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TWIN HILLS

HIGH LEVEL HYDROLOGICAL AND SURFACE WATER STUDY

Rev	Description	Date
A	Issued in Draft	16 September 2021
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Knight Piésold CONSULTING

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ABBREVIATIONS

%	Percent
CRU	Climate Research Unit
km^2	Square Kilometres
KNMI	Koninklijk Nederlands Meteorologisch Instituut
m/m	Meter per Meter (Slope)
m^2	Square Meter (Area)
m^3	Cubic Meter (Volume)
MAP	Mean Annual Precipitation
masl	Meters Above Mean Sea Level (elevation)
m	Meters (Length)
mm	Millimetres (depth)
Mm^3	Million Cubic Meter (Volume)
Mtpa	Million Tonnes Per Annum
NASADEM	National Aeronautics and Space Administration Digital Elevation Model
NMET	Namibian Meteorological Offices for Karibib
QGIS	Quantum Geographical Information Systems
RA	Roads Authority
RANAMRU	Roads Authority of Namibia Rainfall Utility
RSA	Republic of South Africa
SANRAL	Shuttle Radar Topography Mission
SRTM	Shuttle Radar Topography Mission
TR	Technical Report

1.0 INTRODUCTION

1.1 OVERVIEW

Knight Piesold Consulting (Pty) Ltd was appointed by Osino Resources (Pty) Ltd to conduct a high-level freshwater supply and site surface water management study for the Twin Hills Mine.

The mining and prospecting area is in the Erongo Region of Namibia, approximately 17 km northeast of Karibib Town. The Study Area is north of the D1941 District Road with the C33 Road and airport to the west. Figure 1-1 shows a locality map, including:

- Proposed pit
- Main watercourses
- Catchment area
- Longest watercourse, traversing the study area

The prospecting area covers three farms, namely, Twinhill, Okawayo, and Klein Okawayo, which are also used for commercial livestock farming, game farming, and dimension stone mining.

1.2 SCOPE OF WORKS

The scope of works consists of the following components:

- Conduct a meteorology assessment.
- Compile a flood hydrology assessment adjacent and upstream of the proposed mine pit.
- Design a conceptual flood mitigation system layout with sizing; and
- High-level Surface water assessment.

1.3 METHODOLOGY

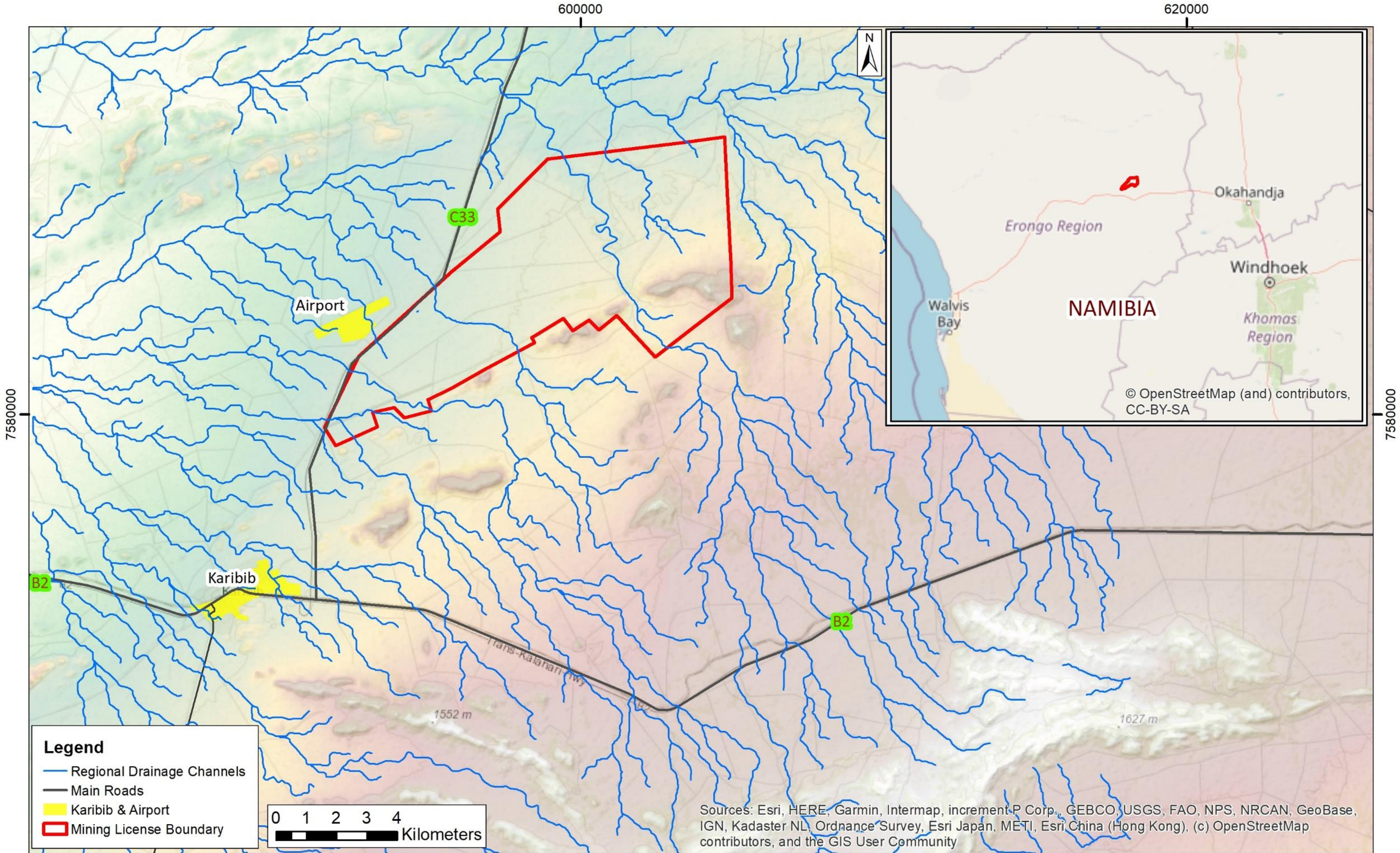
The methodology adopted for this investigation is as follows:

- Review existing studies.
- Based on existing and updated information, conduct flood hydrology assessment near the pit location and a high-level surface water supply alternatives.
- Based on expected flood volumes, create a conceptual stormwater mitigation system; and
- Compare surface water alternatives, reliability, and risk factors.

1.4 STUDY REVIEWS

The following studies were reviewed to inform this assessment:

- The Augmentation of Water Supply to the Central Area of Namibia. Summary Presentation. (LCE and SCE, 2015)
- Technical Report for the Karibib Gold Project in Namibia: Update of Exploration Activities. Osino Resources Corporation. (Underwood, 2019)
- Swakoppoort –Von Bach- Navachab Water Supply Scheme: Updated Environmental Management Plan (Namwater, 2020).
- High-Level Groundwater Supply Study for the Twin Hills Gold Project. (Kambinda and Bittner, 2020a)
- High-Level Surface and Groundwater Impact Assessment for the Twin Hills Gold Project. (Kambinda and Bittner, 2020b)



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Twin Hills Feasibility Study
Locality Map

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FIGURE NO.
1-1

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2.0 HYDROMETEOROLOGICAL STUDY

2.1 CLIMATE

The daytime temperatures near the town of Karibib are warm to hot in summer, with average temperatures around 35 degrees Celsius, and very cold nighttime winter temperatures falling below the freezing point. The climate can generally be described as arid with low humidity and the predominant wind direction from the North-East direction. Long drought periods occur in Namibia and can last for up to 7 years (Mendelsohn et al., 2002). The mean annual rainfall for the Namibian Meteorological Offices Karibib Station is 268 mm (NMET, 2021).

The climate in Namibia is highly variable, with extreme drought periods and rainfall events (MET, 2011). Climate change models indicate that Namibia, especially the eastern and southern parts are adversely affected by rising temperatures and the consequences thereof (WBG, 2021). A mitigation strategy was prepared by the Namibian Ministry of Environment and Tourism (MET), indicating flood protection systems to be investigated affected regions and expanding the water resources infrastructure to supplement the already overstressed water resources throughout Namibia. The focus of the document is on the most populous regions of Namibia, being the Central area of Namibia (CAN) and northern Namibia (MET, 2011). Currently, there is no detailed information or guidelines available to be used by water resources practitioners to account for climate change impacts on floods and water supply, based on the location of the project and short-medium-long term planning horizons. Generally, the guidelines indicate that the climate will become more variable, leaning towards longer more severe drought events and shorter more severe flood events.

2.2 METEOROLOGY

2.2.1 PRECIPITATION

This section discusses the different rainfall data sources, the confidence in the data, and the dataset selected for further assessment. For this study, the following rainfall data sources were utilised:

- Raw daily rainfall data was obtained for Usakos, Omaruru, and Wilhelmstal stations, based on the Koninklijk Nederlands Meteorologisch Instituut (KNMI) international rainfall database, and consists of rainfall data and patched datasets (KNMI, 2021).
- Monthly rainfall data was obtained for the Karibib Station from the Climate Research Unit (CRU) database, the closest station to the study area and the catchment, the data is based on synthetic satellite rainfall data (CRU, 2021).
- Duration frequency processed rainfall data was obtained from the Roads Authority of Namibia Rainfall Utility (RANAMRU) Software (RA, 2014), which is based on TR102 data (Adamson, 1980).
- Daily rainfall records were received from the Namibian Meteorological Offices for Karibib (NMET, 2021).

A data summary table has been generated in Table 2-1, indicating different sources, record lengths and Mean Annual Precipitation (MAP), and the percentage missing record. It is recommended to use the rainfall depths obtained from the Namibian Meteorological Offices for Karibib, with a record period from 1980 to 2016, to determine the flood hydrology peak runoffs.

Table 2-1 Rainfall Data Sources Summary

Station (Source)	Start Year	End Year	Record Length (years)	MAP (mm)	Missing Records (%)	Confidence (High to Low)
Karibib (Namibian MET)	1980	2017	47	268	3.2	High
Usakos (KNMI) [1]	1967	1985	19	109	2.8	Low
Omaruru (KNMI)	1967	1984	18	278	2.3	Medium
Wilhelmstal (KNMI)	1967	1985	19	240	2.5	Medium
Usakos (TR102) [3]	-	-	28	245	-	Medium to High
Karibib (TR102) [3]	-	-	32	269	-	Medium to High
Karibib (CRU) [2]	1900	1998	98	182	-	Low to Medium

NOTES

1. DATA QUALITY ISSUES SUSPECTED; TOO LOW MAP COMPARED TO KARIBIB MET OFFICE DATA.
2. SYNTHETIC SATELLITE-BASED RAINFALL DATA IS KNOWN TO OVER- OR THE MAP FOR THE STUDY AREA IS ESTIMATED TO BE 269 MM, BASED ON THE TR102 DATABASE, AND CONFIRMED WITH THE DAILY RAINFALL RECORD OF THE NAMIBIAN METEOROLOGICAL OFFICES (1980 TO 2016). THE EXCELLENT CORRELATION OF THE DATASETS INDICATES THAT THE RAINFALL DATA IS STATIONARY AND DOES NOT HAVE SIGNIFICANT TREND CHANGES, WHICH WOULD MAKE THE DATA QUESTIONABLE.
3. START AND END YEAR OF DEPTH FREQUENCY BASE DATA IS NOT PROVIDED

The MAP of 216.5 mm presented by SLR (Kambinda and Bittner, 2020a) was significantly lower than the sourced datasets were indicating. According to the Namibian Meteorological Office Rainfall Station map, the rainfall station indicated in the SLR Report, 0826596, is the Usakos Station, and not the Karibib Station. It is expected that the rainfall depths at Usakos are significantly lower compared to Karibib, due to the generalised decrease in rainfall trends towards the Namibian coastline. This could explain the relatively low MAP value. Due to this uncertainty, data obtained for the Karibib Station by the Namibian Meteorological Offices was used in this study which provides a MAP of 268 mm

A statistical regression analysis was done based on the Karibib Namibian Meteorological Offices daily rainfall data to obtain rainfall depths for different return periods. A summary table for the various rainfall station depths and return periods, with notes, is provided in Table 2-2.

