Appendix G

Surface water assessment

Gunlake Quarry Extension Project

Surface Water Assessment

For: Gunlake Quarries Pty Ltd

February 2016

PROJECT INFORMATION

Project Name: Gunlake Quarry Extension Project – Surface Water Assessment

Project Number: 8A0501

Report for: Gunlake Quarries Pty Ltd

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
A	15.10.2015	Chris Kuczera	Ben Patterson	
B	9.12.2015	Chris Kuczera	Ben Patterson & EMM	Ben Patterson
C	3.2.2016	Chris Kuczera	Ben Patterson & EMM & Gunlake	Ben Patterson

COMPANY DETAILS

Royal HaskoningDHV

Level 1, 43 Bolton Street

Newcastle, NSW, 2300

Tel. 4926 9500

www.royalhaskoningdhv.com

ABN 66 153 656 252

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVIATIONS

AHD	*Australian Height Datum*
ARI	*Average Recurrence Interval*
AR&R	*Australian Rainfall and Runoff (1987)*
Blue Book	*An Erosion and Sediment Control Guideline titled Managing Urban Stormwater: Soils and Construction (Landcom, 2004)*
BoM	*Bureau of Meteorology*
C_v	*Volumetric Runoff Coefficients*
DP&E	*NSW Government's Department of Planning and Environment*
EC	*Electrical Conductivity*
EIS	*Environmental Impact Statement*
EMM	*EMM Consulting Pty Limited*
EMP	*Environmental Management Plan*
EPA	*NSW Environment Protection Authority*
EPL	*Environmental Protection License*
ESC	*Erosion and Sedimentation Controls*
Gunlake	*Gunlake Quarries Pty Ltd*
IEAust	*Institution of Engineers Australia*
IFD	*Intensity Frequency Distribution*
ML	*Megalitre*
Mtpa	*Million tonnes per annum*
NOW	*NSW Government's Office of Water*
OEH	*NSW Government's Office of Environment and Heritage*
PET	*Potential Evapotranspiration*
POEO Act	*Protection of the Environment Operations Act 1997*
RHDHV	*Royal HaskoningDHV*
SEARs	*Secretary's Environmental Assessment Requirements*
SWMPs	*Surface Water Management Plans*
The Quarry	*Gunlake Quarry*
TSS	*Total Suspended Solids*
TN	*Total Nitrogen*
TP	*Total Phosphorus*
WMA	*Water Management Act 2000*

1 INTRODUCTION

Gunlake Quarry (the quarry) is a hard rock quarry operated by Gunlake Quarries Pty Ltd (Gunlake). It is located approximately 7 km north-west of Marulan in the Goulburn Mulwaree local government area (LGA). **Plate 1-1** locates the quarry.

The quarry currently operates under New South Wales project approval 07-0074 issued by the Minister for Planning in September 2008 under Part 3A of the NSW *Environmental Planning and Assessment Act 1979*. The project approval has been modified on three occasions. The current development consent permits the production of 750,000 tonnes of saleable product per year for 30 years.

An Environmental Impact Statement (EIS) has been prepared to accompany an application to expand the current operations at the quarry. The EIS describes the proposed extension project, provides an assessment of its potential impacts and details measures that will be implemented to prevent and/or minimise potential impacts. This document details a Surface Water Assessment that forms part of the EIS for the quarry expansion.

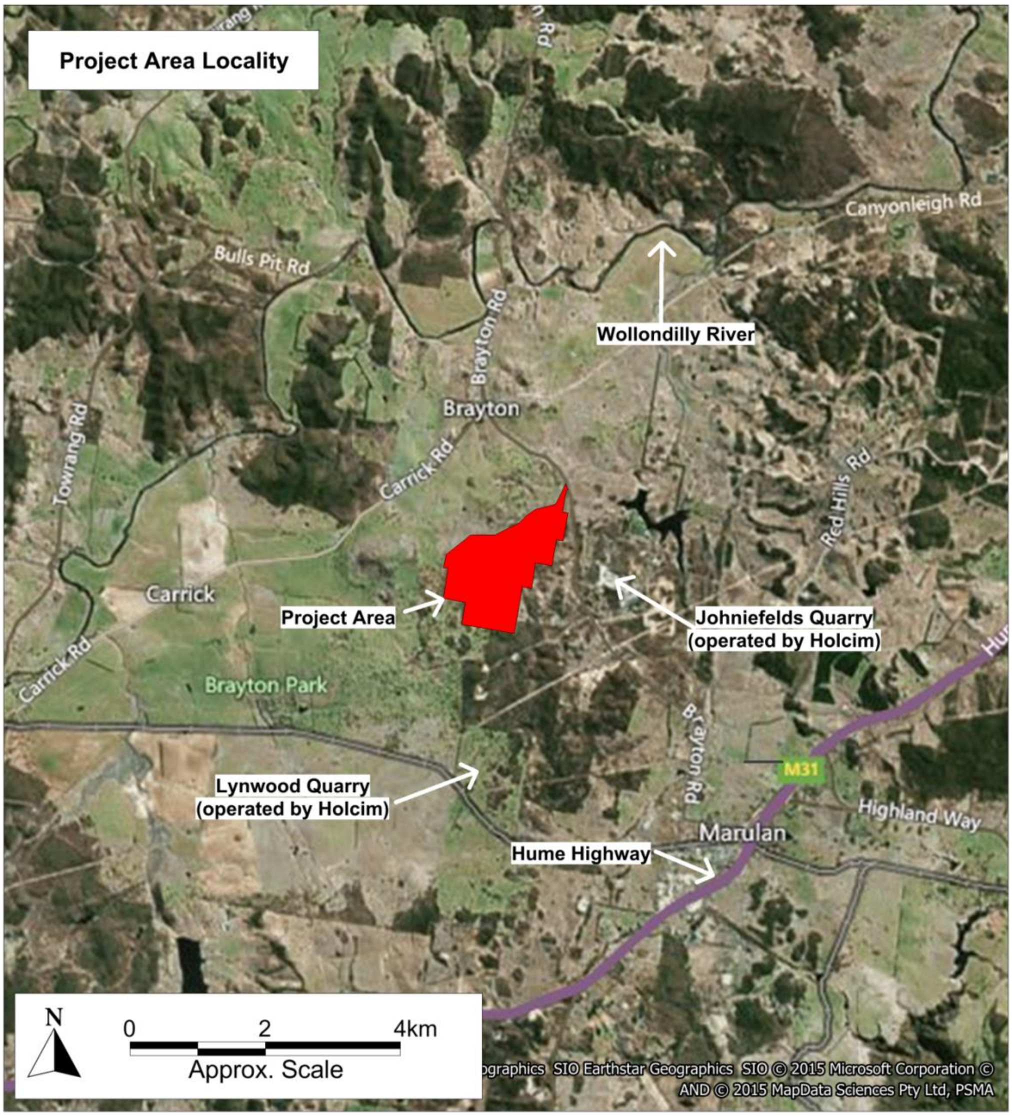


***Plate 1-1** – Site Locality*

1.1 Project Description

The proposed Gunlake Quarry extension (the extension project) seeks to enable an increased rate of extraction at the quarry to assist to meet the identified demand for construction materials, including quarried aggregate, for the local area and Sydney markets. The extension project includes the production of 2 million tonnes per annum (Mtpa) of saleable product for 30 years. Therefore, Gunlake seeks a new development consent that allows:

- 2 Mtpa of saleable products to be produced;
- an increase in truck movements to an average of 440 movements per day;
- extension of the quarry pit footprint by approximately 54 hectares (ha);
- 24 hour per day primary crushing;
- additional overburden emplacement to accommodate the increase in production; and
- blasting twice weekly.

