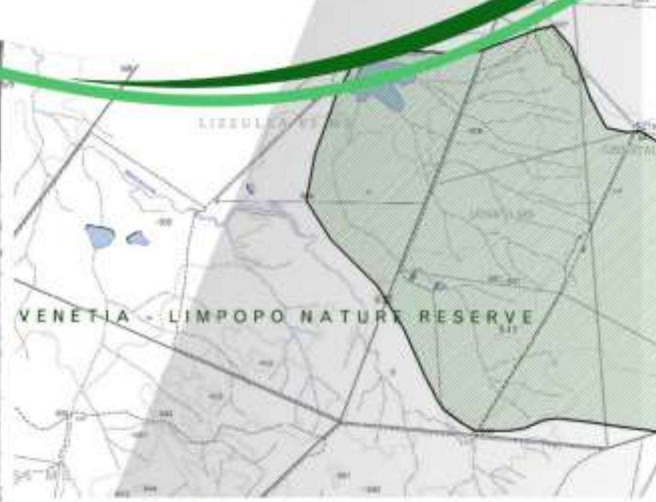

SPECIALIST REPORT ON SURFACE WATER

Venetia Limpopo Nature Reserve Lodge

NOVEMBER 2020

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02	February 2021	Text updated		HG vd Merwe	Engineer
03	March 2021	1:50 year floodline		HG vd Merwe	Engineer

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EXECUTIVE SUMMARY

Background

De Beers Consolidated Mines Ltd is in the process to establish accommodation on the banks of the Lizzulea Dam at their Venetia Operations. This process require Environmental Approvals and a specialist study required for these approvals is a Surface Water Report with the main purpose to provide floodlines.

The Lizzulea Dam is registered at the Department of Water Affairs, Dam Safety Office, as a dam with a safety risk and as a Category I dam.

Lizzulea Dam is located North of the Venetia Operations at coordinates:

- 22°20'41.80"S
- 29°19'38.46"E

Methodology

The Lizzulea Dam embankment and spillway influence the water levels of floods entering the basin. A flood routing procedure is required to model these water levels. This routing procedure require inflow hydrograph, reservoir capacity and spillway characteristics. The Veld type 8 HRU hydrograph (Midgley, 1972) was dimensionlised and proportioned to the Probable Maximum Flood (PMF), 150 and 1:100 year peak flood occurrence. The PMF was determined with the Rational method and the Probable Maximum Precipitation (World Meteorological Organization, 1986) as the point rainfall. The 1:50 and 1:100 year peak flood was chosen from a number of methods.

The capacity of the dam reservoir was determined through topographical survey and the spillway characteristics modelled with the HECRAS river analysis software.

Downstream of the embankment the water levels was modelled with the HECRAS river analysis software.

The Environmental Approvals also require the indication of 100m distance from the river. This distance was determined from the topographical survey.

Results and Conclusions

The VLNR Project boundary fall within the 32 and 100 m plan distance from the FSL of the Lizzulea Dam but outside the 1:50, 1:100 year and PMF floodlines (**Figure 1-1** to Error! Reference source not found.).

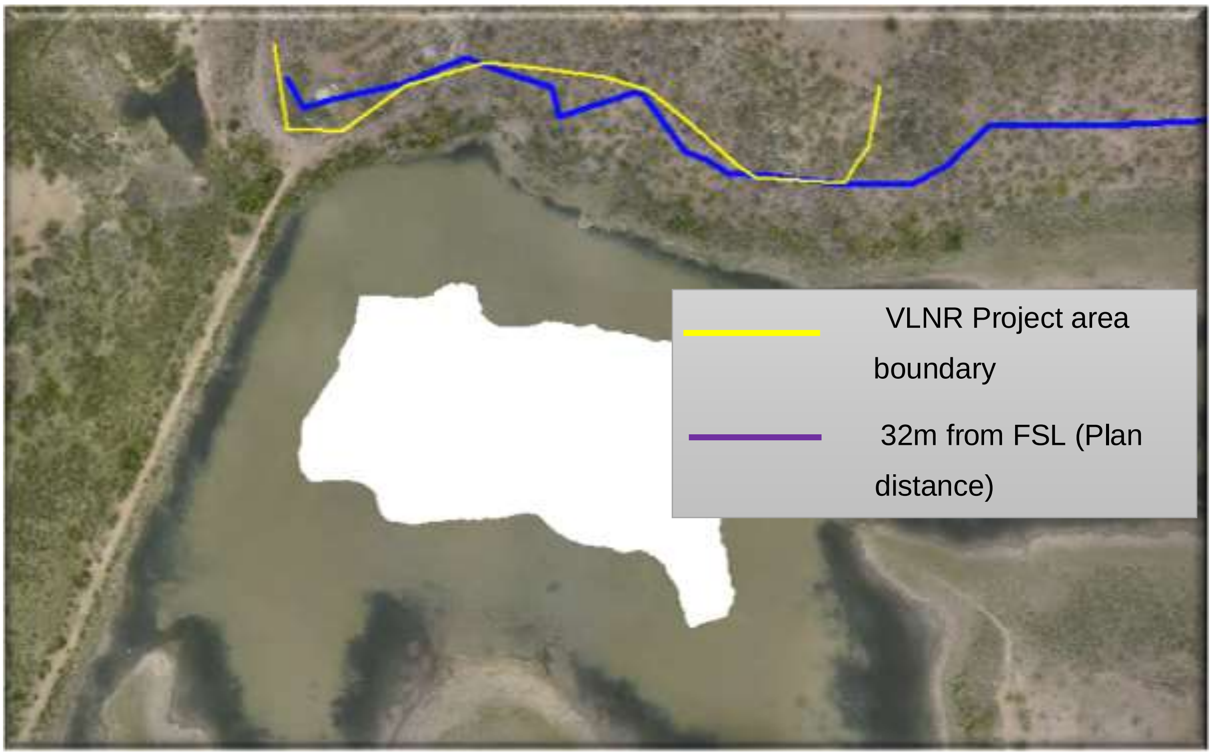

Figure 1-1: 32 m distance estimation

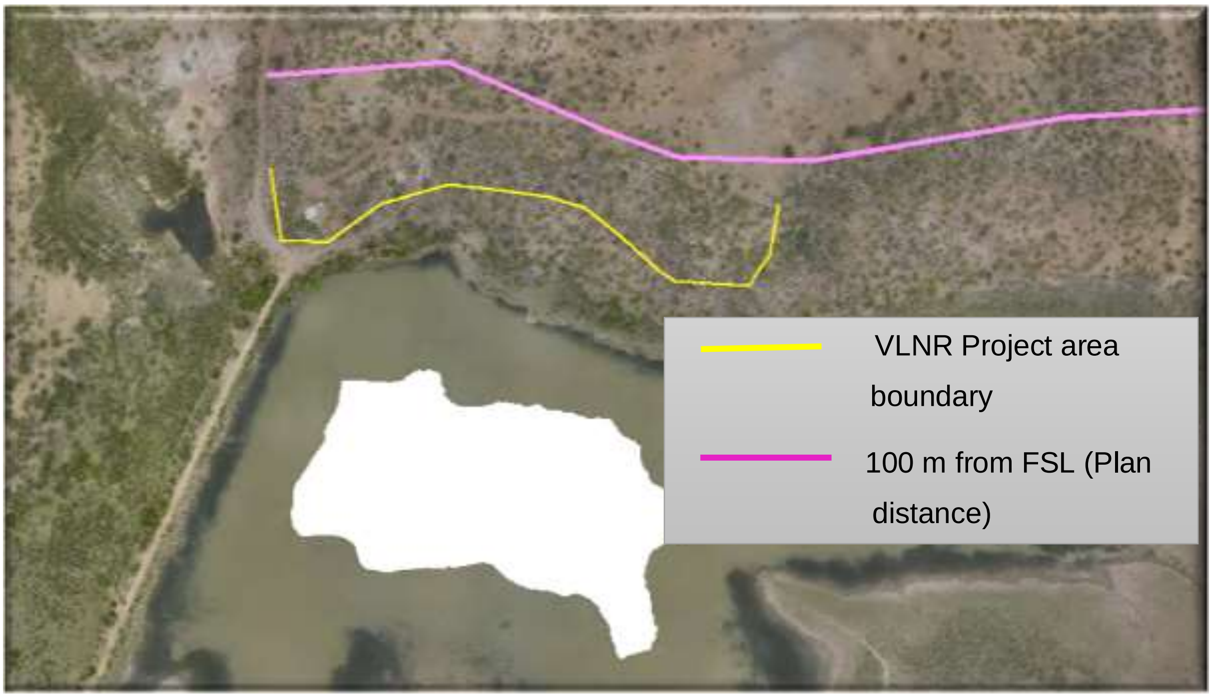

Figure 1-2: 100 m distance from water edge

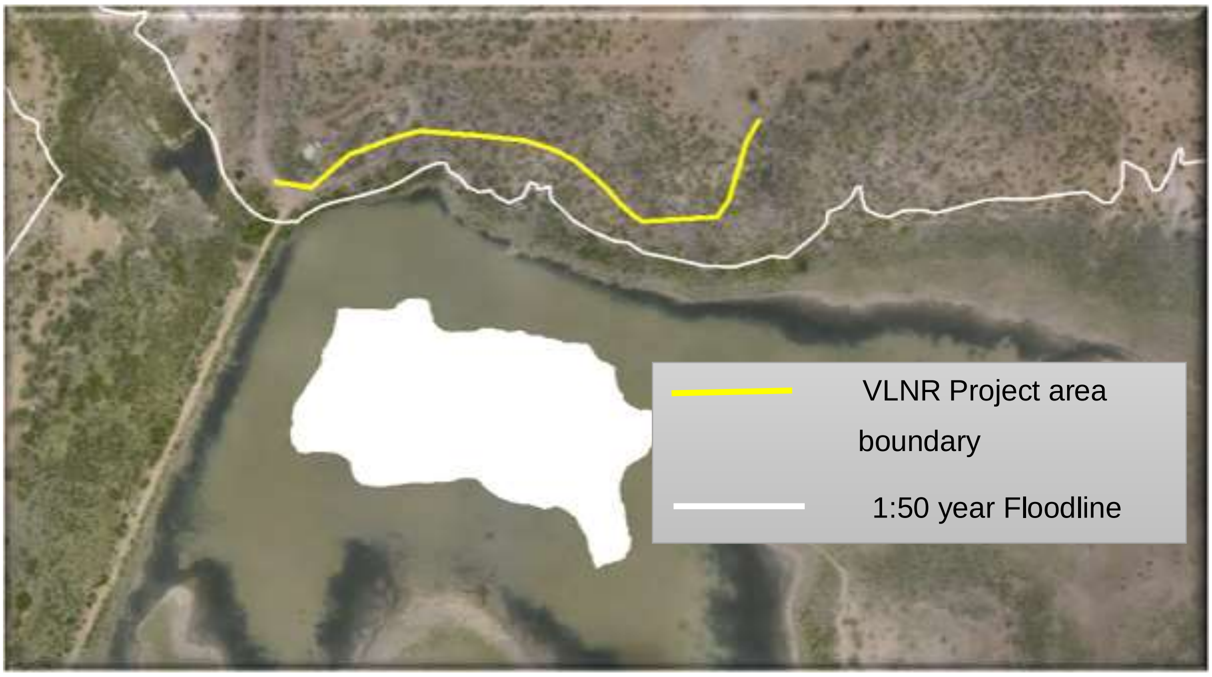

Figure 1-3: 1:50 floodline in relation to the VLNR project boundary

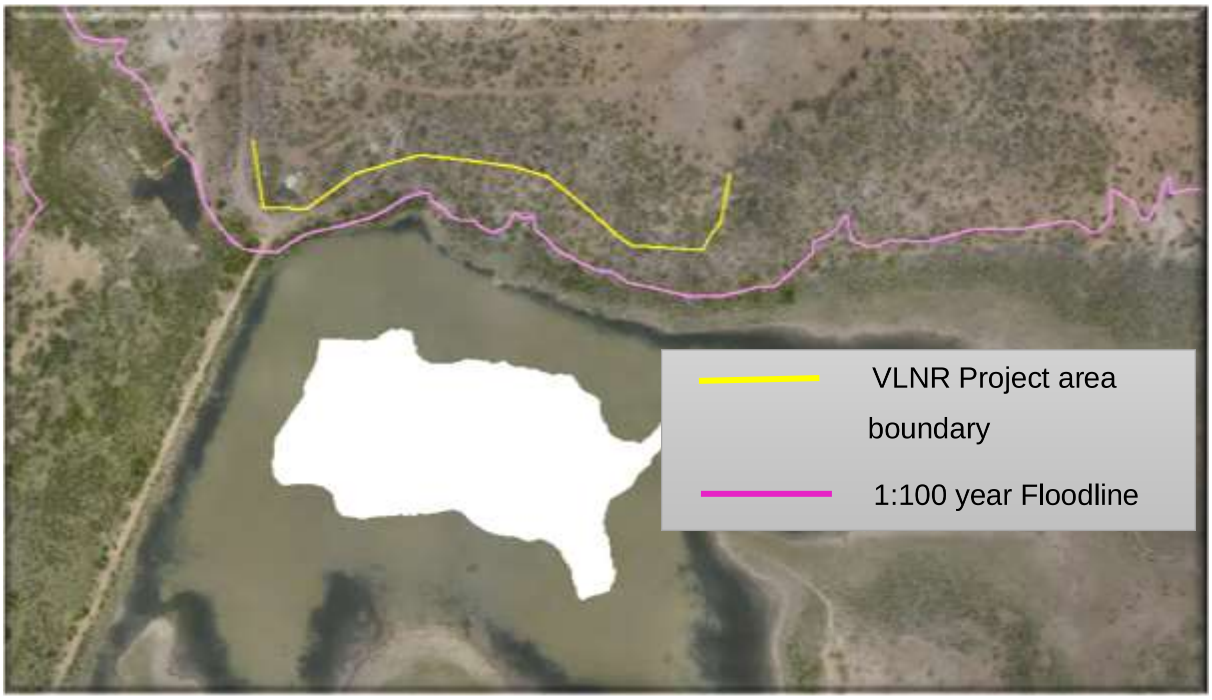

Figure 1-4: 1:100-year floodline in relation to the VLNR project boundary

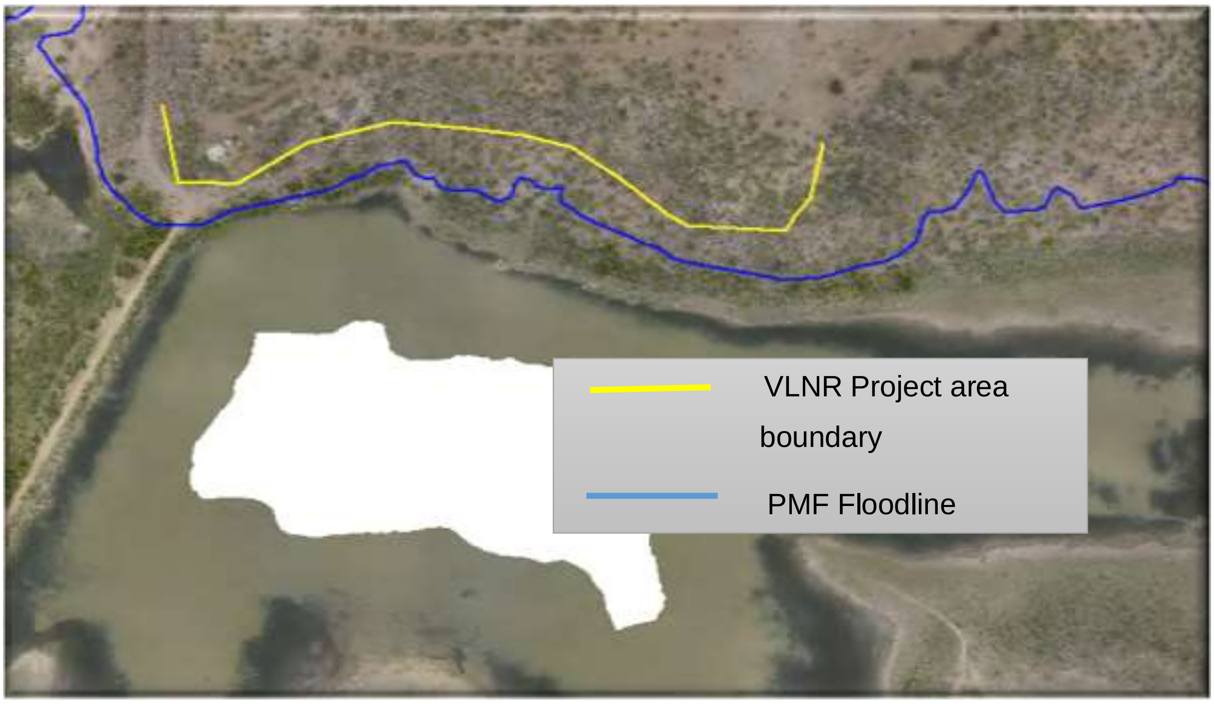

Figure 1-5: PMF Floodline in relation to the VLNR project boundary

Contents

FIGURES

TABLES

ACRONYMS

AEP	Annual Exceedance Probability
C	Run-off coefficient
EA	Environmental Authorisation
FSL	Full Supply Level
HRU	Hydrological Research Unit
I	Rainfall Intensity
NEMA	National Environmental Management Act
NOC	Non-Overspill Crest
masl	Meters above sea level
mamsl	Meters above mean sea level
MOL	Mean Operating Level
NEMA	National Environmental Management Act
NWA	National Water Act
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
RL	Relative level
ROD	Record of Decision
SWMP	Storm Water Management Plan
Tc	Time of Concentration
WUL	Water Use License
WULA	Water Use License Application

1 INTRODUCTION

1.1 Background

De Beers Consolidated Mines Ltd is in the process to establish accommodation on the banks of the Lizzulea Dam at their Venetia Operations. This process require Environmental Approvals and one of the specialist studies for these approvals is a Surface Water Report.