Omaruru and Wilhelmstal stations indicate significantly higher rainfall depths for the short record periods when compared to Usakos. This is due to the decrease in elevation and a general reduction in rainfall depths from the central areas of Namibia towards the coastal regions.

Table 2-2 24 Hour Duration Rainfall Depths for Various Return Periods

Return Period (years)	Rainfall Depth (mm)					
	MET Karibib (1)	KNMI Omaruru (4)	KNMI USAKOS (3)	KNMI WILHELMSTAL (3)	TR102 USAKOS (2)	TR102 KARIBIB (2)
2	39	36	23	37	31	32
5	60	63	40	61	43	49
10	74	85	54	79	52	63
20	89	108	68	98	62	78
50 (4)	110	141	90	124	75	102
100	126	168	107	146	86	123
200	143	198	127	169	98	146
500	166	242	155	202	-	-
1000	185	278	178	229	-	-

NOTES

GENERAL: CRU DATABASE IS MONTHLY; THEREFORE, NO 24-HOUR RAINFALL DEPTHS COULD BE DETERMINED.

1. DATA RECEIVED FROM THE NAMIBIAN MET OFFICE
2. RANAMRU ONLY PROVIDES RAINFALL DEPTHS UP TO THE 200 YEAR RETURN PERIOD AND WERE ADOPTED FROM THE TR102 DATASET (ADAMSON, 1981).
3. LOGNORMAL (LN) DISTRIBUTION WAS USED FOR REGRESSION FITTING.
4. REGRESSION PERIOD RELIABILITY AND CONFIDENCE REDUCES SIGNIFICANTLY IF THE REGRESSION PERIOD EXCEEDS THE RECORD LENGTH TWICE.

The historic daily rainfall record for the Karibib NMET station is shown in Figure 2-1, indicating a peak daily rainfall event 85 mm. A drought period can be observed from 1990 to 1997, with a consistent decrease in rainfall. From 2000 to 2011, above average rainfall seasons were recorded, with droughts occurring from 2012/13 to 2017. The cyclicity of rainfall seasons, is an indicator of highly variable nature of the system, leaning towards a dry climate. No distinct climate change impacts can be observed from the rainfall record, or a change in rainfall stationarity (slope).

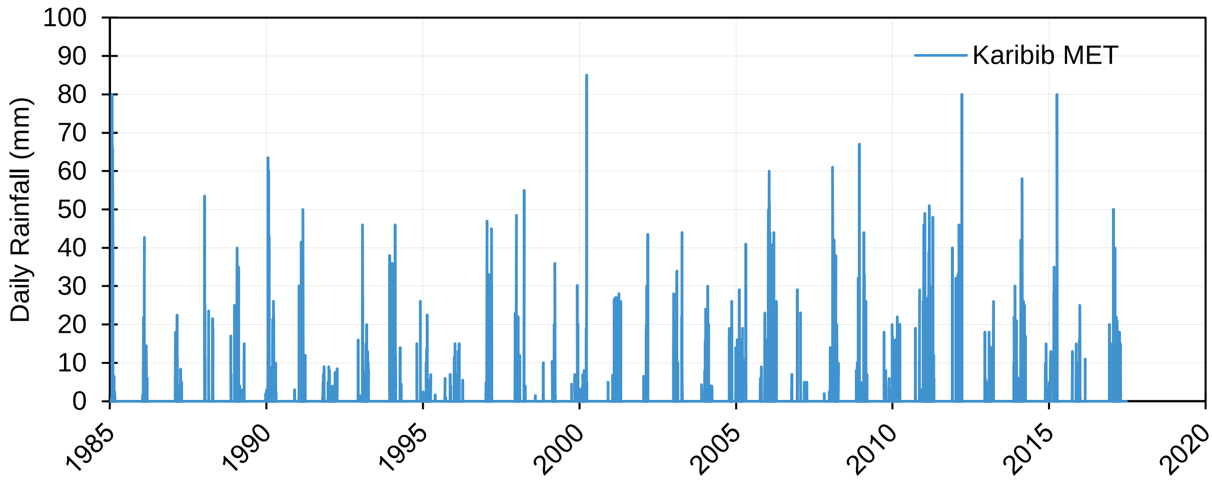
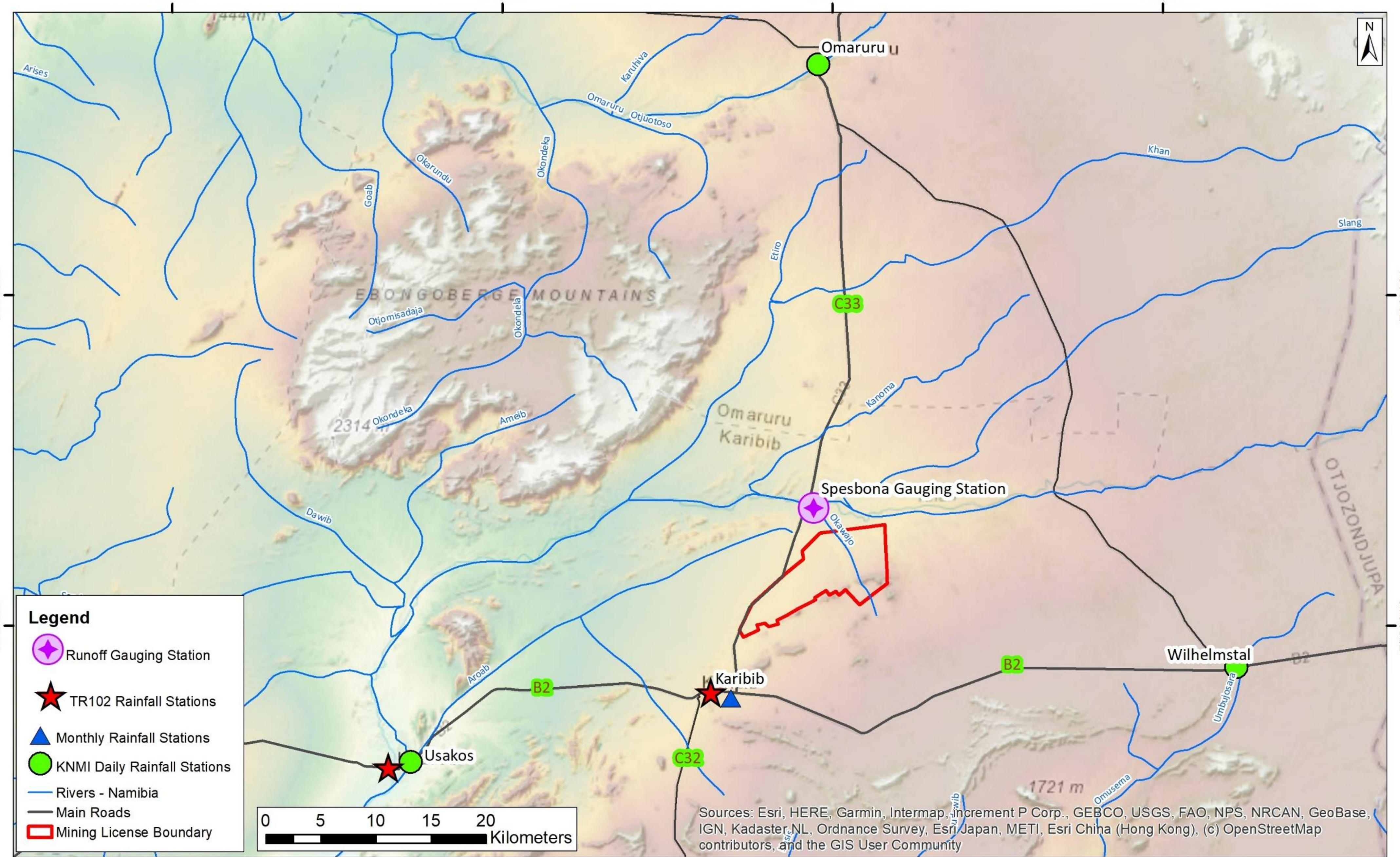


Figure 2-1 Daily Rainfall Record for the Karibib NMET Station



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Twin Hills Feasibility Study
Rainfall Stations & Runoff Gauging Station

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FIGURE NO.
2-2

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2.2.2 EVAPORATION

The gross potential evaporation near the site is reported to be between 3 200 to 3 400 mm per annum (MET, 2002). A map indicating potential evaporation and mean annual evaporation for Namibia has been used to verify expected evaporation values (Adamson, 1981). The A-Pan and open water evaporation were adopted from the SLR Groundwater and Supply Study and are shown in Figure 2-3 and Table 2-3. According to the SLR Groundwater and Supply Study, a conversion factor of 0.7 should be used to convert the A-Pan evaporation to Open Water evaporation (Kambinda and Bittner, 2020b), this value is also mentioned in the TR102 (Adamson, 1980).

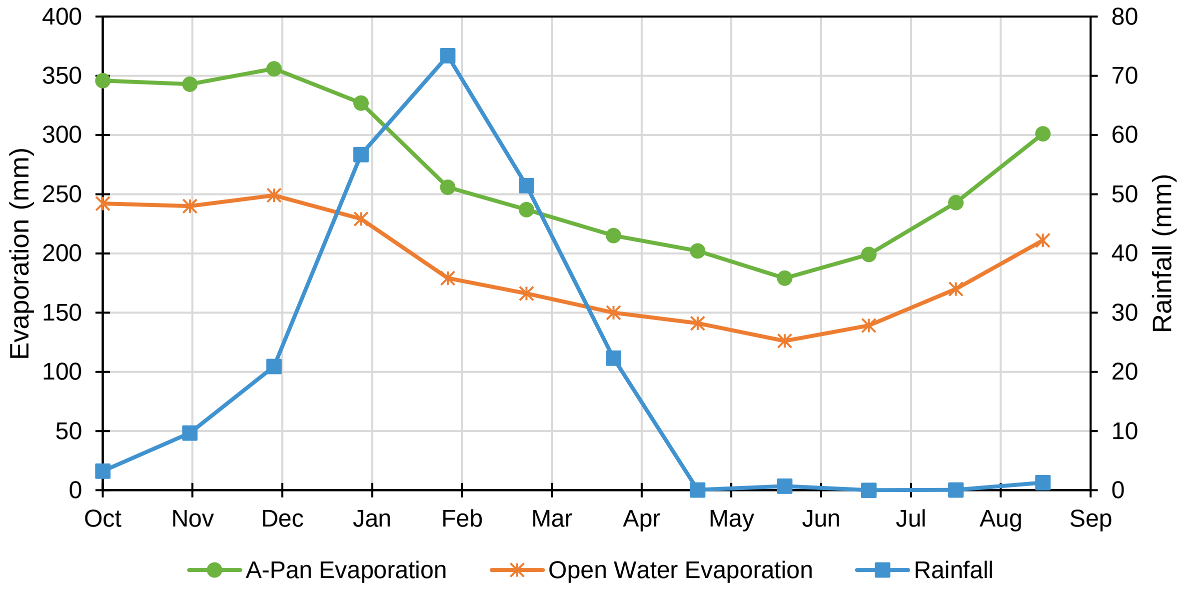


Figure 2-3 Average Rainfall vs. Evaporation

Table 2-3 Monthly A-Pan and Open Water Evaporation (Kambinda and Bittner, 2020b)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Monthly A-Pan Evaporation (mm)	346	343	356	327	256	237	215	202	179	199	243	301	3203
Open Water Monthly Evaporation (mm)	242	240	249	229	179	166	150	141	126	139	170	211	2242

2.3 HYDROLOGY

2.3.1 CATCHMENT CHARACTERISTICS

The study area is in the catchment of a tributary of the Khan River, which joins the Swakop River and discharges into the Atlantic Ocean at the coastal town of Swakopmund. The topography and catchment details were derived from the Shuttle Radar Topography Mission (SRTM, 2021) dataset which was improved in 2020 and is called NASADEM, with a 1 arc second resolution. The catchments and main streams relevant to the study area were delineated using automated procedures in Quantum Geographical Information Systems (QGIS) and manually verified using satellite images

(Gericke & du Plessis, 2012). The topography can be described as steep in the upper reaches, with a maximum elevation of 1 550 meters above sea level (masl), up to the lowest elevation of 1 150 masl.

