heavy industry		0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre		0.8	0
Light bush & farm-lands	100	0.11	11.00	Suburban		0.65	0
Grasslands	0	0.21	0.00	Streets		0.75	0
No vegatation	0	0.28	0.00	Max flood		1	
Total	100	0.64	11.00	Total (C2)			0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.651 hours	0.190		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.302	0.302	0.302	0.302	0.302	0.302	
Adjusted for dolomitic areas, C_{1D}	0.302	0.302	0.302	0.302	0.302	0.302	
Adj factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	
Adjusted run - off coefficient, C_{1T}	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Combined run - off coefficient, C_T	0.2265	0.2416	0.2567	0.2718	0.287	0.302	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	16.2	22.3	27.0	32.1	39.5	45.8	
Point Intensity (mm/h), P_{it}	116.76	161.49	195.30	231.67	285.15	331.33	
Area reduction factor (%),ARF_T	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Average intensity (mm/hour),I_T	116.76	161.49	195.30	231.67	285.15	331.33	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m3/s)	0.95	1.41	1.81	2.27	2.95	3.61	

APPENDIX B: CALCULATION OF THE PEAK FLOWS USING SCS METHOD

SCS-SA						
Description of catchment	Suez Channel Catchment 1					
River detail						
Calculated by	Roxane Schmidt		**Date**	20/06/2019		
Physical charateristics						
Size of catchment (A)	10.02	km^2	Time of concentration	2.002	hours	
Longest watercourse (L)	5.407	km				
Average slope (S_{av})	0.0041921	m/m				
Lag estimate	1.20117565	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.973	0.963	0.956	0.948	0.936	0.926
Catchment desgin rainfall (PxARF/100) (mm)	65.697	89.781	107.720	126.810	154.086	177.087
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crop					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.232	0.412	0.563	0.735	1.000	1.236
Peak discharge (qp, m^3/s)	21.944	38.970	53.232	69.554	94.545	116.911

SCS-SA						
Description of catchment	Suez Channel Catchment 2					
River detail						
Calculated by	Roxane Schmidt		**Date**	28/05/2019		
Physical charateristics						
Size of catchment (A)	0.411	km^2	Time of concentration		1.205	hours
Longest watercourse (L)	1.5	km				
Average slope (S_{av})	0.01050667	m/m				
Lag estimate	0.72314663	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.998	0.997	0.996	0.995	0.994	0.993
Catchment desgin rainfall (PxARF/100) (mm)	67.344	92.903	112.265	133.188	163.674	189.951
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crop					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.010	0.017	0.023	0.030	0.041	0.051
Peak discharge (qp, m^3/s)	1.495	2.655	3.627	4.739	6.442	7.965

SCS-SA						
Description of catchment	Phase 1 Catchment 1					
River detail						
Calculated by	Roxane Schmidt			**Date**	28/05/2019	
Physical charateristics						
Size of catchment (A)	0.1049	km^2	Time of concentration		0.187	hours
Longest watercourse (L)	0.34	km				
Average slope (S_{av})	0.00784314	m/m				
Lag estimate	0.97080222	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.998	0.997	0.996	0.995	0.994	0.993
Catchment desgin rainfall (PxARF/100) (mm)	67.344	92.903	112.265	133.188	163.674	189.951
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crop					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.004	0.006	0.008	0.010	0.013
Peak discharge (qp, m^3/s)	0.475	0.844	1.153	1.507	2.048	2.533

SCS-SA						
Description of catchment	Phase 2 Catchment 1					
River detail						
Calculated by	Roxane Schmidt		**Date**	28/05/2019		
Physical charateristics						
Size of catchment (A)	0.15	km^2	Time of concentration		0.587	hours
Longest watercourse (L)	0.34	km				
Average slope (S_{av})	0.01176471	m/m				
Lag estimate	0.352	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.998	0.997	0.996	0.995	0.994	0.993
Catchment desgin rainfall (PxARF/100) (mm)	67.344	92.903	112.265	133.188	163.674	189.951
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m^3/s)	1.112	1.974	2.696	3.523	4.789	5.922

