# LAFARGE LICHTENBURG
# 1:50 AND 1:100 YEAR FLOODLINE STUDY

**March 2022**

**REVISION 00**


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**SYNOPSIS**

Floodline study as submitted to fulfil the requirements of a water use licence application

**KEY WORDS:**

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**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.

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# LAFARGE LICHTENBURG
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## TABLE OF CONTENTS


**1 INTRODUCTION ..... 1**

1.1 Declaration of Independence ..... 1

**2 SITE DESCRIPTION ..... 2**

2.1 Locality ..... 2

2.2 Site Description ..... 2

**3 FLOODLINE DELINEATION ..... 8**

**3.1 Peak Discharge Calculation** ..... 8

**3.2 Floodline Delineation** ..... 11

**3.3 Floodline Analysis Scenarios** ..... 12

**3.4 Floodlines Results** ..... 12

**4 CONCLUSION AND RECOMMENDATIONS ..... 19**

**5 REFERENCES ..... 21**


## TABLES


Table 2-1 Dimensions of Existing Culverts ..... 7

Table 3-1 Design Rainfall Values ..... 9

Table 3-2 Summary of Inputs for Peak Discharge Calculation ..... 10

Table 3-3 Study Site Catchments C-Factor Calculation ..... 10

Table 3-4 Peak Discharge Results ..... 11

Table 3-5 Manning's n Values (Chow, 1959) ..... 12

Table 3-6 Proposed culvert dimensions ..... 14


## FIGURES


Figure 2-1 Lafarge Cement Plant and Tswana Quarry Locality Map ..... 3

Figure 2-2 Lafarge Cement Plant Site Plan ..... 4

Figure 3-1 Hydraulic analysis results based on current catchment conditions and including blocked culverts and infilling of the drainage line ..... 13

Figure 3-2 Hydraulic analysis results based on unblocked culverts and removal of portions of the dumped materials along the drainage line ..... 15

Figure 3-3 Proposed rehabilitation of the drainage line and locations of increased capacity of road and rail crossings ..... 16

Figure 3-4 Updated Hydraulic analysis results based on increased culvert capacities and a flood diversion berm being constructed ..... 17

Figure 3-5 Simulated 1:50 year flow depths (m) along the proposed flood protection berm ..... 18

# 1 INTRODUCTION

JG Afrika (Pty) Ltd were appointed by Lafarge Industries South Africa (Pty) Ltd (Lafarge) to undertake a floodline study for the Lichtenburg Lafarge Cement Plant in the North West Province. The cement plant is located on Portion 61 of Lichtenburg Town Farm No 27. This floodline is submitted in order to fulfil the requirements of a water use licence application as well as to inform the rehabilitation of an area in which materials have been dumped, which has resulted in impeding of the natural flows along the drainage line.

The following report presents the methodology applied in estimating the peak discharge rates of the drainage line and thereafter, the resultant delineation of the 1:50 and 1:100-year floodlines. The floodline study is based firstly on present day conditions (i.e. showing the impact of the materials dumped along the drainage line) and secondly assuming culverts have been reinstated and the materials impeding flows have been removed. 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. JG Afrika was provided with half-metre contour information for the study area, which was surveyed by Unmanned Tech. 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 half-metre contour information provided by Unmanned Tech. 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 Lafarge Lichtenburg Cement Plant. 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 hydrologist at JG Afrika and has an MSc. in Hydrology and has two years of experience in various hydrological studies. Ms Govender has undertaken the floodline study under the guidance of Mr. Phillip Hull. Mr Hull is a Senior Hydrologist and 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 Lafarge Cement Plant and Tswana Quarry are presented in **Figure 2-1**. As depicted in this map, the cement plant is located 2 km northeast of Lichtenburg town, within the Ditsobotla Local Municipality of the North West Province. A site plan of the project site presenting the cement plant, unnamed drainage line and culverts are provided in **Figure 2-2**.

Hydrologically, the study area is located in Quaternary Catchment C31A, within the Lower Vaal Water Management Area (WMA No. 11). The Mean Annual Precipitation (MAP) of the study area is 614 mm and the Mean Annual Evaporation (MAE) of the study area is 1 860 mm, as per the Water Resources of South Africa 2012 (WR2012) study.

## 2.2 Site Description

The project site consists of a cement factory. At the cement plant, a process of grinding and burning takes place. Fine grinding produces a fine powder (known as raw meal), which is preheated and then sent to a Kiln. The material is heated to approximately 1 500°C before being rapidly cooled. This produces clinker, the basic material required for the production of all cements. The final manufacturing process involves cement grinding and shipping. A small amount of gypsum (3-5%) is added to the clinker to regulate how the cement will set. The mixture is then very finely ground to obtain "pure cement". During this phase, different mineral materials, called "cement additives", may be added alongside the gypsum. Used in varying proportions, these additives, which are of natural or industrial origin, give the cement specific properties such as reduced permeability, greater resistance to sulphates and aggressive environments, improved workability, or higher-quality finishes. Finally, the cement is stored in silos before being shipped in bulk or in bags to the sites where it will be used.

The project site is located on relatively flat terrain. As presented in **Figure 2-2**, a single natural drainage line is located along the eastern boundary of the project site. This drainage line stems from an area that was once mined, and has a catchment area of approximately 5.5 km$^2$ at the point where the drainage line intersects with the Lafarge property. The unnamed drainage line is a tributary of the Groot Harts River, which is a perennial river and contributes flow to the Barberspanand and Beiesiesvlei downstream of the Lafarge Cement Plant.