The Lizzulea Dam is registered at the Department of Water Affairs, Dam Safety Office, as a dam with a safety risk and as a Category I dam.

The owner of the Dam (De Beers Consolidated Mines Ltd) and the dam safety office does not have any information regarding this dam on record.

1.2 Report layout

This report will relate to the requirements of Regulations No. R1147[1] promulgated under NEMA.

The following will be addressed in this report:

- Determination of input information
    - Hydrology
        - Rainfall
    - Run-off catchment parameters
        - Size
        - Watercourse
        - Slope
        - Vegetation of the catchment,
        - Land use of the catchment,
    - Stage-capacity curve of the dam above FSL
    - Spillway and discharge channel parameters
- Methodology
    - Determination of the Probable Maximum Precipitation
    - Peak flood determination
    - Hydrograph compilation
    - Discharge rating curve
    - Level pool routing

[1] National Environmental management Act, 1998 (Act 107 of 1998), Government Notice Regulation 1147 dated 20 November 2015

- Discharge channel routing
- Results
    - Inflow – Outflow dam hydrograph
    - Dam water routing level
    - Discharge routing water levels
    - PMF, 1:50 and 1:100 year peak flood occurrence floodlines

1.3 Locality

Lizzulea Dam is located North of the Venetia Operations at coordinates:

- 22°20'41.80"S
- 29°19'38.46"E

The locality of Lizzulea Dam is shown on **Figure 1-1**.

Figure 1-1: Locality of Lizzulea Dam

The Project area of the accommodation is delineated as shown in **Figure 1-2**.

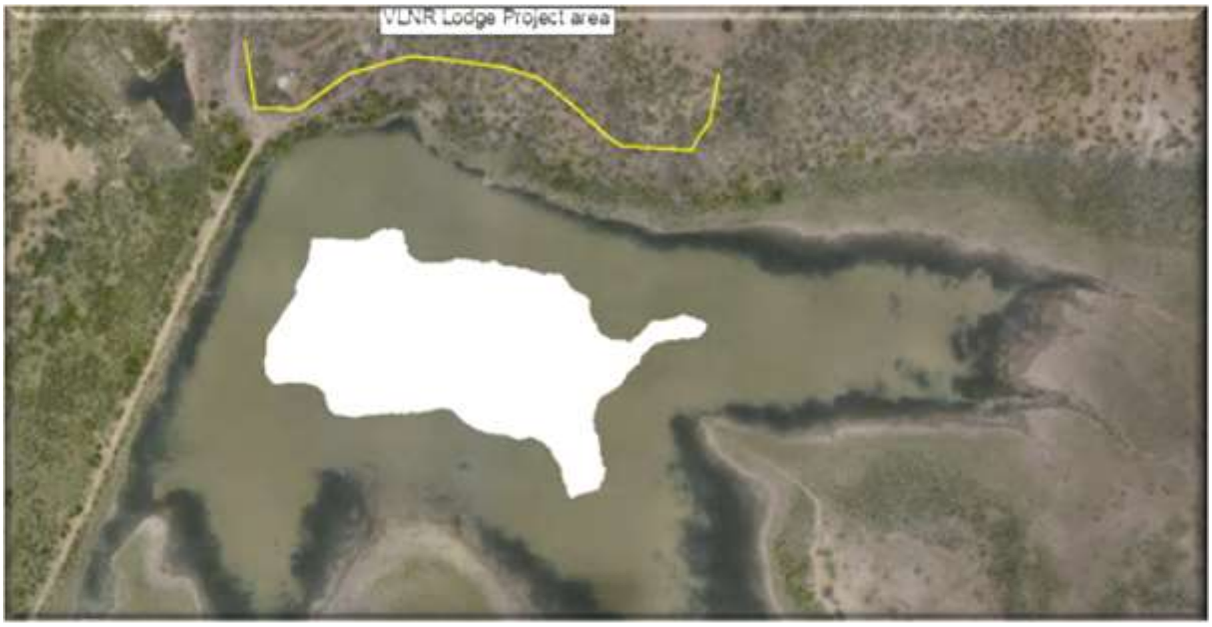

Figure 1-2: VLNR Lodge accommodation project area

1.4 Details of specialist and experience

Hermanus Gideon (Deon) van der Merwe is registered as a Professional Engineer with ECSA, Registration number 960070 and is the Director of the company Hydrological Engineering Solutions (Pty) Ltd situated at: 16 Mountain Jupitor, Centurion, SOUTH AFRICA T:+27(0) 82 895 1538

Deon has 27-years' experience in a wide field. Deon specialises in the design and project management of projects comprising dams, SWMPs, rehabilitation plans, canals, gabion structures and concrete structures. He also has experience in the management and maintenance of pump schemes and general management. He has successfully completed many water-related projects for the mining sector but has undertaken work for an array of other clients in other various sectors.

Deon served as the area manager/deputy regional director of the Tugela-Vaal Government Water Scheme on behalf of the then Department of Water Affairs (DWA), he was the deputy chief engineer for open channel systems and manager of the hydraulic laboratory at the DWA. He is thus aware of the challenges South Africa faces in terms of water resources management. He started his career at the Department of Agriculture and at exiting was the Principal Engineer – Soil Conservation for the North West Province.

His most recent project experience includes the cost closure methods and rehabilitation plans for, Jwaneng Diamond Mine, Thorncliffe Chrome Mine and Mogalakwena Platinum Mine. Deon is also the Approved Professional Person for the Dam Safety Evaluation of the 29 m high earth embankment Imvutshane Dam. Recent detail design work includes a Parshall flume for Mogalakwena Mine and an oil separator for Thorncliffe Mine.

Other large projects include the civil design of the 55 m high ACR Itare Dam components, the detail design for the rehabilitation of the 37 m high Mothusi Dam at Letseng Mine, EPC tender design of the ± 90 m high Arror ECRD, 3 130 m^3/s diversion tunnels, dam intake structure and cofferdams for the 1000 MW Hydroelectric Power Sounda Gorge Project, serving as the Civil Design Engineer for a 40 m high Concrete Gravity Dam and Powerhouse on the Orange River in South Africa for a installed capacity of 22 MW, Assistant Civil Design Engineer for the water infrastructure tender design of the 40 MW Kabompo Gorge Hydroelectric scheme in Zambia, the Assistant Design Engineer for the feasibility investigations and option analysis for the uMkhomazi transfer scheme, Design Engineer on the river diversion tender design for Neckartal Dam, Design Engineer for the review on the river diversion of the Mphanda Nkuwa Hydroelectric Project, Member of the project team for the Safety Evaluation of the Category III Bivane (Paris) Dam, Locumue (Mozambique) Dams, the Category II Doornpoort, Wilge River, 3rd Recovery, the Approved Professional Person for the Category II Raw Water Reservoirs at Lethabo Power Station and Imvutshane Dam and detail design and draughting of a 4 km concrete-lined canal for AngloGold Ashanti's West Complex (R6 million). Deon's full *Curriculum Vitae* is attached as **Annexure A.**

2 TERMS OF REFERENCE (ToR)

2.1 Legal Environment

2.1.1 National Environmental Management Act, Act 107 of 1998 (NEMA)

The following listing triggered this surface water report:

- Listing 1 (12) (x):

  The development of buildings exceeding 100 square metres in size; and if no development setback exists, within 32 metres of a watercourse, measured from the edge of a watercourse;
- Listing notice 3 (5)(c) (ii) (cc)

  Outside urban areas, in areas within 100 metres of a watercourse or wetland;

2.1.2 National Water Act, Act 36 of 1998 (NWA)

The National Water Act requires that:

Section 144: *"For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in every 100 years."*

Section 145 (1): *"A water management institution must, at its own expense, make information at its disposal available to the public in an appropriate manner, in respect of -*

(a) a flood which has occurred or which is likely to occur;

(b) a drought which has occurred or which is likely to occur;

(c) a waterwork which might fail or has failed, if the failure might endanger life or property;

(d) any risk posed by any dam;

(e) levels likely to be reached by floodwaters from time to time;

(f) any risk posed by the quality of any water to life, health or property; and

(g) any matter connected with water or water resources, which the public needs to know.

2.1.3 Anglo American risk

Anglo American have specific requirements in their standards for the position of structures where lives are at risk. The structure must not positioned at:

- "The outer edge of the 1 in 100-year floodline and/or delineated riparian area, whichever is the greatest",
- " In the absence of a determined 1 in 100 year floodline or riparian area the area within 100 m from the edge of the water course where the edge of the watercourse is the first identifiable annual bank fill flood bench"

2.2 Design criteria

The design criteria for determining floodlines are:

- 1:100 year and Probable Maximum Flood Annual Exceedance Probability (AEP) for peak floods and the methods to determine these are,
    - Rational Method Alternative 1 to 3,
    - Standard Design Method (UPD software)
    - Unit Hydrograph Method
    - TR137 method (Regional Maximum Flood),
    - Midgley and Pitman (UPD software)
    - World Meteorological Organization deterministic method for PMP determination ,
- Unit Hydrograph method (Midgley, 1972) for determining the hydrograph at Lizzulea Dam,
- HECRAS software for the spillway discharge rating curve and downstream water level determination,
- HYDRO CAD software for the level pool routing of Lizzulea Dam,
- Topographical survey of the spillway channel and area above the Full Supply (599.1 masl) Level of Lizzulea Dam,

3 TOPOGRAPHICAL SURVEY

A topographical survey was commissioned in order to determine the following characteristics of the dam embankment, basin and spillway channel:

- The stage-area-volume of the dam basin form the Full Supply Level to above the Non Overspill Crest level,
- The spillway channel,
- The embankment dimensions.

3.1 LiDar Survey

A LiDar survey was commissioned through Terrasurvey and the survey was completed at the end of November 2020. The aerial image as shown in **Figure 3-1** delineate the area covered by the LiDar survey.

Control points of a previous survey were used to linked the survey to the National Grid. The survey orientation used are:

- Datum: WGS 84
- Central Longitude: 29°
- Projection : Transverse Mercator

3.2 Challenges

The topographical survey did not cover the dam basin up to the Non-Overspill Crest level of the embankment. The highest contour delineating the basin that could be extracted was at level 600 masl (**Figure 3-2**) while the Non-Overspill Crest at its, highest position, is at 600.5 masl.

Higher contours could be extracted but not for the full area (**Figure 3-3**) as required to determine the area of each contour.

3.3 Mitigation

In order to obtain a full contour above the Non-Overspill crest of the embankment Satellite Radar Topography Mission data and the National Geo Spatial Information Network data was extracted. This data was overlain on the existing LiDar Data and the contours and area of 600.5, 601 and 601.5 masl was estimated (**Figure 3-4**).

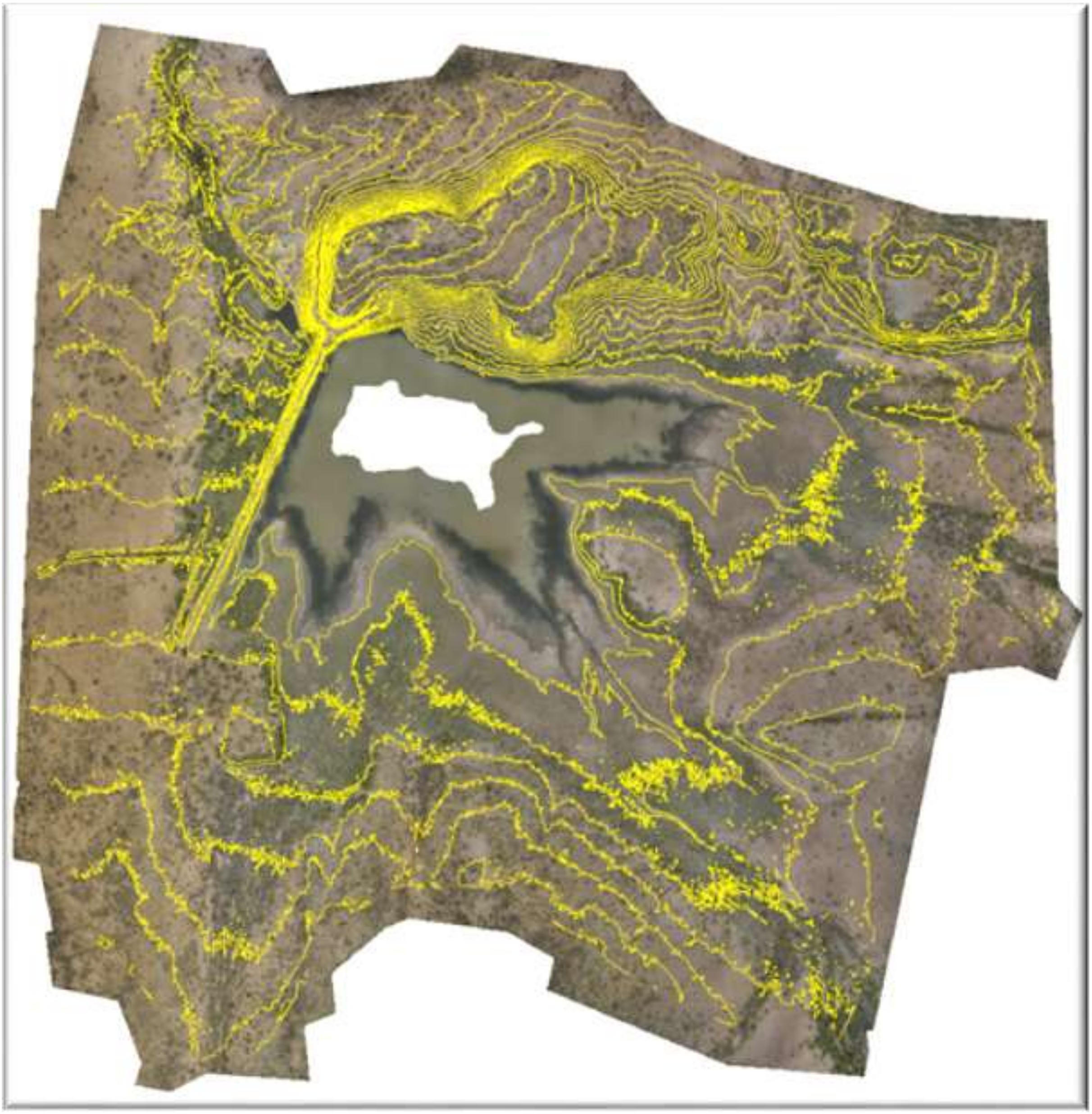

Figure 3-1: Extent of LiDar survey

Figure 3-2: Highest basin level contour 600 masl

Figure 3-3: Contour at level 601 masl

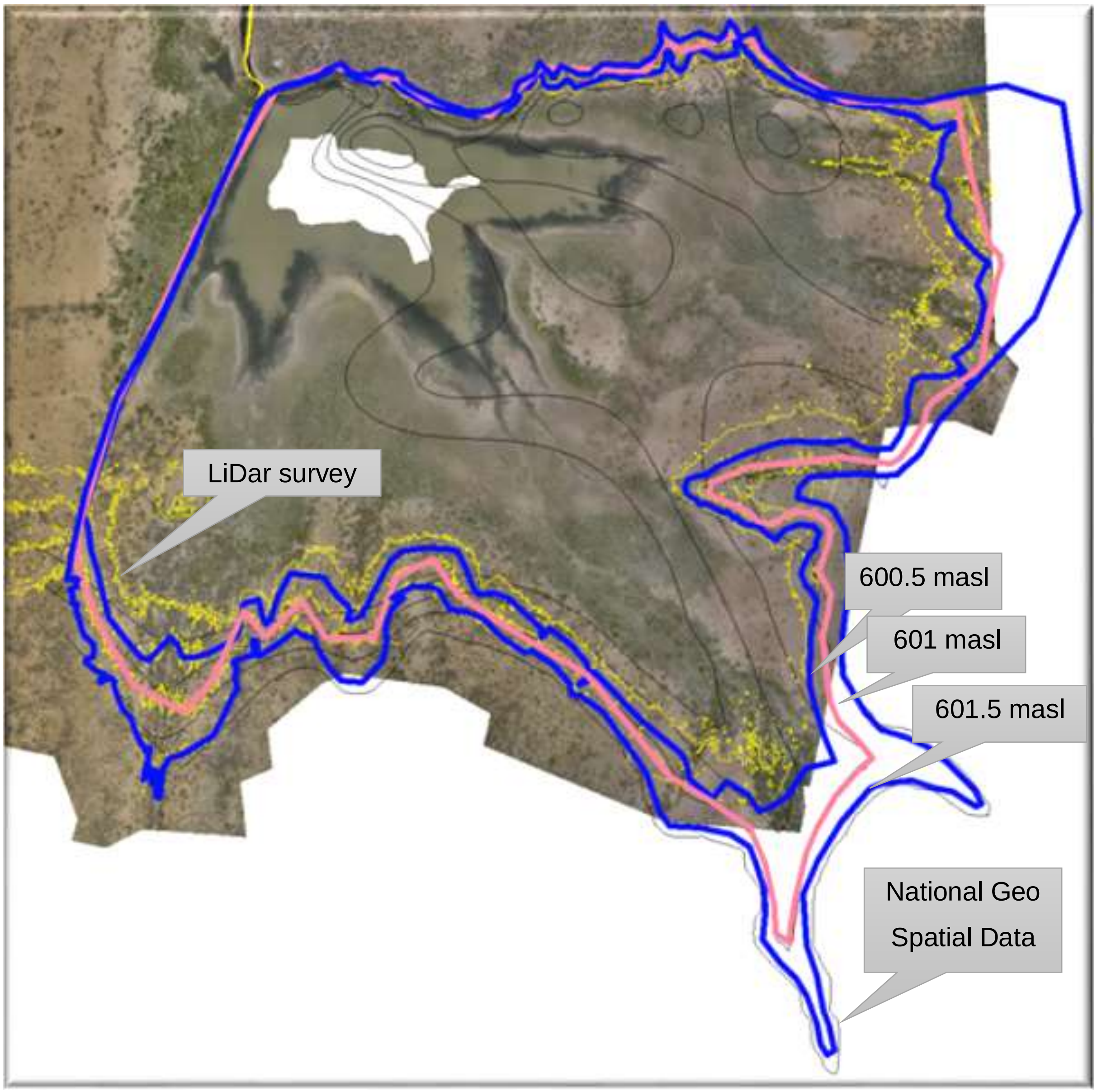

Figure 3-4: Estimation of contour levels 600.5, 601 and 601.5 from National Spatial Data contour data

4 HYDROLOGY

4.1 Basic information

The project area is situated in the quaternary catchment area A63E (**Figure 4-1**).

