LAFARGE TSWANA QUARRY
1:50 AND 1:100 YEAR FLOODLINE STUDY

March 2022
REVISION 01

Prepared by:

JG AFRIKA (PTY) LTD

Pietermaritzburg
6 Pin Oak Avenue
3201
Tel: 033 343 6700
Email: Hullp@jgafrika.co.za
Project leader: Phillip Hull

VERIFICATION PAGE	Qual-frm-026
	Rev 14

TITLE:		
Lafarge Tswana Quarry 1:50 and 1:100 Year Floodline Study		
JGA REF. NO. 5707	**DATE:** 10/03/2022	**REPORT STATUS** Draft

CARRIED OUT BY:	**COMMISSIONED BY:**
JG Afrika (PTY) LTD **Pietermaritzburg** PO Box 794 Hilton 3245 Tel.: +27 33 343 6700 Email: hullp@jgafrika.com	**Lafarge Industries South Africa (PTY) LTD** **Lichtenburg** 1 Manana Road Industrial Site 2740 Tel: +27 21 633 3011 Email: uneysa.taljard@lafargeholcim.com
AUTHOR	**CLIENT CONTACT PERSON**
Jédine Govender	Uneysa Taljard

SYNOPSIS

Floodlines Study required as part of the Water Use Licence Application.

KEY WORDS:

Lafarge Tswana Quarry, 1:50 and 1:100 Year Floodlines Study, Polfonteinspruit River

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO 9001: 2015 which has been independently certified by DEKRA Certification.

Verification	Capacity	Name	Signature	Date
By Author	Hydrologist	Jédine Govender	Jédine	10/03/2022
Checked by:	Executive Associate	Phillip Hull		10/03/2022
Authorised by:	Executive Associate	Phillip Hull		10/03/2022

Filename:	W:\Hydro\JGA\5707 - Lafarge Lichtenburg Specialist WULA Studies and PCD Design (PH)\04 Documents and Reports\JG Reports\Tswana Quarry

LAFARGE TSWANA QUARRY 1:50 AND 1:100 YEAR FLOODLINE STUDY

TABLE OF CONTENTS

TABLES

FIGURES

1 INTRODUCTION

JG Afrika (Pty) Ltd were appointed by Lafarge Industries South Africa (Pty) Ltd to undertake a 1:50 and 1:100-year floodline study for a portion of the Polfonteinspruit River, located adjacent to the Tswana Lime Quarry, which in turn is located in the North West Province near to Lichtenburg. More specifically, the quarry is located on Portion 0 of Driefontein Farm No 46 near Itsoseng. This specialist floodline study is one of a number of specialist studies that are being undertaken as part of a Water Use Licence Application (WULA) processes for the quarry.

The floodline study is based on present day conditions. The process of floodline delineations includes initially calculating the 1:50 and 1:100 year return period peak discharge values, and thereafter hydraulically simulating the respective peak discharge values along the watercourse of interest.

A typical floodline investigation requires detailed spatial information in the form of cross-sectional survey data and/or detailed contour information to produce accurate floodline delineations. The client provided JG Afrika with 2 m contour information for the study area. It should be noted that the 1:50 and 1:100 year return period floodlines produced in this study are as accurate as the topographical information represented through the 2 m contour information provided. The following report outlines the methodologies applied and results obtained through the floodline delineation study.

1.1 Declaration of Independence

JG Afrika have been appointed to undertake an independent floodline study for the drainage line within close proximity to the Tswana Lime Quarry. JG Afrika have undertaken this study in an objective manner, even if this results in views and findings that are not favourable to the Applicant or Client. JG Afrika have the expertise required to undertake the study and the resultant report presents the results in an objective manner. The main author of the report, Ms Govender, is a hydrologist at JG Afrika who is professionally registered and has an MSc. in Hydrology. Ms Govender has undertaken the floodline study under the guidance of Mr. Phillip Hull. Mr. Hull who is a Senior Hydrologist and Executive Associate at JG Afrika, has an MSc. in Hydrology, is professionally registered and has in excess of 14 years relevant project experience.