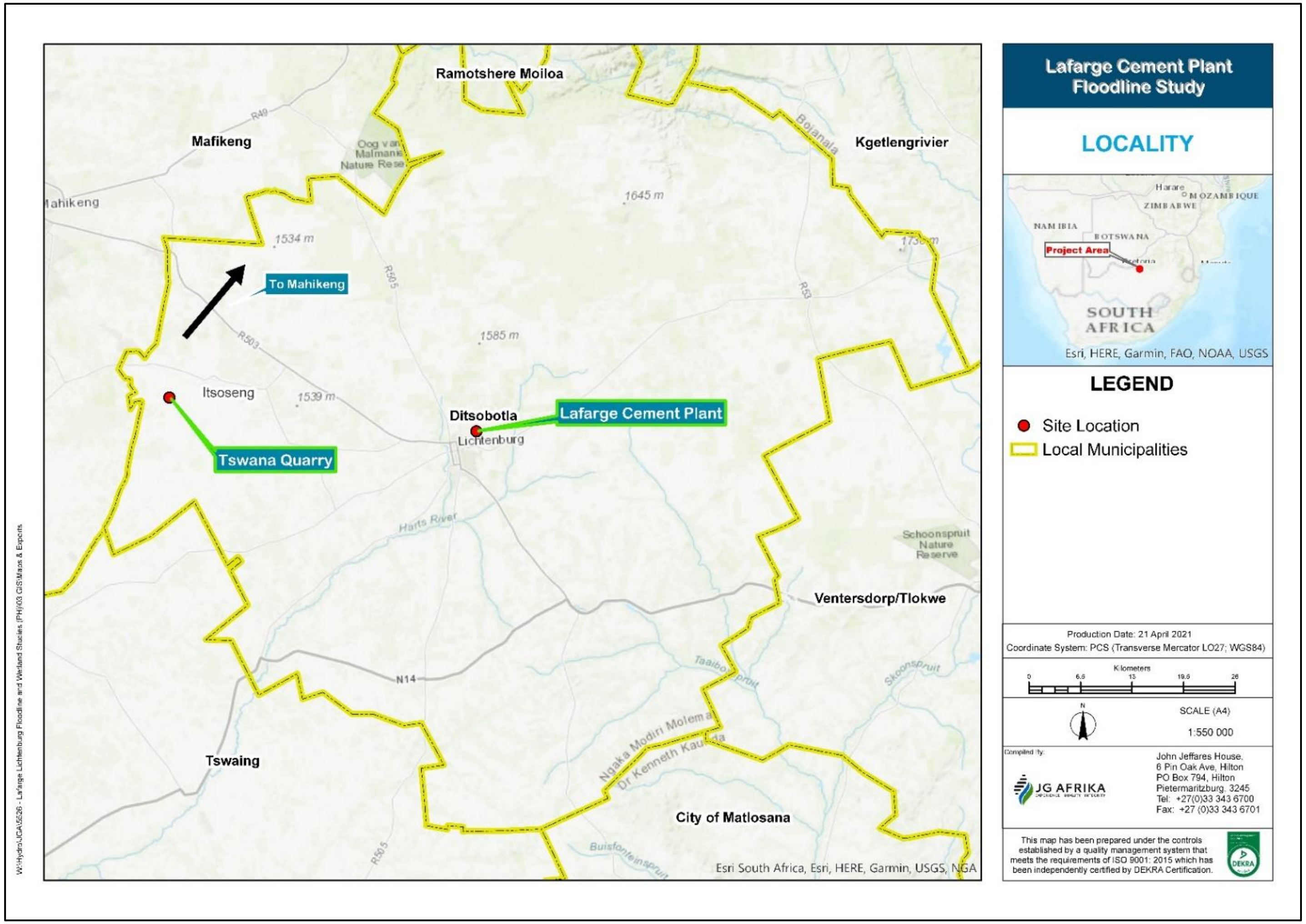


*Figure 2-1 Lafarge Cement Plant and Tswana Quarry Locality Map*

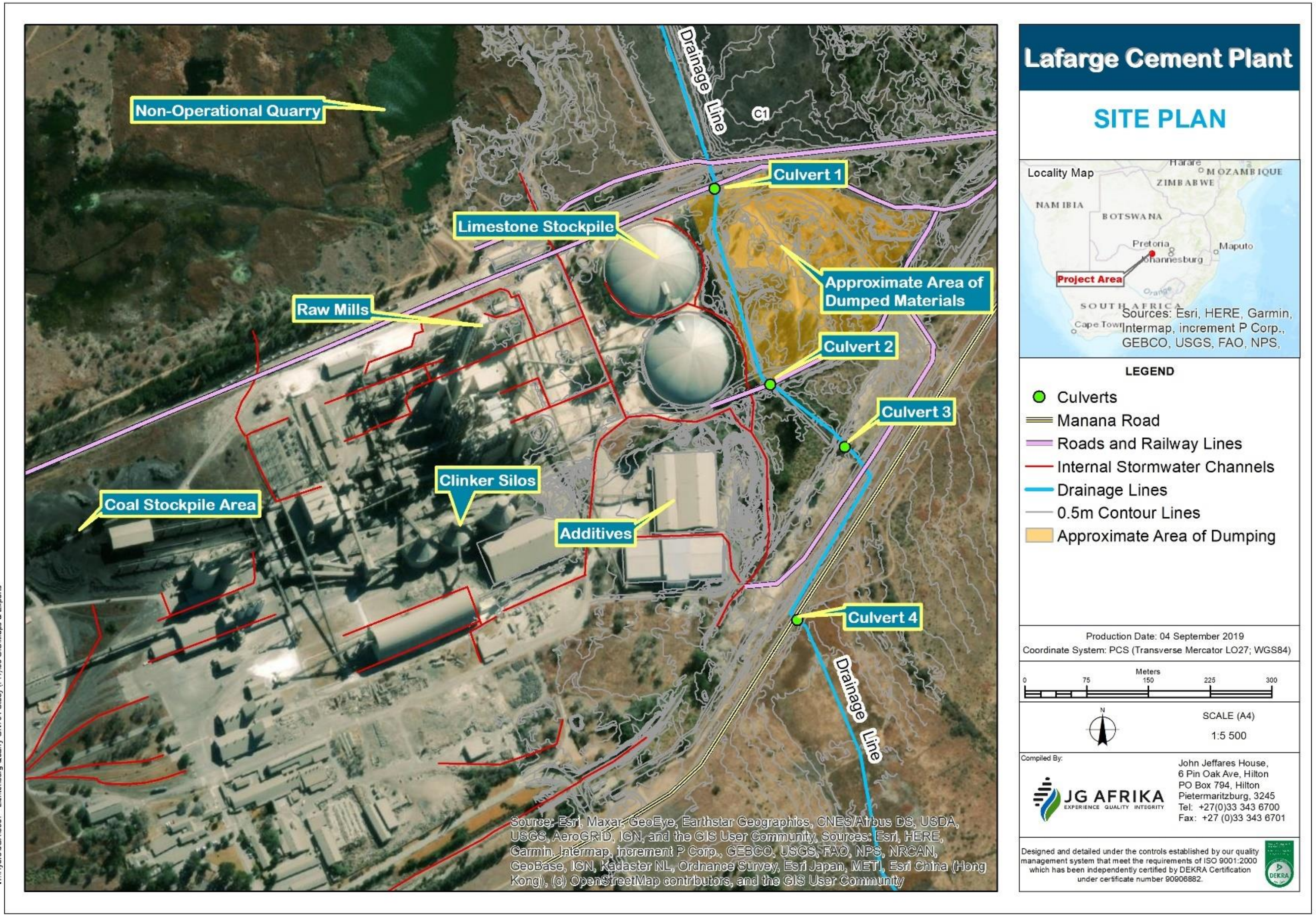


*Figure 2-2 Lafarge Cement Plant Site Plan*

As part of the study, JG Afrika conducted a site assessment of the Lafarge Cement Plant in March 2021. The objective of this site assessment was to gain an understanding of the extent to which materials have been dumped along the drainage line, to identify any existing culverts linking the drainage line to the north to the wetland area to the south of the factory, and to confirm catchment characteristics that determine the runoff generation from the catchment area. Based on the site assessment, the following was noted:

- The catchment area consists predominantly of grasslands and an area that has historically been used to discard of cement related waste materials (as presented in **Plate 2-1**).
- The soils consisted of sandy loam type texture that was classed as permeable (as presented in **Plate 2-2**).
