LICHTENBURG LAFARGE CEMENT PLANT

WATER BALANCE STUDY

August 2022

REVISION 01

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SYNOPSIS

Specialist water balance study required as part of the Water Use Licence Application.

KEY WORDS:

Lafarge Lichtenburg Cement Plant, National Water Act 36 of 1998, Water Balance Study

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

Verification	Capacity	Name	Signature	Date
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LICHTENBURG LAFARGE CEMENT PLANT
WATER BALANCE STUDY

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1 INTRODUCTION

JG Afrika (Pty) Ltd were appointed by Lafarge Industries South Africa (Pty) Ltd to undertake a Water Balance Study for the Lichtenburg Lafarge Cement Plant, located in the North West Province. The cement plant is located on Portion 61 of Lichtenburg Town Farm No 27. This hydrological specialist study is required as part of a Water Use Licence Application (WULA) for the cement plant, based on the requirements of the National Water Act (Act 36 of 1998). The objectives of this water balance study are to:

- Compile a graphic representation of the water flow reticulation for the cement plant,
- Determine the volume of water required in the various processing activities associated with the cement plant, and
- Define the water sources, changes in water storage and mechanisms, and volumes of water losses associated with the quarry.

1.1 Declaration of Independence

JG Afrika were appointed to conduct an independent water balance study for the Lafarge 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 necessary studies and the following report presents the results in an objective manner. The main author of the report, Mr. Phillip Hull, is an Executive Associate and Senior Hydrologist at JG Afrika, has an MSc. in Hydrology, is professionally registered and has 15 years of relevant project experience.

2 SITE DESCRIPTION

2.1 Locality

The location of the Lafarge cement plant is 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 a layout plan of the main infrastructure associated with the cement plant is provided in **Figure 2-2**.

2.2 Lafarge Cement Plant Operations Description

A process of grinding and burning takes place at the cement plant. 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.