2 SITE DESCRIPTION

2.1 Locality

The location of the Tswana Quarry is presented in **Figure 2-1**. As depicted in this map, the quarry is located approximately 37 km northwest from Lichtenburg town, within the Ditsobotla Local Municipality of the North West Province. A site plan of the project site presenting the Tswana Quarry and Polfonteinspruit River are provided in **Figure 2-2**. As depicted in **Figure 2-2**, the Polfonteinspruit River flows alongside the northern boundary of the Tswana Quarry, flowing in a east to west direction, and drains into the Lotlhakane River which is a tributary of the Molopo River.

Hydrologically, the study area is located in Quaternary Catchment D41A, within the Lower Vaal Water Management Area (WMA No. 11). The Mean Annual Precipitation (MAP) of the study area is 522 mm (Smithers and Schulze, 2003) and the Mean Annual Evaporation (MAE) of the study area is 1 952 mm, as per the Water Resources of South Africa 2012 (WR2012) study. The land uses within the study catchment were identified using Google Earth aerial imagery and classed according to the South African National Landcover Database (NLC, 2018) which predominantly consisted of agriculture followed by residential areas and to a lesser degree, grasslands and thickets.

2.2 Site Description (Mining Process)

It is JG Afrika's understanding that the Tswana Quarry operations involve mining limestone rock from opencast pits using conventional drilling and blasting methods. The topsoil and overburden are removed by means of trucks and relocated to an area near the open pit. The mined limestone material is loaded onto haul trucks by excavators and transported to the primary crusher. Following the crushing process, the materials are transported to the Lafarge Cement Plant via railway.

2.3 Site Assessment

As part of the study, JG Afrika conducted a site assessment of the Lafarge Tswana Quarry sites between the 25th and 27th of January 2022. The objectives of this site visit were to assess topographical, soil and land cover characteristics of the study area. These site characteristics form the basis for understanding the hydrology and hydraulics of the project area.

It is also important to note that there were no culverts identified on the Polfonteinspruit to include in the hydraulic modelling.