The catchment area upstream of the pit is approximately 92 km^2, with a watercourse length of roughly 28 km and an average slope of 0.82 % (0.0082 m/m), determined with the Taylor-Schwarz Average Slope Method for large defined watercourses (Gericke & du Plessis, 2012). A summary of the catchment characteristics is shown in Table 2-4.

Table 2-4 Catchment Characteristics

Characteristics	Unit	Value
Catchment area upstream of pit	km^2	92
The total Catchment area of the tributary (Okawajo River)		120
Watercourse Length upstream of pit	km	28.3
Watercourse length for entire tributary		39.5
Slope upstream of pit	m/m	0.0082
The slope for the entire tributary		0.0078
Time of concentration (1) upstream of pit	hours	5.85
Time of concentration for entire tributary		7.07

NOTES

1. TIME OF CONCENTRATION IS PRESENTED BY THE OVERLAND FLOW (KERBY FORMULA). IT WAS SELECTED DUE TO THE RELATIVE ROUGHNESS OF THE MAIN WATERCOURSE (RA, 2014).

2.3.2 FLOOD HYDROLOGY

The flow gauging station closest to the Study Area is Spesbona, with a contributing catchment area of 2 400 km^2 and a record period of 43 years from 1975 to 2018. Scaling of the flow gauging data was done by dividing the sub-catchment area (92 km^2) by the Spesbona catchment area (2 400 km^2).

According to the Namibian Roads Authority Manual (RA, 2014) and the South African National Roads Agency Limited (SANRAL, 2013), the flood hydrology peaks were determined using the rational and statistical method. The Rational Rainfall-Runoff Method is based on rainfall data which is translated to peak runoff values by applying specific runoff factors based on the topography, vegetation, soils, catchment development, and other factors (SANRAL, 2013). The statistical method is used to derive peak floods from the larger Spesbona Catchment for the catchment area upstream of the pit and scaled appropriately to represent the catchment area relevant to the Study Area. The results of the flood peak assessment are presented in Table 2-5.

Most flow gauging stations in Namibia have not been calibrated recently, resulting in poor stage and flow relationships. Calibration information for the Spesbona Station has been requested from the Meteorology.

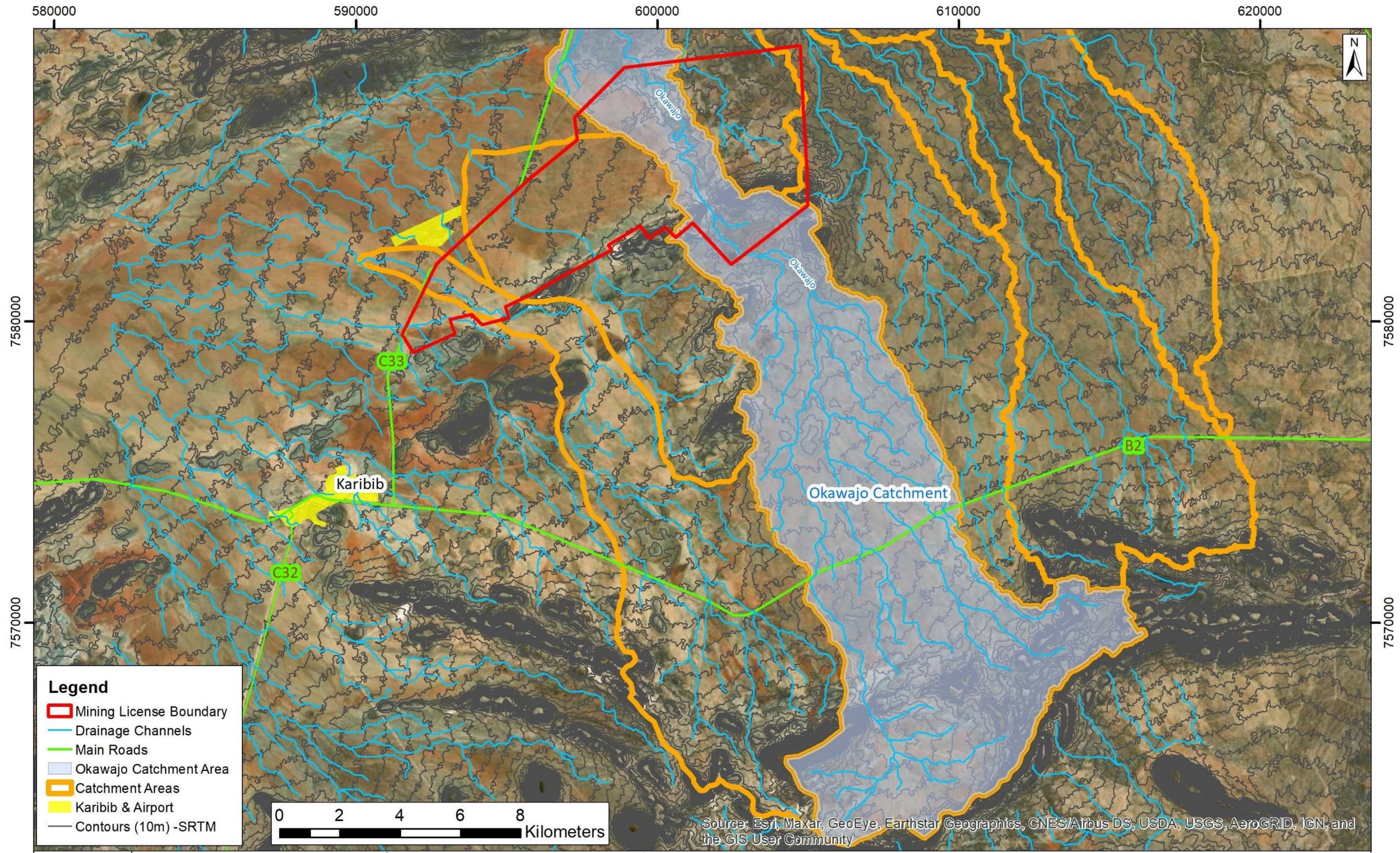
Table 2-5 Flood Peaks for the Twin Hills Catchment Area

Return Period	Flood Peak Rational Method (m^3/s)	Flood Peak Statistical Method (2) (m^3/s)	Empirical Flood Peaks (m^3/s)	Flood Volume for Rational Method at Tc (5.85 hours (3)) (m^3)
2	20	1.3	-	631 800
5	31	5.2	-	979 290
10	42	10.7	30.5	1 326 780
20	58	19.3	41.6	1 832 220
50	89	37.8	58.2	2 811 510
100	127	59.1	73.9	4 011 930
200	185	88.9	-	5 844 150
500	-	146.0	-	-
1 000	-	206.6	-	-
10 000	-	579.0	-	-
Q_{RMF} (1)	-	-	557	-
Q_{PMF}	233	-	-	-

NOTES

1. REGIONAL MAXIMUM FLOOD METHOD KOVACS K-REGION = 4.
2. THE STATISTICAL LOG-PEARSON TYPE III FITTING WAS CONDUCTED.
3. SIMPLE TRIANGULAR DISTRIBUTION WAS ASSUMED USING 1 TC RISING LIMB AND 2 TC FALLING LIMB.

The peak flows based on the Rational Method are recommended to be used for further assessment due to known issues with the recorded glow gauging station data and a general under-representation of the factored Empirical Method flood peaks.



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Twin Hills Feasibility Study
Upstream Catchment Areas

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FIGURE NO. 2-3

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3.0 STORMWATER MANAGEMENT

It is recommended that the South African GN 704 legislation is adopted for the development of the stormwater management plan until an equivalent regulation is developed in Namibia. The GN 704 legislation stipulates that a storm event exceeding the 1 in 50-years return period should be used for sizing relevant infrastructure to separate clean stormwater (non-contact) from dirty water (contact) and vice-versa (RSA, 1998).

3.1 SITE STORMWATER

Runoff generated within the mining area, processing plant, handling, haul, and waste management areas should be managed by adding stormwater infrastructure, consisting of diversion channels, silt traps, berms gutters, pollution control reservoirs, and other components. The infrastructure is required to prevent dirty water, which was in contact with the mining-related activities, to pollute the surrounding areas, and allow for storage and retention of polluted water on site.

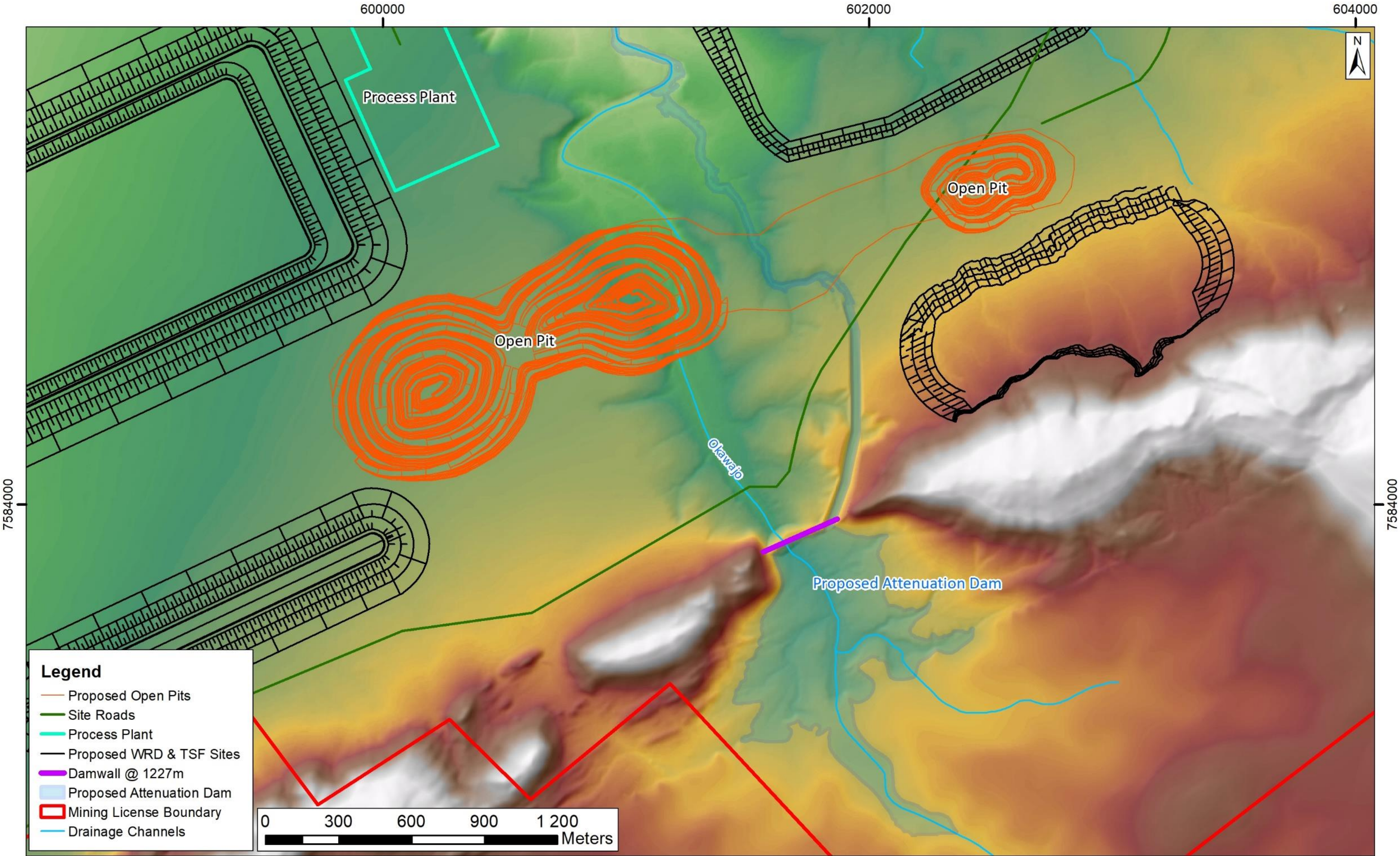
3.2 STORMWATER MANAGEMENT ADJACENT TO PIT

It is proposed that an attenuation dam is constructed upstream of the pit on the main catchment tributary to prevent damage to infrastructure and pollution of the environment. For this assessment, a daily Water Resources Simulation Model (WRSM) was used (Bailey & Pitman, 2016), generating a daily rainfall-runoff sequence.