SCS-SA						
Description of catchment	Phase 2 Catchment 2					
River detail						
Calculated by	Roxane Schmidt			**Date**	28/05/2019	
Physical charateristics						
Size of catchment (A)	0.02	km^2	Time of concentration		0.080	hours
Longest watercourse (L)	0.15	km				
Average slope (S_{av})	0.01	m/m				
Lag estimate	0.486	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.998	0.997	0.996	0.995	0.994	0.993
Catchment desgin rainfall (PxARF/100) (mm)	67.344	92.903	112.265	133.188	163.674	189.951
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m³/s)	0.216	0.384	0.525	0.686	0.932	1.153

SCS-SA						
Description of catchment	Phase 3 Catchment 1					
River detail						
Calculated by	Roxane Schmidt			**Date**	28/05/2019	
Physical charateristics						
Size of catchment (A)	0.15	km^2	Time of concentration		0.538	hours
Longest watercourse (L)	0.3	km				
Average slope (S_{av})	0.01333333	m/m				
Lag estimate	0.936	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.997	0.995	0.995	0.994	0.992	0.991
Catchment desgin rainfall (PxARF/100) (mm)	67.279	92.779	112.085	132.934	163.290	189.434
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m³/s)	0.596	1.059	1.446	1.889	2.568	3.176

SCS-SA						
Description of catchment	Phase 3 Catchment 2					
River detail						
Calculated by	Roxane Schmidt			**Date**	28/05/2019	
Physical charateristics						
Size of catchment (A)	0.09	km^2	Time of concentration		0.170	hours
Longest watercourse (L)	0.40	km				
Average slope (S_{av})	0.01	m/m				
Lag estimate	0.773	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.997	0.995	0.995	0.994	0.992	0.991
Catchment desgin rainfall (PxARF/100) (mm)	67.279	92.779	112.085	132.934	163.290	189.434
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m³/s)	0.499	0.886	1.210	1.581	2.150	2.658

SCS-SA						
Description of catchment	Phase 3 Catchment 3					
River detail						
Calculated by	Roxane Schmidt		**Date**	28/05/2019		
Physical charateristics						
Size of catchment (A)	0.10	km^2	Time of concentration	0.164	hours	
Longest watercourse (L)	0.38	km				
Average slope (S_{av})	0.01	m/m				
Lag estimate	0.793	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.997	0.995	0.995	0.994	0.992	0.991
Catchment desgin rainfall (PxARF/100) (mm)	67.279	92.779	112.085	132.934	163.290	189.434
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m^3/s)	0.526	0.934	1.276	1.667	2.266	2.802

SCS-SA						
Description of catchment	Phase 3 Catchment 4					
River detail						
Calculated by	Roxane Schmidt		**Date**	28/05/2019		
Physical charateristics						
Size of catchment (A)	0.13	km^2	Time of concentration		0.190	hours
Longest watercourse (L)	0.46	km				
Average slope (S_{av})	0.01	m/m				
Lag estimate	0.883	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	67.50	93.20	112.70	133.80	164.60	191.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.997	0.995	0.995	0.994	0.992	0.991
Catchment desgin rainfall (PxARF/100) (mm)	67.279	92.779	112.085	132.934	163.290	189.434
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100					B/C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Crops					Low
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	75					
Final curve number	75.00					
Potenitial maximum soil water retention (S, mm)	84.67					
Initial losses (mm) (Ia=0.12*S)	10.16					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRU	Design Stormflow Depth (Qi)					
1	23.153	41.117	56.165	73.386	99.753	123.352
2						
3						
4						
5						
Total stormflow depth (mm)	23.153	41.117	56.165	73.386	99.753	123.352
Total Runoff Volume (V, m3x10^6)	0.002	0.003	0.004	0.005	0.007	0.009
Peak discharge (qp, m^3/s)	0.640	1.137	1.553	2.029	2.758	3.411