- A number of culverts were found along the drainage line, however, these were largely blocked (as presented in **Plate 2-3**).
- Material dumped along the drainage line has resulted in the disconnection of flows from the catchment area to the north of the Lafarge factory site, with the wetland area to the south of the project area. An example of the dumped materials is presented in **Plate 2-4**.

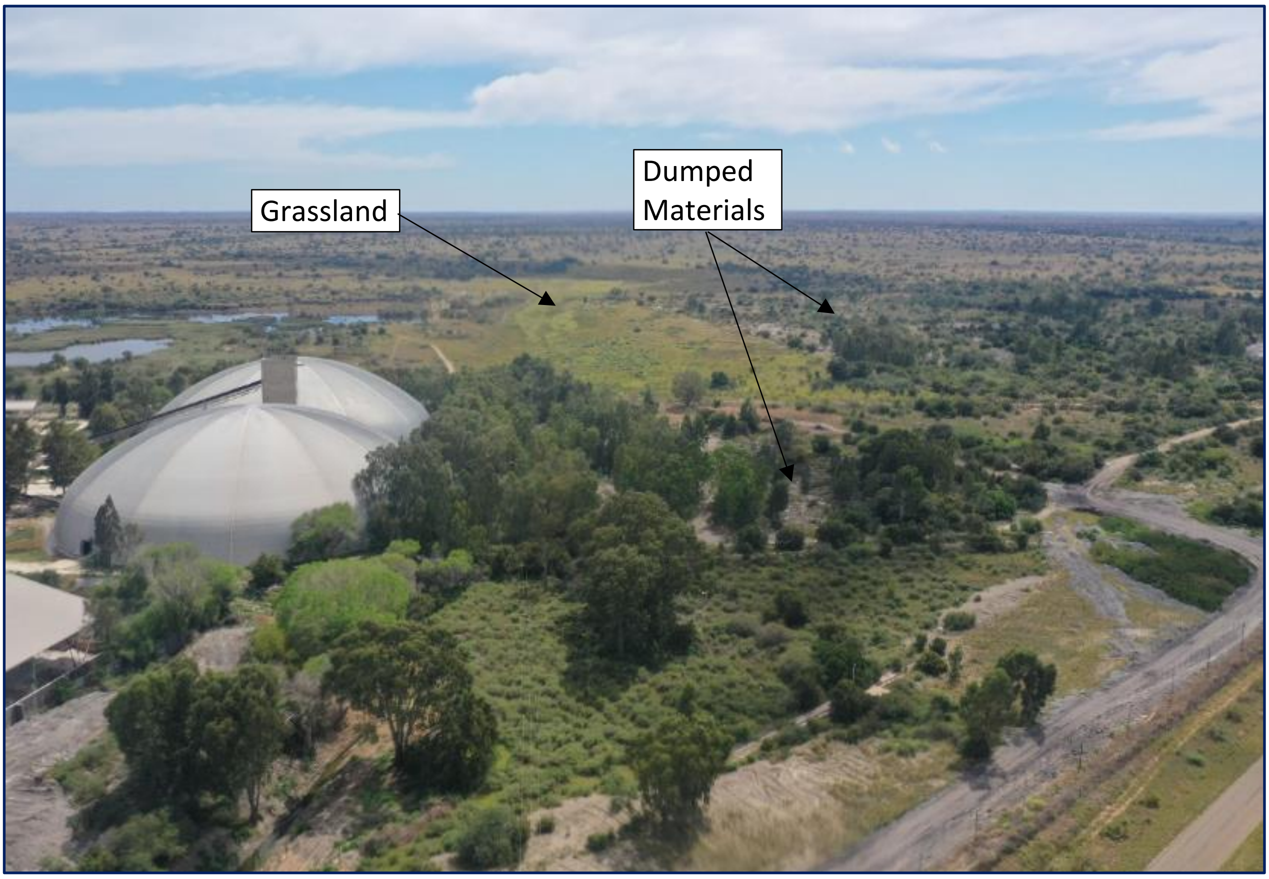


**Plate 2-1** Oblique view of the area where infilling has been undertaken

**Plate 2-2** Example of soil texture in the contributing catchment area


**Plate 2-3** Example of a blocked culvert along the original drainage line

**Plate 2-4** Example of materials dumped, resulting in impeded flows

The estimated (i.e. estimated due to a number of the culverts being blocked at the time of the site assessment) dimensions of the hydraulic structures along the drainage line are presented in **Table 2-1.** These culverts can be cross referenced to the site plan map presented in **Figure 2-2**.