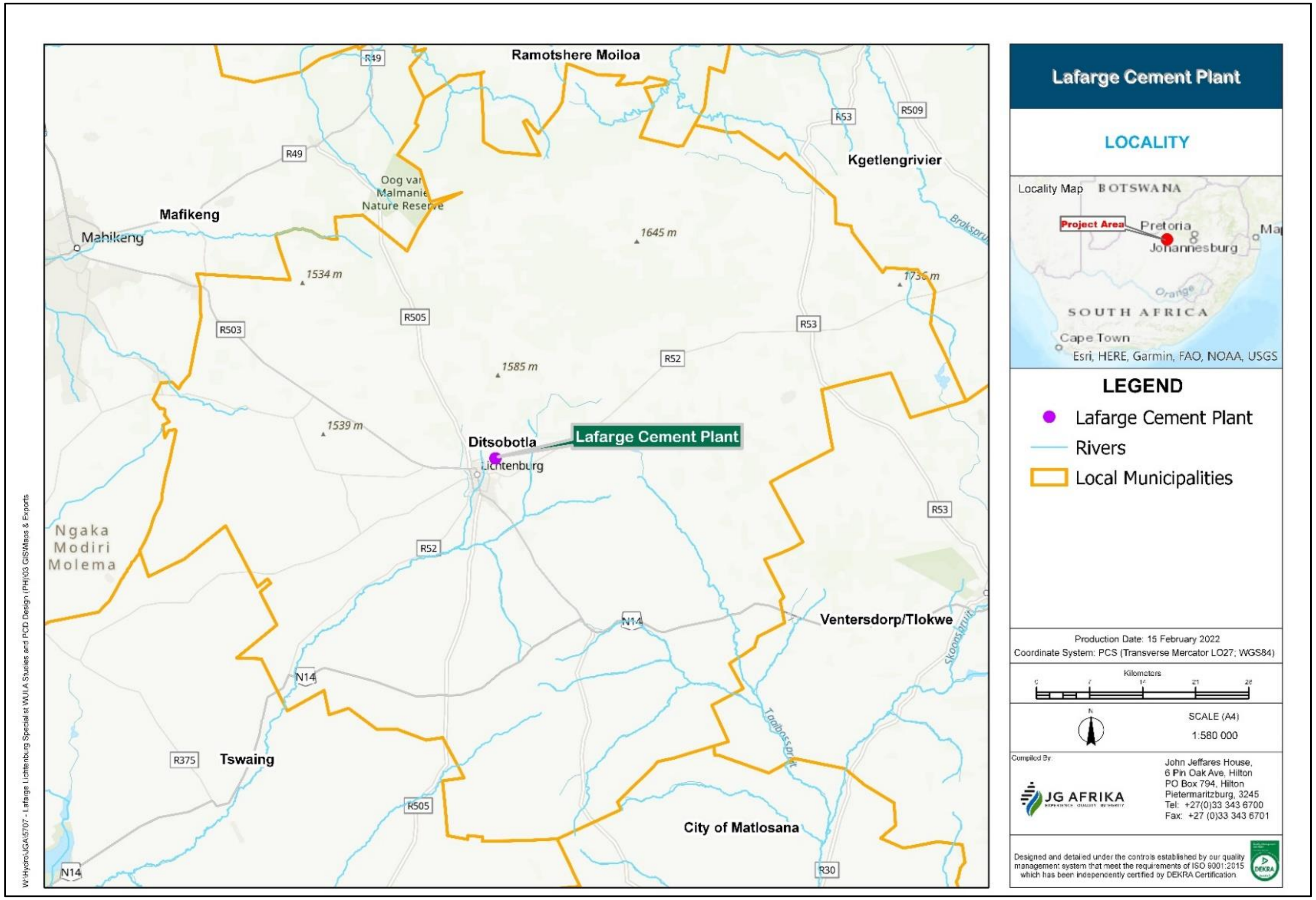

Figure 2-1 Lafarge Cement Plant Locality Map

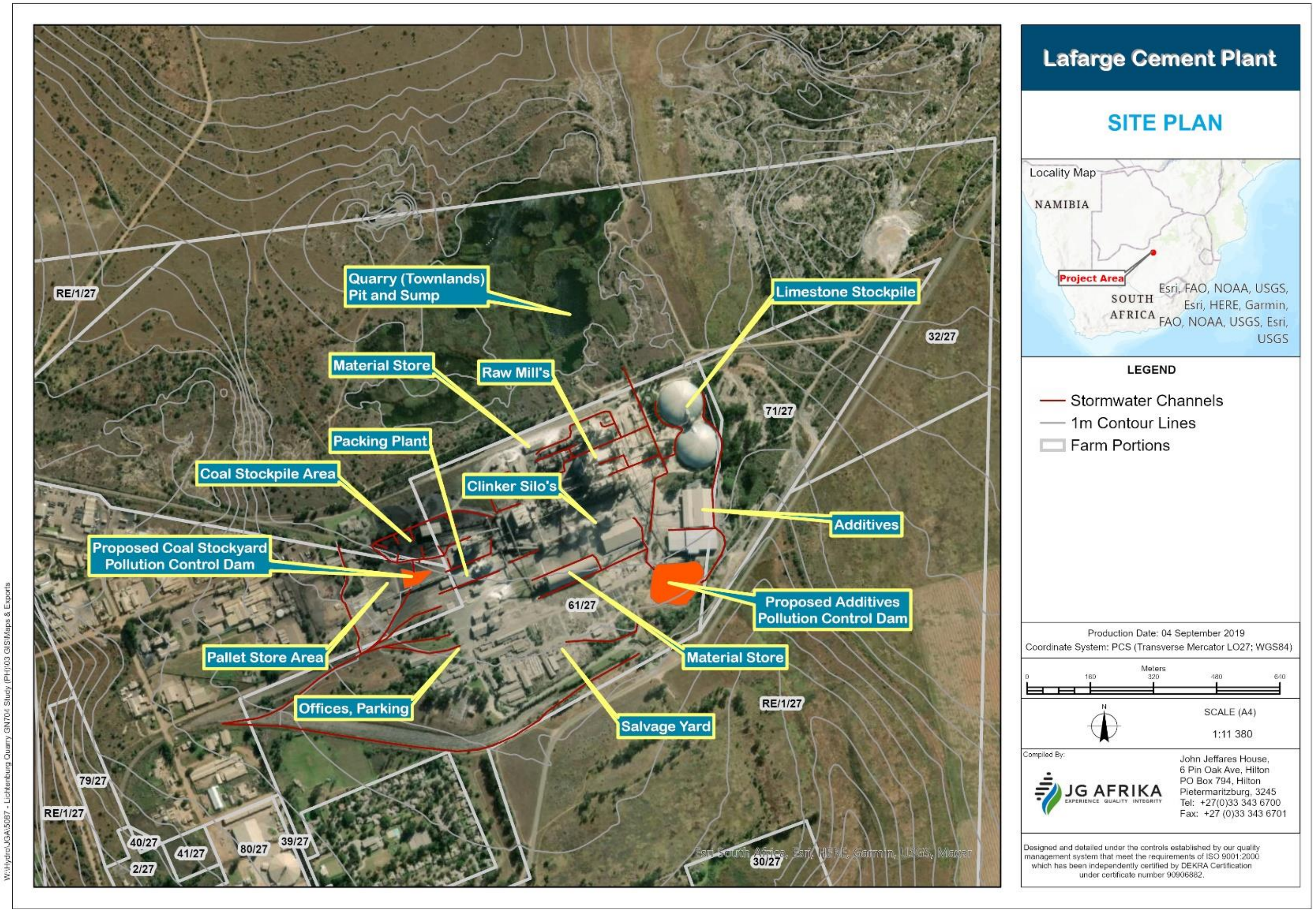

Figure 2-2 Lafarge Cement Plant Site Plan

2.3 Climate Description

The cement plant lies within an arid to temperate climatic region (Köppen-Geiger Climate Classification Maps, 2018). Rainfall occurs mostly during the summer months and the climate category can be described as hot during the summer months and dry and cold during the winter months.

Temperature data for the project area was obtained from the South African Weather Services (SAWS) meteorological station 0472280 A, as presented in **Table 2-1**. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures range from 18.9°C in June to 28.7°C in January. The region is the coldest during June when the temperature drops to -0.4°C on average during the night.

Table 2-1 Temperature Recorded for Years 1950 – 1999 at SAWS 0472280 A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	22.2	21.6	20.0	16.7	12.8	9.3	9.4	12.2	16.7	19.3	21.0	21.8
Min. Temperature (°C)	15.7	15.1	13.2	8.7	3.7	-0.4	-0.3	2.5	7.6	11.4	13.6	15.1
Max. Temperature (°C)	28.7	28.0	26.8	24.6	22.0	18.9	19.2	21.9	25.7	27.3	28.4	28.4

2.3.1 Rainfall and Evaporation

Rainfall data for the project area was obtained from the SAWS rainfall station 0472455 W. This rainfall station is located approximately 3.2 km northeast from the project site and was selected based on its record period and the reliability of the historical rainfall data. The details of this rainfall station are presented in **Table 2-2**. The mean monthly rainfall amounts over the period 1950 to 1999 are presented in **Table 2-3**. From **Table 2-3**, it is evident that most of the rainfall falls over the summer period (November to March), with a total rainfall depth over these six months of 457.1 mm. It is also noted that low rainfall values are recorded over the winter months (May to September), with a total rainfall depth of 51.0 mm over these five months.