The daily rainfall-runoff sequence was correlated against the scaled Spesbona flow gauging data, and it was determined that the simulated runoff sequence is deemed acceptable for stormwater balance purposes upstream of the mining pit.

A high-level topographic assessment of the gorge upstream of the pit was conducted to determine elevation, area, and storage relationships. Two options were investigated;

- **Option 1** covers the construction of an attenuation dam and diversion channel upstream of the farmhouse (Figure 3-1). Studies suggest that there are heritage sites on the banks of the river in that rivine, and this option should not impact them.
    - Figure 3-2 shows cross sections of the infrastructure used in these simulations
- **Option 2** is the construction of a diversion weir and channel closer to the current proposed pit layout (Figure 3-3) which acts as a stormwater diversion structure on the main watercourse between the two open pits.
    - Figure 3-4 shows cross sections of the infrastructure used in these simulations



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Twin Hills Feasibility Study
Option 1: Proposed Attenuation Dam

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FIGURE NO. 3-1

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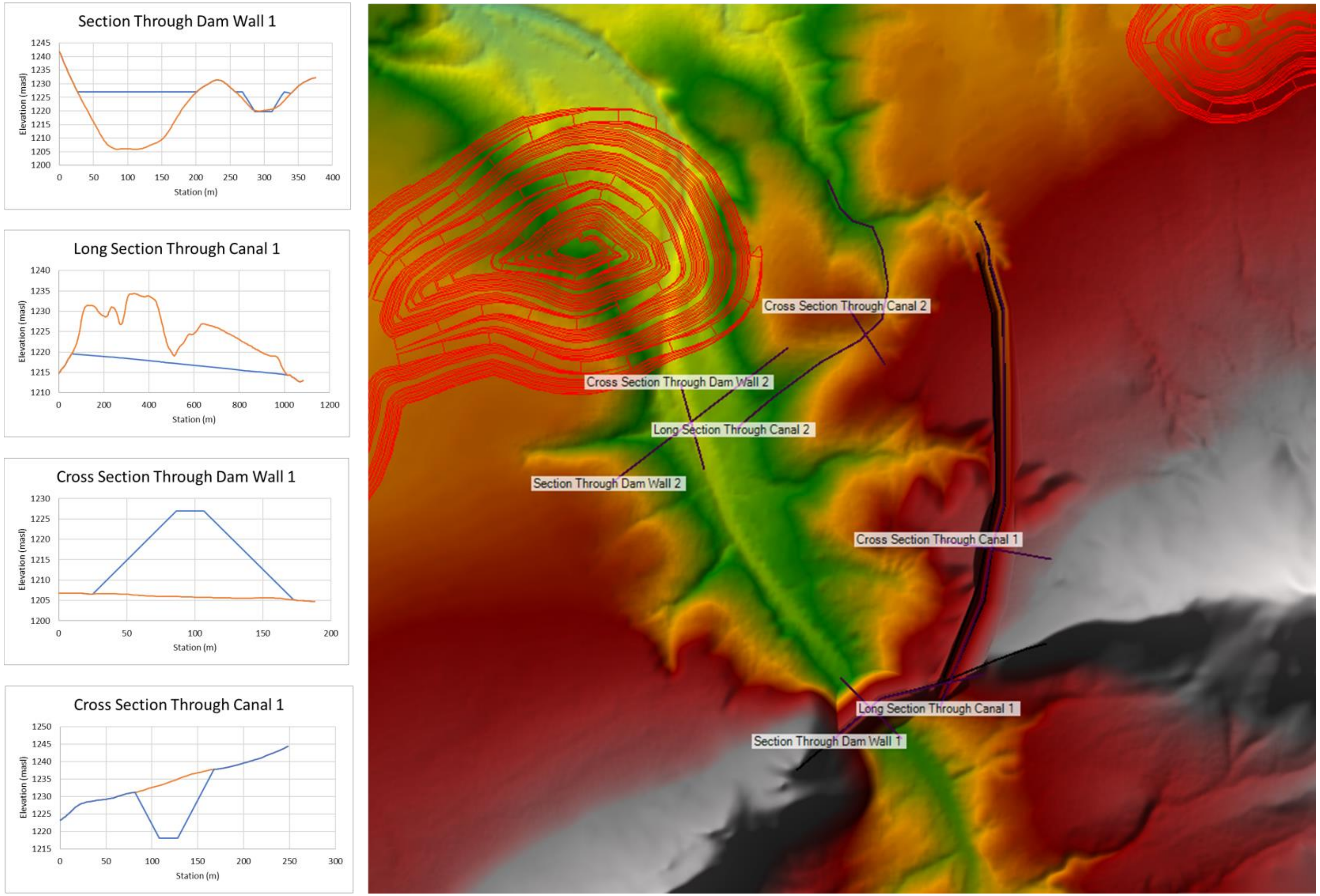
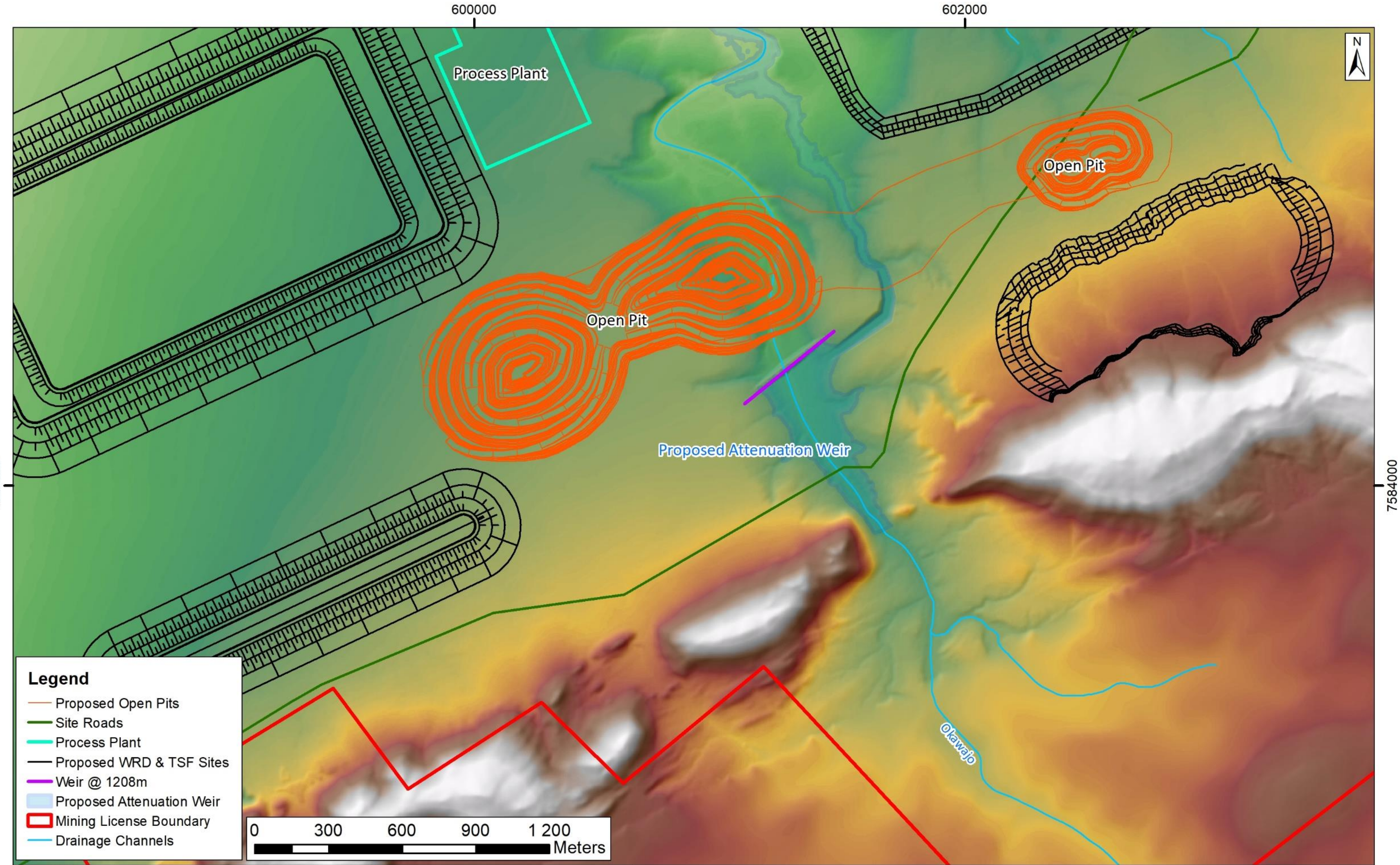


Figure 3-2: Cross Sections through Option 1



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Twin Hills Feasibility Study
Option 2: Proposed Attenuation Weir