*Table 2-1 Dimensions of Existing Culverts*

| Culvert | Type | Opening | Dimensions (m) |
|---|---|---|---|
| Culvert 1 | Pipe | 1 | 0.45 |
| Culvert 2 | Pipe | 1 | 0.90 |
| Culvert 3 | Pipe | 1 | 0.90 |
| Culvert 4 | Unknown (due to it being blocked) | | |

## 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 dependent on reliable streamflow records, of a sufficient length, within a reasonable proximity to the study site being available. 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. 5.48 $km^2$) 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)* **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 1:100 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 | 22.70 |
| **10 min** | 30.20 | 33.70 |
| **15 min** | 38.00 | 42.40 |
| **30 min** | 48.20 | 53.70 |
| **45 min** | 55.30 | 61.70 |
| **1 hour** | 61.00 | 68.00 |
| **1.5 hour** | 70.00 | 78.10 |
| **2 hour** | 77.20 | 86.10 |
| **4 hour** | 90.20 | 100.60 |
| **6 hour** | 98.80 | 110.20 |
| **8 hour** | 105.40 | 117.60 |
| **10 hour** | 110.90 | 123.70 |
| **12 hour** | 115.50 | 128.80 |
| **16 hour** | 123.20 | 137.50 |
| **20 hour** | 129.60 | 144.50 |
| **24 hour** | 135.00 | 150.60 |
| **2 day** | 138.10 | 154.00 |
| **3 day** | 155.80 | 173.80 |
| **4 day** | 169.00 | 188.50 |
| **5 day** | 180.00 | 200.80 |
| **6 day** | 189.50 | 211.40 |
| **7 day** | 198.00 | 220.80 |

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 classed as predominantly thicket and bushland. The South African National Land Cover Database (NLC) (2018) together with aerial imagery and observations made during the site visit in May 2019, 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 1 m contour data of the project area. The surface slopes were classed according to the threshold slopes of less than 3%, 3 – 10% and 10 – 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 unnamed drainage line are presented in **Table 3-2** and **Table 3-3**. The resultant peak discharge value of the unnamed drainage line 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) |
|---|---|---|---|---|
| Unnamed Drainage Line | 5.48 | 2.53 | 0.005 | 2.98 |

*Table 3-3 Study Site Catchments C-Factor Calculation*

| Variable | Unnamed Drainage Line Catchment |
|---|---|
| **Catchment Land Use Distribution (%)** | |
| Urban | 0.00 |
| Rural | 100 |
| Water Bodies | 0.00 |
| **Catchment Slope Distribution (%)** | |
| <3 | 0.00 |
| 3-10 | 100 |
| 10-30 | 0.00 |
| > 30 | 0.00 |
| **C - Factor (Cs)** | **0.06** |
| **Catchment Soil Permeability Distribution (%)** | |
| Very permeable | 0.00 |
| Permeable | 60.00 |
| Semi-permeable | 40.00 |
| Impermeable | 0.00 |
| **C - Factor (Cp)** | **0.08** |
| **Rural Component Vegetation Distribution (%)** | |
| Thick bush and forests | 0.00 |

| Variable | Unnamed Drainage Line Catchment |
| --- | --- |
| Light bush and agriculture | 20.00 |
| Grasslands | 80.00 |
| Bare | 0.00 |
| **C - Factor (Cv)** | **0.15** |
| **Final (adjusted) C-Factor Value (1:50 Year Return Period)** | **0.24** |
| **Final (adjusted) C-Factor Value (1:100 Year Return Period)** | **0.29** |

*Table 3-4 Peak Discharge Results*

| Catchment | 1:50 Year Peak Discharge ($m^3/s$) | 1:100 Year Peak Discharge ($m^3/s$) |
| --- | --- | --- |
| Unnamed Drainage Line | **10.42** | **14.01** |

## 3.2 Floodline Delineation

### 3.2.1 Survey Data

The HEC-RAS Model (US Army Corp of Engineers) was used to undertake two-dimensional hydraulic modelling along the unnamed drainage line to determine the extent of the floodlines corresponding to the 1:50 and 1:100-year return period. Hydraulic modelling was based on half-metre contour information provided by Unmanned Tech. The half-metre 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 and on aerial imagery (Google Earth Imagery). **Table 3-5** presents the general Manning's n values for the drainage line and the surrounding floodplains that were modelled.

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

| Drainage Line | Location | Manning's n Value | Description |
|---|---|---|---|
| Unnamed Drainage Line | Channel | 0.030 | Winding, weeds, some pools and shoals. |
| | Right Left and Floodplains | 0.030 - 0.045 | Grassland to medium brush and trees |

### 3.3 Floodline Analysis Scenarios

As part of the floodline analysis, three flood scenarios were simulated. These included:

- Hydraulic analysis of the catchment area under current catchment conditions, including the impact of the blocked culverts and drainage line on the delineated floodlines.
- Hydraulic analysis of the project area if the existing hydraulic structures (maintaining their current sizes) were to be unblocked, and an area of at least 6 m wide were cleared (i.e. dumped materials removed) along the original flow path of the identified drainage line (as presented in **Figure 2-2**).
- Hydraulic analysis of the 1:50 and 1:100 flood events, based on the recommendations provided to Lafarge for the rehabilitation of the drainage line and wetland area long the drainage line, including increasing of the hydraulic capacity of the road and rail crossings (with reference: project number 5526 and report title "*Environmental Management Plan: Rehabilitation of the Wetland in the Vicinity of the Lafarge Cement Factory in Lichtenburg*".

### 3.4 Floodlines Results

As presented in **Figure 3-1**, which shows the simulated floodlines based on current catchment conditions (including the existing blockages to flow along the drainage line), the delineated floodlines inundate extensive areas to the north and east of the project area. Simulations indicated that flows from the drainage line will backup against (and overtop) the railway line, until such time that flood waters both backup and flow into the non-operational quarry (Townlands Pit and flood infrastructure in the north-eastern portion of the factory. This results in the current lime silos becoming flooded, as well as other infrastructure along the eastern border of the plant. Towards the lower end of the project site, simulations indicated limited flooding, particularly for the 1:50 year flood event. This is due to the majority of flood water being dammed up along the northern boundary of the project site during this flood event. During the 1:100 year flood event, more flood waters will overtop the railway line and roads, resulting in more extensive flooding along the southern areas of the project site.