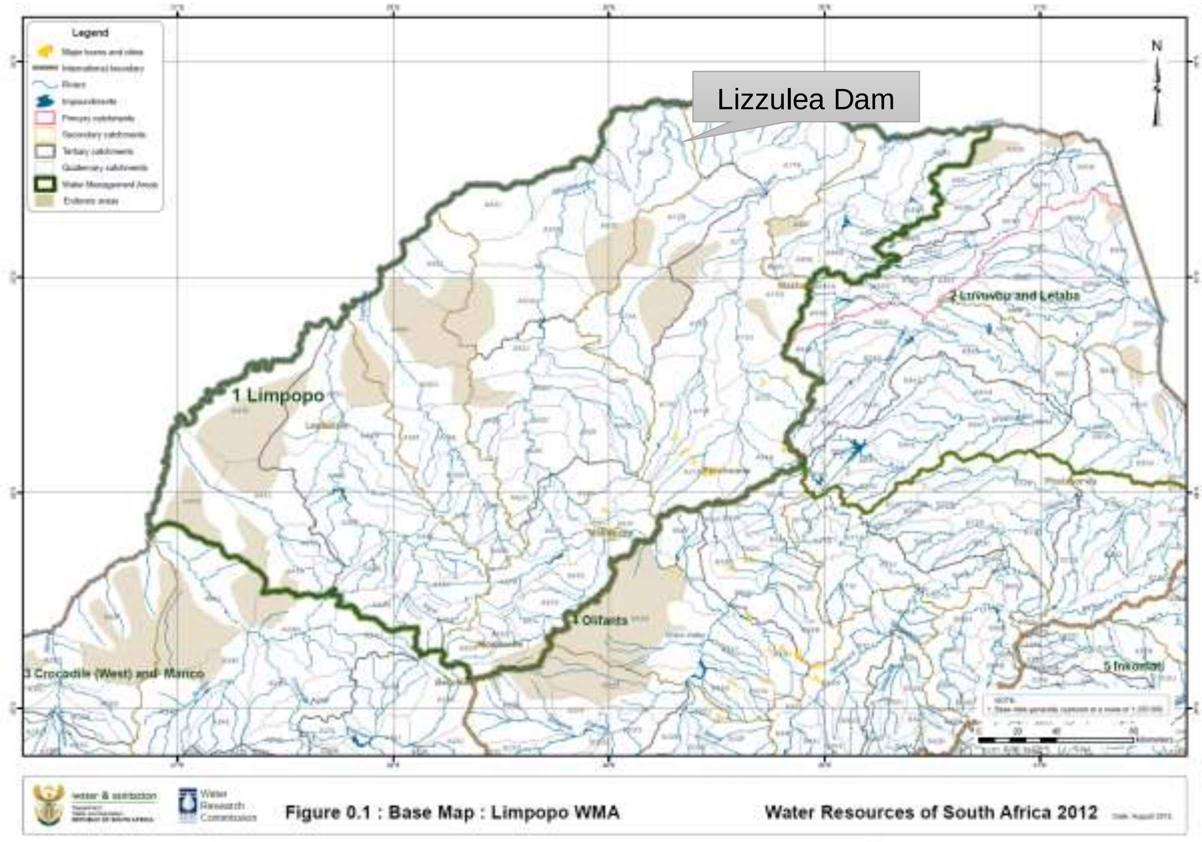

Figure 4-1: Orientation of water relevant area for Lizzulea Dam (WRC Report 2012)

4.2 Rainfall

The daily annual maximum rainfall information is required for the determination of the Probable Maximum Rainfall at Lizzulea Dam. The data of three stations were obtained, Goeree, Pontdrift and Alldays. This information was obtained from the Weather Bureau. This data is shown in **Table 4-1**.

The rainfall stations data obtained was verified on a high level through the double mass plot method. The results of these double mass plots are shown in **Figure 4-2** and **Figure 4-3.** These mass plot is an indication to the consistency of the data. The data verification on the raw daily rainfall will provide a higher degree of correlation and can provide a base for adjustment. The raw data can also provide the consistency of data measurements.

The consistency of the data of these stations are accepted for peak flood determination. However, only the data from Alldays and Pontdrift are used in the determination of the annual daily maximum rainfall as:

- Need overlapping data in order to prevent patching or extrapolation of data,
- Pontdrift is favoured as it has more recent data,
- Pontdrift has overlapping rainfall data from 1965 with Alldays

The weighed average of the annual daily maximum rainfall values of Alldays and Pontdrift were used with the distance to the position of Lizzule Dam. Alldays is 42.82km and Pontdrift is 27.2 km from Lizzulea Dam. The measured annual daily maximum values needs to be converted to allow for different durations to allow for the required time of concentration (Gericke & Pietersen, 2018). This is indicated in **Table 4-2**.

The results of the data to be used in the Probable Maximum Precipitation is shown in **Table** 4-3.

Table 4-1: Daily maximum rainfall data in mm as obtained from the Weather Service

Year	Goeree	Allday	Pontdrift	Year	Goeree	Allday	Pontdrift
1930		106.4		1967	93	86.5	70
1931		40.1		1968		48	84.5
1932		63.5		1969		40.4	71
1933		78.5		1970		63	114.5
1934		34.8		1971		52.5	76
1935		16.8		1972		64.5	50
1936	16.8	97.3		1973		79	60
1937	42.7	47.8		1974		58.5	48
1938	47	110		1975		78.5	59.5
1939	50.8	47.8		1976		82	86.5
1940	86.1	99.3		1977		44.5	52
1941	39.9	45.7		1978		80	52
1942	35.1	100.3		1979		60	75
1943	43.7	39.4		1980		88.8	119.6
1944	45.7	30.5		1981		70	70
1945	27.9	55.9		1982		30	35
1946	61	62		1983		48	91
1947	22.9	33.3		1984		36	64
1948	38.1	72.4		1985		60	83.5
1949	60.5	72.4		1986		42	62
1950	57.2	33		1987		52	92
1951	62.2	80.5		1988		53	38.5
1952	63.5	48.3		1989		40	27.5
1953	35	75		1990		23.5	36
1954	44	43		1991		55	94
1955	50	54		1992		40	44
1956	29	76		1993		66	52.5
1957	30	80		1994		99	45
1958	63.4	44		1995		32	125
1959	30	44		1996		46	60
1960	52.6	55.5		1997		64	53
1961	30	56		1998		52	53
1962	50.6	79.5		1999		69	40
1963	70	33		2000		82	120
1964	76	36.5		2001		60.2	104
1965	38	44.5	10.5	2002		33	32
1966	50	53	48.5				

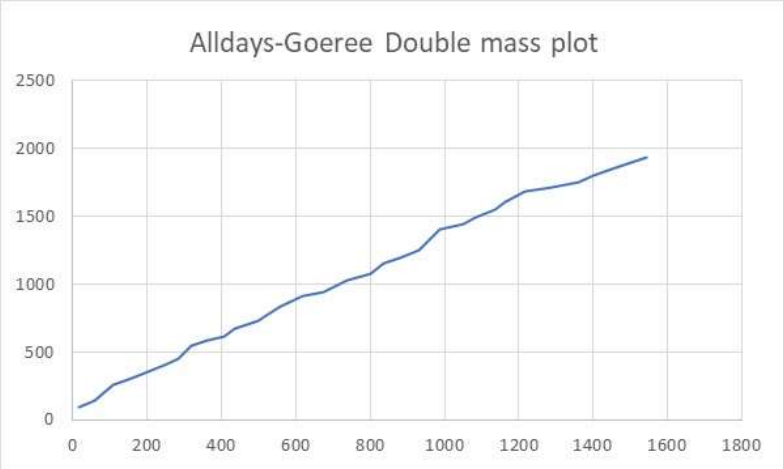

Figure 4-2: Alldays-Goeree mass plot for period 1936 to 1967

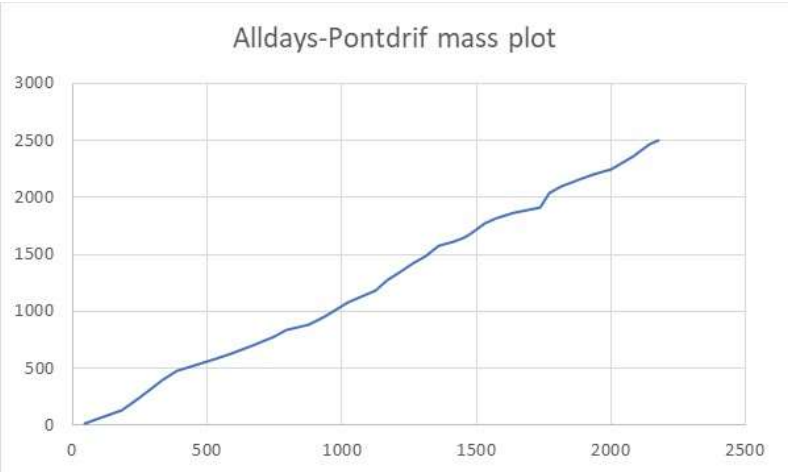

Figure 4-3: Double mass plot; Alldays - Pontdrift for period 1965 to 2002

Table 4-2: Conversion for rainfall duration

Table 3 Conversion of daily to hourly rainfall (Van der Spuy and Rademeyer, 2008)		
Duration		Conversion factor
From (days)	To (hours)	
1	24	1.11
2	48	1.07
3	72	1.05
4	96	1.04
5	120	1.03
7	168	1.02
> 7	> 168	1

Table 4-3: Annual maximum daily rainfall for Lizzulea Dam

Year	Allday	Pontdrift	Weighted value	24h	1h	1.5h	2h	3h	4h
1965	44.5	10.5	36	40	24.3	27	29	32	33
1966	53	48.5	52	58	34.6	38	42	45	47
1967	86.5	70	83	92	55.0	60	66	71	75
1968	48	84.5	57	63	37.7	42	45	49	52
1969	40.4	71	48	53	31.7	35	38	41	43
1970	63	114.5	75	84	50.1	55	60	65	68
1971	52.5	76	58	64	38.7	43	46	50	53
1972	64.5	50	61	68	40.7	45	49	53	56
1973	79	60	74	83	49.6	55	60	64	68
1974	58.5	48	56	62	37.3	41	45	48	51
1975	78.5	59.5	74	82	49.3	54	59	64	67
1976	82	86.5	83	92	55.3	61	66	72	76
1977	44.5	52	46	51	30.8	34	37	40	42
1978	80	52	73	81	48.8	54	59	64	67
1979	60	75	64	71	42.3	47	51	55	58
1980	88.8	119.6	96	107	64.0	70	77	83	87
1981	70	70	70	78	46.6	51	56	61	64
1982	30	35	31	35	20.8	23	25	27	28
1983	48	91	58	65	38.8	43	47	50	53
1984	36	64	43	47	28.4	31	34	37	39
1985	60	83.5	66	73	43.7	48	52	57	60
1986	42	62	47	52	31.1	34	37	40	43
1987	52	92	62	68	41.0	45	49	53	56
1988	53	38.5	50	55	33.0	36	40	43	45
1989	40	27.5	37	41	24.7	27	30	32	34
1990	23.5	36	26	29	17.6	19	21	23	24
1991	55	94	64	71	42.8	47	51	56	58
1992	40	44	41	45	27.3	30	33	35	37
1993	66	52.5	63	70	41.8	46	50	54	57
1994	99	45	86	96	57.4	63	69	75	78
1995	32	125	54	60	36.0	40	43	47	49
1996	46	60	49	55	32.9	36	39	43	45
1997	64	53	61	68	40.9	45	49	53	56
1998	52	53	52	58	34.8	38	42	45	48
1999	69	40	62	69	41.4	46	50	54	57
2000	82	120	91	101	60.6	67	73	79	83
2001	60.2	104	71	78	47.0	52	56	61	64
2002	33	32	33	36	21.8	24	26	28	30

5 VEGETATION

The simplified veld types in the catchment is classified as bushveld (**Figure 5-1**).

Figure 5-1: Veld type at Lizzulea Dam – Bushveld (WRC Report 2012)

6 SOILS

The soil at Lizzulea Dam is classified as moderate to deep sandy soils (**Figure 6-1**).

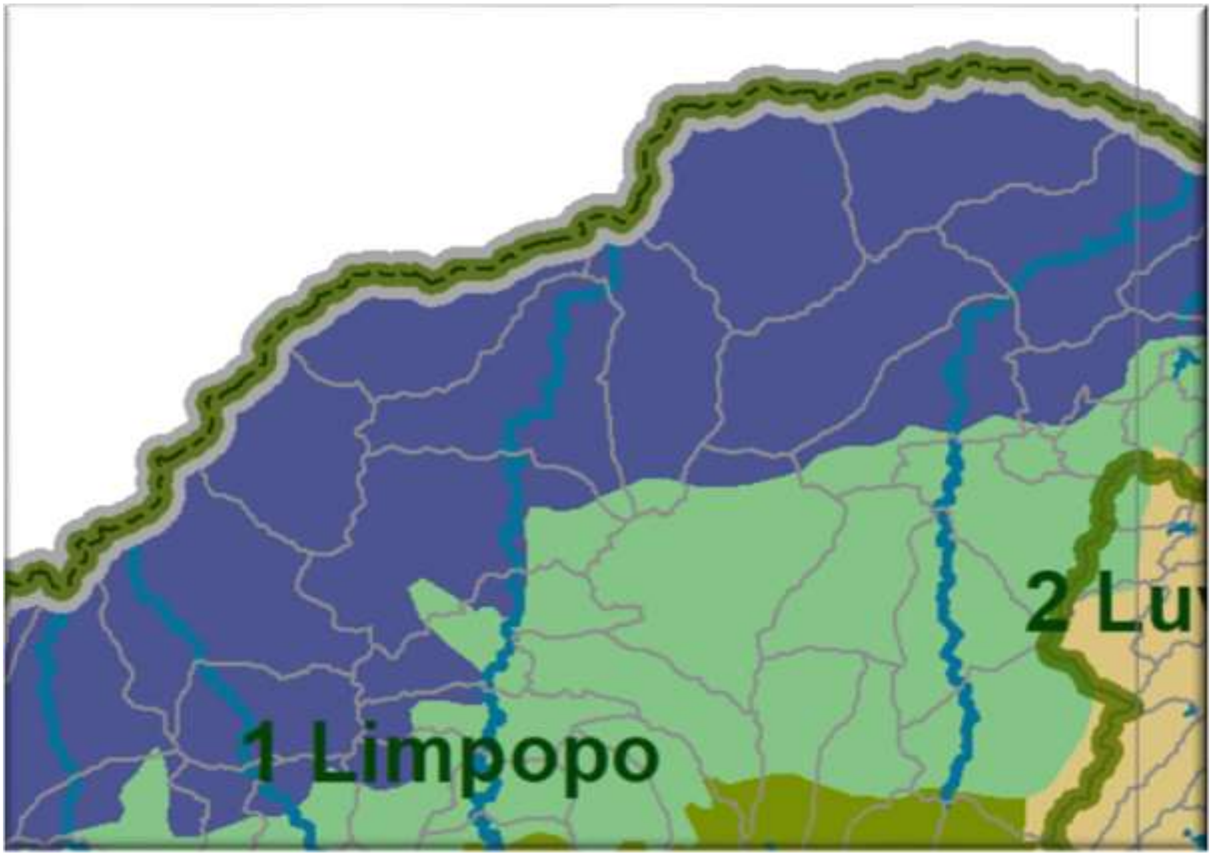

Figure 6-1: Soil classification at Lizzulea Dam (WRC Report 2012)

7 GEOLOGY

The simplified geology at Lizzulea Dam consist of compact sedimentary extrusive and intrusive rocks with intercalated arenaceous and argillaceous strata (**Figure 7-1**).