Table 2-2 Rainfall Station Details

Station Number	Station Name	MAP (mm)	Years Assessed	Reliability (%)	Longitude	Latitude
0472455 W	Manana	614	1950 - 1999	91	26⁰ 13' E	26⁰ 6' 1" S

Table 2-3 Average Rainfall Depths Recorded for Years 1950 – 1999 at Rainfall Station 0472455 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAP
Rainfall Depth (mm)	108.9	89.8	89.1	58.4	17.8	5.9	4.0	6.7	16.6	47.2	74.4	94.9	614

A high degree of variation in the annual rainfall data obtained from rainfall station 0472455 W has been noted. The lowest recorded annual rainfall value over the assessed period is 254.7 mm, recorded in the year 1965. **Table 2-4,** which presents the 10 wettest years over the 1950 to 1999 period, indicates the wettest recorded year over this period was 1 017.3 mm in 1967.

Table 2-4 Ten Wettest Years Recorded for Period 1950 – 1999

Ranking	Year	MAP (mm)
1	1967	1 017.3
2	1957	894.5
3	1975	885.2
4	1976	831.9
5	1997	814.7
6	1989	773.3
7	1991	749.0
8	1995	747.4
9	1979	717.6
10	1977	700.0

While rainfall is generally variable on a month-to-month and year-to-year basis, this is not the case with evaporation. Monthly evaporative demands do not vary significantly from one year to next (i.e. evaporation in one October-month, for example, is similar to evaporation in the next October-month). Therefore, it is generally considered to be acceptable to apply 12 average monthly evaporation values over the year. The evaporation data used for the cement plant was obtained from Evaporation Zone 8A (Middleton and Bailey, 2008). Catchment evapotranspiration is calculated by applying 12 monthly evapotranspiration conversion factors, as presented in **Table 2-5**. Similarly, evaporation losses from an exposed water body are calculated by applying 12 monthly lake evaporation conversion factors, as presented in **Table 2-5**. The annual potential evaporation rate for the area is 1 860 mm (WR, 2012).

From **Table 2-5**, the highest evaporation rates occur during the hotter summer months of November to March.

Table 2-5 Cement Plant Potential Evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Evaporation Rate (mm)	214	167	151	118	98	78	91	130	173	207	213	221	1 860
Lake Evaporation Factor	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0.81	0.81	0.82	0.83	
Evapotranspiration Factor	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.80	0.80	1.00	1.00	

2.3.2 Design Rainfall

The 24-hour design rainfall depths (point rainfall) for the 1:2, 1:10, 1:20, 1:50, 1:100 and 1:200 year recurrence intervals were extracted using the Design Rainfall Estimation Utility (Smithers and Schulze, 2003) and are shown in **Table 2-6**, below.

Table 2-6 24-hour Design Rainfall Depths

Duration (hr)	Rainfall Depth (mm)						
	1:2	**1:5**	**1:10**	**1:20**	**1:50**	**1:100**	**1:200**
24	62	84.3	99.7	114.9	135	150.6	166.5

2.4 Site General Hydrology

The project site is located in the Harts River Catchment within the Quaternary Catchment C31A of the Lower Vaal Water Management Area (WMA No. 10). Based on Department of Water and Sanitation (DWS) river coverages and 5 m contours, a drainage line (unnamed drainage line) alongside the eastern boundary of the cement plant drains into an unnamed tributary and eventually into the Harts River, The Harts River is located approximately 15 km downstream of the project site.

3 WATER BALANCE STUDY

The methodology used to configure the water balance is based on the methodology outlined by the DWS, Best Practice Guidelines G2 for water and salt balances. As per the guidelines, the water balance was compiled using the following steps:

1. Define the objectives of the water balance,
2. Define the boundaries for the individual balances,
3. Identify all water circuits and develop a schematic flow diagram,
4. Develop and solve balances for the respective units,
5. Develop an output format,
6. Assess the level of detail required, and
7. State assumptions.

The following sections present details for each of the above-mentioned steps, used in the compilation of the water balance.

3.1 Methodology

Step 1: Define the objectives of the balances

The objective of this study is to prepare a water balance to simulate:

- Water pumped from three supply boreholes, located on the northern boundary of the Lafarge property.
- The volume of water treated at two treatment plants (Softening Plant A and Softening Plant B),
- The volume of water used for potable water and the volume of water that is currently pumped from septic pits located throughout the plant. It is noted that a project to refurbish the Lafarge Wastewater Treatment Works (WWTW) has been initiated. The water balance therefore presents both the volume of water that is being pumped from septic tanks and the volume that will report to the WWTW in the future,
- The circulation of water from the Quarry (Townlands) Dam to the Cement Plant and Kiln 4 and back to the Townlands Dam,
- The changes in storage of Townlands Dam over the simulation period, and

- The water balance of the proposed Additives and Coal Stockyard Pollution Control Dams (PCD's), with the objective of ensuring that the dams are sized and managed correctly such that spills from the dams will not occur more than once in fifty years.

Step 2: Define the boundaries for the individual balances

This water balance is limited to the water reticulation associated with the cement plant. This includes water abstracted from the three supply boreholes, water used for cooling purposes, potable and wastewater generated at the cement plant and water associated with the PCD's.