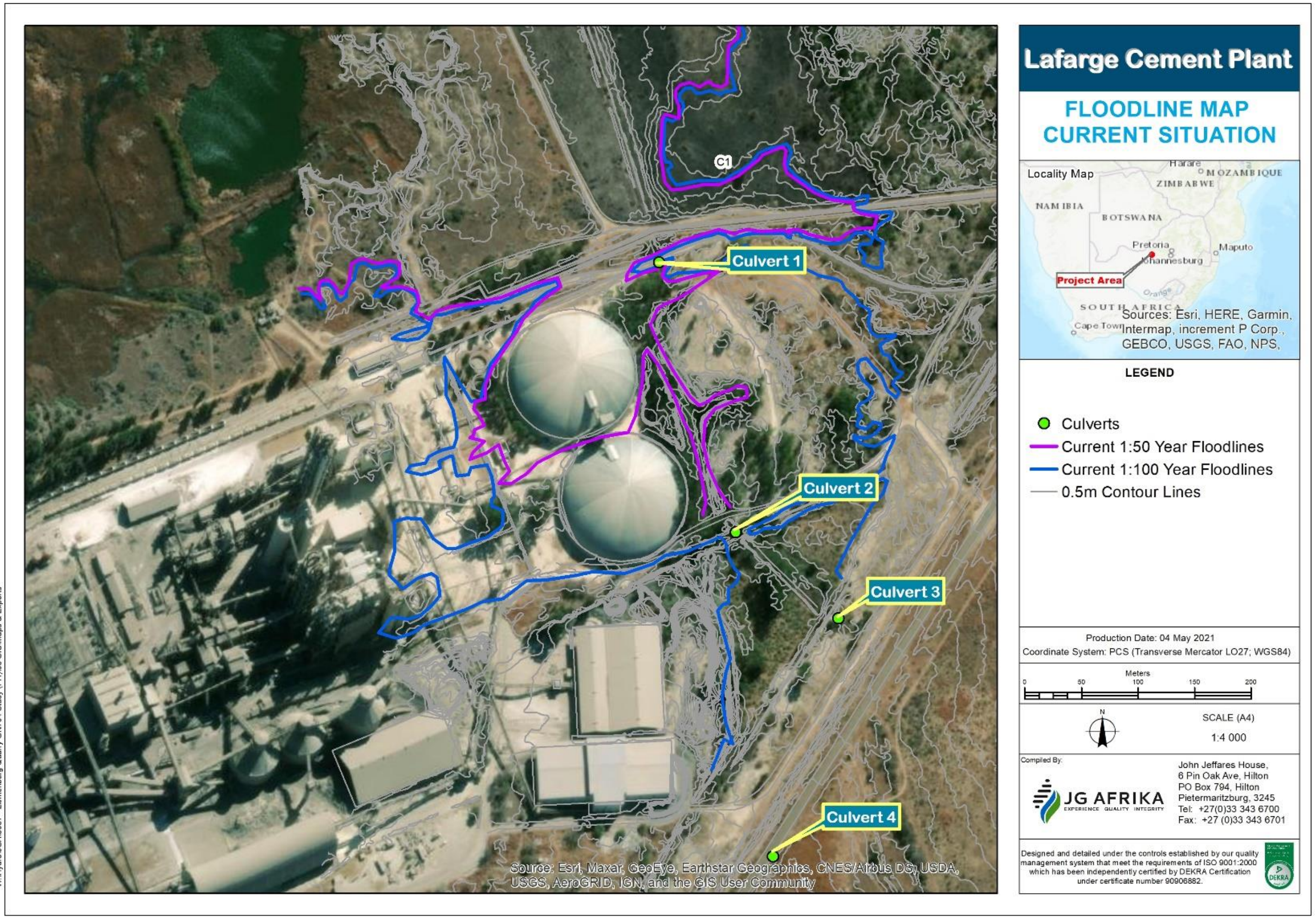


*Figure 3-1 Hydraulic analysis results based on current catchment conditions and including blocked culverts and infilling of the drainage line*

In order to ascertain the degree to which the flooded areas will reduce, if the existing culverts are unblocked and some of the materials dumped along the drainage line are removed, a simulation of this scenario was undertaken. As mentioned previously, the extent to which the materials were removed included an area of 6 m wide along the original drainage line. As presented in **Figure 3-2**, extensive flooding of infrastructure associated with the cement plant was simulated. It is hypothesized that this flooding is as a result of the limited capacity of the culverts through which flood water are required to pass (based on existing culvert sizes). Simulations indicated that backing up of floodwaters occurred upstream of the culverts, resulting in extensive areas along the eastern boundary of the plant being flooded, as presented in **Figure 3-2**.

The third scenario, as mentioned above, included simulating the 1:50 and 1:100-year floodlines for the drainage line, based on the assumption that the drainage line and wetland rehabilitation plan had be implemented on site. The proposed rehabilitation plan included the following:

- Phase 1 – Removal of Alien Vegetation,
- Phase 2 – Construction of Hydraulic Crossings (Culverts),
- Phase 3 – Removal of the Infill Material and Landscaping of the Wetland Area,
- Phase 4 – Construction of Water Reintroduction Facility,
- Phase 5 – Construction of the Diversion Berm, and
- Phase 6 – Revegetation of the Wetland and Rehabilitation Area.

Of particular importance to this floodlines study, is the increase in the hydraulic capacity of road and rail crossings, the inclusion of a diversion berm and the removal of infill material along the drainage line. A summary of the proposed rehabilitation measures is presented in **Figure 3-3**. The proposed dimensions of the road and rail crossings, which can be cross reference to **Figure 3-3**, are detailed in **Table 3-6**. The resultant floodlines, including the proposed removal of dumped materials and inclusion of increased capacities of hydraulic crossings and the diversion berm, is presented in **Figure 3-4**.