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FIGURE NO. 3-2

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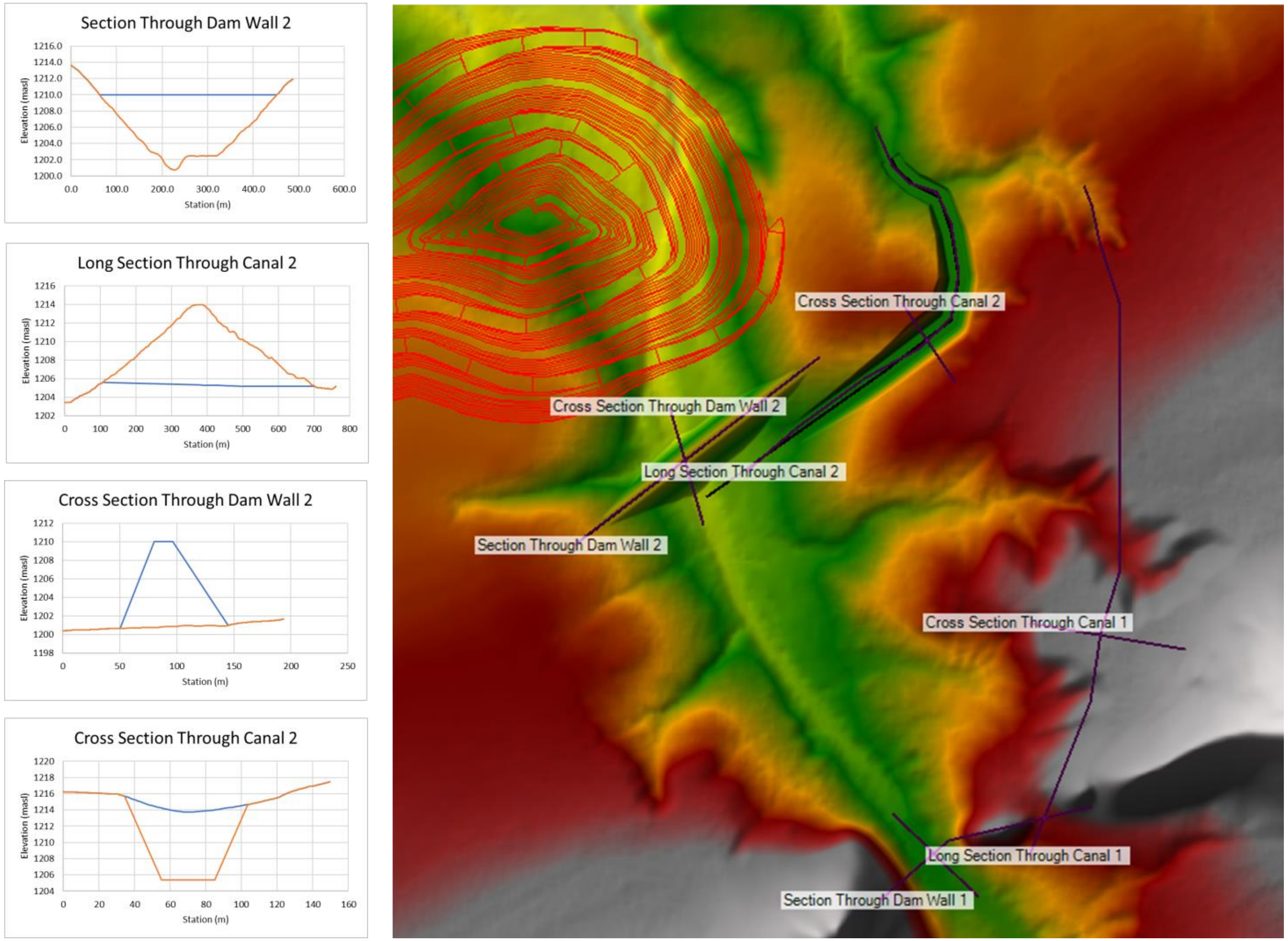


Figure 3-4: Cross sections through Option 2

3.2.1 STORAGE AND ELEVATION ASSESSMENT FOR OPTION 1 AND 2

The storage and elevation assessment for **Option 1** indicated that the lowest elevation of the stormwater facility is at 1 205 masl, and the highest level of the reservoir at 1 235 masl, resulting in an approximate total storage volume of 18.4 Mm³ as determined from NASDEM terrain data. The storage elevation curve is presented in Figure 3-5, and the elevation-storage-area data are summarised in Table 3-1.

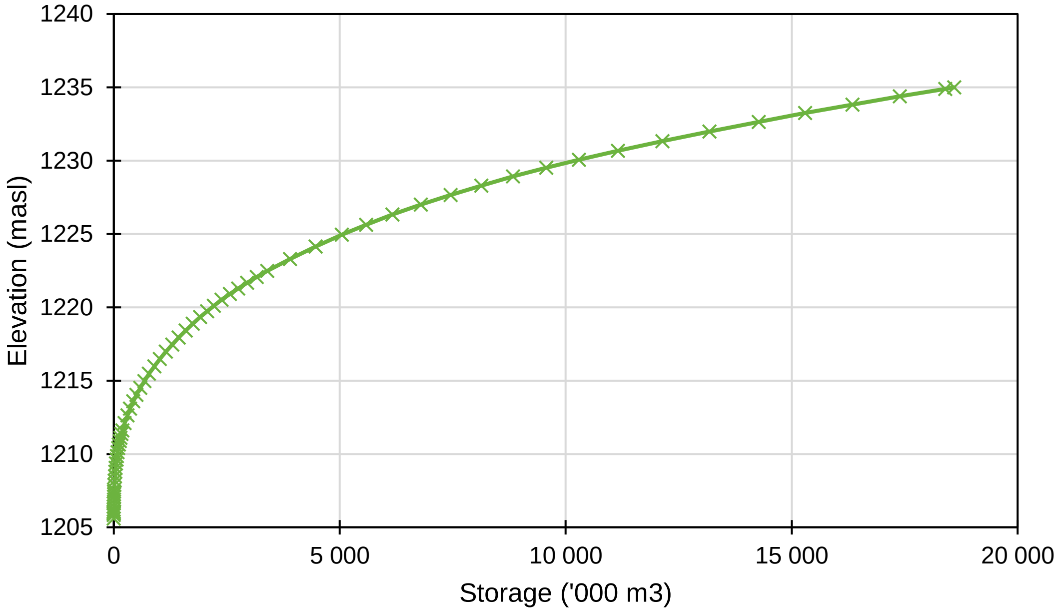


Figure 3-5 Approximate Storage-Elevation relationship Option 1

Table 3-1 Approximate Elevation-Volume-Storage relationships Option 1

Elevation (masl)	Volume (m^3)	Area (m^2)	Elevation (masl)	Volume (m^3)	Area (m^2)
1205.6	10	50	1221.6	2,758,660	477,220
1207.6	8,600	11,071	1223.6	3,945,970	622,500
1209.6	57,420	36,690	1224.2	4,466,810	661,128
1211.6	174,820	83,276	1225.6	5,584,820	792,397
1213.6	421,340	139,404	1227.0	6,797,290	925,794
1215.6	787,520	213,463	1228.3	8,134,480	1,058,938
1217.6	1,195,700	269,673	1230.1	10,293,960	1,307,509
1219.6	1,873,230	350,212	1232.7	14,271,330	1,653,318
1221.6	2,758,660	477,220	1,234.9	18,402,450	1,977,647

The storage and elevation assessment for **Option 2** indicated that the lowest elevation of the stormwater facility is at 1 200.8 masl, and the highest level of the reservoir is at 1 210 masl, resulting in an approximate total storage volume of 864 000 m³ as determined from NASDEM terrain data. The storage elevation curve is presented in Figure 3-5, and the elevation-storage-area data are summarised in Table 3-1.

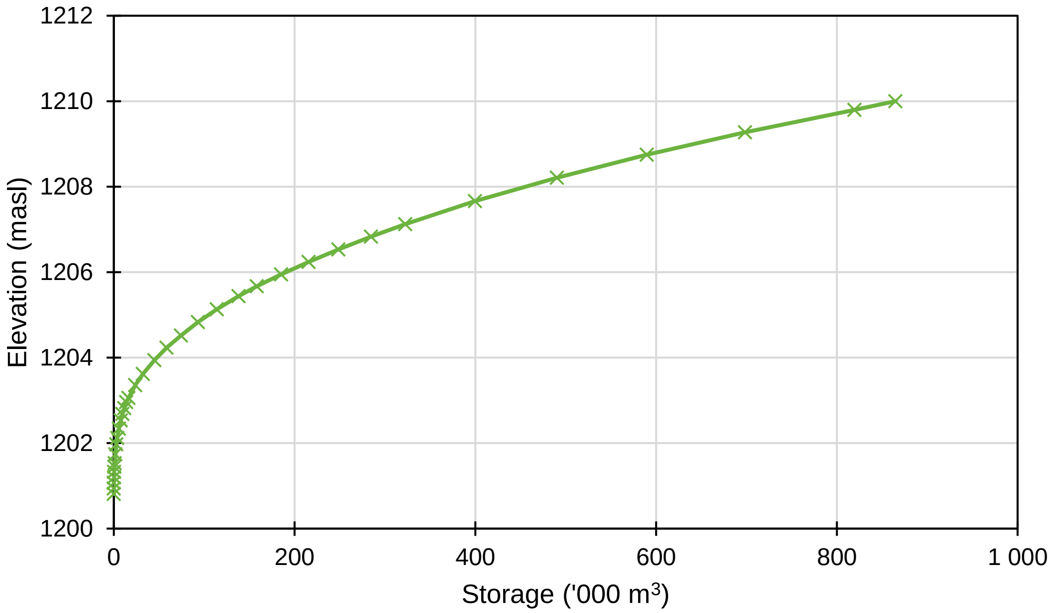


Figure 3-6 Approximate Storage-Elevation relationship Option 2

Table 3-2 Approximate Elevation-Volume-Storage relationships Option 2

Elevation (masl)	Volume (m^3)	Area (m^2)	Elevation (masl)	Volume (m^3)	Area (m^2)
1,200.9	20.0	153.8	1,204.2	58,260.0	200,896.6
1,201.2	240.0	1,846.2	1,204.8	93,180.0	300,580.6
1,201.5	690.0	5,750.0	1,205.4	138,160.0	445,677.4
1,201.7	1,690.0	8,047.6	1,206.0	185,260.0	661,642.9
1,202.1	3,880.0	25,866.7	1,206.5	248,400.0	856,551.7
1,202.5	7,620.0	40,105.3	1,207.1	322,570.0	1,112,310.3
1,202.8	11,590.0	82,785.7	1,208.2	490,290.0	891,436.4
1,203.1	16,140.0	161,400.0	1,209.3	698,390.0	1,343,057.7
1,203.6	32,200.0	123,846.2	1,209.8	819,580.0	1,546,377.4

3.2.2 DAILY RAINFALL/RUNOFF AND ATTENUATION MODEL

The size and nature of the upstream catchment of the proposed pit area require a daily time step rainfall and runoff model. The attenuation assessment aims to indicate which upstream reservoir storage capacity is required to capture a storm event and to indicate which spillway sizes are required to convey spills for different sizes. This assessment pertains to Option 1, as Option 2 is not designed to capture all runoff, but to divert it.

The runoff sequence was simulated using the daily Water Resources Simulation Model (WRSM) 2000. The daily rainfall data from the Namibian Meteorological Offices for the Karibib Rainfall Station was converted into the required input format to be used for the rainfall/runoff simulation. The calibration parameters from the WRSM 2000 software are shown in Table 3-3 and are based on known catchment characteristics. The daily model resolution is essential to size the spillway and diversion system.

Table 3-3 WRSM 2000 Daily Calibration Parameters

Parameter	Value
Power in the soil	1
Soil moisture state (mm)	0
Soil moisture storage (mm)	150
Subsurface flow (mm/day)	0.1
Portion of impervious area	0
Min. absorption rate	0
Max. absorption rate	15
Interception storage	5
Lag of flow	5
Overall time delay	0
Lag of groundwater	10
Coefficient in the evaporation	0.5

A graph comparing the daily rainfall to the simulated runoff is shown in Figure 3-7. The left vertical axis (orange) indicates the daily precipitation for the Karibib MET Station, the right vertical axis (blue) shows the average simulated runoff based on the calibrated WRSM 2000 output. The rainfall runoff patterns can be described as arid, with occasional floods due to cloud bursts.