Step 3: Identify all water circuits and develop a schematic flow diagram

There is an inherent difficulty in representing a complicated dynamic water reticulation system in a simplified water balance model. In order to achieve the objectives of this study, the circuits through which water flows at the Lafarge Lichtenburg Cement Plant have been simplified into ten circulation areas, as presented in **Figure 3-1**. This schematic is based on information provided by the Client and notes taken during the site visit in January 2022. As per the information provided, the following water reticulations have been included in the water balance schematic:

- **Main Tank.** The majority of water that is pumped from the well field is pumped to the Main Tank. As presented in **Figure 3-1**, water is then circulated from the Main Tank to water used at the Cement Mill Toilets, the Quality Lab, irrigation at the Old Packaging Plant gardens, water used for fire protection (Fire Tanks) and then water that is distributed to Softening Plants A and B.
- **Softening Plant A.** Water treated at the Softening Plant A is distributed to the Safety Offices, Stores, Offices and Boiler Shop, Plumber Stores, Clinic, Main Offices and to the Village, which is the greatest user of water from the Softening Plant A. A portion of the water used at the Village is lost to the environment. This water is assumed to be used for irrigation of gardens and for washing cars for example. As presented in **Figure 3-1**, potable water is assumed to be returned to the circuit as wastewater, which is either removed by honey suckers (as it currently is) or reports to the WWTW (once the WWTW has been refurbished/commissioned).
- **Softening Plant B.** Water from Softening Plant B is predominantly used for process water at the Kiln 3 and Cement/Raw Mills. In addition to this, water is also used from Softening Plant B to supply the Packaging Plant Ablutions.

- **Quarry (Townlands) Pit and Sump.** Water from the Townlands Sump is used both for cooling product at the Cement Mills (which is then lost to evaporation) and for water to Kiln 4, for cooling purposes. Based on information provided by Lafarge, it is noted that the cooling water does not come into direct contact with Trunnion Bearings but is rather piped through the Kilns to cool the mechanical processes. This water is, therefore, understood to be of the same chemical makeup as water that is pumped from the dam (only the temperature of the water is changed). This water is then discharged, via stormwater channels, back into the Townlands Quarry Sump.
- **Additives and Coal Stockyard PCD's.** These PCD's are currently at a preliminary level of design, and are therefore not currently in place on site (proposed dams). The purpose of these dams is to capture contaminated stormwater runoff from the Additives and Coal Stockyard areas (in line with statutory requirements). In order to ensure that the dams do not spill more than once in fifty years, it is proposed that the water captured in the PCD's is circulated back into the process water system. This may require treatment to ensure that the quality of the water being re-introduced into the process water system is of an adequate standard for its intended uses.

Step 4 and 5: Develop and solve balances for the respective units, and develop an output format

Figure 3-1 to **Figure 3-4** presents the resulting water balance for the cement plant for the annual average, annual daily average, dry season daily average (represented by average water use in the July months) and wet season daily average (represented by average water use in the January months) water usage. Water inputs into the various infrastructure are generally presented on the left of the diagram and outflows are presented on the right of the diagram. Values provided in **Figure 3-1** are in cubic meters per annum (m^3/annum), and values provided in **Figures 3-2** to **3-4** are in cubic meters per day (m^3/day).