In addition, Gunlake seeks to maintain the approval for all aspects of the existing operations for Gunlake Quarry under Project Approval 07-0074. The proposed extension area is shown in **Plate 1-2**.

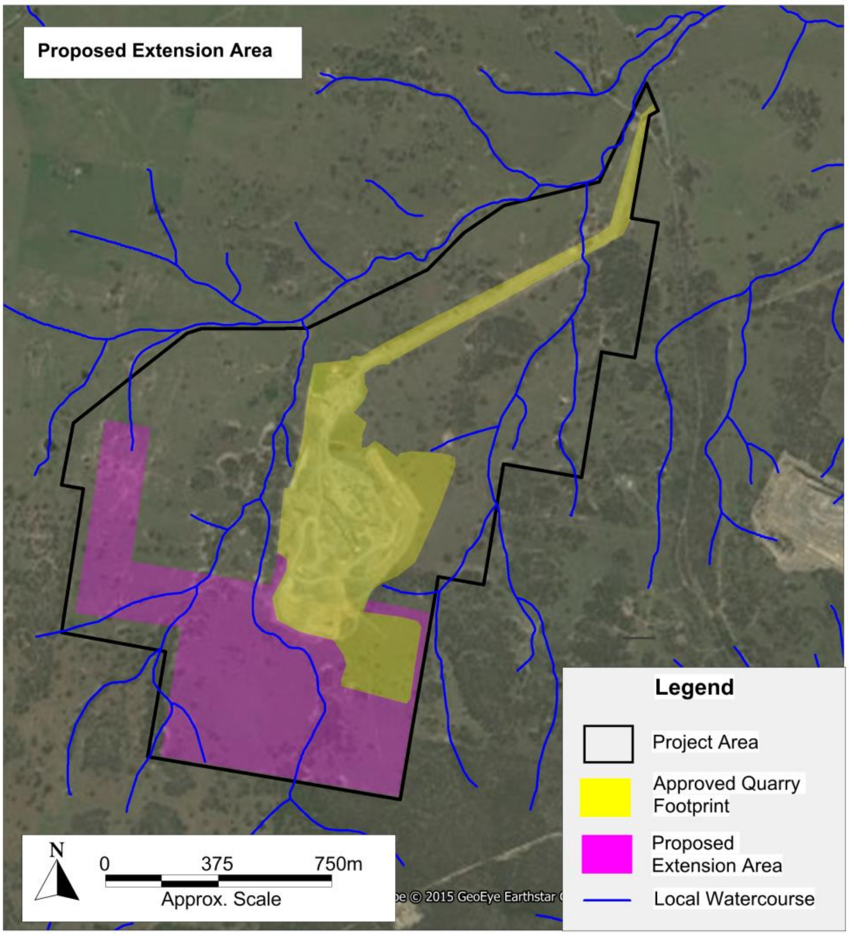


***Plate 1-2** – Proposed Extension Area*

1.2 Report Overview

This report documents the Surface Water Assessment that has been prepared for the extension project. The report is structured as follows:

- **Section 2** discuses statutory requirements and relevant guidelines.
- **Section 3** reviews the existing surface water environment at the quarry site.
- **Section 4** describes the proposed surface water management strategy and presents Surface Water Management Plans and water balance results for various stages of the 30 year quarry life.
- **Section 5** summarises the predicted surface water impacts.
- **Section 6** details water licencing requirements for the extension project.
- **Section 7** details monitoring and contingency measures for the extension project.

2 STATUTORY REQUIRMENTS

2.1 Environmental Assessment Requirements

The NSW Government's Department of Planning and Environment (DP&E) provided the Secretary's Environmental Assessment Requirements (SEARs) for the preparation of an EIS for the Gunlake Quarry Extension Project. **Table 2-1** lists the SEARs that are applicable to this surface water assessment and provides a reference to the relevant section of the report that addresses each SEAR.

***Table 2-1** – Secretary's Environmental Assessment Requirements*

Secretary's Environmental Assessment Requirements	Applicable Sections
Detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including impacts on the regional water supply.	**Sections 4 and 5 and the Groundwater Assessment[1]**
Preparation of a detailed water balance, including a description of site water demands, water disposal methods (including volume and discharge frequency), water supply infrastructure and water storages.	**Section 4**
An assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives.	**Section 4**
Identification of any licensing requirements or other approvals under the Water Management Act 2000.	**Section 6 and the Groundwater Assessment[1]**
Demonstration that all water supplies for the life of project can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of the relevant Water Sharing Plan.	**Sections 4, 6 and 7**
An assessment of potential risks to surface and groundwater from construction and operation, demonstrating clear consideration of the principle of achieving a neutral or beneficial effect on water quality in the Sydney Drinking Water Catchment. The EIS must include a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation.	**Sections 5 and 7 and the Groundwater Assessment[1]**
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant Water Sharing Plan or water source embargo.	**Section 6 and the Groundwater Assessment[1]**
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	**Sections 4, 5 and 7 and the Groundwater Assessment[1]**

Note 1: The Groundwater Assessment has been prepared by EMM (2015).

2.2 Applicable Polices and Guidelines

There are a number of legislative and guidance documents for water resource management and assessment in NSW. The following policies, plans and guidelines have been considered in this assessment.

Water Plans and Statutory Provisions

Water Sharing Plan for the Greater Metropolitan Region Unregulated Water Sources 2011

Water Access Licenses (WALs) in the Wollondilly River Catchment are administered by the *Water Sharing Plan for the Greater Metropolitan Unregulated Water Sources 2011*. The Water Sharing

Plan is administered on the basis of catchment scale Water Sources. Gunlake quarry is located within the *Upper Nepean and Upstream of Warragamba* Water Source. The licensing provisions of the Water Management Act 2000 (WMA 2000) are also applicable to the plan area.

The Water Sharing Plan is administered by the NSW Office of Water (NOW). **Section 6** addresses the water licensing requirements for the quarry.

Protection of the Environment Operations Act 1997

The Protection of the Environment Operations (POEO) Act establishes the NSW environmental regulatory framework and includes licensing requirements for certain activities. Environmental Protection Licenses (EPL) for water discharge are administered by the NSW Office of Environment and Heritage (OEH) under the POEO Act.