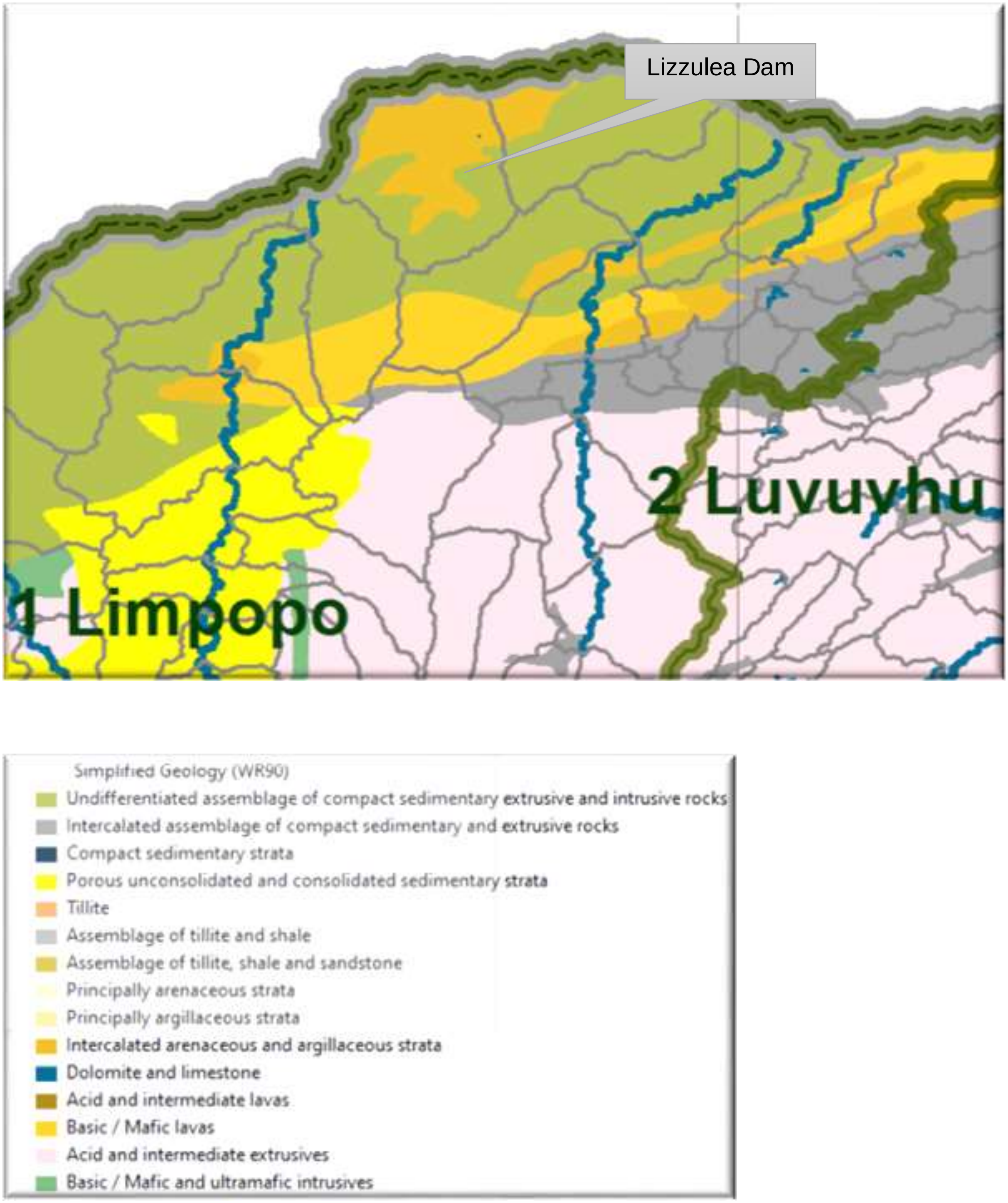

Figure 7-1: Simplified geology at Lizzulea Dam

8 STAGE- AREA-CAPACITY CURVE

The stage-area-capacity curve is obtained through the determination of the area of a contour and determining the volume from these areas and contour level. The results of this determination is shown in **Table 8-1** and **Figure 15-1**. The result of this determination is an input into the hydrograph routing process.

Table 8-1: Stage-area-capacity

Contour (m)	Area A (m^2)	Interval H (m)	Height H (m)	Volume between Contours (m^3)	Volume up to Contour (m^3)
596.5	120 000	0.5	0	0	0
597	172 819	0.5	0.5	73 205	73 205
597.5	226 687	0.5	1	99 877	173 081
598	284 883	0.5	1.5	127 893	300 974
598.5	354 166	0.5	2	159 762	460 736
599	462 325	0.5	2.5	204 123	664 859
599.5	538 381	0.5	3	250 177	915 035
600	634 639	0.5	3.5	293 255	1 208 290
600.5	720 669	0.5	4	338 827	1 547 117
601	805 705	0.5	4.5	381 594	1 928 711
601.5	920 806	0.5	5	431 628	2 360 339
602	983 333	0.5	5.5	476 035	2 836 373

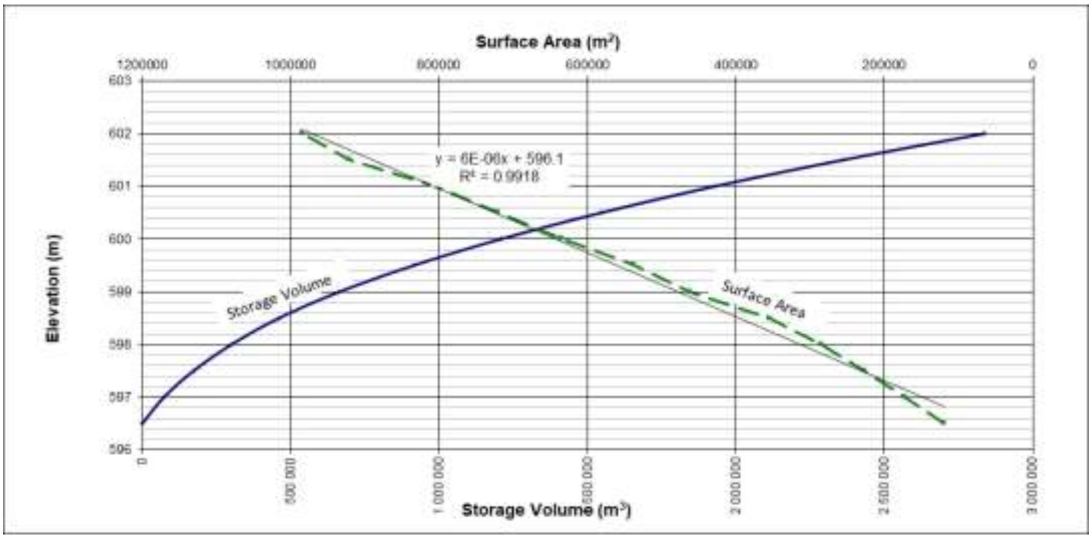

Figure 8-1: Stage-area-capacity curve

9 FLOODHYDROLOGY

9.1 Point rainfall

9.1.1 Point rainfall to 1: 50 and 1:100 year probability

The point rainfall for the Lizzulea Dam catchment is determined through the KwaZulu Natal Point Rainfall Estimation Tool – Design Rainfall. The point rainfall at the centroid of the catchment was abstracted for different durations and the results are shown in **Table 9-1**.

Table 9-1: Results of point rainfall abstraction for different duration and probabilities

User selection has the following criteria:
Station Name: Alldays
Durations requested: 1 h, 1.5 h, 2 h, 4 h, 6 h
Return Periods requested: 20 yr, 50 yr, 100 yr, 200 yr
Block Size requested: 20 minutes

Data extracted from Daily Rainfall Estimate Database File
The station selected and the five closest stations are listed

Station Name	SAWS Number	Distance (km)	Record (Years)	Latitude (°)	Latitude (')	Longitude (°)	Longitude (')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 20	20L	20U	50	50L	50U

Gridded values of all points within the specified block

Latitude (°)	Latitude (')	Longitude (°)	Longitude (')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 20	20L	20U	50	50L	50U	100	100L	100U	200	200L	200U
22	21	29	20	331	595	1 h	60.7	49.6	71.8	72.5	58.5	86.8	81.8	65.2	98.9	91.5	72.0	111.6
						1.5 h	73.1	59.0	87.4	87.4	69.7	105.6	98.7	77.6	120.4	110.3	85.8	135.7
						2 h	83.3	66.7	100.2	99.6	78.7	121.1	112.4	87.7	138.1	125.7	96.9	155.7
						4 h	91.9	73.0	111.1	109.8	86.2	134.2	124.0	96.0	153.0	138.5	106.1	172.5
						6 h	97.3	77.0	117.9	116.3	90.9	142.5	131.2	101.2	162.4	146.7	111.8	183.2

9.1.2 Point rainfall for Probable Maximum Precipitation

The Probable Maximum Precipitation (PMP) is determined with the deterministic method as per the World Meteorological Organization (World Meteorological Organization, 1986). The input into this method is the evaluated rainfall data as per **Section 4.2.** The results of the Probable Maximum Precipitation determination is shown in **Table 9-2**.

Table 9-2: Probable Maximum Precipitation for different durations

Probable Maximum Precipitation					
Period	1hr	1.5 hr	2 hr	3 hr	4 hr
PMP (mm)	152	176	198	219	246

9.2 Input parameters

The input parameters of the catchment were determined from the 1:50 000 topographical map 2999AD. From this map the catchment area, longest water course, average slope (1085 method), average catchment slope, centroid and land use was determined. The information from **Section 5, 6 & 7** was also used in the derivation of the catchment parameters. The catchment delineation is shown in **Figure 9-1**.

The derived and obtained input parameters for the determination and execution of the peak flood methods are summarised in **Table 9-3**.

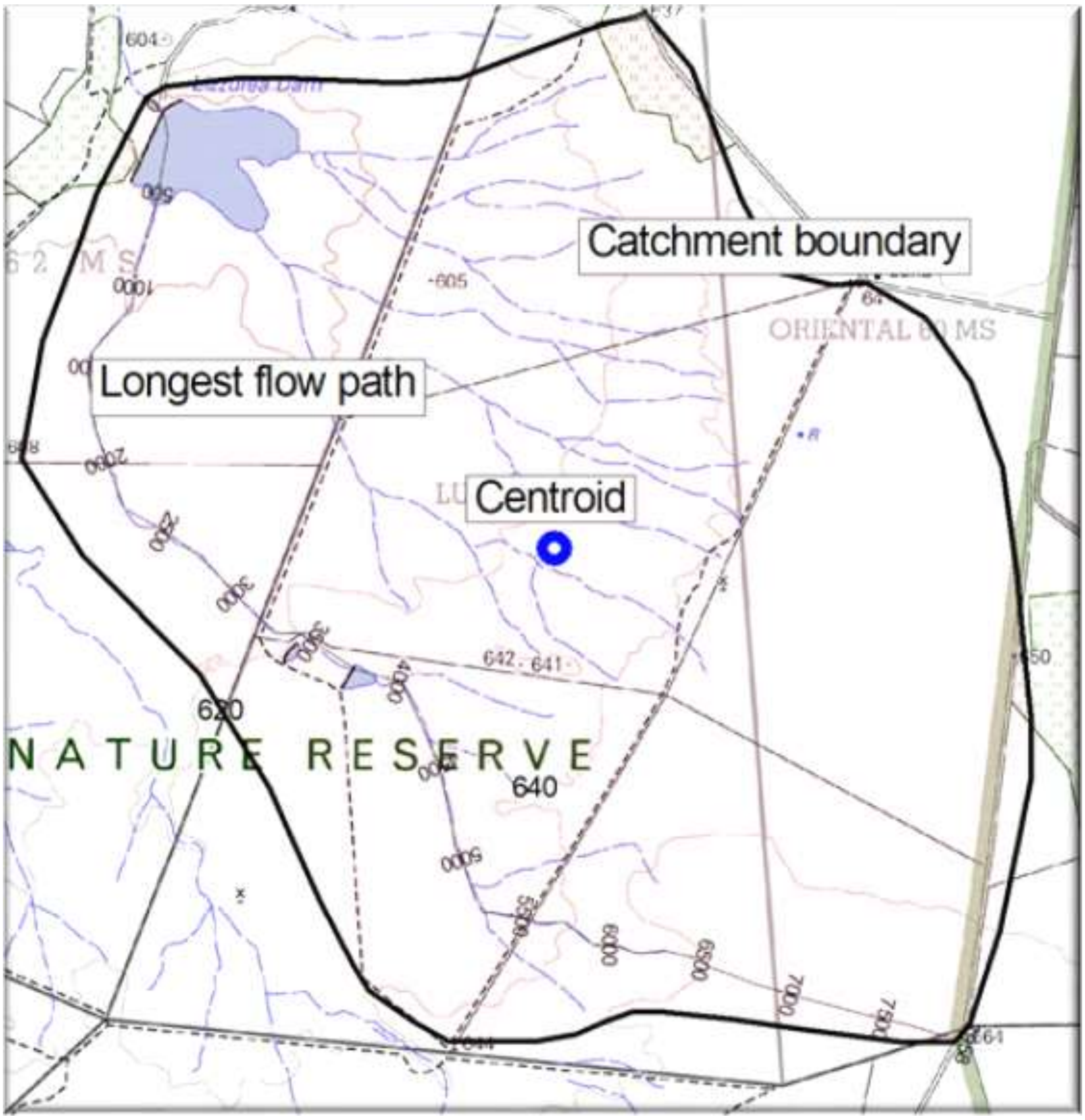

Figure 9-1: Lizzulea Dam Catchment

Table 9-3: Input for peak flood methods

Item	Value
Area of catchment (km²)	20.4
Longest watercourse (km)	7.96
Slope of watercourse (1085 method) (m/m)	0.011
Distance of overland flow (km)	0.1
Slope of overland (m/m)	0.0029
Overland factor	0.3
Distance to centroid (km)	3.4
Veld type (Region, Unit Hydrograph)	8
Urban %	0
Rural %	100

Item	Value
Rural slope below 3%	93
Rural slope (3 to 10%)	7
Rural slope (10% to 30%)	0
Permeable (%)	50
Semi-Permeable (%)	50
No vegetation (%)	50
Grassland (%)	50
Time of concentration (hr)	2.3
Lag time (hr)	1.5
Area reduction factor (%)	1
Saturation provision	1
Point rainfall for the 1:100 exceedance probability (mm)	118
Point rainfall PMP- 2hours (mm)	198
Kovacs region	4.6

9.3 Results

The results of all methods are summarised in **Table 9-4**. The Rational Method alternative 3 is a preferred result (between the rational methods) due to the more accurate interpolation of the catchment point rainfall. The SDF method is a correlation from gauge data and there is not a gauge near the Lizzulea Dam in the quaternary catchment A36C.

The TR137 and Unit Hydrograph method provide upper values for the 1:100 year probability. The Rational method (Alt3) results is chosen for the 1:100 year probability (91m^3/s).

As the TR137 method provide a higher value than the PMF method the maximum value of 315 m^3/s is accepted as the upper value.

Table 9-4: Results of peak flood determination

Method	1:2	1:5	1:10	1:20	1:50	1:100	1:200	RMF	PMF
Rational method (Alt1)	15	22	29	38	52	67			
Rational method (Alt2)	22	39	54	71	93	113	128		
Rational method (Alt3)					70	91	102		
Rational (PMP)									232
Unit Hydrograph (TR102 data)	8	14	20	28	41	56			
Unit hydrograph (Alt3)						252			
SDF	4	27	49	74	111	143	177		
MIPI			19	25	35	44			
TR137					126	160	193	315	

10 SPILLWAY AND DISCHARGE CHANNEL

10.1 Introduction

The HECRAS model from the Hydrologic Engineering Centre, US Army Corps of Engineers (Brunner, 2010) was utilised to model the water levels in the spillway channel as well as the flow through the spillway at the embankment. The input into this model require cross sections of the flow channel, the peak flows, the roughness estimate and the boundary conditions.

10.2 Methodology

10.2.1 Model layout and input

The HECRAS cross sections are extracted with the main purpose for embankment spillway modelling. Upstream from the spillway section (Section 90) interpolation of cross Sections 90, 100, 110 is included (**Figure 10-1**).

As downstream from the embankment the floodlines are past the area of interest these floodlines are for completeness sake.

The manning values for channel flow are adopted as 0.03 to 0.05, the downstream slope was determined as 0.00565 m/m and the upstream slope adopted as flat.

Figure 10-1: Model cross sections

10.3 Results

The results indicate that up to the 1:100 year event will be contained inside the designed spillway while the PMF flood will overtop the embankment (less than 500 mm) due to the uneven level of the embankment Non-Overspill Crest Level (**Figure 10-2**).

A summary of the water level results is provided in **Table 10-1** and the rating curve of the embankment spillway is provided in **Table 10-2**.