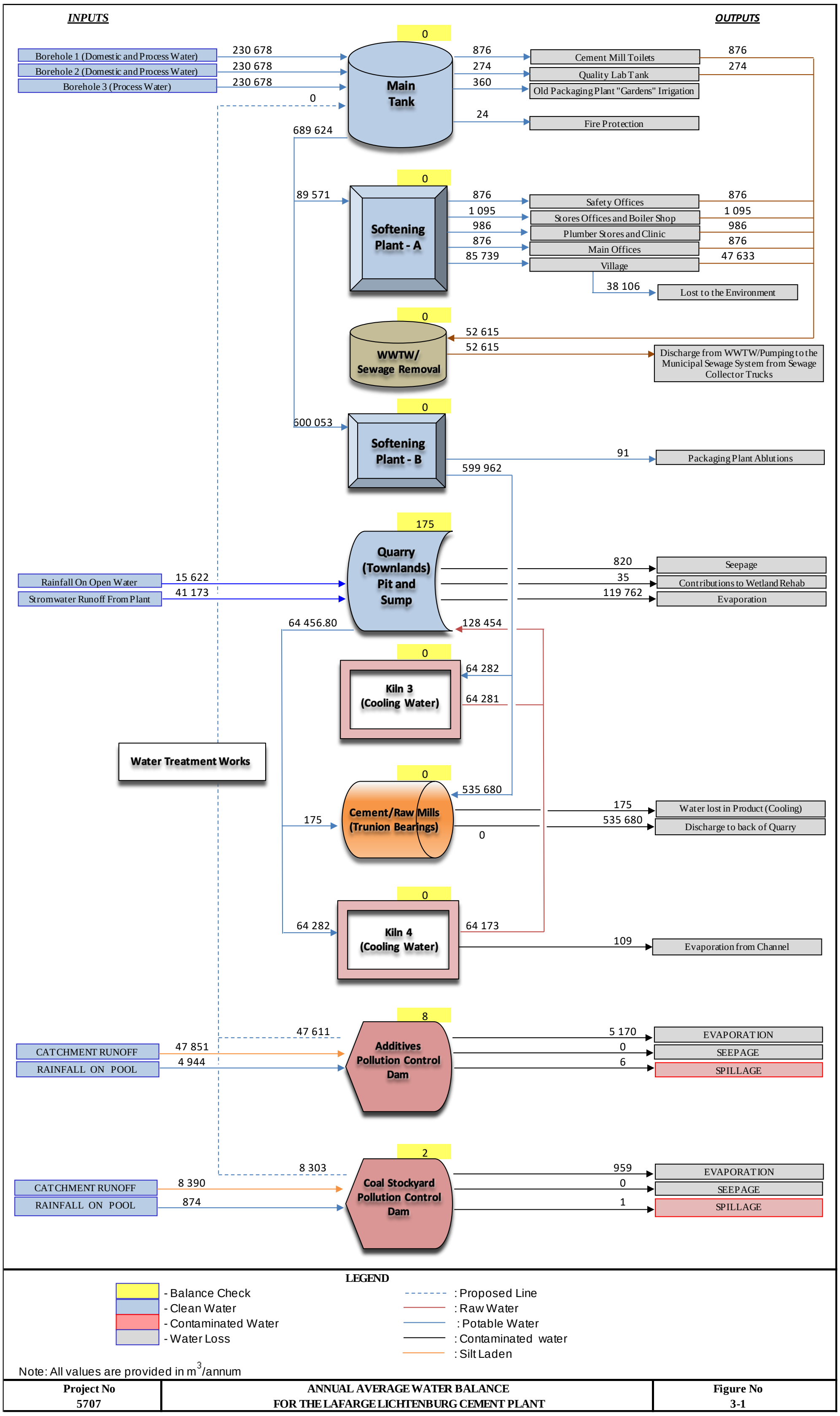

Figure 3-1 Lafarge Lichtenburg Cement Plant Average Annual Water Balance

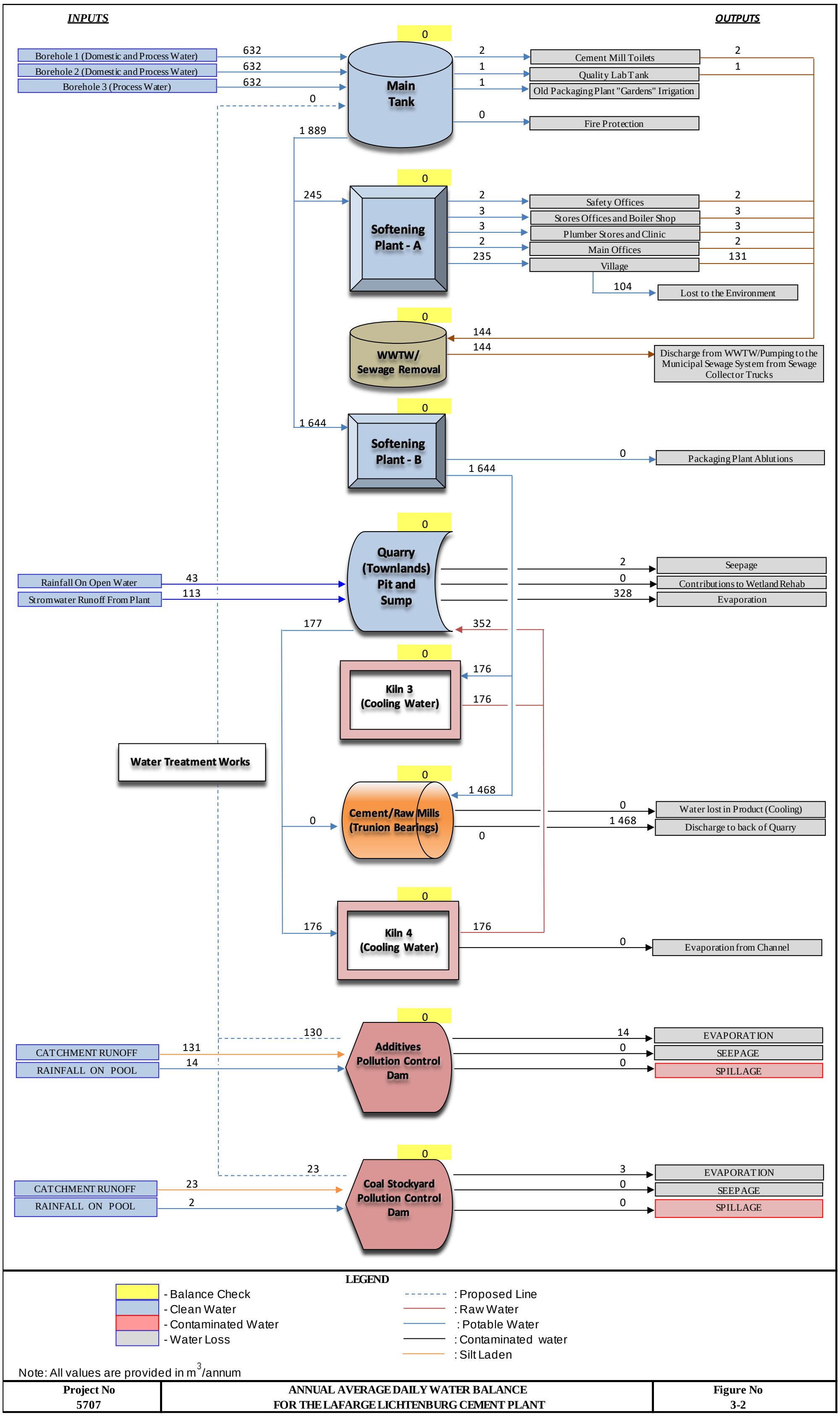