Guidelines

Australian Rainfall and Runoff

Australian Rainfall and Runoff (IEAust, 1987) is a document published by the Institution of Engineers, Australia. This document has been prepared to provide practitioners with the best available information on design flood estimation and is widely accepted as a design guideline for all flood and stormwater related investigation and design in Australia.

Erosion and Sediment Control Guidelines

There are numerous guidelines which document best practice for erosion and sediment control. The following NSW government guidelines are typically referred to when developing Erosion and Sedimentation Control Plans for mines and quarries:

- *Managing Urban Stormwater: Soils and Construction- Volume 1 (Landcom, 2004*) – This guideline is often referred to as the 'Blue Book'.
- *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008).

Specifically, these guidelines detail calculation methodologies to size sedimentation basins.

Bunding and Spill Management Guidelines

The following NSW Government guidelines detail best practice storage, handling and spill management procedures for liquid chemicals:

- *Liquid Chemical Storage, Handling and Spill Management: Review of Best Practice Regulation* (DECC, 2005).
- *Storing and Handling Liquids: Environmental Protection: Participant's Manual* (DECC, 2007).

Australian Guidelines for Water Quality Monitoring and Reporting – ANZECC, 2000

These guidelines are the benchmark documents of the National Water Quality Management Strategy which is used for comparison of water quality monitoring data throughout Australia.

State Water Management Outcomes Plan (NSW Government)

The *Water Management Act* (2000) provides for the establishment of the State Water Management Outcomes Plan to set out the over-arching policy context, targets and strategic outcomes for the development, conservation, management and control of the State's water sources.

NSW Government Water Quality and River Flow Objectives – EPA

There are no water quality or river flow objectives for the Wollondilly, Hawksbury and Nepean River system's provided on the relevant website.

NSW Water Conversation Strategy – NSW Department of Land and Conservation (2000)

This strategy document details the outcomes of a review undertaken by the *New South Wales Water Conservation Task Force* in 2000. The scope of the review included water availability in New South Wales, the regulatory framework and the way water is being used in each sector compared with 'best practice' water management within the constraints of existing information. Water efficiency projects and programs were reviewed by sector, and the constraints to improving water use efficiency were analysed.

NSW Guidelines for Controlled Activities on Waterfront Land (NOW)

This guideline reference refers to a series of guidelines that provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

2.3 Previous Studies

The following Water Management Plans and Surface Water Assessments were prepared by others for previous approvals. These documents were reviewed and applicable information was used in this Surface Water Assessment.

Managing Soil and Water (SEEC, 2008)

This document was prepared as part of the original (2008) Environmental Assessment for the quarry. The document outlines a conceptual surface water management plan and water balance for the quarry.

Water Management Plan: Environmental Management System (Olsen Consulting Group, 2009)

This document forms part of the current Environmental Management Plan for the quarry and outlines a site water balance, erosion and sediment control plan, pasture irrigation monitoring program and surface and groundwater monitoring programs.

Water Assessment (Cardno, 2014)

This document was prepared as part of the 2014 EIS for the quarry's expansion and is the most recent surface water assessment. The document outlines a conceptual surface water management plan and water balance for the quarry.

3 EXISTING CONDITONS

This section discusses the existing surface water environment at the quarry site.

3.1 Climatic Data

This section reviews available climatic information and establishes representative climatic databases for the quarry site.

3.1.1 Rainfall Records

There are three Bureau of Meteorology (BoM) operated rainfall gauges that provide representative rainfall records for the quarry site. These gauges are located in **Plate 3-1**.

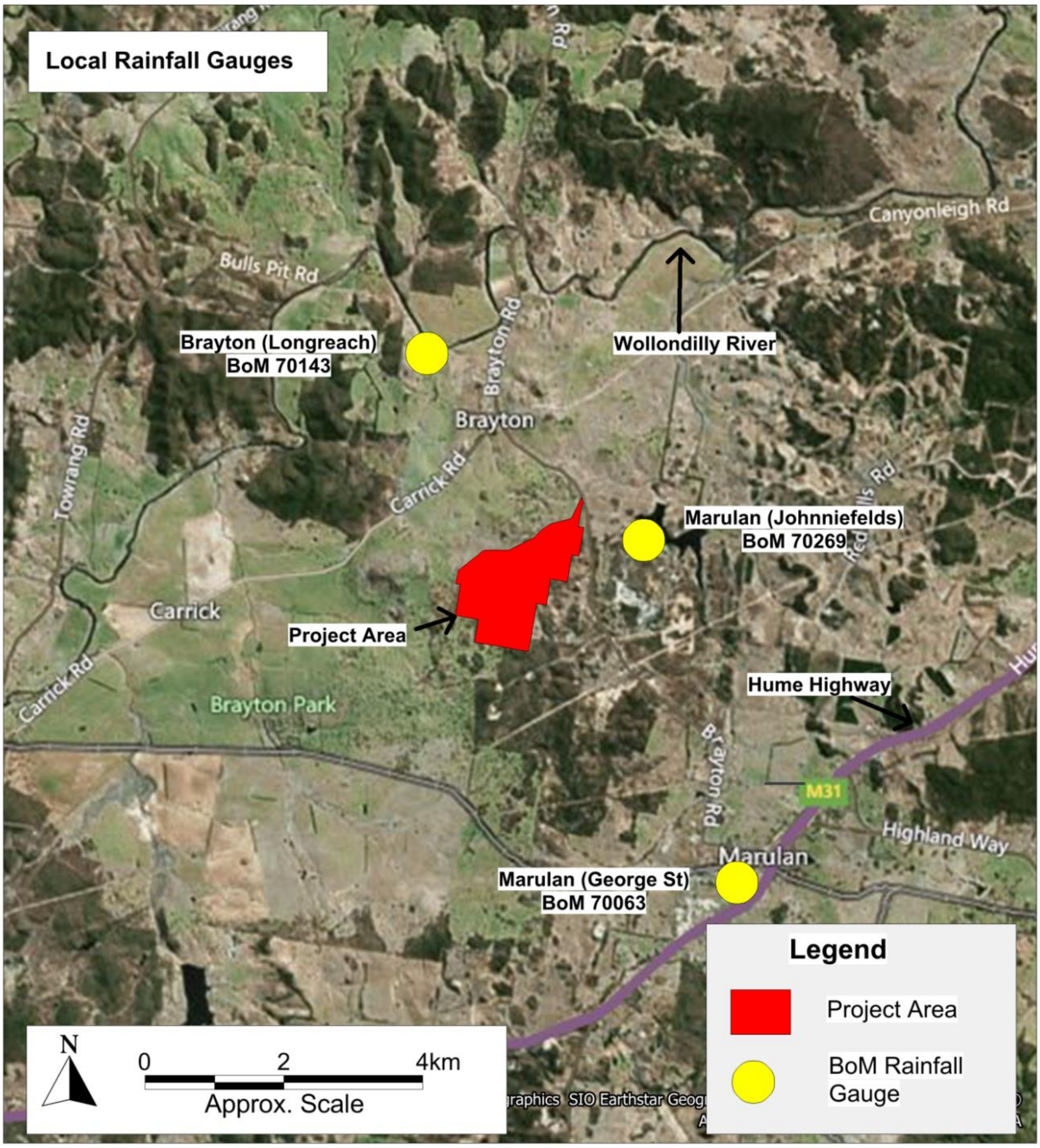


Plate 3-1 – *Local Rainfall Gauges*

Table 3-1 presents key information and statistical data from the three gauges shown in **Plate 3-1**.