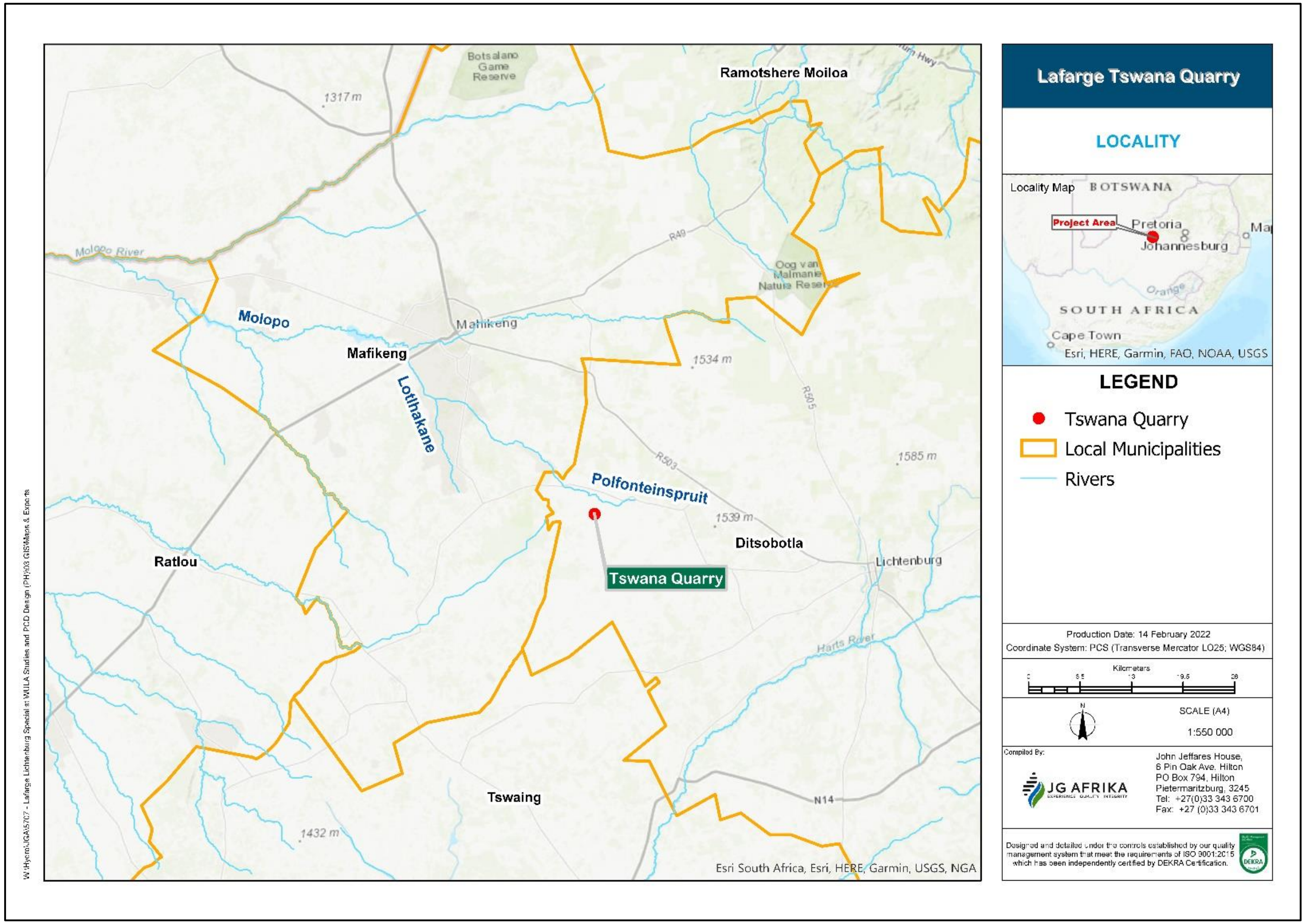

Figure 2-1 Lafarge Tswana Quarry Locality Map

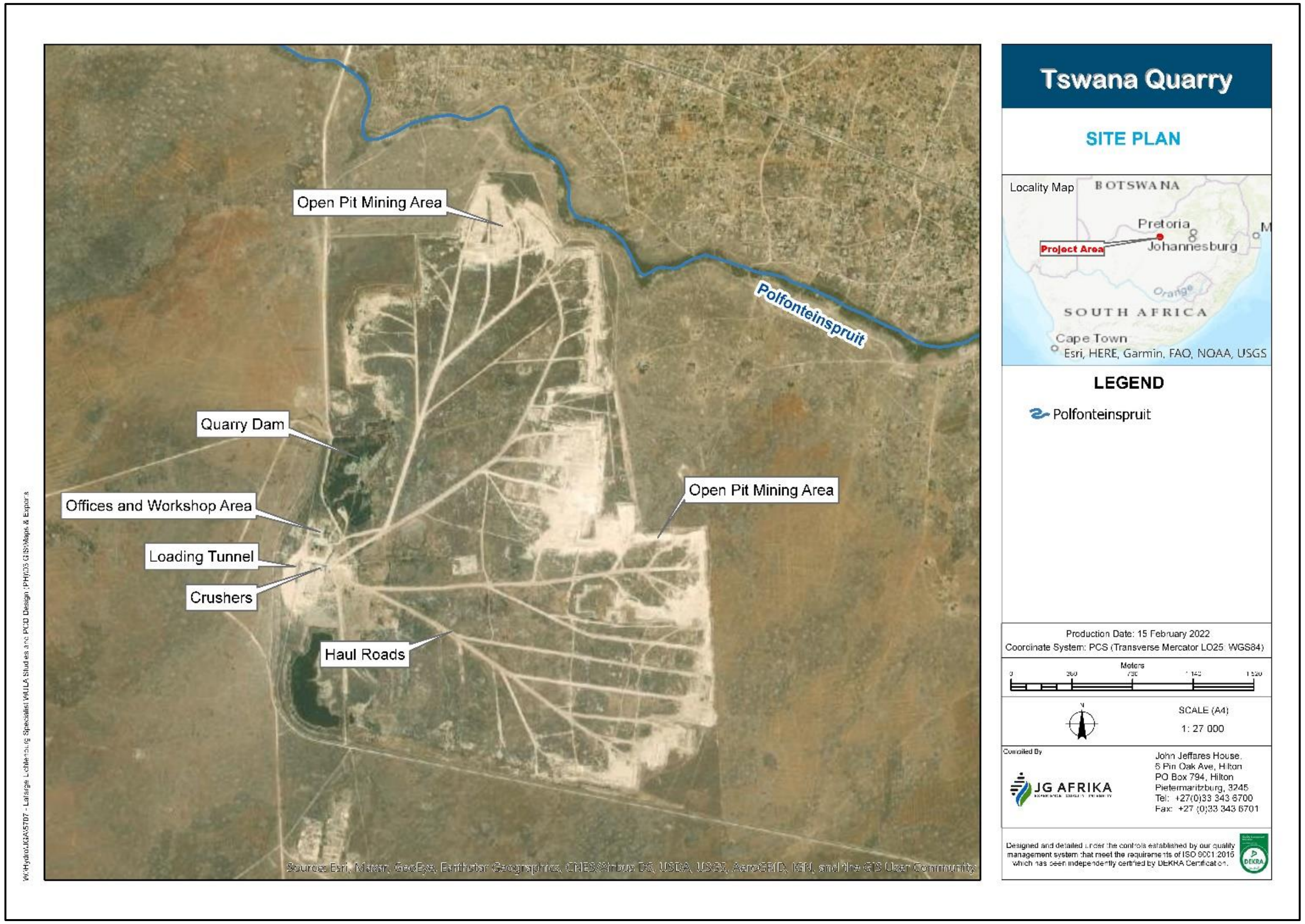

Figure 2-2 Lafarge Tswana Quarry Plant Site Plan

3 FLOODLINE DELINEATION

The methodology used to calculate the design flood values and the hydraulic model used to simulate the resultant floodlines are presented in the following sub-sections.

3.1 Peak Discharge Calculation

A design flood peak discharge value associated with a specific recurrence interval can be calculated using various methodologies that typically fall into three categories, namely Deterministic; Empirical; and Statistical Methods. All three approaches have been widely applied in South Africa (Smithers, 2012). The appropriate methodology to be applied in calculating a design flood peak discharge value depends largely on the size of the contributing catchment and the level of hydrological data available (i.e. gauged streamflow values and design rainfall data). Statistical methods are typically preferred as these methods estimate design floods based on site-specific historical streamflow data. However, these methods are reliant on reliable streamflow records of a sufficient length within a reasonable proximity to the study site. Empirical methods generally estimate design floods through the use of regional parameters, while deterministic methods typically employ catchment specific parameters such as land use, soil type and site-specific design rainfall. Statistical methods were not used for design flood estimation in this study due to the lack of adequate historical streamflow data at, or near to, the project site. Based on the size of the catchment area (i.e. 48.34 km^2) and a lack of available gauged streamflow data, it was decided that the Rational Method (Deterministic Method) is the most appropriate method to calculate the peak discharge values.

The Rational Method is widely used throughout the world for both rural and urban catchments (Alexander, 2001; Pilgrim and Cordery, 1993) and it is the most commonly used method of estimating design flood peak discharge values. The method is sensitive to design rainfall intensity and the selection of the runoff coefficient (C factor). The method assumes that the peak discharge occurs when the duration of the rainfall event is equal to the Time of Concentration (Tc), and that the rainfall intensity is distributed uniformly over the catchment. As a consequence of these assumptions, the Rational Method is best suited to catchments with areas of less than 100 km^2 (HRU, 1972). However, it can be applied to larger catchments if care is taken in the estimation of the catchment C-factor. The Rational Method Equation is presented as follows (*cf.* **Equation 1**):

$$Qp = 0.278(CIA) \qquad \textbf{Equation 1}$$

Where:

Qp	=	peak flow (m^3/s)
C	=	run-off coefficient (dimensionless)
I	=	average rainfall intensity over catchment (mm/hour)
A	=	effective area of catchment (km^2)

Design rainfall is required as an input into the Rational Method for calculating design flood peak discharge values associated with various recurrence interval storm events (floods). Design rainfall for the study site was obtained from the Design Rainfall Estimation Program (Smithers and Schulze, 2003). This Design Rainfall Estimation software calculates the design rainfall depths using a regionalised L-moment Algorithm and scale invariance at any 1' × 1' grid interval in South Africa. The design rainfall depths for the 1:50 and 1:100 year return period, used in calculating the design peak discharge value, are presented in **Table 3-1**.

Table 3-1 Design Rainfall Values

Duration	1:50 Year Design Rainfall Depths (mm)	1:100 Year Design Rainfall Depths (mm)
5 min	20.30	22.60
10 min	30.20	33.60
15 min	38.00	42.40
30 min	48.10	53.70
45 min	55.20	61.60
1 hour	60.90	67.90
1.5 hour	69.90	78.00
2 hour	77.10	86.00
4 hour	90.10	100.50
6 hour	98.70	110.10
8 hour	105.30	117.40
10 hour	110.70	123.50
12 hour	115.30	128.60
16 hour	123.00	137.20
20 hour	129.30	144.30
24 hour	134.70	150.30
2 day	137.80	153.70
3 day	155.50	173.50
4 day	168.70	188.20
5 day	179.70	200.40
6 day	189.20	211.00
7 day	197.60	220.40

Catchment C factors, required as input into the Rational Method, are determined by accounting for a combination of catchment landcover types (Cv), soil types (Cp) and catchment slopes (Cs). The land uses of the contributing catchment area were predominantly classed as agriculture followed by informal residential areas and to a lesser degree, grasslands and thickets. The South African National Land Cover Database (NLC) (2018) together with aerial imagery and observations made during the site visit in January 2022, were used to classify different land use classes.

The catchment permeability and SCS-SA soil groupings were obtained from maps and soil classifications developed by Schulze and Schütte (2018). The catchment soil permeability was predominantly permeable. The surface slopes for the catchment were estimated from a Digital Elevation Model (DEM), created from 5 m contour data of the project area. The surface slopes were classed according to the threshold slopes of less than 0 – 3%, 3 – 10%, 10 – 30% and >30 %. A summary of the input variables used in the Rational Method to calculate the 1:50 and 1:100 year peak discharge values of the Polfonteinspruit River are presented in **Table 3-2** and **Table 3-3**. The resultant peak discharge value of the Polfonteinspruit River is presented in **Table 3-4**.

Table 3-2 Summary of Inputs for Peak Discharge Calculation

Catchment	Catchment Area (km^2)	Longest Water Course (km)	Average Water Course Slope (m/m)	Time of Concentration (hours)
Polfonteinspruit	48.34	7.88	0.004	6.78

Table 3-3 Study Site Catchments C-Factor Calculation

Variable	Polfonteinspruit Catchment
Catchment Land Use Distribution (%)	
Urban	28.10
Rural	71.40
Water Bodies	0.50
Catchment Slope Distribution (%)	
>3	100
0-10	0.00
10-30	0.00
> 30	0.00
C - Factor (Cs)	**0.01**
Catchment Soil Permeability Distribution (%)	
Very permeable	0.00
Permeable	100.00

Variable	Polfonteinspruit Catchment
Semi-permeable	0.00
Impermeable	0.00
C - Factor (Cp)	**0.06**
Rural Component Vegetation Distribution (%)	
Thick Bush and Forests	11.50
Light Bush and Agriculture	67.20
Grasslands	20.30
Bare	1.00
C - Factor (Cv)	**0.09**
Final (adjusted) C-Factor Value (1:50 Year Return Period)	**0.16**
Final (adjusted) C-Factor Value (1:100 Year Return Period)	**0.17**