Figure 3-2 Lafarge Lichtenburg Cement Plant Average Annual Daily Water Balance

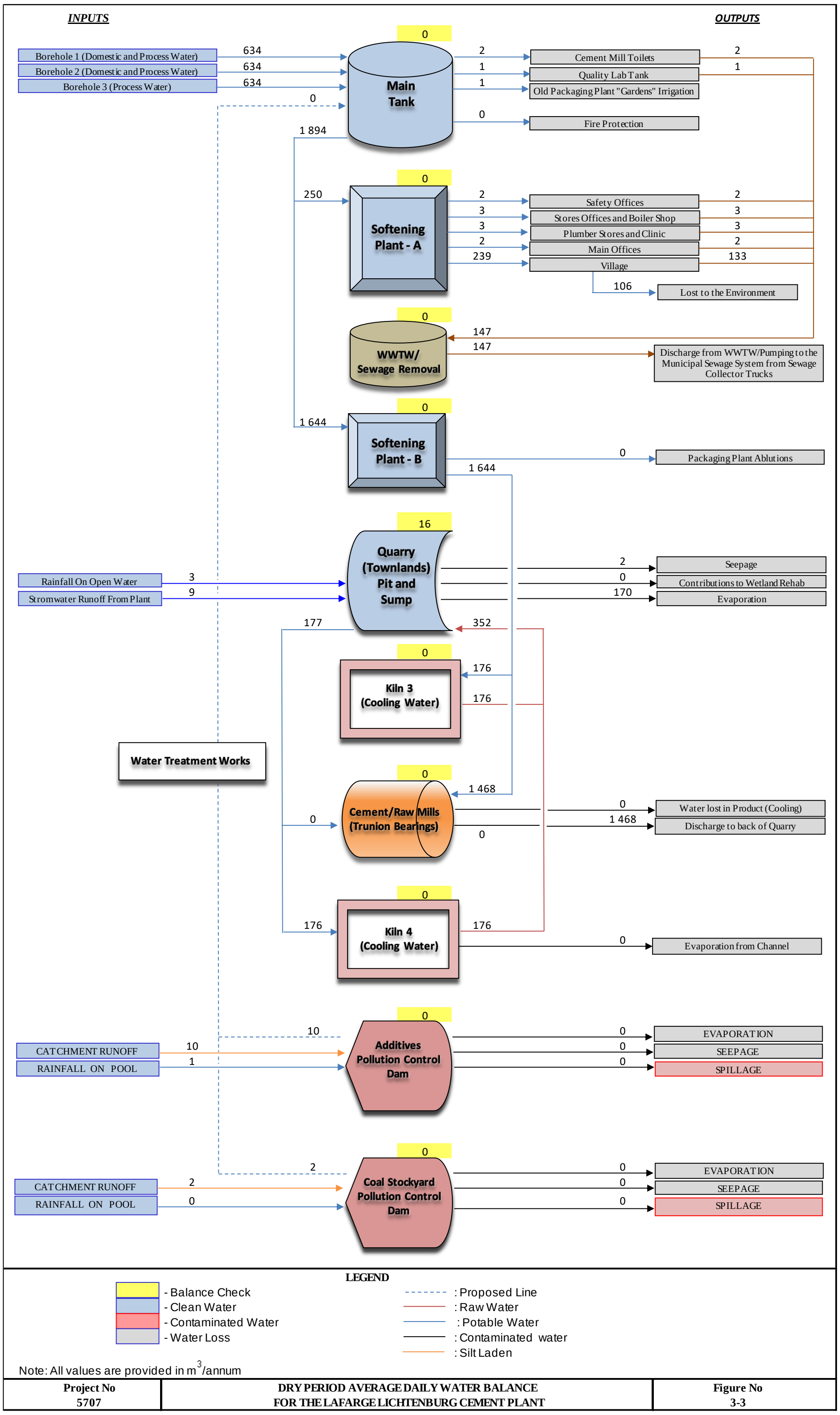

Figure 3-3 Lafarge Lichtenburg Cement Plant Average Daily Dry Period (July) Water Balance