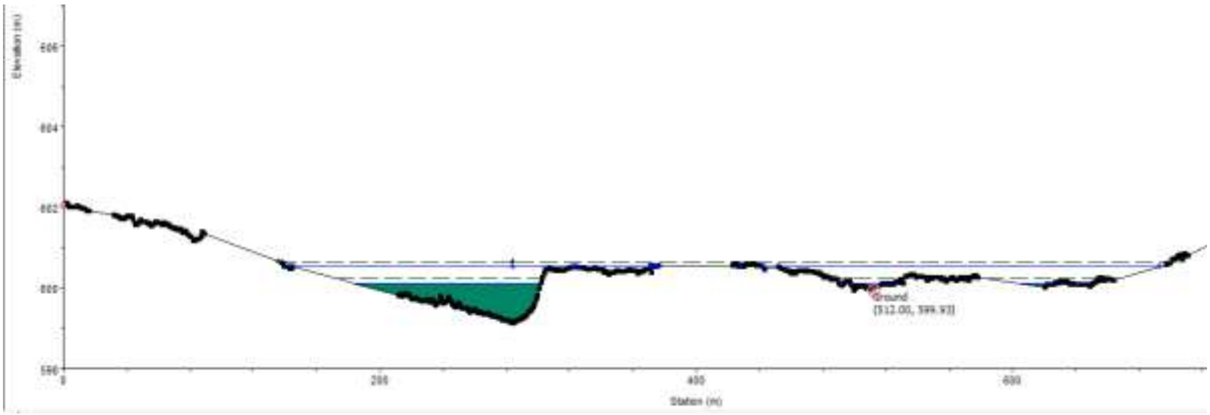

Figure 10-2: Embankment spillway and Non-Overspill Crest Section

Table 10-1: Results of HECRAS modelling

River Sta	Q Total (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)	Flow Area (m^2)	Top Width (m)	Froude # Chl
110	1:50	596.55	600.14	0.04	1885.27	731.66	0.01
110	1:100	596.55	600.24	0.05	1961.1	746.76	0.01
110	PMF	596.55	600.69	0.14	2310	818.12	0.03
100	1:50	596.57	600.14	0.05	1553.72	700.84	0.01
100	1:100	596.57	600.24	0.06	1626.37	715.05	0.01
100	PMF	596.57	600.69	0.16	1951.07	754.37	0.03
90	1:50	599.13	600.02	1.49	46.94	114.75	0.74
90	1:100	599.13	600.12	1.46	62.34	189.6	0.81
90	PMF	599.13	600.54	1.58	199.59	483.22	0.78
80	1:50	599.07	599.87	1.85	37.75	109.2	1.01
80	1:100	599.07	599.96	1.9	48.06	132.96	1.01
80	PMF	599.07	600.4	1.89	166.69	465.07	1.01
75	1:50	597.55	598.98	3.69	18.96	69.16	2.25
75	1:100	597.55	599.05	3.77	24.14	81.09	2.21
75	PMF	597.55	599.56	3.78	83.29	149.55	1.62
70	1:50	592.67	594.12	1.23	56.85	58.6	0.4
70	1:100	592.67	594.27	1.37	66.27	62.59	0.43
70	PMF	592.67	595.26	2.09	150.63	111.57	0.57
60	1:50	592.13	593.05	2.03	34.48	82.89	1
60	1:100	592.13	593.14	2.18	41.84	85.84	1
60	PMF	592.13	593.85	2.75	114.66	127.12	0.92
50	1:50	591.17	592.32	1.55	45.02	60.81	0.58

River Sta	Q Total (m³/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)	Flow Area (m²)	Top Width (m)	Froude # Chl
50	1:100	591.17	592.47	1.67	54.41	65.39	0.59
50	PMF	591.17	593.31	2.48	127.63	106.62	0.71
40	1:50	592.06	591.91		38.8	53.81	0
40	1:100	592.06	592.02		45.04	57.2	0
40	PMF	592.06	592.79	1.83	117.65	133.77	1.04
30	1:50	590.09	591.45	1.66	42.06	77.16	0.72
30	1:100	590.09	591.55	1.82	50.18	80.81	0.74
30	PMF	590.09	592.36	2.4	131.3	139.56	0.79

Table 10-2: Rating curve for embankment spillway

Q	Water Level	Q	Water Level
m³/s	m	m³/s	m
0.00	599.132	91.1	600.122
5.00	599.479	95.0	600.140
10.00	599.569	100.0	600.162
15.00	599.637	120.0	600.242
20.00	599.695	140.0	600.298
25.00	599.749	160.0	600.338
30.00	599.788	180.0	600.373
35.00	599.826	200.0	600.406
40.00	599.864	220.0	600.433
45.00	599.894	240.0	600.457
49.70	599.919	260.0	600.480
55.00	599.945	270.0	600.494
60.00	599.969	290.0	600.515
65.00	599.994	298.9	600.521
70.00	600.015	300.0	600.522
75.00	600.036	310.0	600.532
80.00	600.059	315.0	600.536
85.00	600.093	320.0	600.541

11 FLOOD ROUTING

11.1 Introduction

The input into the flood routing procedure is:

- Stage-area-capacity curve,
- Discharge rating curve,
- Inflow hydrograph while,

the output of the flood routing is the discharge flow in m^3/s and the water level in the Lizzulea Dam reservoir.

11.2 Methodology

The commercially available software HydroCAD 10.5 is used for the routing of the inflow hydrograph. The continuity equations: conservation of mass with the assumption that the pool is level are used in this software.

The inflow hydrograph is derived from the HRU (Midgley, 1972) dimensionless hydrograph for veld type 8. The Dimensionless hydrograph is dimensionlised to provide a peak flood as in **Section 9.1.1.** The 1:100 year and PMF 2hour inflow hydrographs are provided in **Table 11-1** . The 3-hour duration hydrograph provide a larger volume with a lower peak. This 3-hour hydrographs was also routed to ensure that the higher volume does not provide a higher routed water level. This 3-hour inflow hydrograph is provided in **Table 11-2**. The hydrographs are also depicted in **Figure 11-1**.

The stage-area-capacity curve and spillway rating curve are already discussed and provided in previous sections.

Table 11-1: 2 Hour 1:50, 1:100 year & PMF Inflow hydrographs

HRS	Qmax (1:50)	Qmax (1:100)	Qmax (PMF)
	m^3/s	m^3/s	m^3/s
0	0.0	0.0	0.0
0.25	0.5	0.6	2.0
0.5	2.3	2.9	10.2
0.75	14.1	18.4	63.6
1	32.1	41.8	144.6
1.25	45.8	59.6	206.2
1.5	54.8	71.3	246.9
1.75	61.3	79.7	275.9
2	65.8	85.6	296.2
2.25	68.7	89.4	309.4
2.5	69.5	90.5	313.1
2.75	59.9	77.9	269.7
3	43.8	56.9	197.0
3.25	31.7	41.2	142.6
3.5	23.8	31.0	107.2
3.75	18.4	23.9	82.7
4	14.6	19.0	65.6
4.25	11.8	15.3	53.1
4.5	9.6	12.5	43.1
4.75	7.7	10.0	34.7
5	6.0	7.9	27.2
5.25	4.6	5.9	20.5
5.5	3.4	4.4	15.2
5.75	2.4	3.1	10.8
6	1.6	2.1	7.4
6.25	1.1	1.4	4.8
6.5	0.6	0.8	2.9
6.75	0.3	0.4	1.3
7	0.1	0.1	0.4
7.25	0.0	0.0	0.0

Table 11-2: 3 Hour PMF Inflow Hydrograph

Hrs	Qmax
	m^3/s
0.000	0.0
0.250	1.5
0.500	7.5
0.750	46.7
1.000	106.1
1.250	151.3
1.500	181.2
1.750	202.5
2.000	217.4
2.250	228.6
2.500	237.3
2.750	244.6
3.000	250.8
3.250	254.5
3.500	252.4
3.750	216.5
4.000	159.4
4.250	116.2
4.500	87.7
4.750	67.6
5.000	53.3
5.250	42.5
5.500	33.7
5.750	26.4
6.000	20.3
6.250	15.1
6.500	11.1
6.750	7.9
7.000	5.4
7.250	3.5
7.500	2.1
7.750	1.0
8.000	0.3
8.250	0.0

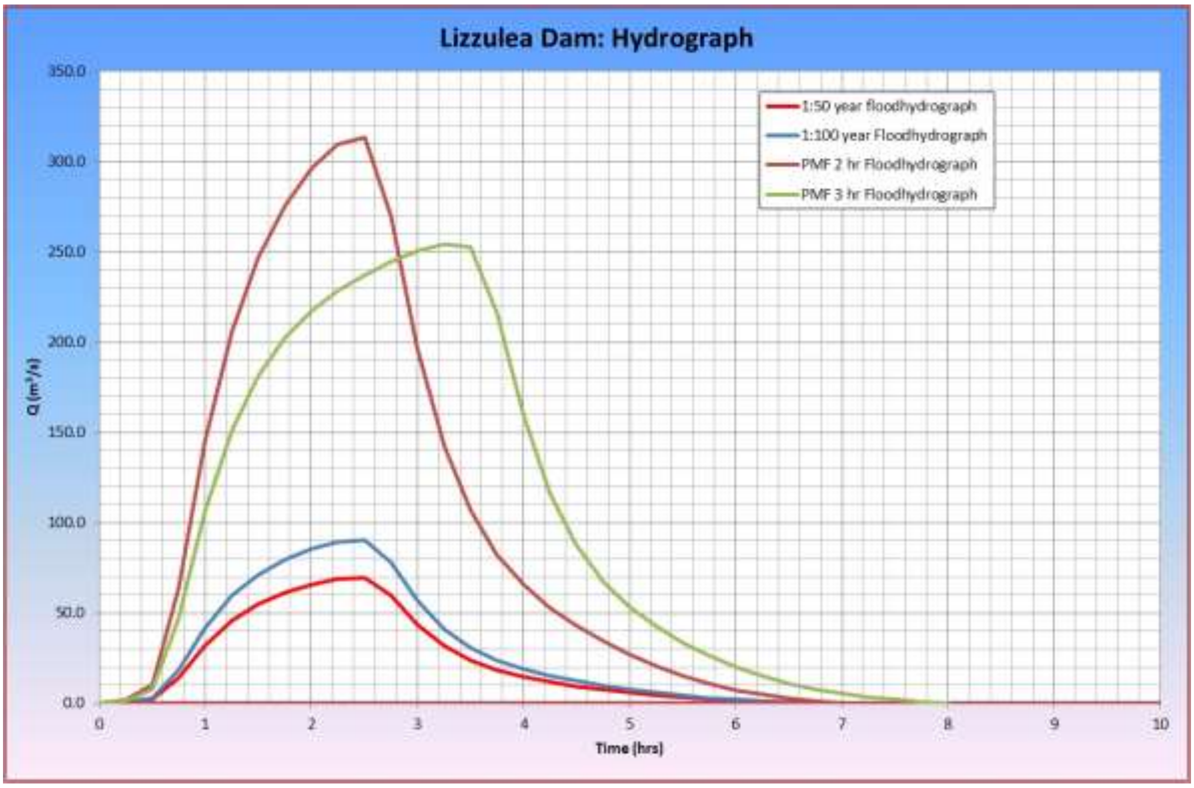

Figure 11-1: Lizzulea Dam inflow Hydrographs

11.3 Results

The results of the routing is provided graphically in **Figure 11-2** to **Figure 11-5** and in table format in Error! Reference source not found. to **Table 11-6.**

The highest water level in the reservoir estimated for a 1:50 year occurrence is 599.8 masl 1:100 year occurrence is 599.9 masl and for the Probable Maximum Flood occurrence 600.52 masl

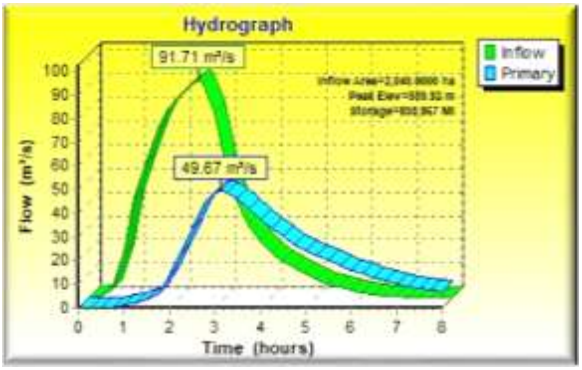

Figure 11-2: 2 Hour 1:100 year peak food routing result

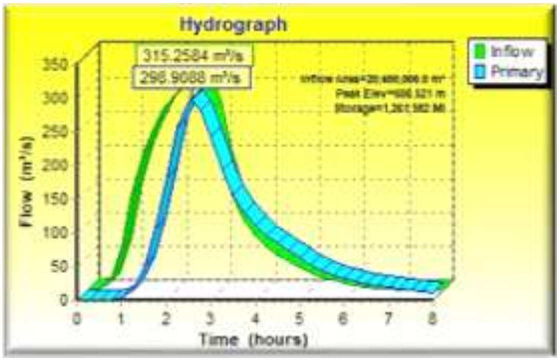

Figure 11-3: 2 Hour PMF routing result

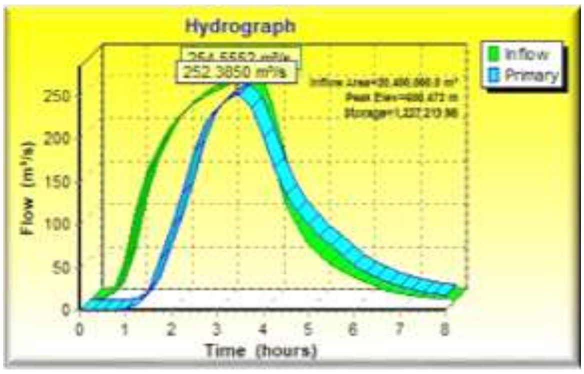

Figure 11-4: 3 Hour PMF routing result

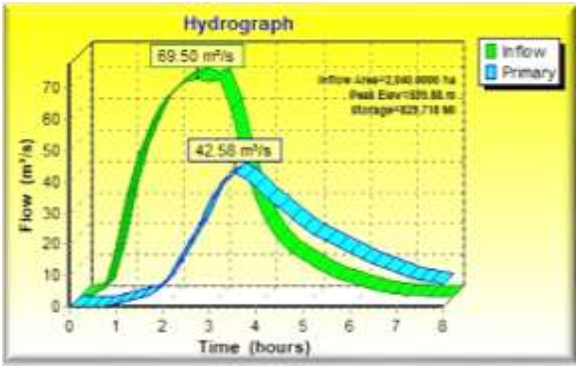

Figure 11-5: 2 Hour 1:50 year peak flood routing result

Table 11-3: 2-Hour 1:50 year routed hydrograph

Time (hours)	Inflow (m^3/s)	Storage (Mega-liters)	Elevation (meters)	Primary (m^3/s)
0	0	410.824	599.1	0
0.25	0.6	411.092	599.101	0.007
0.5	2.9	412.646	599.104	0.0475
0.75	18.4	422.101	599.123	0.2936
1	41.8	448.655	599.178	0.9756
1.25	56.9	491.722	599.265	2.0615
1.5	71.3	546.965	599.373	3.4135
1.75	79.7	611.166	599.495	4.9336
2	85.6	678.435	599.617	11.2193
2.25	89.4	743.382	599.731	19.3369
2.5	90.5	802.315	599.83	30.0349
2.75	77.9	846.688	599.903	39.1386
3	56.9	869.175	599.939	44.9071
3.25	41.2	872.268	599.944	45.7315
3.5	31	864.414	599.932	43.6298
3.75	23.9	851.371	599.911	40.1229
4	19	835.978	599.886	36.9564
4.25	15.3	819.648	599.859	33.6138
4.5	12.5	803.418	599.832	30.2637
4.75	10	787.785	599.806	26.9982
5	7.9	772.913	599.781	24.1018
5.25	5.9	758.531	599.757	21.6669
5.5	4.4	744.705	599.733	19.5002
5.75	3.1	731.278	599.71	17.8432
6	2.1	718.286	599.687	16.2398
6.25	1.4	705.941	599.666	14.7006
6.5	0.8	694.366	599.645	13.2356
6.75	0.4	683.614	599.626	11.8747
7	0.1	673.722	599.609	10.6228
7.25	0	664.693	599.593	9.6264
7.5	0	656.374	599.577	8.87
7.75	0	648.708	599.563	8.173
8	0	641.645	599.551	7.5308