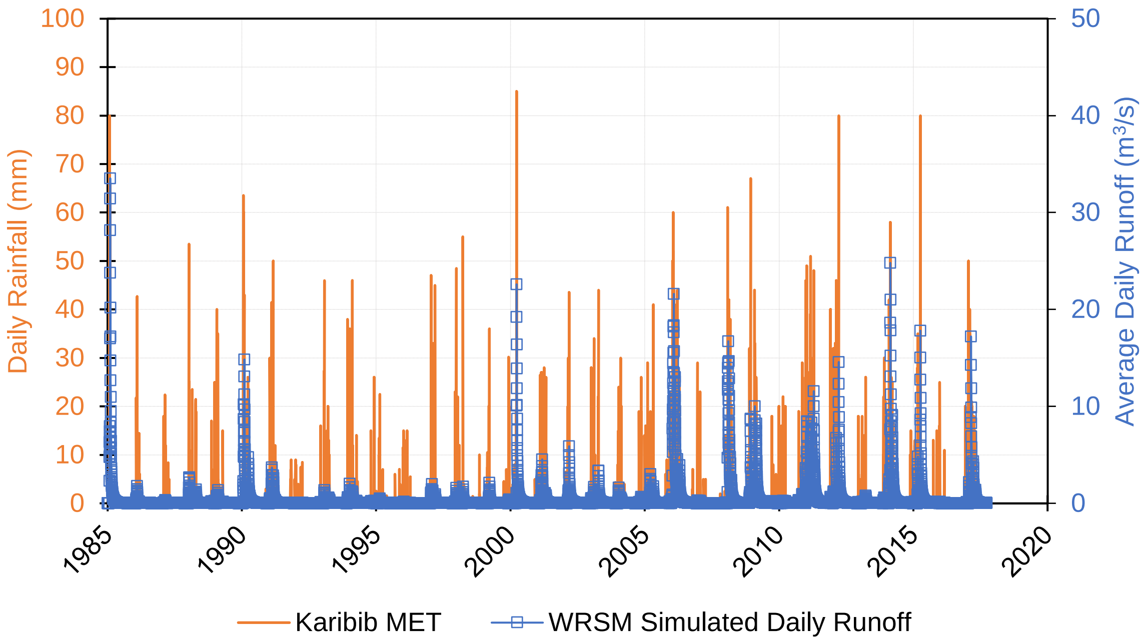


Figure 3-7 Daily Rainfall vs Runoff Plot

Based on the daily rainfall data and simulated runoff sequence, a daily water balance model was developed in Microsoft Excel, taking the following components into account:

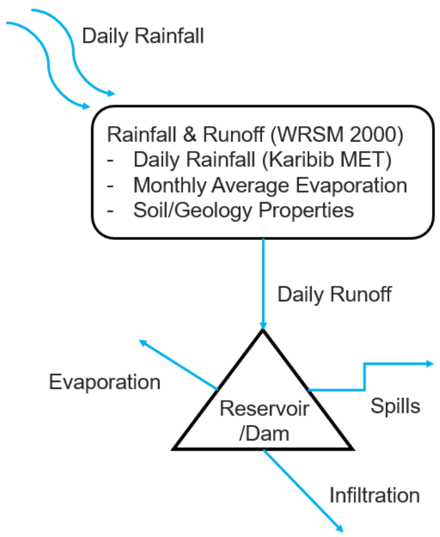


Figure 3-8 Daily Reservoir Routing Model

The attenuation storage volume for Option 1 over time is shown in Figure 3-9, indicating that storage of 17.9 Mm^3 is required and a dam height of 28 m to contain all the floods without any spills over the 36-year record period, which is statistically equivalent to a 1 in 50-year return period flood.

The storage volume was decreased incrementally to determine the relationship between spillway sizes and reservoir storage volume, which can route the flood without the dam spilling, as shown in Figure 3-10. If a smaller flood attenuation structure of about 50 000 m^3 in storage size is used, which results in a maximum daily flood peak of 34 m^3/s to be routed.

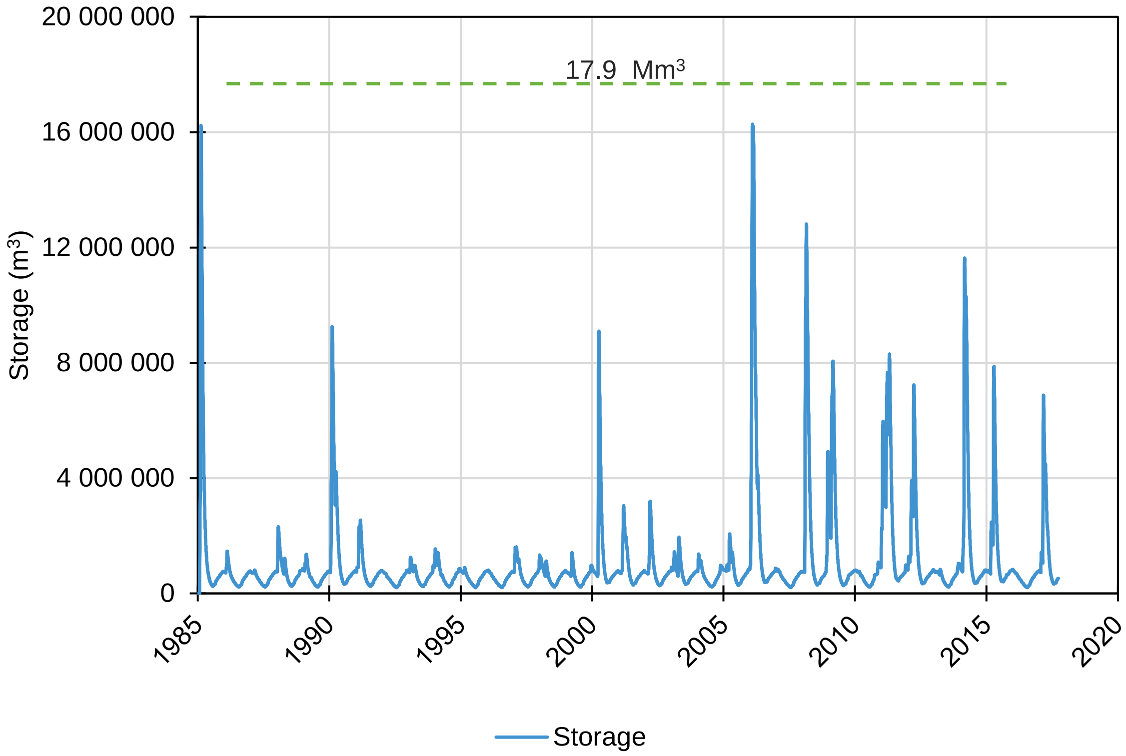


Figure 3-9 Daily Reservoir Plot

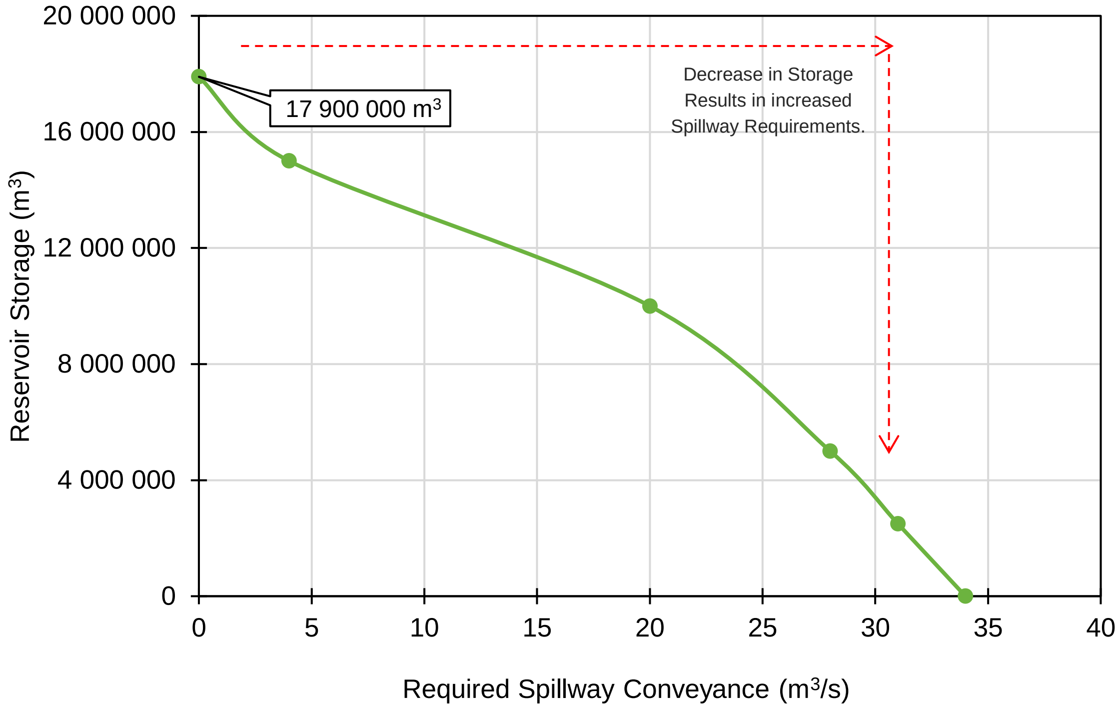


Figure 3-10 Spillway size vs storage

4.0 SURFACE WATER SUPPLY

4.1 OVERVIEW

This section focuses on surface water resources alternative to the stormwater options discussed in Section 3.0. The current mine design indicates a daily requirement of 4 100 m^3/day (1.5 million m^3/annum) for the estimated 3.5 million tonnes per annum (mtpa), to sustain mining operations and related activities (KP, 2021).

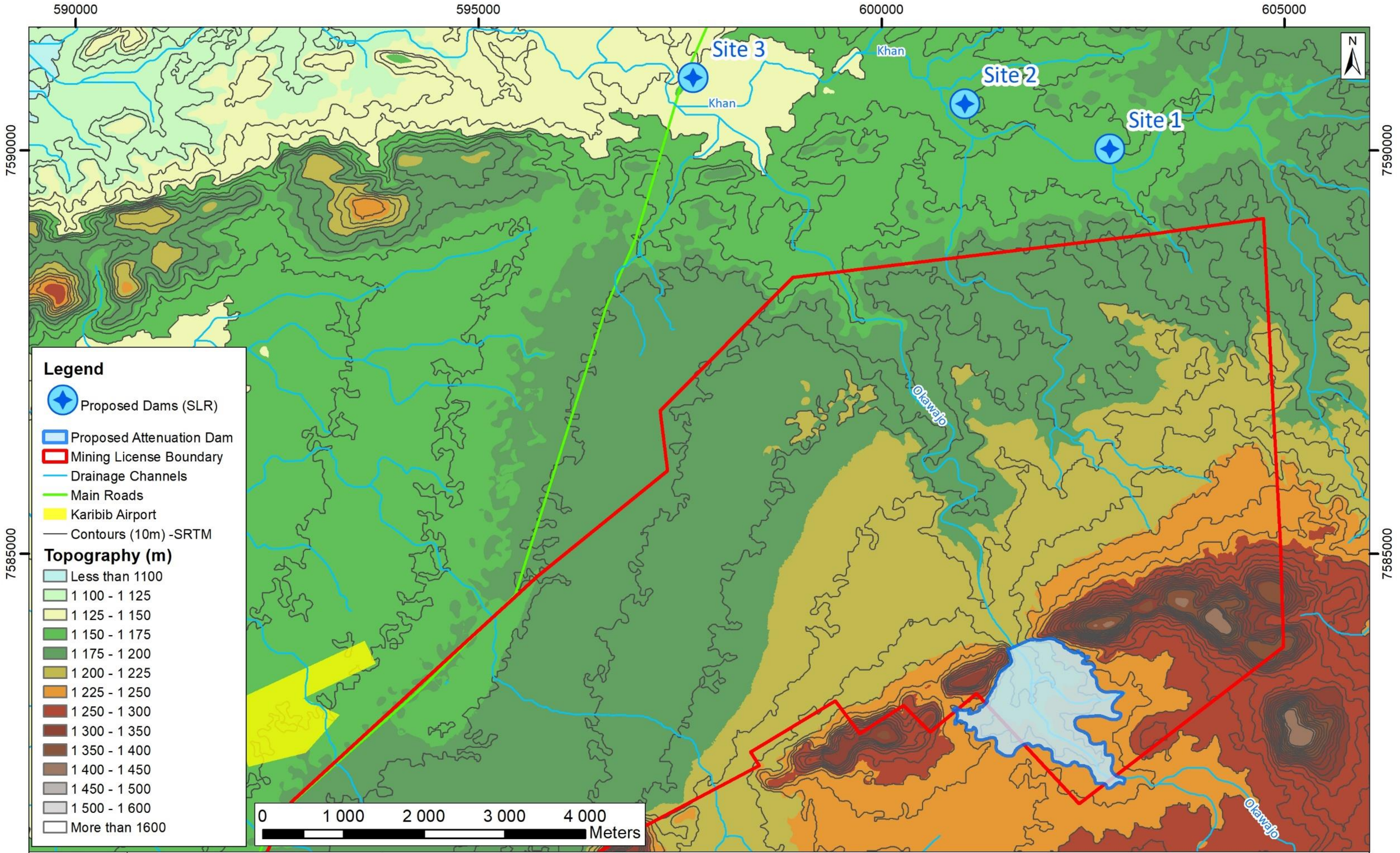
Water supply options, that were also addressed in the SLR Report (Kambinda and Bittner, 2020b), are listed below and discussed further in the subsequent sections:

- Three potential local dam sites on the Khan River, with catchment areas ranging from approximately 2 100 km^2 to 2 400 km^3.
- Obtaining a water use license from the existing Namwater Swakoppoort to Karibib Pipeline given that there is sufficient capacity for mining activity.
- Planned desalination pipeline, which will primarily be used to support the Central Area of Namibia (CAN). According to the CAN Surface Water Augmentation Report, the desalination pipeline will supply water at the earliest in 10 years (LCE and SCE, 2015).
- Local groundwater sources were also discussed, and it was indicated that high yields are expected from the boreholes. This study does not discuss groundwater options as it is being addressed by another study being undertaken by KP.