Table 3-1 – *Rainfall Statistics from Local Gauges*

Statistics	Marulan (George Street) (70063)	Marulan (Johnniefelds) (70269)	Brayton (Longreach) (70143)
Rainfall Record	1894 to present	1972 to present	1959 to present
Distance from site	5.5km to the South-East	2km to the East	3.5km to the North
Elevation (m AHD)	645	630	610
Average Rainfall (mm/year)	710	706	701
Lowest Annual Rainfall (mm/year)	287	321	262
5th Percentile Rainfall (mm/year)	406	410	369
10th Percentile Rainfall (mm/year)	459	468	466
Median Rainfall (mm/year)	701	698	696
90th Percentile Rainfall (mm/year)	984	934	931
95th Percentile Rainfall (mm/year)	1071	1027	981
Highest Annual Rainfall (mm/year)	1469	1091	1104

Source: Bureau of Meteorology

The three rainfall records presented in **Table 3-1** correlate well indicating that there is no substantial spatial variation in rainfall characteristics in the vicinity of the quarry site. A representative long term rainfall time series was prepared using daily rainfall records from the three gauges. Preference was given to the data from the Marulan (George Street) gauge: BoM 70063, with data from the other gauges used to fill gaps in the BoM 70063 record. This time series was used for water balance modelling that is discussed in **Section 4**. Annual rainfall totals between 1900 and 2014 are shown in **Plate 3-2**.

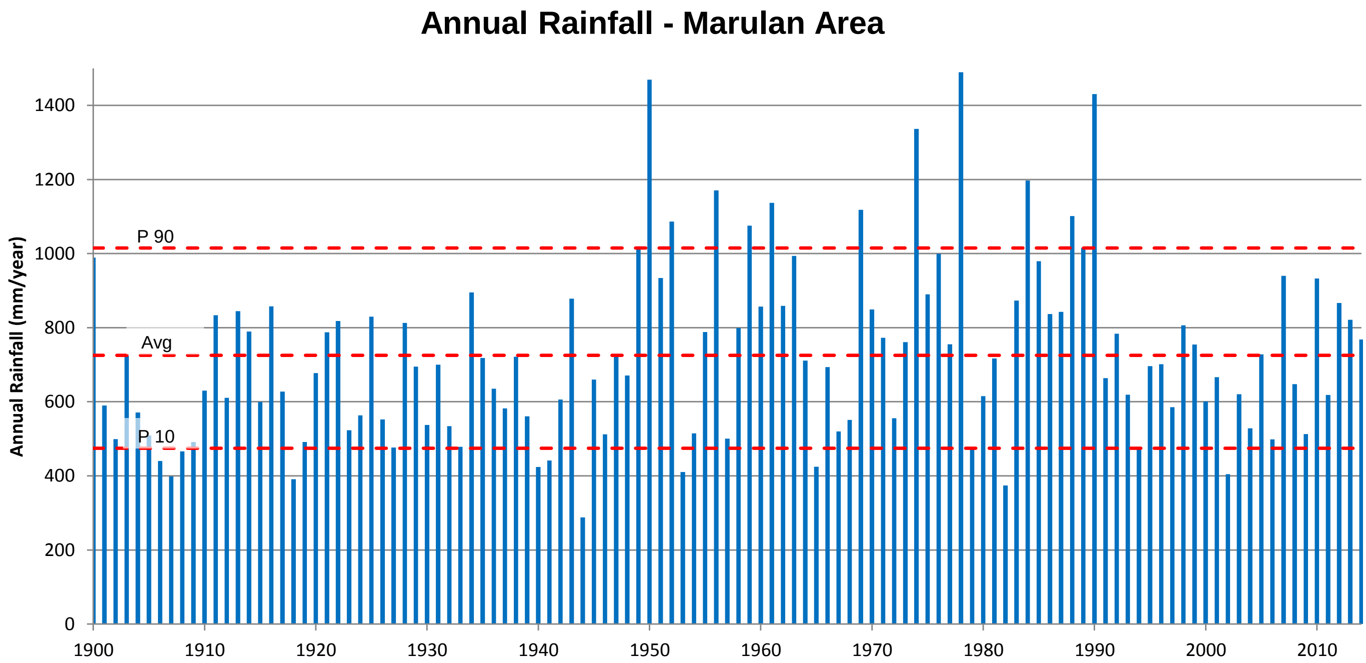


***Plate 3-2** – Annual rainfall totals for the Marulan Area*

The following climatic events are evident in the annual rainfall totals presented in **Plate 3-2**:

- Extended periods of below 10th Percentile rainfall were recorded in 1905-1909, 1918-1919, the 1940s,1979-1980, 1982 and 2002. These periods correspond with recorded droughts in Eastern Australia.
- The period between 1950 to 1990 comprised above average rainfall, featuring the only 11 years of above 90th Percentile rainfall totals in the 115 year record.

Plate 3-3 plots the average and 10th and 90th Percentile monthly rainfall totals recorded at BoM 70063. The chart clearly demonstrates the high variability in monthly rainfall across all seasons.

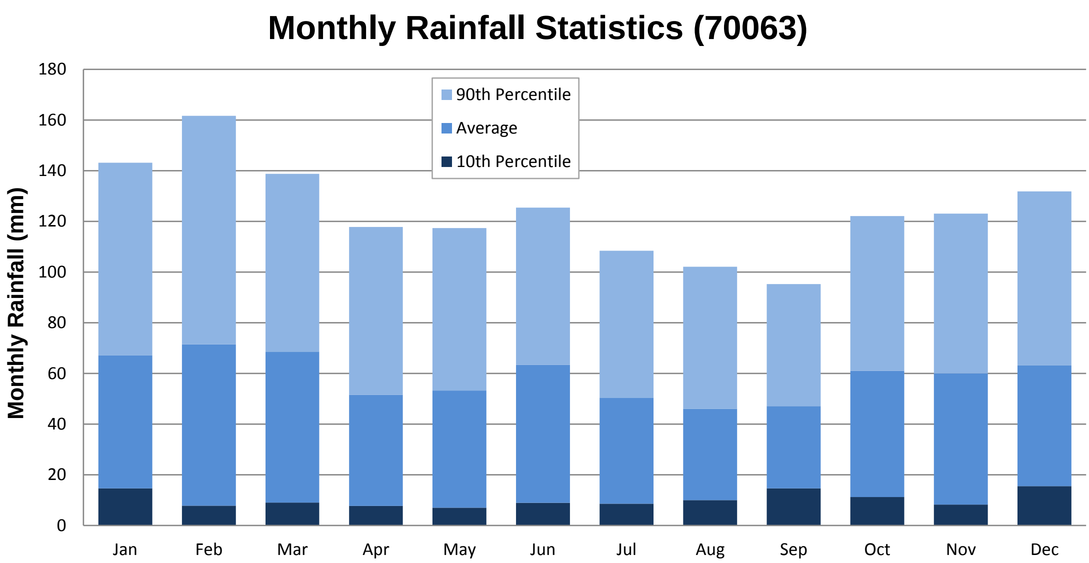


***Plate 3-3** – Monthly rainfall statistics at Marulan (George Street) – 70063 (Source: BoM)*

3.1.2 Evaporation Data

Table 3-2 presents the average monthly pan evaporation and Areal Potential Evaporation (PET) rates at the quarry site. This information was extracted from the monthly climate maps provided by the BoM and indicates that the pan evaporation rate is approximately double the average annual rainfall depth.