Table 11-4: 2-Hour 1:100 year routed hydrograph

Time (hours)	Inflow (m^3/s)	Storage (Mega-liters)	Elevation (meters)	Primary (m^3/s)
0	0	410.824	599.1	0
0.25	0.6	411.092	599.101	0.007
0.5	2.9	412.646	599.104	0.0475
0.75	18.4	422.101	599.123	0.2936
1	41.8	448.655	599.178	0.9756
1.25	56.9	491.722	599.265	2.0615
1.5	71.3	546.965	599.373	3.4135
1.75	79.7	611.166	599.495	4.9336
2	85.6	678.435	599.617	11.2193
2.25	89.4	743.382	599.731	19.3369
2.5	90.5	802.315	599.83	30.0349
2.75	77.9	846.688	599.903	39.1386
3	56.9	869.175	599.939	44.9071
3.25	41.2	872.268	599.944	45.7315
3.5	31	864.414	599.932	43.6298
3.75	23.9	851.371	599.911	40.1229
4	19	835.978	599.886	36.9564
4.25	15.3	819.648	599.859	33.6138
4.5	12.5	803.418	599.832	30.2637
4.75	10	787.785	599.806	26.9982
5	7.9	772.913	599.781	24.1018
5.25	5.9	758.531	599.757	21.6669
5.5	4.4	744.705	599.733	19.5002
5.75	3.1	731.278	599.71	17.8432
6	2.1	718.286	599.687	16.2398
6.25	1.4	705.941	599.666	14.7006
6.5	0.8	694.366	599.645	13.2356
6.75	0.4	683.614	599.626	11.8747
7	0.1	673.722	599.609	10.6228
7.25	0	664.693	599.593	9.6264
7.5	0	656.374	599.577	8.87
7.75	0	648.708	599.563	8.173
8	0	641.645	599.551	7.5308

Table 11-5: 2-Hour PMF routed hydrograph

Time (hours)	Inflow (m^3/s)	Storage (Mega-liters)	Elevation (meters)	Primary (m^3/s)
0	0	410.878	599.1	0
0.25	2	411.77	599.102	0.0245
0.5	10.1	417.14	599.113	0.172
0.75	63.2	449.658	599.18	1.0526
1	143.7	540.857	599.361	3.4381
1.25	204.8	690.92	599.639	15.7688
1.5	245.3	865.01	599.933	53.1588
1.75	274.1	1,027.254	600.184	106.0018
2	294.4	1,157.236	600.374	182.0001
2.25	307.4	1,229.901	600.476	256.2129
2.5	311.1	1,259.797	600.518	297.2349
2.75	267.9	1,254.573	600.51	283.3329
3	195.8	1,221.935	600.465	245.135
3.25	141.7	1,175.375	600.4	194.8872
3.5	106.5	1,128.418	600.333	156.36
3.75	82.1	1,085.469	600.27	130.0857
4	65.2	1,043.333	600.208	111.9963
4.25	52.7	1,002.508	600.147	96.7319
4.5	42.8	964.314	600.089	84.7828
4.75	34.5	927.128	600.031	75.1793
5	27	893.781	599.979	62.1471
5.25	20.4	863.501	599.93	52.5517
5.5	15.1	836.178	599.886	44.3194
5.75	10.7	811.033	599.845	37.4356
6	7.4	788.093	599.806	32.0494
6.25	4.8	766.774	599.771	27.5663
6.5	2.8	747.175	599.737	23.9241
6.75	1.3	728.692	599.705	21.2719
7	0.4	711.444	599.675	18.7788
7.25	0	695.774	599.648	16.4807
7.5	0	681.878	599.623	14.435
7.75	0	669.716	599.602	12.6269
8	0	659.084	599.582	11.0311

Table 11-6: 3-Hour PMF hydrograph result

Time (hours)	Inflow (m^3/s)	Storage (Mega-liters)	Elevation (meters)	Primary (m^3/s)
0	0	410.878	599.1	0
0.25	1.5	411.547	599.101	0.0184
0.5	7.5	415.541	599.11	0.1281
0.75	46.7	439.584	599.159	0.7802
1	106.1	506.925	599.295	2.5648
1.25	151.3	619.043	599.509	6.6233
1.5	181.2	754.916	599.75	25.0517
1.75	202.5	890.127	599.973	60.6986
2	217.4	1,006.529	600.153	98.2513
2.25	228.6	1,101.350	600.294	137.8353
2.5	237.3	1,163.921	600.384	186.75
2.75	244.6	1,197.779	600.431	220.9062
3	250.8	1,214.398	600.455	236.4122
3.25	254.5	1,223.787	600.468	247.7104
3.5	252.4	1,226.656	600.472	251.7007
3.75	216.5	1,215.905	600.457	237.8184
4	159.4	1,184.064	600.412	202.0527
4.25	116.2	1,140.888	600.351	167.0814
4.5	87.7	1,097.484	600.288	135.9489
4.75	67.6	1,054.315	600.224	116.0908
5	53.3	1,011.465	600.16	100.1149
5.25	42.5	971.143	600.099	86.5257
5.5	33.7	932.092	600.039	76.4667
5.75	26.4	897.081	599.984	63.4548
6	20.3	865.728	599.934	53.4478
6.25	15.1	837.848	599.889	44.7754
6.5	11.1	812.504	599.847	37.8402
6.75	7.9	789.643	599.809	32.3734
7	5.4	768.509	599.773	27.933
7.25	3.5	749.185	599.741	24.2124
7.5	2.1	731.092	599.709	21.6162
7.75	1	714.14	599.68	19.1741
8	0.3	698.514	599.653	16.8825

12 SPILLWAY CHANNEL

The routed PMF, 1:50 and 1:100 year peak flood values are used in the determination of the water levels at each section of the HECRAS model (Described in **Section 10)**. The results of this modelling are provided in **Table 12-1**.

Table 12-1: Spillway channel water level model results

River Sta	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(m³/s)	(m)	(m)	(m/s)	(m²)	(m)	
110	1:50	596.55	600.14	0.04	1885.27	731.66	0.01
110	1:100	596.55	600.24	0.05	1961.1	746.76	0.01
110	PMF	596.55	600.69	0.14	2310	818.12	0.03
100	1:50	596.57	600.14	0.05	1553.72	700.84	0.01
100	1:100	596.57	600.24	0.06	1626.37	715.05	0.01
100	PMF	596.57	600.69	0.16	1951.07	754.37	0.03
90	1:50	599.13	600.02	1.49	46.94	114.75	0.74
90	1:100	599.13	600.12	1.46	62.34	189.6	0.81
90	PMF	599.13	600.54	1.58	199.59	483.22	0.78
80	1:50	599.07	599.87	1.85	37.75	109.2	1.01
80	1:100	599.07	599.96	1.9	48.06	132.96	1.01
80	PMF	599.07	600.4	1.89	166.69	465.07	1.01
75	1:50	597.55	598.98	3.69	18.96	69.16	2.25
75	1:100	597.55	599.05	3.77	24.14	81.09	2.21
75	PMF	597.55	599.56	3.78	83.29	149.55	1.62
70	1:50	592.67	594.12	1.23	56.85	58.6	0.4
70	1:100	592.67	594.27	1.37	66.27	62.59	0.43
70	PMF	592.67	595.26	2.09	150.63	111.57	0.57
60	1:50	592.13	593.05	2.03	34.48	82.89	1
60	1:100	592.13	593.14	2.18	41.84	85.84	1
60	PMF	592.13	593.85	2.75	114.66	127.12	0.92
50	1:50	591.17	592.32	1.55	45.02	60.81	0.58
50	1:100	591.17	592.47	1.67	54.41	65.39	0.59
50	PMF	591.17	593.31	2.48	127.63	106.62	0.71
40	1:50	592.06	591.91		38.8	53.81	0
40	1:100	592.06	592.02		45.04	57.2	0
40	PMF	592.06	592.79	1.83	117.65	133.77	1.04

River Sta	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(m³/s)	(m)	(m)	(m/s)	(m²)	(m)	
30	1:50	590.09	591.45	1.66	42.06	77.16	0.72
30	1:100	590.09	591.55	1.82	50.18	80.81	0.74
30	PMF	590.09	592.36	2.4	131.3	139.56	0.79

13 MAPPING

The following distances in terms of the project area are delineated:

- Listing notice 1; 32m from the edge of the water course, **Figure 13-1** (Note this show the plan distance),
- Listing notice 3; 100 m from a water course or wetland, **Figure 13-2**,
- Water Act; Outside the 1:100 year floodline, **Figure 13-4**,
- Water Act; Any risk posed by a dam, PMF Floodline, **Figure 13-5**.

The 100 m distance from the centre of the flow of the river is estimated as shown in **Figure** 13-1.

The floodlines are constructed from the water level heights as determined for the reservoir through the level pool routing and the water levels in the spillway channel as provided from the HECRAS model. The results of the floodlines are shown in **Figure 13-7**.