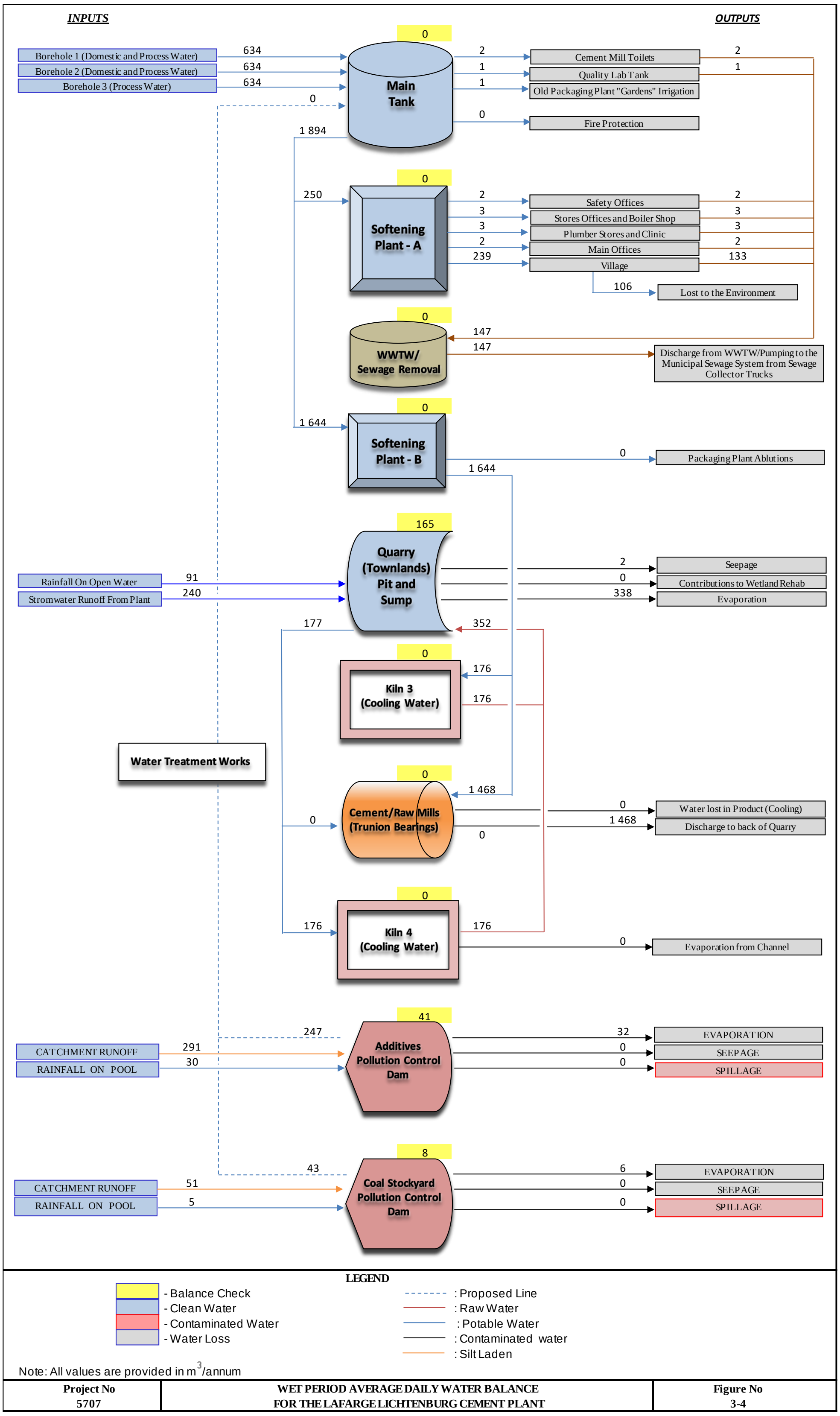

Figure 3-4 Lafarge Lichtenburg Cement Plant Daily Wet Period (January) Water Balance

Step 6: Assess the level of detail required

The level of detail provided in the water balance is average annual and average daily flow values in cubic meters. The water balance has been simulated over the period of 50 years (1950 to 2000). This is done so that the variability of climate, which affects the water balance results, is accounted for. This level of detail is sufficient for this study (for the purposes of a WULA). In addition to the water balances based on average annual water balance figures (as presented in **Figure 3-1**), average annual daily, average daily dry season (July months) and average daily wet season (January months) water balance scenarios are presented in **Figure 3-2** and **3-4**, respectively.

Step 7: Assumptions

It was necessary to apply a series of assumptions in the compilation of the water balance and these have been presented in **Table 3-1**.

Table 3-1 Assumptions Made for the Water Balance

Section	Variable	Value	Comment
Climate	MAP (mm)	614	Obtained from the rainfall station (0472455 W) for the years 1950-2000, as presented in **Section 2.3.1**
	MAE (mm)	1 860	Obtained from the WR2012 Study for quaternary catchment C31A. evaporation zone **8A**, as outlined in **Section 2.3.1**
Cement Mill Toilets	Potable Water Usage (m^3/day)	2.40	Based on 80 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)
Quality Lab Tank	Potable Water Usage (m^3/day)	0.80	Based on 25 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)
Safety Offices	Potable Water Usage (m^3/day)	2.40	Based on 80 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)
Stores and Offices and Boiler Shop	Potable Water Usage (m^3/day)	3.00	Based on 100 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)
Plumber Stores and Clinic	Potable Water Usage (m^3/day)	2.70	Based on 90 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)
Main Offices	Potable Water Usage (m^3/day)	2.40	Based on 80 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge)

Section	Variable	Value	Comment
Village	Potable Water Usage (m^3/day)	130.50	Based on 450 people using an average of 290 litres/person/day (Estimated based on information provided by Lafarge)
Village	Water used for Irrigation etc. (m^3/day)	104.40	Based on 450 people using an average of 230 litres/person/day (Estimated by Consultant)
Kiln 3	Process Water Requirement (m^3/day)	176.11	Based on a requirement of 120 litres per minute being used for 24 hours a day for all days of the month, sourced from Softening Plant B (Estimated based on discussions with Lafarge Lichtenburg Cement Plant Staff)
Cement Mills	Product Cooling Water (m^3/day)	0.48	Based on a requirement of 20 litres per minute being used for 24 hours a day for all days of the month sourced directly from the Townlands Dam (Estimated based on discussions with Lafarge Lichtenburg Cement Plant Staff)
Cement Mills	Mechanical Cooling Water (m^3/day)	1 467.62	Based on a requirement of 1000 litres per minute being used for 24 hours a day for all days of the month sourced from the Softening Plant B (Estimated based on discussions with Lafarge Lichtenburg Cement Plant Staff)
Kiln 4	Process Water Requirement (m^3/day)	176.11	Based on a requirement of 120 litres per minute being used for 24 hours a day for all days of the month, sourced from Townlands Dam (Estimated based on discussions with Lafarge Lichtenburg Cement Plant Staff)
Additives PCD	Area of Dam at Full Supply Capacity (m^2)	9050	Based on preliminary designs of the dam
	Maximum Volume of the PCD (m^3)	20 216	Based on preliminary designs of the dam
	Catchment Area (m^2)	146 000	Based on JG Afrika Stormwater Management Plan
	Runoff Factor from Catchment	0.6	Estimated
Coal Stockyard PCD	Area of Dam at Full Supply Capacity (m^2)	1 600	Based on preliminary designs of the dam
	Maximum Volume of the PCD (m^3)	4 054	Based on preliminary designs of the dam
	Catchment Area (m^2)	25 600	Based on JG Afrika Stormwater Management Plan
	Runoff Factor from Catchment	0.6	Estimated
Townlands Quarry and Sump	Area of Open Water (m^2)	26 000	Based on aerial imagery of the dam and measured in GIS
	Area of Wetlands (m^2)	270 500	Based on aerial imagery of the dam and measured in GIS

Section	Variable	Value	Comment
	Maximum Volume of the PCD (m^3)	675 000	Estimated based on the area of the open pit multiplied by an average depth of 2.5 m
	Soft (semi-permeable) Catchment Area (m^2)	167 000	Based on aerial imagery of the dam and measured in GIS
	Plant (hardened surfaces) Catchment Area (m^2)	110 000	Based on JG Afrika Stormwater Management Plan
	Runoff Factor from Plant Area Catchment	0.6	Estimated
	Runoff Factor from Semi-Permeable Catchment	0.05	Estimated