4.1.1 LOCAL DAM SITES

SLR proposed the construction of one local dam, at three potential sites, indicated in Figure 4-1 (Kambinda and Bittner, 2020a). The proposed dam sites are located on the main Khan River. The large catchment areas allow for larger volumes of runoff to be captured compared to the attenuation dam, located upstream of the dam. Three potential dam sites are discussed in the SLR Report (Kambinda and Bittner, 2020a).

In addition to these dams, the construction of a flood attenuation facility upstream of the pit area is proposed. Erratic rainfall patterns with long critical periods, where limited rainfall occurs, results in a low yield of the reservoir. It is estimated that the average annual unit runoff is less than or equal to five millimetres, based on rainfall and runoff calculations in the area conducted by the Department of Water Affairs in the 1980s. The proposed flood attenuation reservoir has a maximum wall height of 30 meters and a full supply capacity of approximately 18 Mm^3. The SLR dam sites and proposed attenuation facility with the inundated area are shown in Figure 4-1.



PROJECT NO. RI301/0913/03	Coordinate System: WGS 1984 UTM Zone 33S Projection: Transverse Mercator Datum: WGS 1984 Units: Meter	**Twin Hills Feasibility Study** **Proposed Dam Sites**	
BY TJO			
CHECKED NAME		CLIENT: Osino Resources	FIGURE NO. 4-1
DRAWING DATE Aug. 04, 2021			

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4.1.2 SWAKOPPOORT DAM TO KARIBIB PIPELINE

This water supply option consists of a pipeline from the Swakoppoort Dam to the Okangawa Reservoir, followed by the water treatment plant and storage at Karibib. The infrastructure is described in detail in the Swakoppoort – Von Bach - Navachab Water Supply Scheme Report (Namwater, 2020).

A water supply system schematic is shown in Figure 4-2 and a map of the pipeline route in Figure 4-3. The schematic indicates the location of dams (triangles), reservoirs (cylinders), and other features. The red lines in the diagram indicate the two pipeline route options, either directly from the terminal reservoir at Karibib, with an estimated pipeline length of 18 km, or an offtake from the Spesbona Reservoir, which has an estimated pipeline length of 8 km. Namwater sales or consumption data could not be obtained for the system, for this report, it is estimated that there is sufficient capacity to support the mine water requirements. The availability of water from this system will need to be negotiated with Namwater, as there might not be sufficient capacity and resources to support additional users. Namwater was not able to provide additional information on the current capacity of the system and its ability to supply the mining activity with potable or raw water.

The Swakoppoort Dam has an estimated capacity of 63.5 Mm^3, with a yield of 4.5 Mm^3 at a 95% assurance level. There are water quality issues at the Swakoppoort Dam when the water level is low in the dam, resulting in hyper eutrophication from high nutrient loads released in the upper reaches of the catchment near Windhoek. The high nutrient load in the raw water might have a significant impact on the hydraulic efficiency of the pipeline network, due to biofilm growth reducing the diameter of the pipelines. As the storage level decreases in the dam the nutrient concentration increases. Adequate care should be taken to ensure that the water treatment process caters to the highly variable water quality (Namwater, 2020).

The pipe length from the Karibib Reservoir to the Study area is about 25 kilometres and a recommended pipe diameter of 200 mm is required to meet the water demand of the mine.

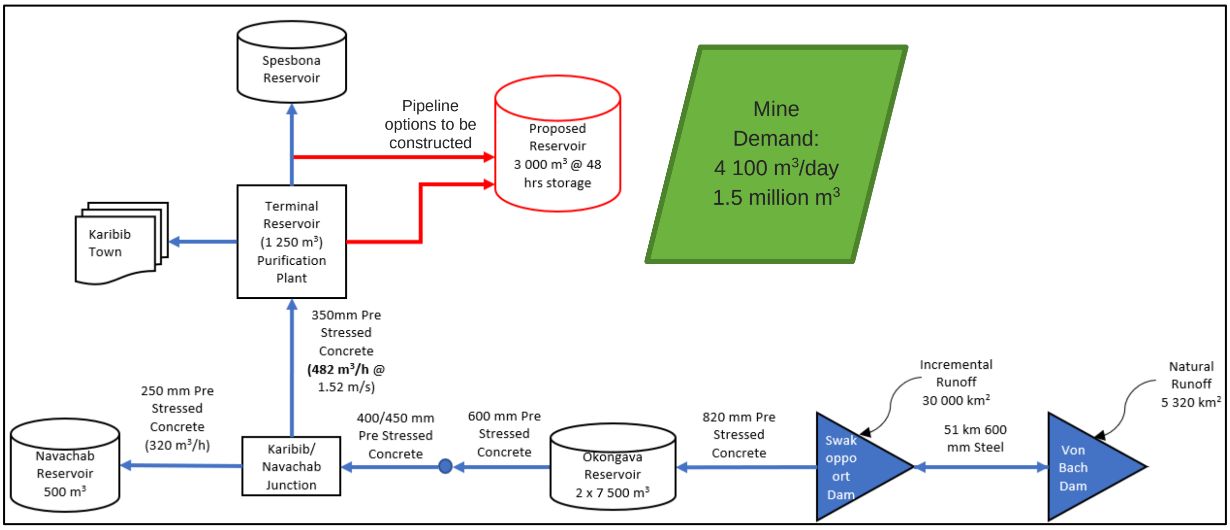
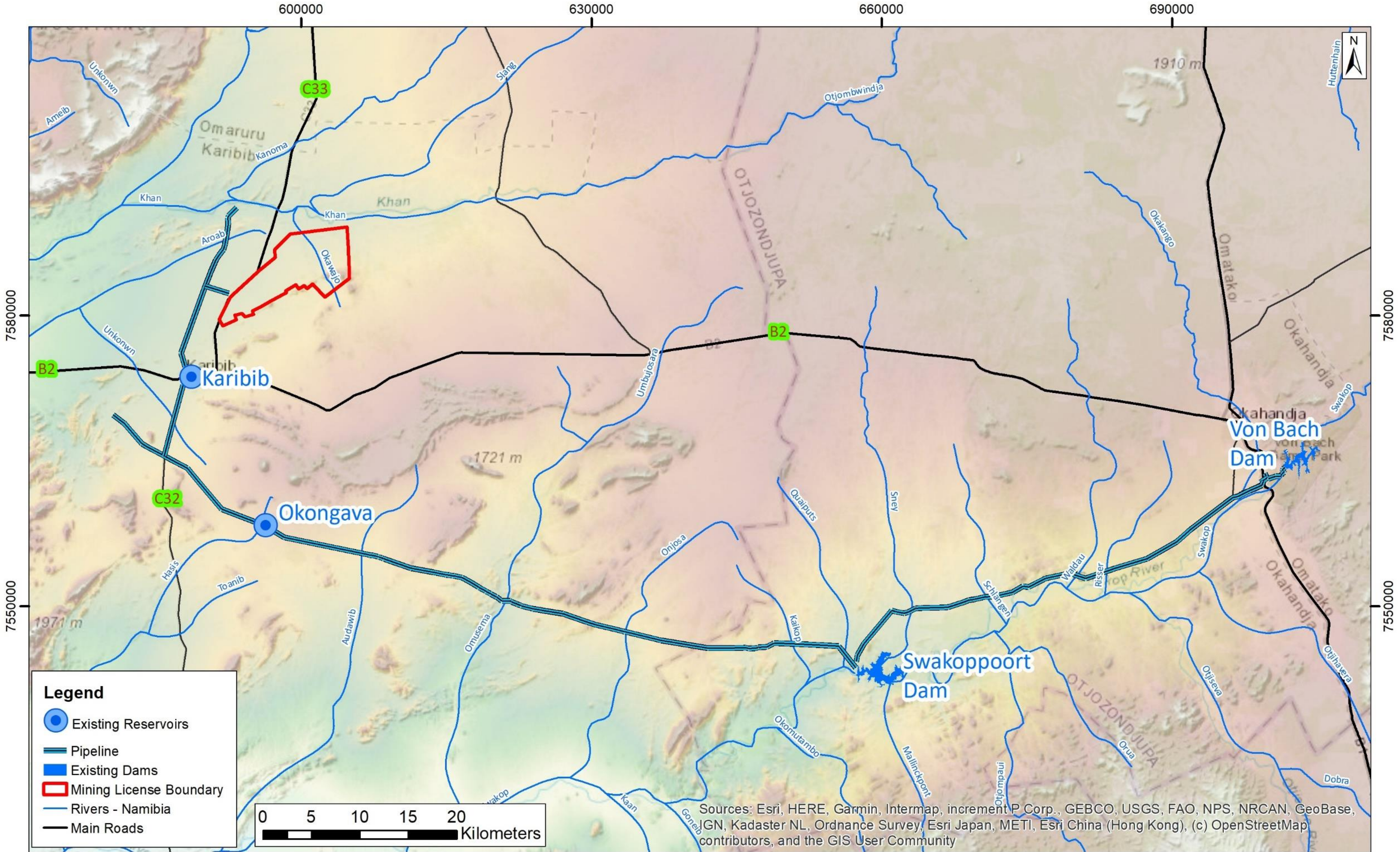


Figure 4-2 Namwater Supply Schematic



PROJECT NO.	RI301/0913/03
BY	TJO
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DRAWING DATE	Aug. 04, 2021

Coordinate System: WGS 1984 UTM Zone 33S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

Twin Hills Feasibility Study
Namwater Pipeline Route

CLIENT:
Osino Resources

FIGURE NO.
4-4

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4.1.3 PLANNED DESALINATION PIPELINE

The pipeline route for the desalination support to the CAN will follow the B2 Road from Swakopmund to Okahandja, adjacent to the mining operation, as shown in Figure 4-4 (LCE and SCE, 2015). Support from the pipeline will be costly due to the high pumping costs and the expensive desalination process itself. The desalination plant and pipeline are planned to be implemented in 2031 and it is estimated that one cubic meter of water is going to cost more than N$ 45 at 2020 infrastructure costs. The official reports have not yet been made publicly available. The unit cost is likely going to increase significantly, due to inflation of electricity and general costs.