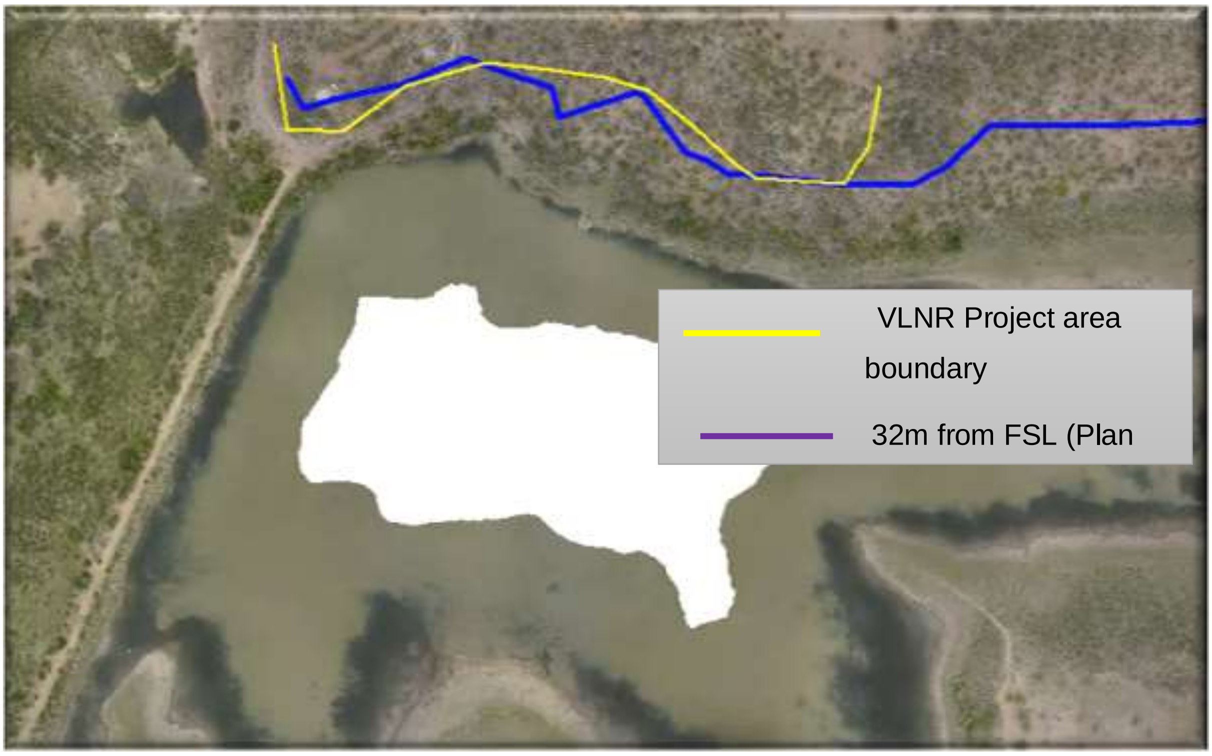

Figure 13-1: 32 m distance estimation

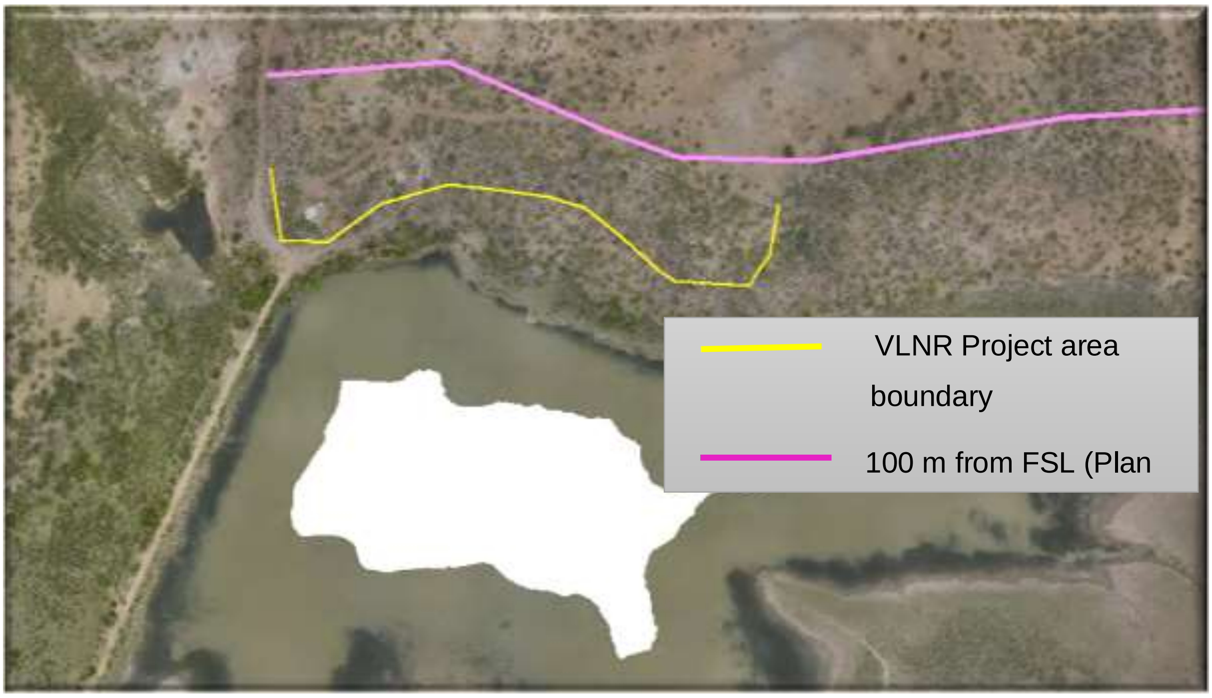

Figure 13-2: 100 m distance from water edge

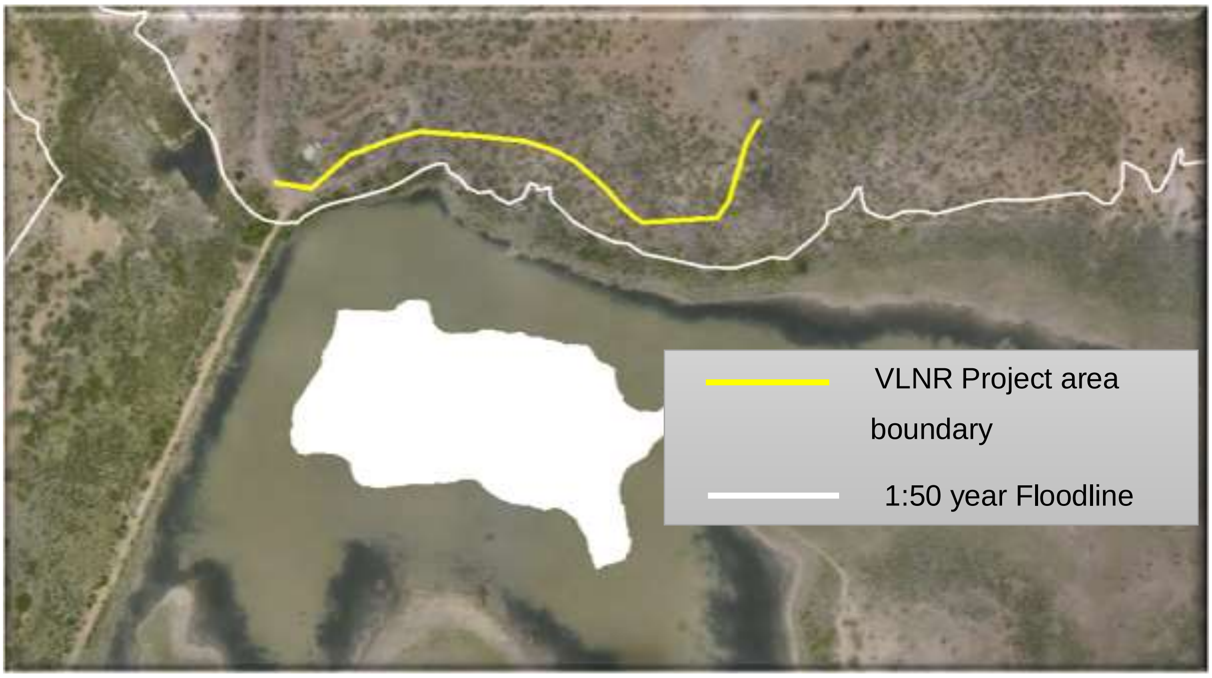

Figure 13-3: 1:50 year floodline in relation to the VLNR project boundary

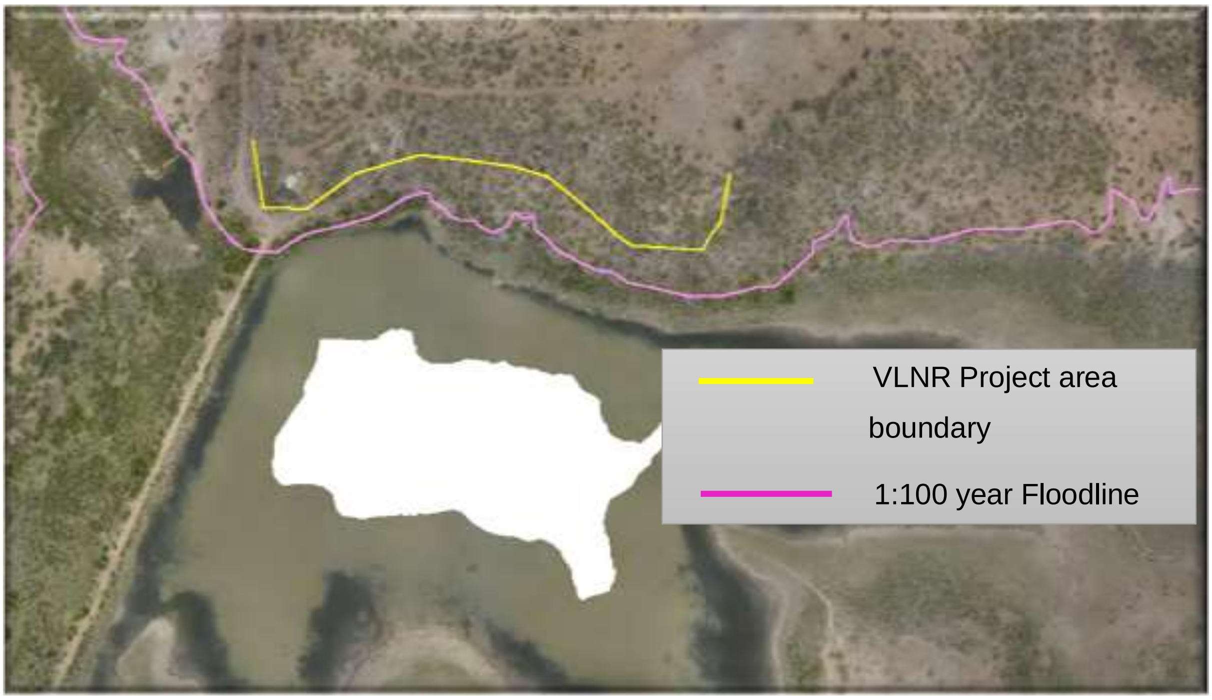

Figure 13-4: 1:100 year floodline in relation to the VLNR project boundary

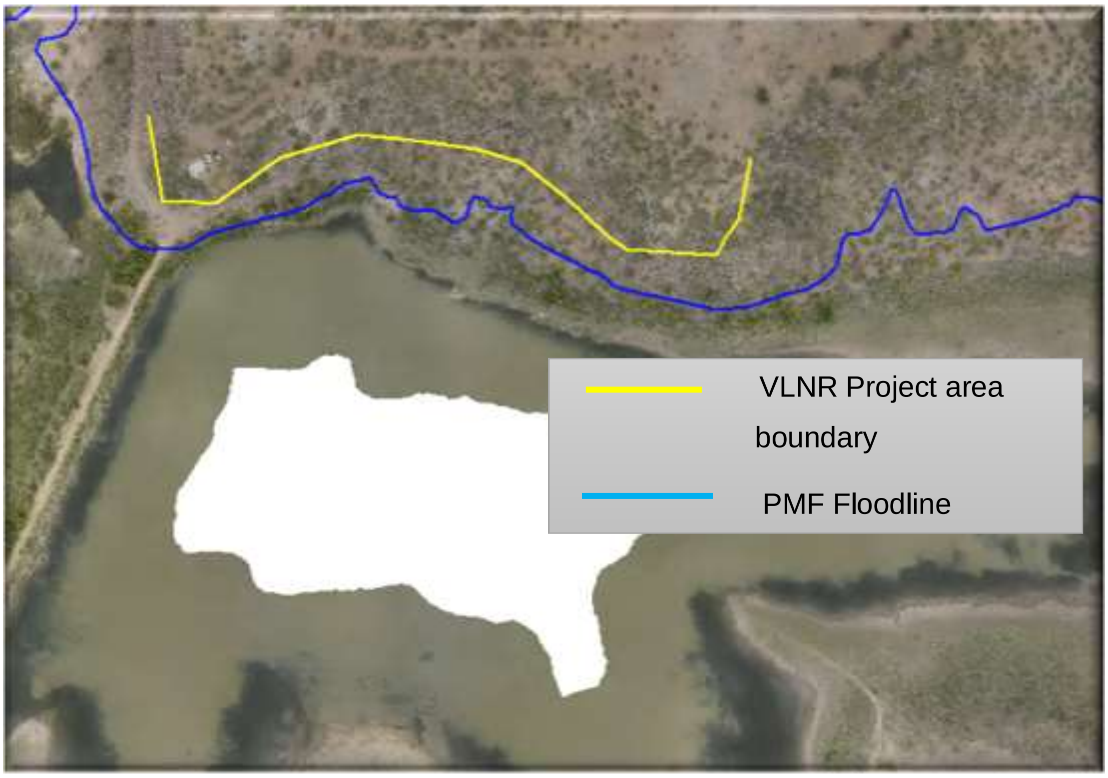

Figure 13-5: PMF Floodline in relation to the VLNR project boundary

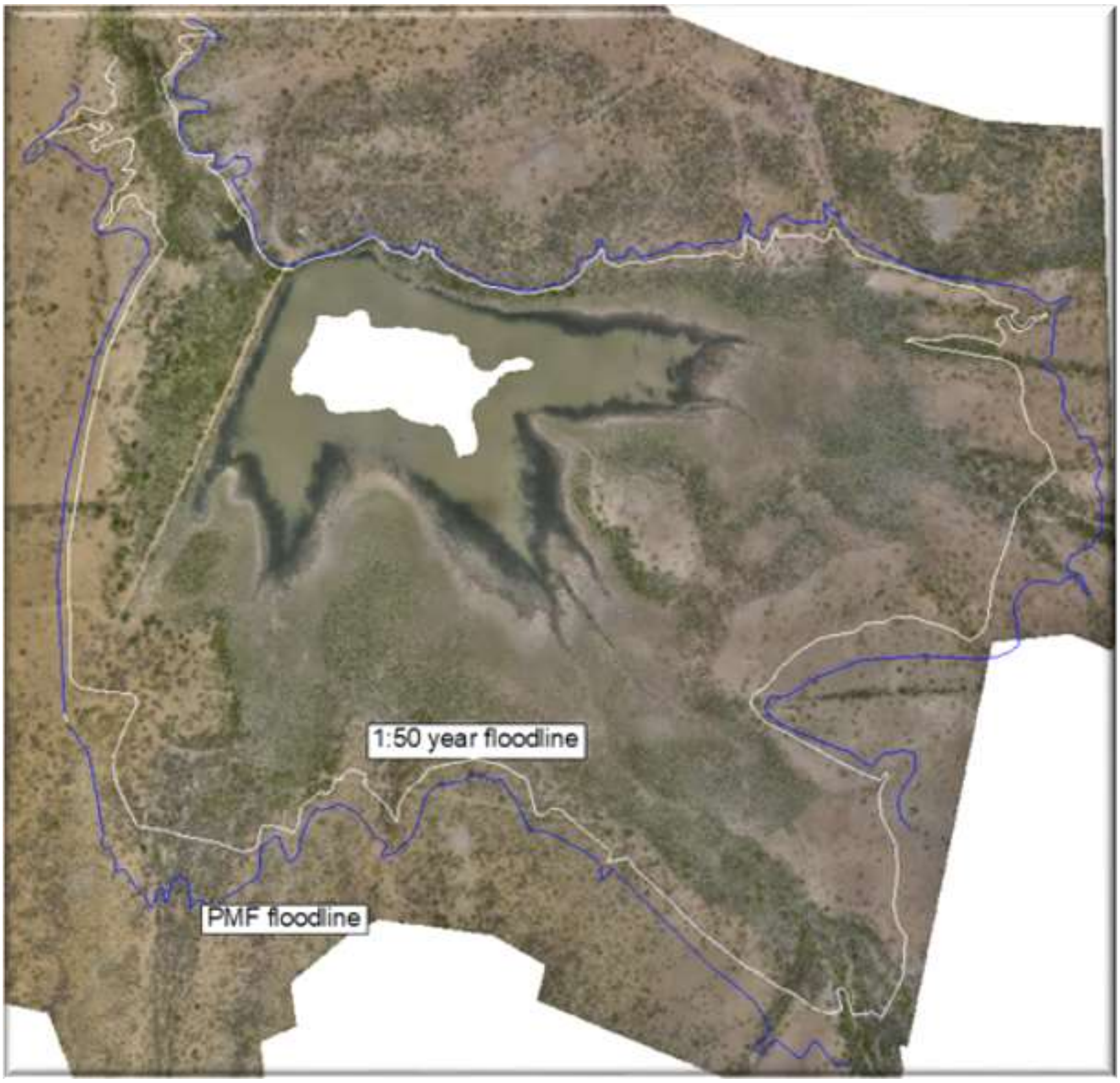

Figure 13-6: 1:50 year flood and PMF occurrence floodlines

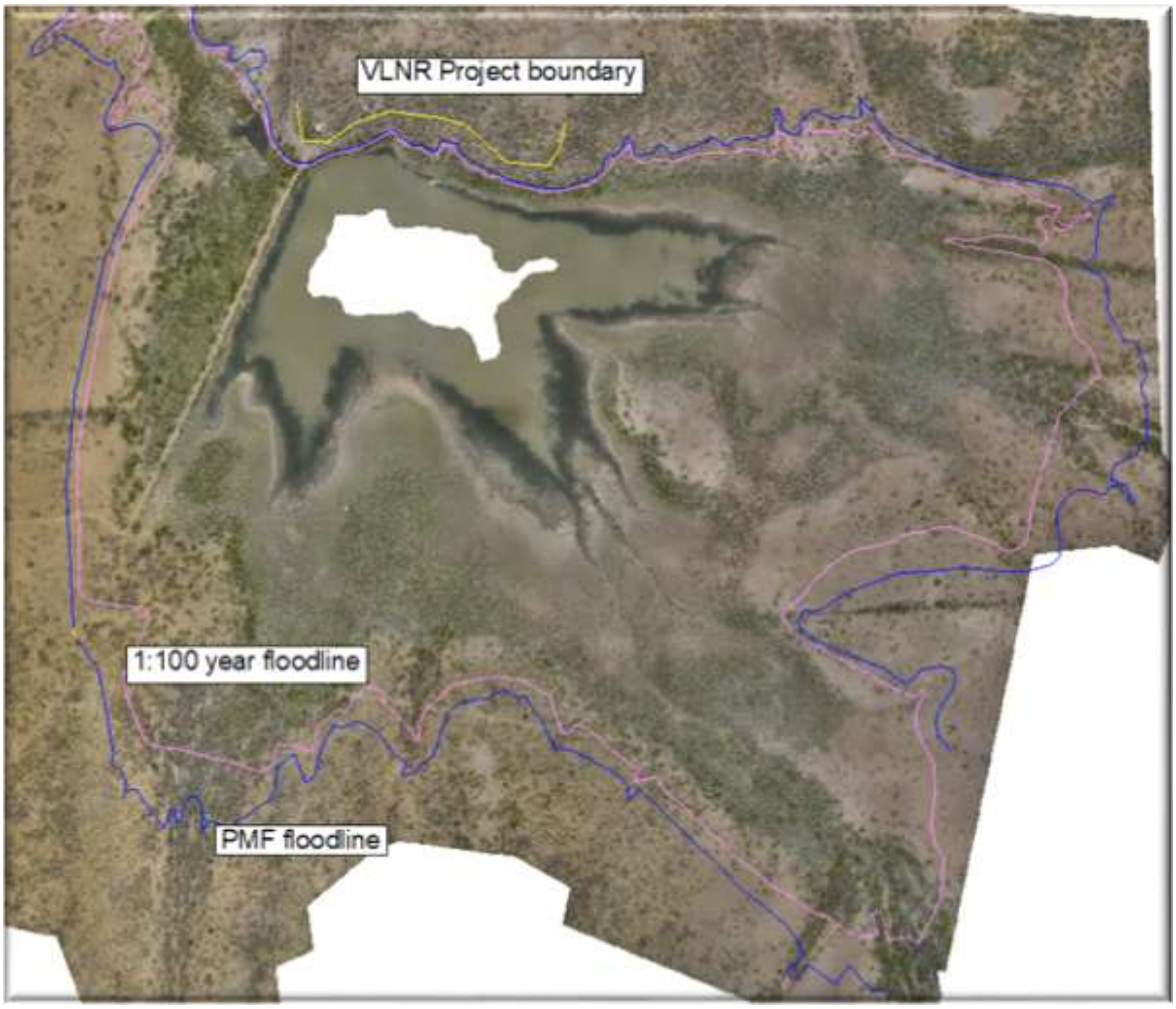

Figure 13-7: 1:100 year flood and PMF occurrence floodlines

14 CONCLUSIONS

The VLNR Project boundary fall within the 32 and 100 m plan distance from the FSL of the Lizzulea Dam but outside the 1:50, 1:100 year and PMF floodlines.

15 REFERENCES

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Midgley, D. (1972). *Design Flood Determination in South Africa, Report No. 1/72.* JOhannesburg: University of the Witwatersrand.

Minister of Water Affairs. (1999). *Regulations on the use of water for mining and related activities aimed at the protecion of water resources.* Pretoria: Water Affairs.

Pulles, W., & van Rensburg, H. (2006). *Best Practice Guideline: Storm Water Management.* Pretoria: Department of Water Affairs and Forestry.

Smithers, J., & Schulze, R. (2002). *Rainfall Statistics for Design Flood Estimation.* Pretoria: Water Research Commission.

World Meteorological Organization. (1986). *Manual for the estimation of Probable Maximum Precipitation, No. 332.* Geneva: WMO.

ANNEXURE A: CURRICULUM VITAE OF SPECIALIST

Hermanus Gideon van der Merwe (Deon)
Professional Engineer

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Key skills
Dam design, Dam safety, Rehabilitation plans, Fin provisioning

Years of experience
27

Years owner of HEES (Pty) Ltd
2

Education
B.Eng(Agric), University of Pretoria, 1992
MBL, University of South Africa

Registrations/Certifications
Pr Eng, ECSA, 960070

Professional affiliations
SAIAI, 1992; SANCOLD, 2009

Training
Civil Designer, HEC RAS, Geoslope, Geotech

Language skills
English and Afrikaans

Date of birth
9 July 1968

Nationality
South African

Deon is a qualified professional engineer with more than 27 years' experience.

Deon specialises in the design and project management of projects comprising Dams, SWMP, rehabilitation plans, canals, gabion structures and concrete structures. He also has experience in the management and maintenance of pump schemes and general management. He has successfully completed many water-related projects for the mining sector but has undertaken work for an array of other clients in other sectors.

Deon served as the area manager/deputy regional director of the Tugela-Vaal Government Water Scheme on behalf of the Department of Water Affairs (DWA), he was the deputy chief engineer for open channel systems and manager of the hydraulic laboratory at the DWA. He is thus aware of the challenges South Africa faces in terms of water resources. He started his career at the Department of Agriculture and at exiting was the Principal Engineer – Soil Conservation for the North West Province.