4 WATER BALANCE RESULTS AND CONCLUSIONS

The water balance for the Lafarge Lichtenburg Cement Plant was based on a number of assumptions (based on experience with similar projects), information supplied by management of the cement plant and notes taken during the site visit in January 2022. The accuracy of the resulting water balance is therefore related to the accuracy of the assumptions/estimations made in the compilation of the water balance. The water balance compiled as part of this project provides average daily water movement in cubic meters for annual average, dry period average (based on the months of July) and wet period (based on the months of February). The water balance results are summarised as follows:

- As presented in **Figure 3-1** and **3-2**, the annual average daily potable water requirement for the plant area equates to approximately 248 m^3/day (or 89 571 m^3/annum). The volume of water used for domestic purposes was estimated based on historical information provided by Lafarge, on the volume of wastewater collected by external service providers (i.e. honey suckers abstracting waste water from the septic pits) who transfer this water by truck to the Lichtenburg sewage treatment works.
- The most significant user of potable water is the Lafarge staff village, which is estimated to use 130.5 m^3/day (47 633 m^3/annum) on average for domestic consumption and approximately 104.4 m^3/day (38 106 m^3/annum) for irrigation and washing purposes (i.e. water estimated to be lost to the environment). The majority of water used for domestic purposes is sourced from Softening Plant A (with the exception of water sent to the Packaging Plant Ablutions).
- The average volume of wastewater generated from the plant and village equates to 144.15 m^3/day (or 52 615 m^3/annum). Currently this water is collected by service providers and transferred to the municipal sewage treatment works, however, Lafarge are in the process of upgrading/refurbishing their WWTW, and so the wastewater generated in the future will report to the Lafarge WWTW.
- Water treated at the Softening Plant B is used predominantly for water supply to Kiln 3 and the Cement/Raw Mills for cooling water. The estimated water used from Softening Plant B equates to 1 643.98 m^3/day (approximately 600 053 m^3/annum). This water is used predominantly at the Cement/Raw Mills (1 467.6 m^3/day or 89% of the water treated at Softening Plant B).
- Water used at Kiln 3, which is sourced from the Softening Plant A (equating to 176.11 m^3/day), is returned to the Quarry (Townlands) Dam. A portion of this water (from the Townlands Dam) is then recycled for product cooling at the Cement Mill (0.48 m^3/day) and is also used at Kiln 4 for cooling purposes.

- A significant volume of water (1 467.6 m^3/day or 535 680 m^3/annum) is discharged from the Cement/Raw Mills to the wetland area located at the back of the cement plant. During consultations with Lafarge, it was noted that there are plans to construct a reservoir to capture this water so that it can be recycled back into cooling process at the Cement/Raw Mills, without being discharged to the environment. Based on the location of the discharge point, water discharged from the Cement/Raw Mills may eventually link into the Townlands Dam, however, based on discussions with Lafarge, it was indicated that this linkage is uncertain. Therefore, it is assumed that the water discharged to the wetland area is evaporated or seeps into the groundwater reserves.
- The majority of water used at Kiln 4 for cooling processes is returned to the Townlands Dam. Some water is lost to evaporation along the length of the channel linking Kiln 4 to the Townlands Dam.
- Analysis of the proposed Additives and Coal Stockyard PCD's indicated that in order for the dams not to result in a spillage to the environment, water from these dams needs to be recycled and reused in the cement plant. Based on a proposed storage of approximately 20 000 m^3 at the Additives PCD and 4 000 m^3 at the Coal Stockyard PCD, the total volume of water that should be returned to the process water system equates to 153.2 m^3/day (or 4 660 m^3/month). In the wet season, due to the increased rainfall and runoff into the dams, the volume of water that needs to be recycled back to the plant equates to approximately 295 m^3/day (or 55 914 m^3/annum). In order to reintegrate this water into the process water stream, there may be a requirement to treat the water, however, this will only be confirmed once the chemical makeup of the wastewater is known and water quality requirements for the process water used at the cement plant are known.

Based on the water balance study, the following recommendations are provided:

- If the current water quality monitoring plan does not include the water being discharged to the Townlands Dam from Kiln 4 and water being discharged from the Cement/Raw Mills to the back of the plant (wetland area), then the water quality monitoring plan should be extended to these areas.
- It was noted that the feasibility of constructing a reservoir to capture and recycle water used for cooling process at the Cement/Raw Mills is being investigated. It is recommended that this receives due attention as it would both reduce the volume of water than needs to be brought onto site from the wellfield, as well as reduce the risk of any contamination to the environment (although it should be noted that the status of the current water being discharged is not known).
- It has also been noted that there is a suggestion (from Lafarge) to capture water discharged from the Kiln 3, which currently recycles through the Townlands Dam and back to the Kiln 3 for cooling

purposes, in a reservoir. This would mean that water from the cooling process does not go into the Townlands Dam. As mentioned above, a significant benefit of this would be that the risk of contamination of the Townlands Dam would be reduced.

- The water that will need to be recycled from the PCD's needs to be incorporated into the water management system and water management philosophy in the future. It is stressed that in order to ensure that the proposed PCD's wont spill, there must be an allowance to recycle water back into the process water stream for the plant.
- Flow meters should be installed on water supply lines throughout the plant. Of particular importance would be the measurement of water sent to the Cement/Raw Mills and Kiln 3 and 4 as well as to measure water recycled back from cooling process to the Townlands Dam and wetland area at the back of the cement plant. In addition to this, measurement of water sent to each of the Softening Plants would also provide great value in firming up on estimated water consumption values.

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