Table 3-2 - *Average monthly evaporation and PET data*

Month	Average Monthly Pan Evaporation	Average Areal Potential Evapotranspiration
	(mm/month)	(mm/month)
January	200	150
February	160	115
March	136	100
April	93	69
May	64	48
June	49	37
July	55	38
August	80	58
September	104	80
October	139	116
November	163	135
December	202	149
Annual	**1,445**	**1,095**

Source: Bureau of Meteorology

3.2 Local Watercourses

The quarry is located within the upper reaches of the Chapmans Creek Catchment. Chapmans Creek is an ephemeral watercourse that drains to the north-east, flowing into Jaorimin Creek approximately 3 km downstream of the quarry. Jaorimin Creek then flows in a northerly direction to its confluence with the Wollondilly River, approximately 8.6 km downstream from the quarry. The Wollondilly River is the major river in the region and is one of the key tributaries to Warragamba Dam, which is located 65 km to the north-east of the quarry. Johniefelds Dam is located on Jaorimin Creek upstream of its confluence with Chapmans Creek and does not receive runoff from Chapmans Creek, or the quarry site.

Information provided by DPI indicates that there are no licenced surface water users that rely on extraction from either Chapmans or Jaorimin Creeks, in the immediate downstream receiving water.

Plate 3-4 locates the abovementioned watercourses relative to the project area. The existing condition of Chapmans Creek is discussed further below.

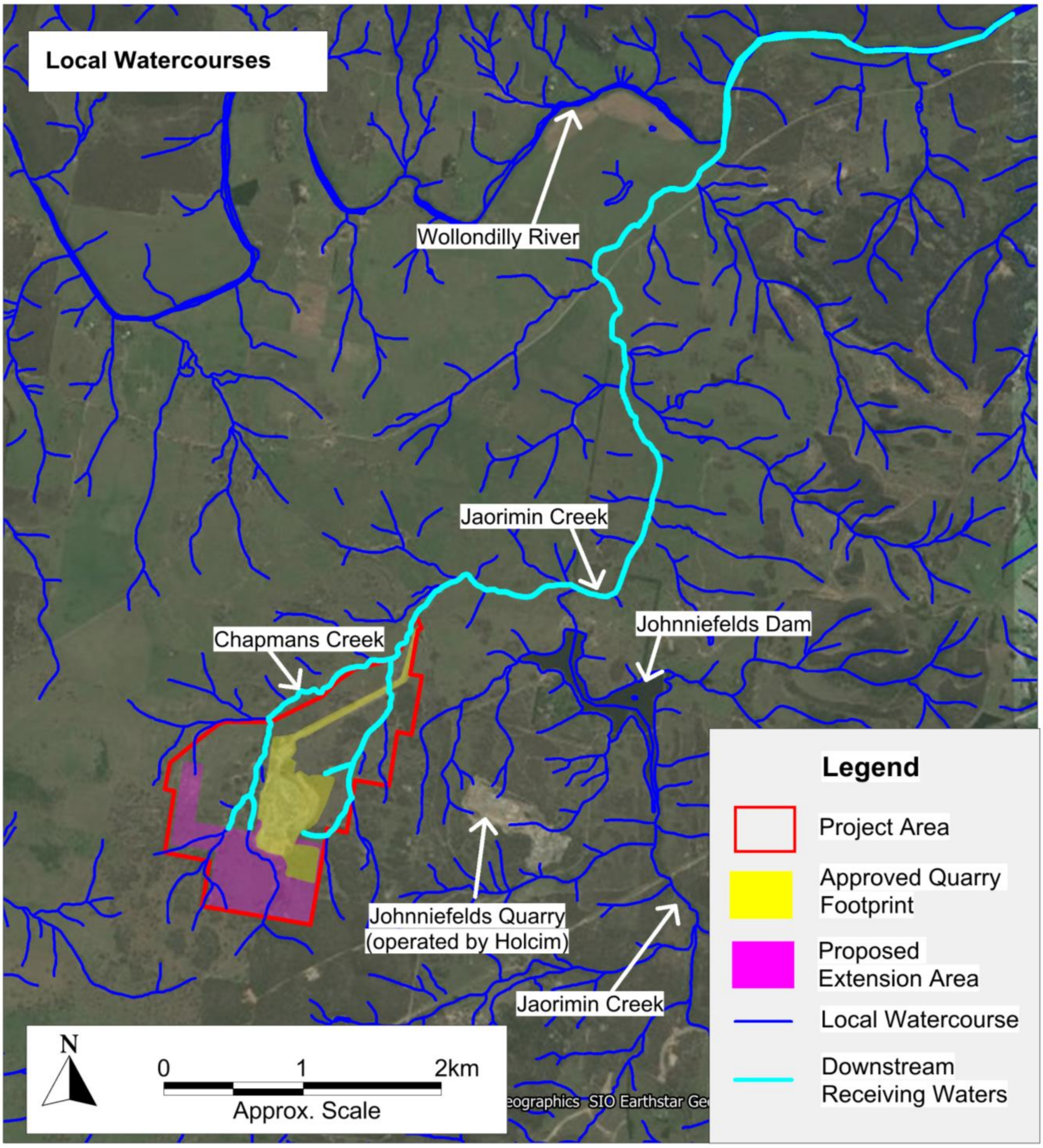


Plate 3-4 *– Local Watercourses*

3.2.1 Chapmans Creek

As discussed above, the quarry is located in the upper extents of the Chapmans Creek Catchment. Chapmans Creek is an ephemeral watercourse that generally drains in a north-easterly direction towards its confluence with Jaorimin Creek. The catchment area and riparian zones have been predominantly cleared and are currently used as grazing land. The creek channel is generally degraded, with moderate to severe bed lowering and bank erosion observed in most sections during a site inspection. Site observations indicate that the degradation is attributed to combination of grazing pressure and the possible effects of soil sodicity.

Photo 1 (taken adjacent to the quarry) and **Photo 2** (taken downstream of the quarry) show typical sections of Chapmans Creek. **Photo 3** shows a weir that has been constructed immediately upstream of the Brayton Road Culvert, downstream of the quarry area.