The most relevant projects for in relation to dam experience are:

- Design Engineer and Project Manager for the Preliminary Design of the 40 m high Concrete Gravity Rooikat Dam and 22 MW hydropower project on the Orange River,
- Senior Engineer for the Preliminary Design of the 45 m high Kabombo Gorge Earth Core Rockfill dam in Zambia and powerhouse of 40 MW,
- Civil Design Engineer for the feasibility design of the 3.6 MW, R450 million, run-off river project at Nyamba , Uganda (comprising of a 10 m concrete gravity weir, 3.1 km, 5.5 m³/s headrace canal, penstock and power house,
- Design Engineer for the 1000 MW Hydroelectrical Sounda Gorge Project – 3 130 m³/s diversion tunnels,
- Design Engineer for the Detail Design, Tender Evaluation and Project Management for the R34 million rehabilitation of the 37 m high earth fill Mothusi Dam at Letseng Mine in Lesotho,
- Design Engineer for the 55 m high Asphalt Core Rockfill Itare Dam in Kenya,

- Design Engineer for the optineering studies in terms of Penstock (2.8 m diameter, 605 m) and cofferdams for the 40 m high concrete gravity embankment at Kinguele Aval, Gabon,
- Senior Civil Engineer on the 90m high Arror Earth Core Rockfill Dam in Kenya. An EPC tender design was required by the client,
- Design Engineer on components of the Preliminary design of the R16 billion uMkomazi transfer scheme. This include the Dam position of the 86 m high Smithfield Dam, the 44 m high Earth fill Langa Dam and preliminary design of three gauging stations,

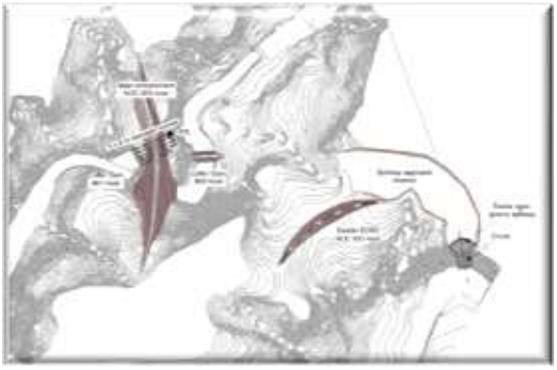

Figure 15-1: Model compiled by Deon van der Merwe for Smithfield Dam

- Design Engineer of the Rehabilitation of the 12 m high Homogenous Embankment of Pretoria Country Club,
- Design Engineer for the Evaluation and Emergency Rehabilitation of the Padda Dam, University of Johannesburg,
- Hydraulics Engineer for the Muldersvlei Clean Water Reservoir near Paarl,
- Design Engineer for the crack rehabilitation of the 145 m high Mohale Dam in Lesotho,
- Tender Design Engineer for the Stability Analysis, River diversion, 605 m long penstock optimization, Floodlines and reservoir influence for Kinguele Aval Concrete gravity dam, Gabon, with Piano Key weir
- Design Engineer for the detail design of the sedimentation trap at Thorncliffe Mine, Steelpoort,
- Design Engineer for the WULA designs for the Akanani project: 44 m high Tailings Storage Facility, **100 000 m³ lined return Water Dam (PCD)**, Waste Rock Stockpile and Ore Stockpile,
- Design Engineer on the WULA designs of 6 Pollution Control Dams for the plant for Akanani Platinum Expansion Project,
- Design Engineer on the WULA designs of 2 Pollution Control Dams for N'Komati Anthracite mine,
- Design Engineer for the spillway on the Fairbreeze Pollution Control Dam (R 500 000),
- Design Engineer for the rehabilitation of the Category I, Lethabo Main Storm Water Dam, R 4 million
- Assistant Civil Design Engineer on Banhoek intake weir with a project value of R20 million

Approved Professional Person for **Dam Safety Evaluation** (including dam breach information review, where relevant) of the:

  - Raw Water Reservoirs at Lethabo Power Station(Cat II)
  - Raw Water Reservoirs (Cat II), **Ash Dam (Cat II) and third Overflow Dam at Komati Power Station**,
  - 29 m high Earth embankment Imvutshane Dam (Cat II),
  - Earth embankment Rustfontein Dam (Cat II) near Bronkhorstpruit,
  - 12 m high Concrete Gravity Wilgeriver Dam,
  - 9.9 m high Kleinplaas earth embankment Dam
  - Adma Dam for Anglo American,

- Team member and author in the **Dam Safety Evaluation Report** of:
  - 69 m high Double curvature Bivane Dam (Cat III),
  - 12 m high concrete gravity Doornpoort Dam (Cat III),
  - 14.5 m high earth Locume Dam in Mozambique,
  - AngloGold Ashanti – Bird Dam project – Dam safety evaluation of Category I dam
- Dam breach analysis of:
  - Execution of the dam breach analysis of the 55m high earth embankment Kithino Dam in Kenya,
  - Responsible person for the Dam breach analysis of the 7m high Padda dam ay the University of Johannesburg, Souh Africa,
  - Responsible person for the Dam breach analysis of the Muldersvlei clean water reservoir in South Africa

Activities performed in relation to work history

FROM 2018 to date

(Director: HEES (Pty) Ltd)

- Design Engineer for the construction of the 55m high Itare ACRDam, Kenya, for AECOM SA
- Approved Professional Person for the Dam Safety Inspection of the 8.5 m high earth embankment Rustfontein Dam
- Approved Professional Engineer for the Wilgeriver Dam. Safety Inspection
- Design Engineer for the Dam Break analysis for 55m high dam in Kenya (Kithino Dam)
- Tender Design Engineer for the Stability Analysis, River diversion, 605 m long penstock optimization, Floodlines and reservoir influence for Kinguele Aval Concrete gravity dam, Gabon, with Piano Key weir
- Design Engineer for the SWMP for the WUL and EIA applications of the Mooifontein Cemetery
- Design Engineer for the detail design of the sedimentation trap at Thorncliffe Mine, Steelpoort
- Design Engineer for the detail design of the Oil Separator system at Thorncliffe Mine, Steelpoort
- Rehabilitation costing review of the Jwaneng mine, Botswana
- Rehabilitation design and costing of Mogalakwena mine TSF
- Stormwater review for the Itare WtW
- Design Engineer for the Detail design installation for Parshall Flume at Mogalakwena mine (24" and 36")
- Design Engineer for the review of Manganang gauging weir in Swaziland and the Feasibility design of rehabilitation of this weir to the value of R20 million
- Approved Professional Person for the Dam safety Evaluation of the 8.5 m high Earth Rustfontein Dam
- Design Engineer for the toe drain design of the Rustfontein Dam
- Competent Person for the Rehabilitation Plan, Financial Provisioning (R1.2 million) and Storm Water Management Plant for N'Komati Anthracite Mine,
- Design Engineer for the Conceptual design of the 45 m high Akanani Tailings facility, Return water Dam, Waste Rock Dam and Ore stockpile.
- Design Engineer for the conceptual design of the clean-dirty water separation of Akanani Mine with four storm water pollution control dams as part of the Storm Water Management Plan including the floodlines of the Mohlosane River,
- Dam Safety Evaluation of 10 PCDs at the Goedgevonden, Middelkraal and Tweefontein mines of Glencore,
- Dam Safety Evaluation of 4 PCDs for the Exaro Matla Coal mine.
- Design Engineer for the optineering studies in terms of Penstock (2.8 m diameter, 605 m) and cofferdams for the 40 m high concrete gravity embankment at Kinguele Aval, Gabon,
- Design Engineer for the Dam breach analysis and hydraulic studies of the 50 n high earthy embankment Kithino Dam in Kenya.

From 2011 to 2018 BKS / AECOM SA

(Executive: Dams and Hydropower)

- Approved Professional Person for the Safety Evaluation of the 29m high Imvutshane earth fill dam in Kwa-Zulu Natal (Supervisor and reviewer – Danie Badenhorst Pr Eng) (2018).
- Design Engineer for the detail design of components of the 55 m high Itare Dam an ACRD in Kenya. The components include, Embankment (plinth, core and shells), monitoring, spillway, river diversion conduit and grouting (±R1 billion construction value (2016 to -).
- Design Engineer for the tender submission design of the 90 m high ECRD Arror Dam in Kenya (2017).
- Sounda Gorge Hydropower Project, Congo. River diversion optimization of 3 310 m³/s (Design Engineer).
- Itare Dam, 55 m high ACRD, Kenya. Dam optimisation tender study. Peak flood determination, embankment stability design (± R800 mill construction value).
- Vioolsdrift/Noordoewer Dam on the Orange River. Peak flood determination for design purposes with a RMF of ± 32 589 m³/s and ± 884 206 km² catchment. (APP, supervisor - Danie Badenhorst).
- Mothusi Dam, Lesotho. Detail design and assistance to the construction of the rehabilitation of the dam to the value of R34 million. (Supervisor and APP role - Danie Badenhorst).
- Mohale Dam: Assistant Design Engineer on the rehabilitation of the crack on the concrete face. (APP role and supervisor, Danie Badenhorst)
- Nyamba B Hydropower Project, Uganda. Civil Design Engineer for the feasibility design of the 3.6 MW, R450 million, run-off river project (comprising of a 10 m concrete gravity weir, 3.1 km, 5.5 m³/s headrace canal, penstock and power house) (APP role and supervisor – Danie Badenhorst).
- Rooikat Hydropower Project, Orange River, South Africa. Design Engineer for the design, for tender, of the 40 m high concrete gravity dam and power house with installed capacity of 22 MW (2014) (> R400 million) (APP – Danie Badenhorst)
- uMkhomazi transfer scheme (Project value ± R16 Billion) (APP role – Danie Badenhorst).
    - Project manager for the Geotechnical investigations of the transfer scheme to the value of ±R 6 million (2013),
    - Assistant Design Engineer for the hydraulic design of the tunnel, connecting pipe, Intake works and project layout (2014),
    - Cost estimator.
- Approved Professional Person for the Dam Safety Inspection for the Category II Lethabo Power Station Raw Water Reservoir (2014).
- Design Engineer for the spillway on the Fairbreeze Pollution Control Dam (2014) (R 500 000),
- Design Engineer for the rehabilitation of the Category I, Lethabo Main Storm Water Dam (2013 - 2014, R 4 million)
- Dam Safety Inspections on the Lethabo Station Dams and Ash Water Storm Water Dams (2013).

- Pretoria Country Club. Dam Engineer responsible for the embankment stability evaluation with professional fees to the value of R 40 000 (2013-15).
- Mphanda Nkhuwa hydroelectric project. Assistant Design Engineer for the review of the diversion works of the project (2013) with estimated value of R 5 million.
- Prefeasibility studies for three Hydroelectric sites on the Orange River (2012 -). Civil Design Engineer for hydraulic, hydrology, financial and structural design with a project value of a possible R20 million.
- 3rd Overflow Dam Komati Power Station (2012). Dam Engineer on the Dam Safety Evaluation of the dam. Professional fees ± R100 000.
- uMkhomazi transfer scheme (2012) – Assistant Civil Design Engineer on the preliminary calculation on the hydropower potential for the transfer scheme with a project value of R 200 million (Technical supervisor – Willem van Wyk & Danie Badenhorst)
- uMkhomazi transfer scheme (2013) – Assistant Civil design Engineer on the hydraulic optimization of the transfer of water from the uMkhomazi River to the Mgeni system with an estimated project value of R10 billion. (Technical supervisor – Willem van Wyk & Danie Badenhorst)
- Neckertal Dam (2013) – Dam Engineer on the hydraulic calculation, program and design of the diversion works valued at approximately R 2 million (Supervisor – Danie Badenhorst).
- Lethabo Raw Water Reservoir – Dam Safety Inspection. APP for the evaluation of the safety of this Category II dam (R100 000 professional fees)(2013).
- Assistant Civil Design Engineer, water infrastructure, on the tender design of the 40 MW Kabompo Gorge Hydroelectric Scheme in Zambia to the value of R 800 million (2011) (Technical supervisor – Willem van Wyk & Danie Badenhorst).
- Assistant Civil Design Engineer for the feasibility design and option analysis on the eMkhomazi transfer scheme. Feasibility design of the ± 62 m high Smithfield Dam (R 1 100 million) and 44 m high Langa Dam (R 800 million) (Technical supervisor – Danie Badenhorst)(2012).
- Design Engineer for the 7 m high Fairbreeze pollution control dam (R1 million)(2012).
- Team member for the Safety Evaluation of the 69 m double curvature concrete arch Category III Bivane Dam near Vryheid (Professional fees – R 180 000) (APP – Danie Badenhorst)(2011).
- Team member for the Safety Evaluation of the 12 m high concrete gravity Category II Doornpoort Dam, near Middleburg, Gauteng (Professional fees – R 120 000) (APP – Danie Badenhorst)(2012).
- Team member for the Safety Evaluation of the 14.5 m high earth embankment Locume Dam in Mozambique (Project value of R 4 million) (APP role – Danie Badenhorst) (2012).
- Civil Design engineer for the Preliminary design of the ± 10 m high earth Embankment, Hanna Lodge near Orighstad (R 2 million).

2010 to 2011 – Environmental Engineering Solution

(Owner)

- Civil Design Engineer and draught person of 5 m high earth fill embankment of Wonderstone Dam with a project value of R1.3 million (2011) (Supervisor – Helmuth Keller).
- Engineer responsible for hydrological investigations - Dam break analysis, flood line determination and dam safety investigation (not classified) for Wonderstone mine (2011).
- Design engineer for sub- surface drainage investigation for West Complex tailings facility with estimated project cost of R3.5 million (2011).
- Design Engineer and draughts person for an 800 m long storm water diversion berm with a project value of R400,000 (2011).
- Design Engineer and draught person of 4 km concrete lined trench for West Complex, AngloGold Ashanti with a project value of R6 million (2010).
- Design engineer and draught person of 1.5 km rectangular concrete lined trench, Mponeng Mine, AngloGold Ashanti with a project value of R7.5 million (2010).
- Supervisory Engineer and draught person of 1.5 km concrete lined trench at EGAF facility, AngloGold Ashanti to the value of R1 million (2010).
- Specialist modeler for airspace modelling of Waste Rock Dump for Modikwa Platinum (2010).
- Engineer responsible for the clean and dirty water separation investigations and recommendations for TauTona (R6 million), Great Noligwa (R40 million), Kopanang (R15 million), Moab Khotsong (R4 million) Mines and Rand Carbide (R35 million) (2010-2011).
- Engineer responsible for the storm water management plans for Van Ouds and Baken mines (2010).

2008 to 2010 - Tugela Vaal Water Transfer Scheme
(Deputy Regional Manager)

- Project Manager for all mechanical, electrical and civil maintenance on scheme (Sterkfontein, Woodstock, Killburn Dams, Driel barrage, TUVA and subsidiary canals, Driel and Jagersrust Pump stations) (2008-2010).
- Manager responsible for all expenditure on scheme: Operational budget R 60 million per year (2008-2010).
- Manager responsible for all operations on scheme (2008-2010).
- Manager responsible for all dam safety aspects (Sterkfontein, Woodstock, Killburn Dams and Driel barrage) (2008-2010).
- Manager responsible for a staff compliment of 170 employees (2008-2010).

2006 to 2008 – Department of Water Affairs

(Deputy Chief Engineer – Open canal systems)

- Project manager for the Department on the:
    - Increase of Rietfontein weir to the value of R1.5 million (2007) (Supervisor - Kobus van Deventer, Client Danie Badenhorst).

- Feasibility study of the rehabilitation of Vlakfontein canal to the project value of R700 million (2007-2008).
- Oranje-Riet balancing Dam to the project value of R20 million (2008) (Supervisor – Kobus van Deventer Pr Eng, Client Danie Badenhorst).

- Manager with the responsibility of the construction and design of hydraulic models at Pretoria west to the value of R1.5 million per year (2006-2008).
- Assistant Civil Design Engineer on Banhoek intake weir with a project value of R20 million (2006-2008) (Supervisor – Kobus van Deventer Pr Eng).
- Construction supervision on rehabilitation of Tugela – Vaal Canal to the value of R4 million (2007).

2003 to 2006 – Administrator and Engineering consultant

(Owner)

- Rehabilitation of mines. Undertook the modelling of rehabilitation for:
- Eerstelingfontein (2005).
- Lovedale Quarry (2005).
- Corheim Asbestos mine (2006).
- AngloGold Ashanti – Bird Dam project (2006) – Dam safety evaluation of Category I dam.
- Administrator of estates under Section 74 of the Magistrates Court Act with branches in:
    - Ermelo and Standerton

1999 to 2003 – Administrator

(Manager – Hannatjie van der Merwe Administrators)

- Administrator of estates under Section 74 of the Magistrates Court Act
    - Manager for Hannatjie van der Merwe Attorneys
    - Branches in Potchefstroom, Klerksdorp, Wolmaranstad, Witbank, Thabazimbi, Northam.

1992 to 1999 – Department of Agriculture

(Candidate to Principal Engineer – Soil Conservation)

- Project manager, Design Engineer, Contracts administrator and Site Engineer of 4m high Magogong gabion erosion structure to a project value of R400,000 (1999) (Supervisor – W Viljoen Pr Eng).
- Engineer responsible for the design, contract administration and construction supervision of 32 km² Heuningsvlei water reticulation scheme with a project value of R3 million (1998).
- Design Engineer and construction supervision of 25 m high steel lighting for Agricultural Sport fields with a project value of R100 000 (1998).

- Design Engineer, Contracts Engineer and Site Engineer of ± 400 ha sub–surface drainage at Taung irrigation scheme to a project value of R500,000 (1997-1999).
- Design and Site Engineer of 2 ha sub-surface drainage at Bultfontein to the project value of R30,000 (1998).
- Engineering team member for the evaluation of centre pivot system at Taung irrigation scheme (1996).
- Design Engineer of 0.5 ha tunnel micro-sprinkle irrigation at Potchefstroom to a project value of (R25 000) (1995).
- Design Engineer of 30 ha micro-sprinkle irrigation at Reitz to a project value of R300,000 (1994).
- Soil Conservation Engineer responsible for the technical standards under the R4 million per year Soil Conservation scheme. Eastern Free State and North West Province (1992-1996).
- Project Engineer on the Grootlaagte soil conservation diversion structures (1996-1998).
- Specialist Engineer on Soil Conservation for Soil conservation enforcement (1996-1999).

Continuous professional development

#	Description	Entity	Validation number (ECSA)	Year	Days
Course attended					
1	Dam design course	US		2007	2
2	Drainage manual	SAICE		2007	2
3	Applied Geomechanics	US		2008	2
4	Pipeline design course	Sinotech		2008	2
5	Level 1 – First Aid	SA Red Cross		2009	1
6	Hazard identification and risk assessment	NOSA		2009	2
7	SHE Management tools	NOSA		2009	2
8	Sustainable rural livelihoods	ARC, Ag Engineering	AGEng006	2011	3
9	Management and design of Dams in Africa	University of Stellenbosch	3250	2011	4
10	Dam Engineering short course and symposium	University of Stellenbosch	K2922	2012	5
11	5th Annual Hydropower Africa	Spintelligent	UP2012-43	2012	4
12	Flood hydrology	UP		2014	
13	Pipeline design, Operation and Maintenance course	Sinotech	SAICEwat13/01343/16	2014	2
14	Modelling of free surface flow and dam break analysis	Sinotech	CESA-328-01/2016	2016	3

Conferences attended

SANCOLD, 2014 to 2019

SAIAE, 1992 to 2018

Publications

I. Curry, HG. Van der Merwe, R. Van Wyk, G. Benade, SANCOLD 2014, Feed Design for EPC contract of the Rooikat Hydropower project on the Orange River