### Table 3-6 Proposed culvert dimensions

| Culvert Name | Culvert Shape | Culvert Span (m) | Culvert Height (m) | Number of Openings | Approximate Culvert Capacity ($m^3/s$) |
|---|---|---|---|---|---|
| Upstream Culvert (Culvert 1) | Box | 1.5 | 0.6 | 8 | 12.3 |
| Downstream Culvert | Box | 1.5 | 0.6 | 8 | 12.3 |

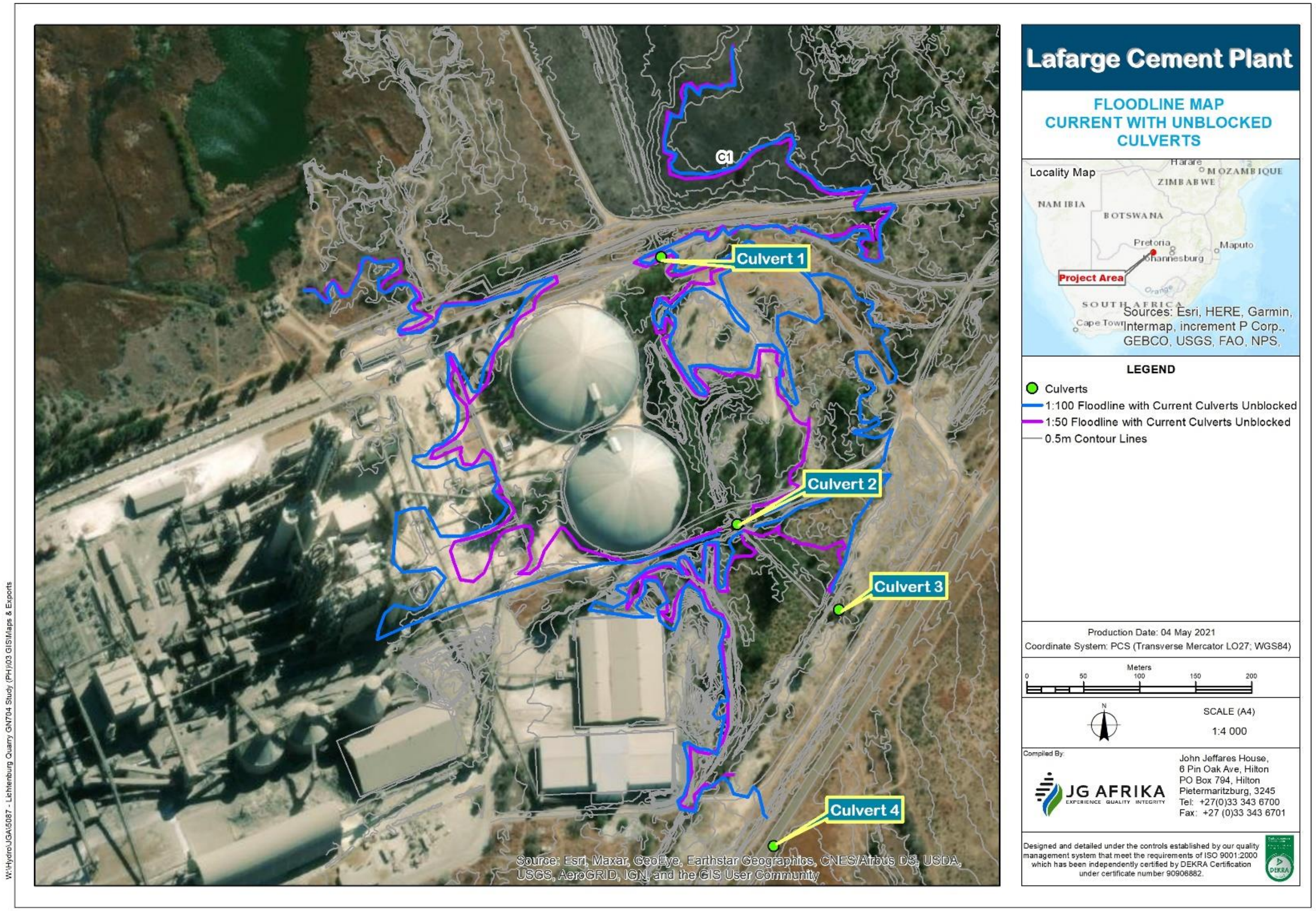


*Figure 3-2 Hydraulic analysis results based on unblocked culverts and removal of portions of the dumped materials along the drainage line*