Plate 3-5 displays the alignment and Stream Order (as defined by the Strahler System of stream classification) of Chapmans Creek and its tributaries and locates Photos 1, 2 and 3, which are provided below. **Plate 3-5** shows that the proposed quarry expansion will disturb two second order watercourses that are tributaries to Chapmans Creek.

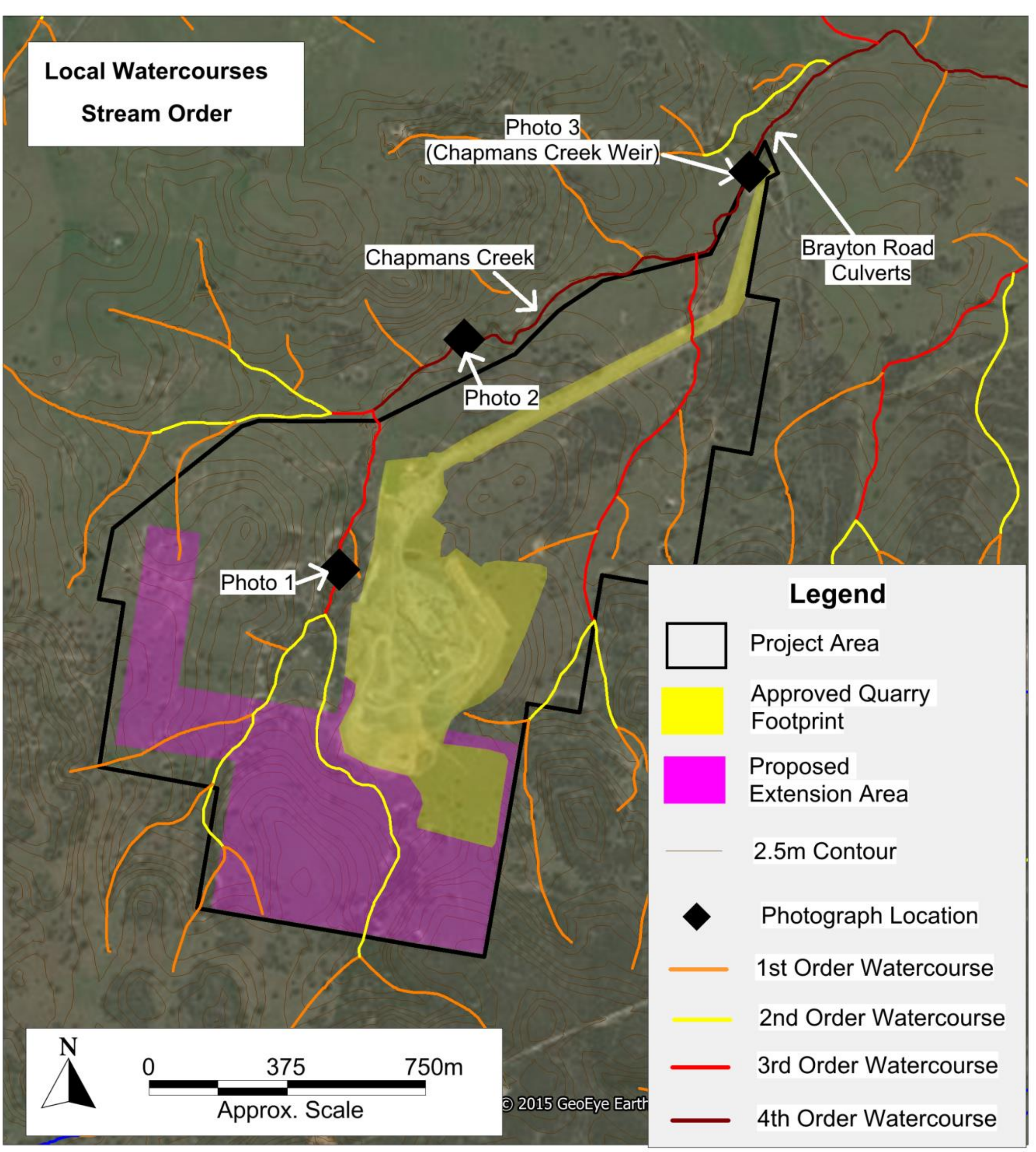


Plate 3-5 *– Location and Stream Order of Local Watercourses*

Photo 1: *Upper Chapmans Creek (adjacent to the quarry site). Moderate bed lowering and bank erosion is evident.*

Photo 2: *Chapmans Creek (downstream of the quarry site). Severe bed lowering and bank erosion is evident.*

Photo 3: *Chapmans Creek Weir which is located upstream of the Brayton Road Culverts.*

In summary, the proposed expansion will directly disturb two second order watercourses that are tributaries to Chapmans Creek.

3.3 Existing Water Quality Conditions

A surface water monitoring program was established by Gunlake in February 2007, prior to the establishment of the quarry. The program is ongoing. A total of 49 monitoring rounds have been completed between February 2007 and May 2015. Monitoring has been undertaken at three locations, referred to as Sites I, O and D. These locations are shown in **Plate 3-6**. **Table 3-3** details the analytes that were generally tested for each sample.

***Table 3-3** – Water Quality Analytes Tested*

	Water Quality Analytes Tested
Physical Parameters	• Electrical Conductivity (EC) • Total Suspended Solids (TSS) • Total Dissolved Solids (TDS) • Dissolved Oxygen (DO)
Chemical Parameters	• pH • Sodium • Chloride • Total Nitrogen (TN) • Total Phosphorus (TP) • Metals (As, Fe, Mn)