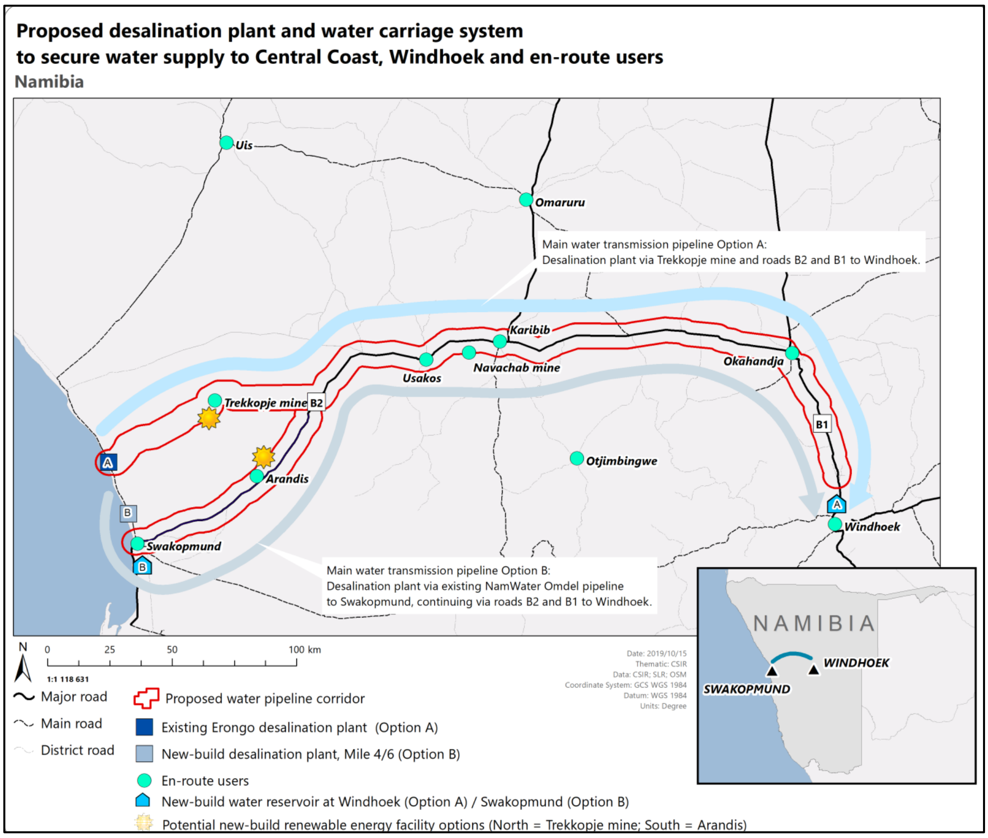
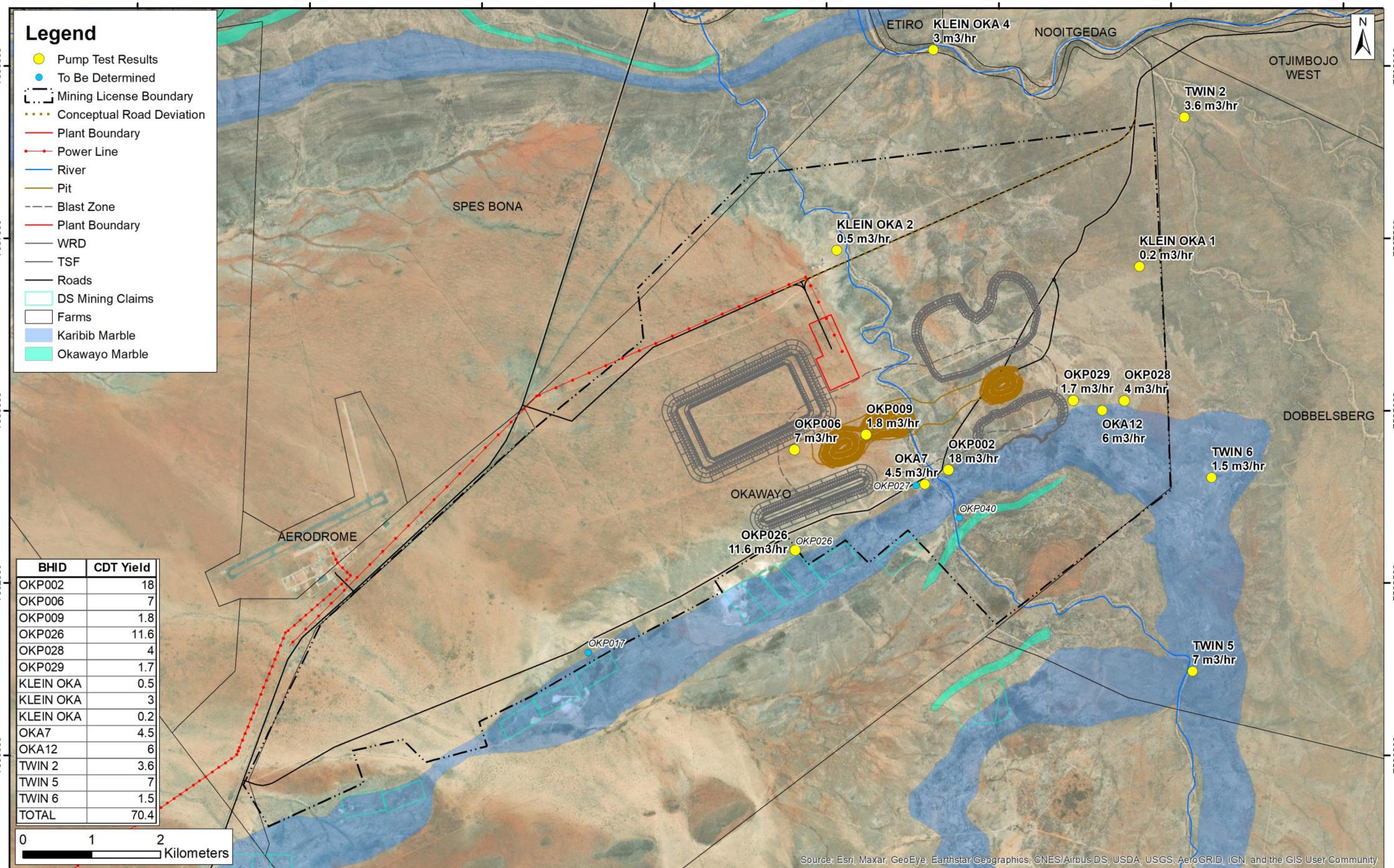


Figure 4-4 Desalination pipeline route (LCE and SCE, 2015)

4.1.4 SUPPLEMENTING WITH GROUNDWATER

Knight Piesold is currently undertaking groundwater exploration on-site to determine the groundwater resource potential and have conducted drilling and aquifer test pumping. Figure 4-5 indicates the current distribution of boreholes that have been pump tested (Including those from the SLR, Nov 2020 report), with the associated individual yields. As of the date of this report, the accumulated indicative yield is 70m^3/hr.

Additional boreholes that had higher blow yields are currently undergoing long term Constant Discharge Tests and will be added to the overall groundwater resource, which is estimated to add another 20-30m^3/hr, making an estimated total of between 90-100m^3/hr. Once the exploration program is completed, the test pumping results will be integrated into a Feflow numerical model to determine sustainable yields when abstracting from multiple boreholes and identify further exploration targets. The model will also determine the inflow volumes to the pit over the LOM, which can be added to the total groundwater resource.



BHID	CDT Yield
OKP002	18
OKP006	7
OKP009	1.8
OKP026	11.6
OKP028	4
OKP029	1.7
KLEIN OKA	0.5
KLEIN OKA	3
KLEIN OKA	0.2
OKA7	4.5
OKA12	6
TWIN 2	3.6
TWIN 5	7
TWIN 6	1.5
TOTAL	70.4

PROJECT NO.	WI301-00913/03
BY	C Kraak
CHECKED	C Kraak
DRAWING DATE	Oct. 01, 2021

Coordinate System: WGS 1984 UTM Zone 33S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

Karibib Gold Project - Twin Hills
Indicative Yields m3/hr

CLIENT: Osino Resources

FIGURE NO. 4-5

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4.2 SURFACE WATER SUPPLY RELIABILITY AND RISKS

Long drought periods of up to 7 years, typically referred to as critical periods, are common to the Namibian climate. During a long critical period, the groundwater table drops significantly due to limited recharge, causing some boreholes to dry up. Similarly, surface water sources, which are already stressed, might not be able to support priority users, resulting in water restrictions being enforced to prevent the failure of the water resource. Local dam options are typically developed over a long-time frame, in excess of 5 to 10 years, due to land acquisition, environmental and social studies, and full design and construction cycles. Developing water resources is also very costly due to the aforementioned factors. Making use of existing infrastructure up to Karibib should be considered as an intermediate solution until further water resources can be developed. A pipeline link from Karibib to the mine is required, provided there is excess capacity available.

A basic assessment scheme was created to determine the reliability and associated risk of the different supply options. The following three overarching categories were used to compare the five water supply options with each other:

- Accessibility concerns describe if the infrastructure already exists, the effort involved in developing the infrastructure and the distance from the infrastructure to the mine site. (Low to medium weight)
- Overall lifecycle cost based on all the capital and operating expenses related to the water supply option. (Medium weight)
- Reliability and yield concerns relate to the expected resource reliability, if and how often the resource is expected to fail, as well as the available volume. (High weight)

It is therefore advised to consider the development of groundwater sources, if readily available, in combination with a Namwater connection to the existing Karibib Scheme. A graphical matrix was created to emphasise how the different options were compared based on their reliability and associated risk, as shown in Table 4-1.

Table 4-1 Risk Matrix

Option		Accessibility Concerns	Overall Lifecycle Cost	Reliability and Yield Concerns	Overall Risk
Local Dams	Khan River (3 Potential Sites)	High	High	Low – Medium	High
	Storm Attenuation	High	High	Medium - High	High
Namwater Pipeline		Low	Low	Medium	Medium
Desalination		High	High	High	High
Groundwater		Medium	High	Medium	Medium

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on this study, the following conclusions can be made:

- The mean annual runoff volume for the catchment is expected to be 650 000 m^3, based on a unit runoff of 7 mm per annum over the catchment upstream of Option 1.
- The flood attenuation model captures multiple day events, indicating that a dam size of 17.9 million m^3 is required to absorb a flood without any spills.
- A spillway must be considered to safely route floods through the attenuation dam or diversion weir, the maximum capacity attenuation dam capacity is therefore not required.
- The attenuated flood water in conjunction with a Namwater connection and/or groundwater resources are indicating that they can likely support the mining activities.
- The desalination water supply options should be considered once it becomes available to prevent water supply shortages and minimise water supply issues.

The following recommendations are made:

- The final dam and spillway capacity depends on a detailed financial and risk assessment, with detailed design.
- The flood mitigation options should be implemented over time to match the open pit progression, to allow for timely construction.
- A more detailed topographical survey upstream of the mine pit should be conducted to determine a more accurate inundation boundary near the existing farmhouse and other relevant structures.
- Once the final mine layout is available, internal stormwater infrastructure and management should be assessed and stormwater intervention designed.
- Engage with the relevant government departments to be accounted for the water requirements along the desalination pipeline.
- Engagement with Namwater is required for the development of a connection to the Swakoppoort to Karibib Water Supply Scheme, water quality and capacity details should be clarified to inform further study details.
- If the Namwater pipeline does not have spare capacity, the development of local dams will need to be considered, as the desalination support pipeline from the Namibian coast to the CAN will only be operational after 10 years.
- Review of the proposed water supply options with the updated mine layout plan as well as including the groundwater resource options.

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7.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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