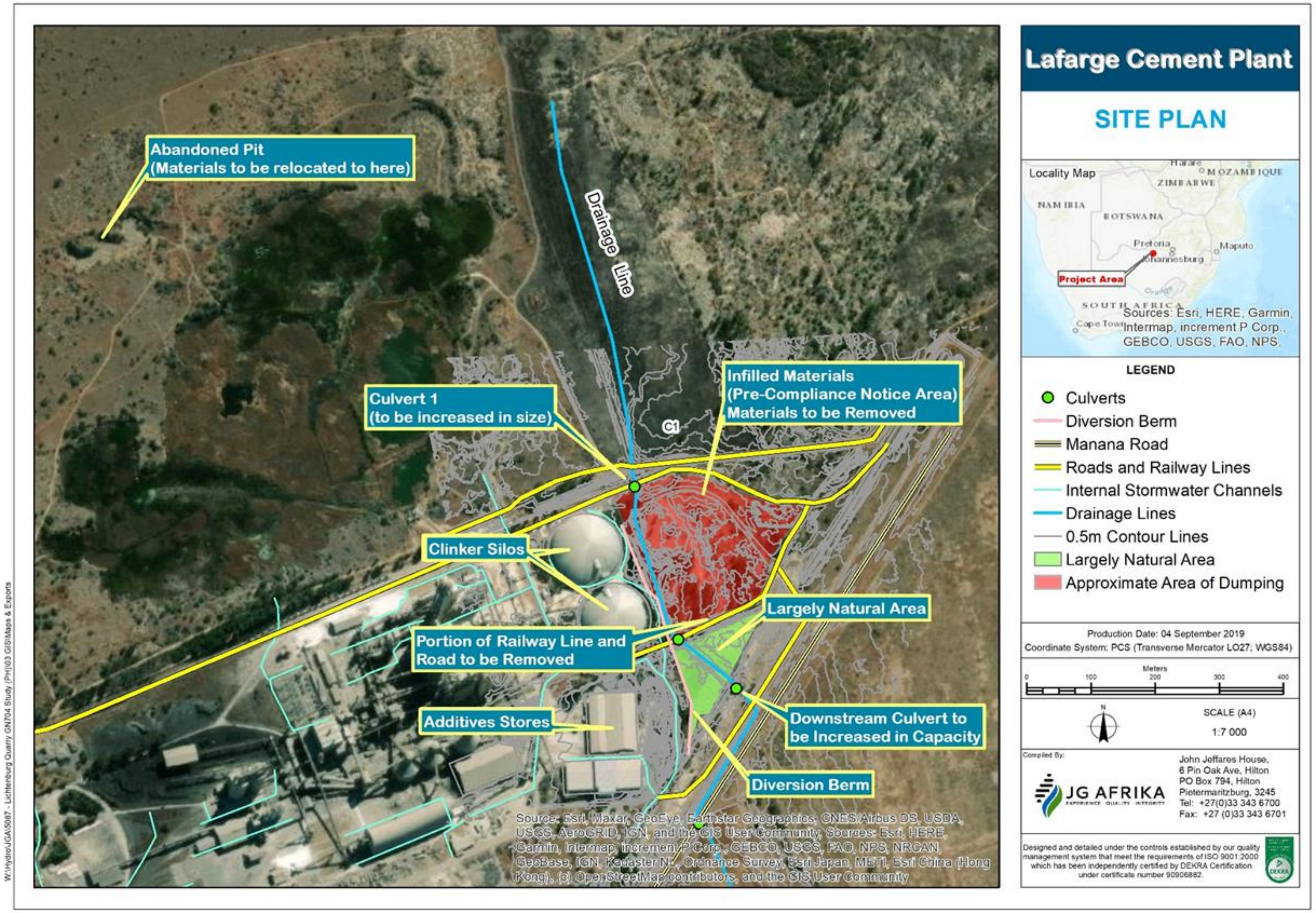


*Figure 3-3 Proposed rehabilitation of the drainage line and locations of increased capacity of road and rail crossings*

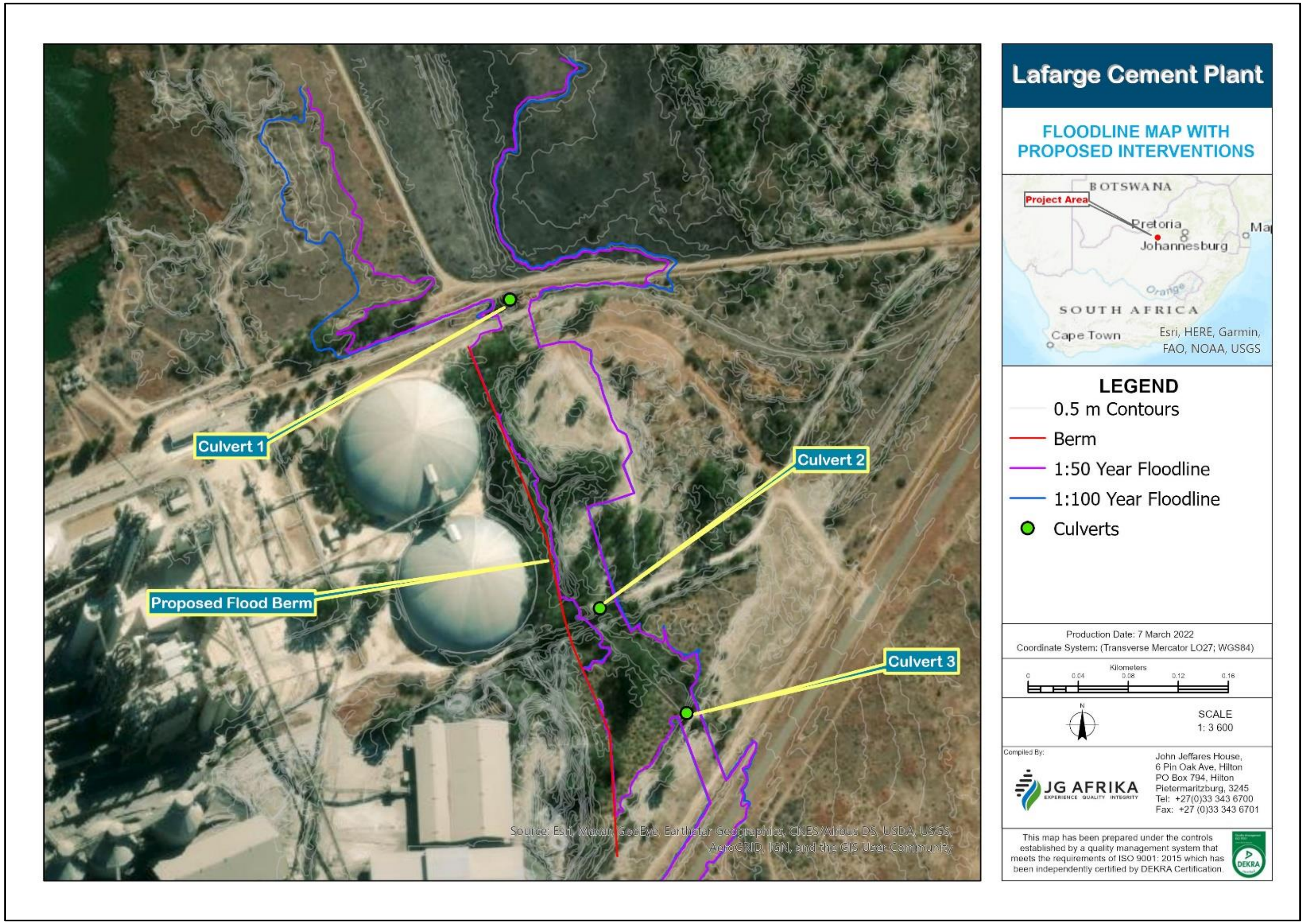


*Figure 3-4 Updated Hydraulic analysis results based on increased culvert capacities and a flood diversion berm being constructed*

In order to simulate the proposed rehabilitation scenario, the terrain upon which the hydraulic analysis is based, was modified within HEC-GEO-RAS (i.e. the hydraulic model). It should be noted that the altering of the terrain was based on hypothetical changes in the ground levels, assumed to be in place after the area has been rehabilitated. However, the final changes in the terrain will only be known once the rehabilitation has been completed (as it was recommended that the dumped materials are removed until the original soil layers are reached). Therefore, it is recommended that the floodlines generated in this study are verified upon the completion of the rehabilitation. This will require an updated survey of the rehabilitated area, which will then be incorporated into the hydraulic model.