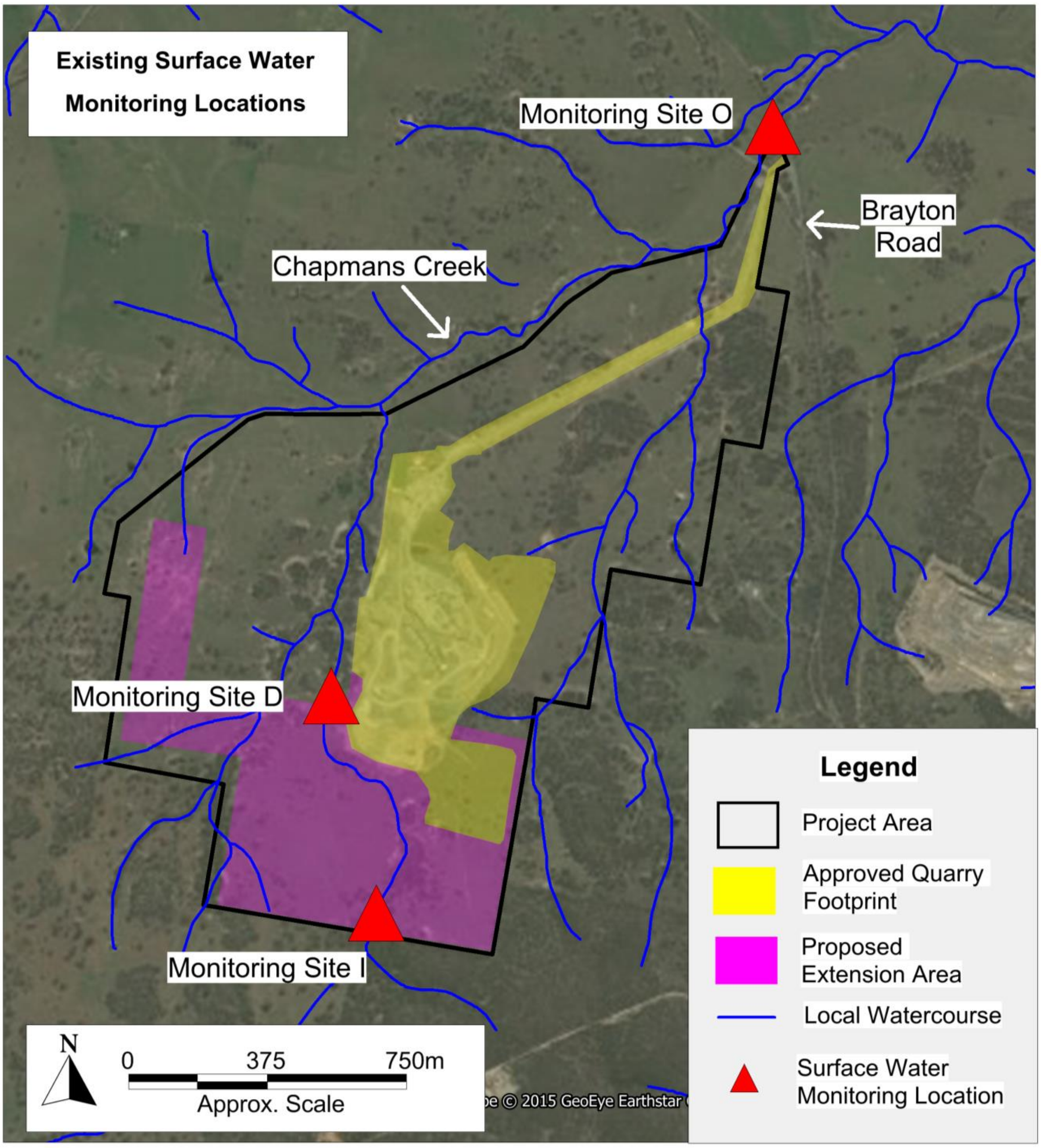


***Plate 3-6** – Existing Surface Water Monitoring Locations*

Table 3-4 presents a statistical summary of the water quality results. All monitoring data is presented in table form in **Appendix A**. **Plates 3-7** and **3-8** plot the recorded EC and TSS time series respectively. The preceding 90 day rainfall total is also plotted to enable the monitoring data to be compared to medium term rainfall trends.

It is noted that limited sampling was undertaken at monitoring Site I as it was dry during most sampling events.

Table 3-4 – Surface Water Monitoring Results Summary

Analyte	Relevant Trigger Value	Detection Limit	Statistic[3]	Monitoring Site D	Monitoring Site O	Monitoring Site I
pH	6.5 – 8.0[2]	0.1	Samples	49	47	14
			90%ile or Max	8.2	8.4	8.1
			Avg	7.0	7.7	6.7
			10%ile or Min	6.1	6.6	5.9
DO (mg/L)	-	-	Samples	14	14	-
			90%ile or Max	11	10	-
			Avg	9	7	-
			10%ile or Min	7	2	-
EC (µS/cm)	30-350[2]	5	Samples	49	47	17
			90%ile or Max	300	1820	2372
			Avg	188	919	610
			10%ile or Min	63	206	96
TDS (mg/L)	-	1	Samples	21	18	3
			90%ile or Max	41	79	21
			Avg	22	46	10
			10%ile or Min	5	4	5
TSS (mg/L)	-	2	Samples	29	29	14
			90%ile or Max	151	1360	1605
			Avg	125	665	519
			10%ile or Min	77	234	120
CL (mg/L)	-	1.0	Samples	28	28	14
			90%ile or Max	18.4	473.0	583.5
			Avg	11.5	191.2	134.0
			10%ile or Min	4.4	26.5	8.2
Na (mg/L)	-	2	Samples	28	28	14
			90%ile or Max	8.8	113.8	247.6
			Avg	6.0	65.2	61.0
			10%ile or Min	3.7	16.7	8.0
As (mg/L)	0.013[1]	0.001	Samples	29	29	14
			90%ile or Max	0.001	0.001	0.003
			Avg	0.001	0.001	0.002
			10%ile or Min	0.001	0.001	0.001
Fe (mg/L)	-	0.05	Samples	30	30	14
			90%ile or Max	0.479	0.110	0.787
			Avg	0.211	0.061	0.358
			10%ile or Min	0.030	0.004	0.024
Mn (mg/L)	1.9[1]	0.001	Samples	30	30	14
			90%ile or Max	2.66	1.44	16.80
			Avg	1.67	0.61	6.96
			10%ile or Min	0.41	0.06	0.35
TN (mg/L)	0.25[2]	0.1	Samples	29	28	15
			90%ile or Max	4.3	2.3	4.1
			Avg	3.0	1.4	2.4
			10%ile or Min	1.7	0.7	1.0
TP (mg/L)	0.02[2]	0.01	Samples	30	28	15
			90%ile or Max	0.26	0.18	1.10
			Avg	0.24	0.07	0.61
			10%ile or Min	0.04	0.01	0.03

Shading denotes ANZECC (2000) trigger value has been exceeded

nd denotes “not detected” i.e. the analyte concentration is below laboratory detection limits.

Note 1: Trigger Values for 95% protection of fresh water species adopted as relevant trigger value

Note 2: ANZECC Trigger Values for physical & chemical stressors for South-East Australia for slightly disturbed ecosystems (Upland River) adopted

Note 3: Maximum and minimum values are reported when the number of samples is less than 10. 10th and 90th Percentiles are reported when the number of samples is 10 or greater.