Table 3-4 Peak Discharge Results

Catchment	1:50 Year Peak Discharge (m^3/s)	1:100 Year Peak Discharge (m^3/s)
Polfonteinspruit River	31.06	38.91

3.2 Floodlines Delineation

3.2.1 Survey Data

The HEC-RAS Model (US Army Corp of Engineers) was used to undertake two-dimensional hydraulic modelling of the portion of interest of the Polfonteinspruit River to determine the extent of the floodlines corresponding to the 1:50 and 1:100-year return periods. Hydraulic modelling was based on 2 m contour information provided by the Client. The 2 m interval contour information was used to create a DEM of the project site, which in turn allowed for cross-sectional elevations and other topology to be extracted for the project area utilising HEC-GeoRAS (an ArcMAP extension that links directly with the hydraulic model). This data was subsequently exported into the HEC-RAS model for hydraulic modelling of the previously calculated peak discharge value.

3.2.2 Manning's n Values

The roughness of the channel and floodplain surface needs to be accounted for within the hydraulic model. In this case, Manning's n values (Chow, 1959) were used to describe the surface roughness within HEC-RAS. The Manning's values were based on site observations during January 2022 and on aerial imagery (Google Earth Imagery). **Table 3-5** presents the general Manning's n values for the Polfonteinspruit River and the surrounding floodplains that were modelled.

Table 3-5 Manning's n Values (Chow, 1959)

Drainage Line	Location	Manning's n Value	Description
Polfonteinspruit	Channel	0.045	Winding, weeds, some pools and shoals.
	Right and Left Floodplains	0.040	Grassland to medium brush and trees

3.3 Floodlines Results

Based on the 2 m contour information provided, the estimated 1:50 and 1:100 year peak discharge values and catchment conditions, the resultant delineated 1:50 and 1:100-year return period floodlines for the study site, are presented in **Figure 3-1**. It was noted that both the delineated 1:50 and 1:100-year floodlines are outside of the Tswana Limestone Quarry and its associated infrastructure.