As presented in **Figure 3-4**, once the proposed rehabilitation has been finalised, including the removal of dumped materials, the construction of a diversion berm and the increase in the hydraulic capacity of hydraulic capacities, the flooding extents are limited to areas outside of the factory infrastructure. **Figure 3-5** presents the simulated flow depths across the project area for the 1:100 year flood event. As presented in this figure, the depths of flow along the proposed diversion berm range from 0.01 m to a maximum depth of approximately 0.60 m.

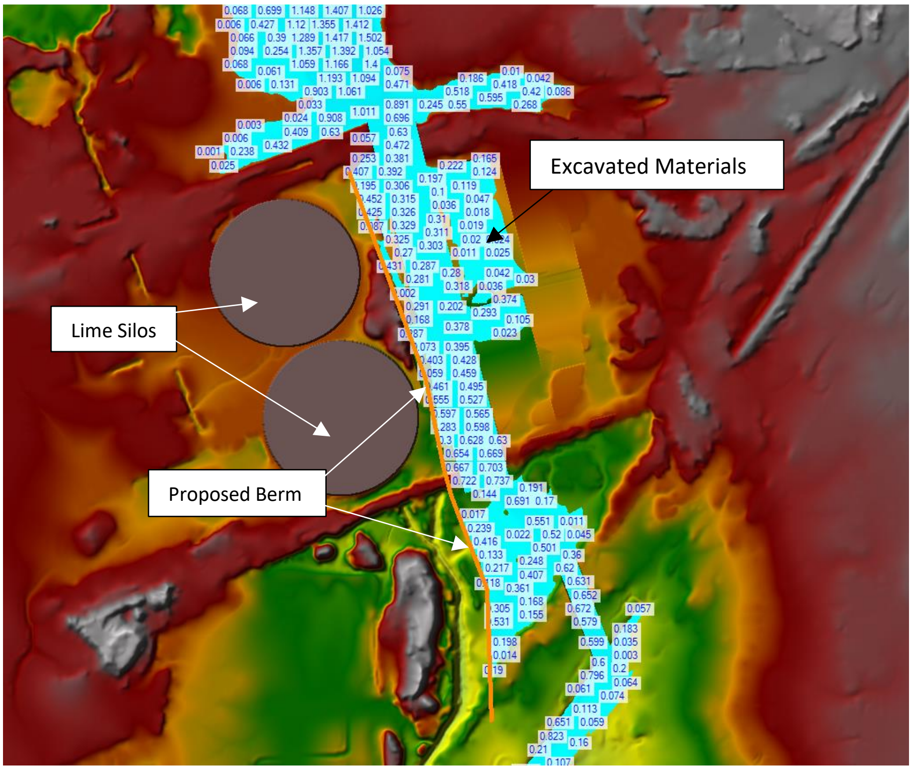


*Figure 3-5 Simulated 1:50 year flow depths (m) along the proposed flood protection berm*

## 4 CONCLUSION AND RECOMMENDATIONS

JG Afrika (Pty) Ltd were appointed by Lafarge to undertake a floodline study for the Lichtenburg Lafarge Cement Plant in the North West Province. The cement plant is located on Portion 61 of Lichtenburg Town Farm No 27. This floodline is submitted in order to fulfil the requirements of a water use licence application.

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. JG Afrika was provided with half-metre contour information for the study area, which was surveyed by Unmanned Tech. 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 half-metre contour information provided by Unmanned Tech.

As part of this study, the 1:50 and 1:100 year return period peak discharge values of the drainage line located to the east of the Lafarge Plant, were calculated using the Rational Method. The extent of the corresponding floodlines were determined through hydraulic modelling using the HEC-RAS model.

As part of the floodline analysis, three flood scenarios were simulated. These included:

- Hydraulic analysis of the catchment area under current catchment conditions, including the impact of the blocked culverts and drainage line on the delineated floodlines.
- Hydraulic analysis of the project area if the existing hydraulic structures (maintaining their current sizes) were to be unblocked, and an area of at least 6 m wide were cleared (i.e. dumped materials removed) along the original flow path of the identified drainage line.
- Hydraulic analysis of the 1:50 and 1:100 flood events, based on the recommendations provided to Lafarge for the rehabilitation of the drainage line and wetland area long the drainage line, including the removal of materials deposited along the drainage line, increasing of the hydraulic capacity of the road and rail crossings and the construction of a diversion berm running parallel with the drainage line.

The resultant floodlines for each of the scenarios were plotted using ArcGIS Pro software. Based on the floodline analysis, it was noted that simulations of flooding extents for current site conditions (including blocked culverts and the drainage line with materials impeding flows), for both the 1:50 and

1:100 year return periods, significant portions of the plant will be inundated. In addition to flooding of infrastructure, it was noted that flood waters would back up to the non-operational open pit (Townlands Pit) to the north of the plant.

The hydraulic analysis of flooding extents if the existing culverts were to be unblocked and material removed along the drainage line indicated similarly extensive (if not worse) flooding extents. The increase in flooding extents in the plant area is as a result of flood waters being allowed to flow into the property (through opening the culverts), however, due to the culverts being undersized, flooding extents upstream of the culverts were exacerbated. This is likely as a result of backing up of floodwaters upstream of the identified culverts.

The final simulation included increasing the capacity of the culverts, the construction of a flood protection berm and the removal of materials dumped along the drainage line (as per the proposed wetland rehabilitation plan submitted to Lafarge in December 2021). The results of this analysis showed significantly reduced flooding extents. In this scenario, no infrastructure associated with the Cement Plant fell within the delineated floodlines.

It is therefore recommended that the rehabilitation of the area impacted upon by the dumping of waste materials is undertaken. This will include increasing the capacity of culverts at road and rail crossings, the construction of a berm running between the drainage line and the Cement Plan and the removal of materials dumped within the drainage line and floodplain. It is recommended that the proposed rehabilitation interventions are included in water use licence applications.

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