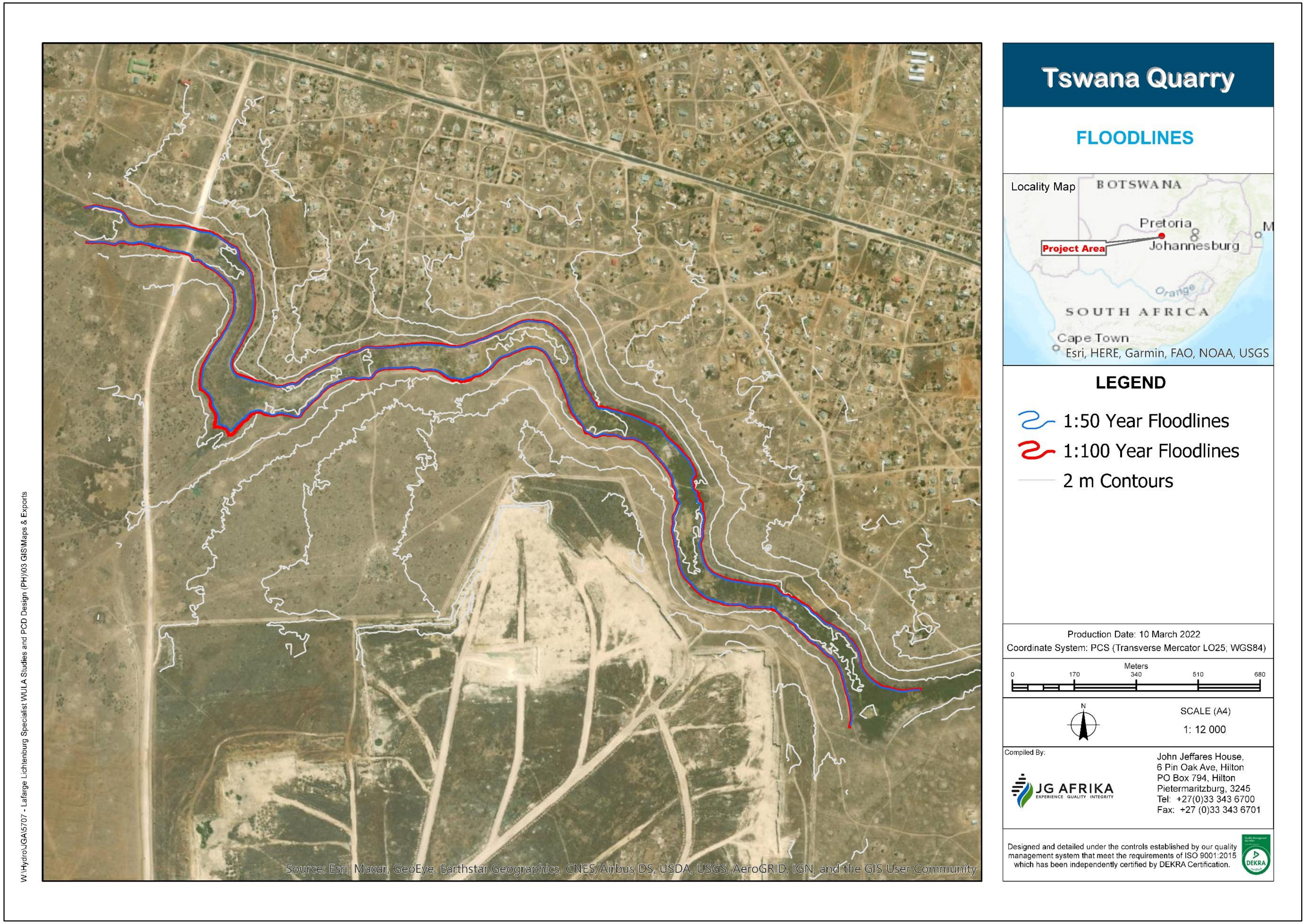

Figure 3-1 1:50 and 1:100 Year Floodlines for the Polfonteinspruit River

4 CONCLUSION AND RECOMMENDATIONS

The objective of this assessment was to undertake a floodline study to delineate the 1:50 and 1:100 year floodlines for a portion of the Polfonteinspruit River, located adjacent to the Tswana Lime Quarry, which is located in Portion 0 of Driefontein Farm No 46 near Itsoseng in the North West province.

As part of this study, the 1:50 and 1:100-year return period peak discharge values of the Polfonteinspruit were calculated using the Rational Method. The extent of the corresponding floodlines were determined through hydraulic modelling using the HEC-RAS model. The floodlines were modelled using 2 m contour information, which were surveyed for the purposes of this study.

The resultant floodlines were plotted using ArcGIS Pro software. Based on the floodline analysis, it was noted that 1:50 and 1:100-year floodlines are located outside of the Tswana Quarry and any of its associated infrastructure.

5 REFERENCES

Chow, V.T., 1959. Open channel hydraulics. McGraw-Hill, New York, USA.

DWAF. (1998). The South African National Water Act (36 of 1998). DWAF.

GeoTerraImage. 2018. South African National Landcover (2018) Dataset.

Kunz, R (2004). Daily Rainfall Data Extraction Utility, Version 1.4.

Schulze, R and Schütte, S. 2018. *Mapping SCS Hydrological Soil Groups over South Africa at Terrain Unit Resolution*. Internal Report. School of Agricultural, Earth and Environmental Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Smithers, J.C., Schulze, R.E., 2003. Design rainfall and flood estimation in South Africa. WRC Report No. 1060/01/03, Water Research Commission, Pretoria, RSA.

South African National Roads Agency Limited. 2016. Drainage Manual (Sixth Edition). South African National Roads Agency Ltd, Pretoria, South Africa.

US Army Corps of Engineers. (1995). HEC RAS Hydraulic Modelling Software. Version 5.0.7 California.