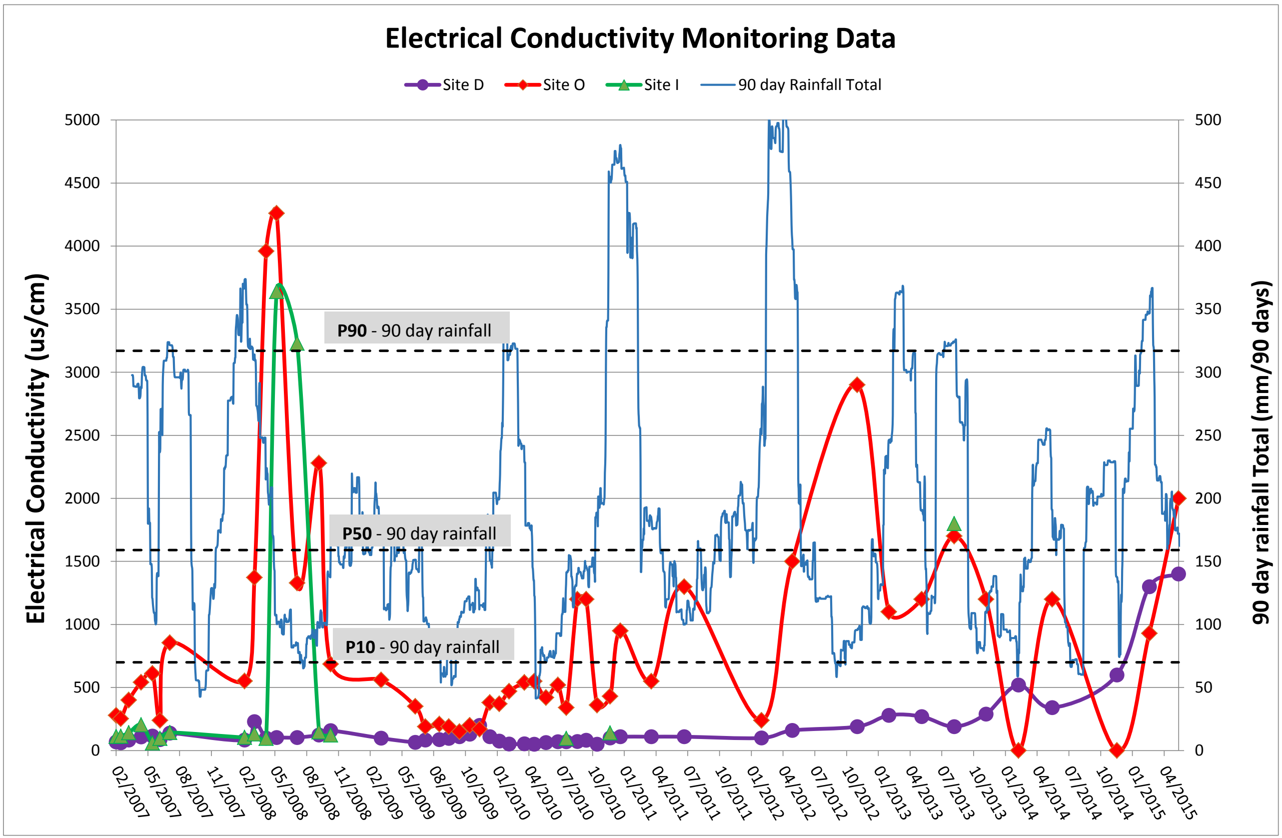


***Plate 3-7** – Recorded Electrical Conductivity (EC)*

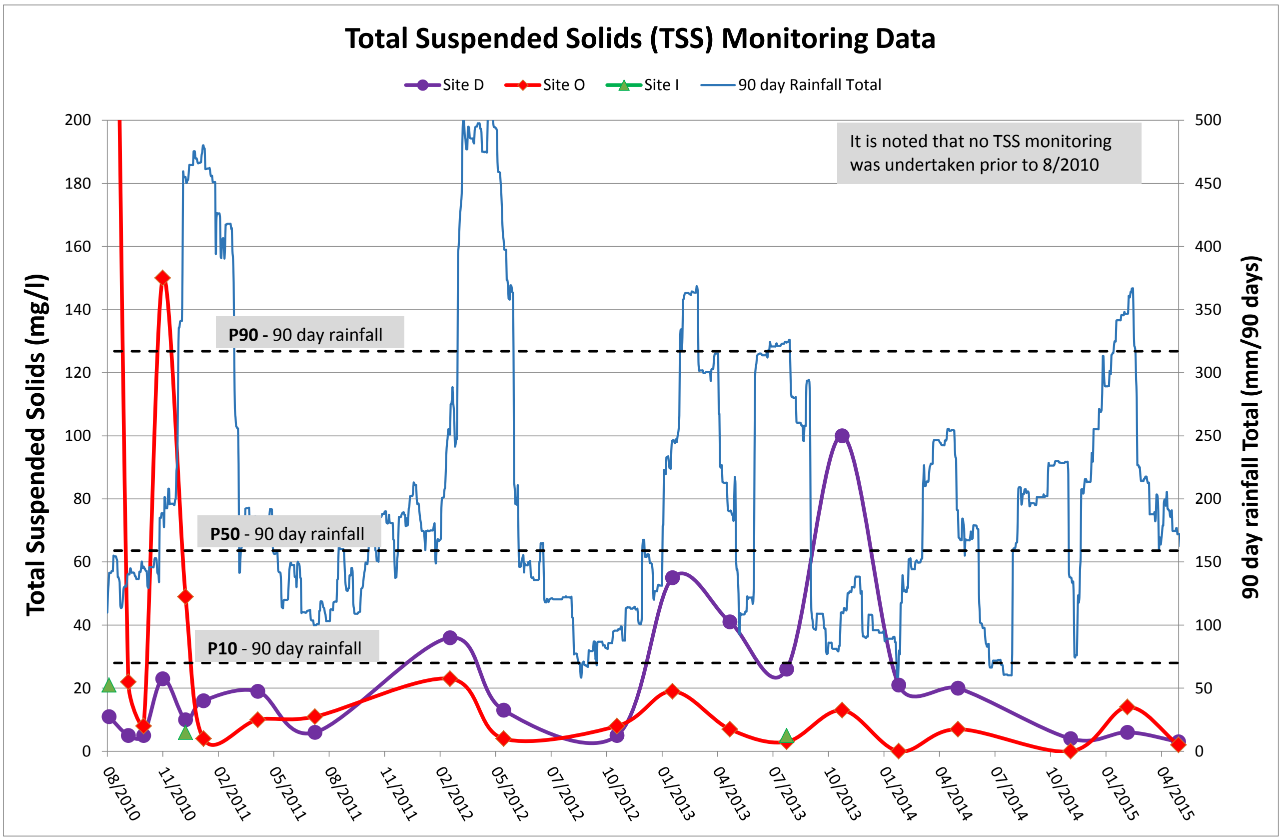


Plate 3-8 – *Recorded Total Suspended Solids (TSS)*

Summary of Water Quality Results

The following key trends have been observed from the surface water monitoring data that is presented in **Table 3-4**:

- With reference to **Plate 3-7**, recorded EC was generally substantially higher at Site O (downstream of the Chapmans Creek Weir) than Site D (adjacent to the quarry site). Higher EC levels were generally associated with dry conditions following periods of runoff. The elevated EC at Site O is likely to be attributed to the degraded state of Chapmans Creek and possible soil sodicity issues, which may lead to the leaching of salts from sodic sub soils followed by the concentration of salts through evaporation in shallow pools within the creek.

- With reference to **Plate 3-8**, the recorded Total Suspended Solid (TSS) concentrations at Site O (downstream of the Chapmans Creek Weir) were generally below 20mg/l indicating that the quarry operation is not contributing sediment laden water to downstream receiving waters.

- Recorded nutrients (Total Nitrogen and Total Phosphorus) were consistently 5 to 10 times above the ANZECC default trigger values for upland fresh water streams. With reference to results presented in **Appendix A**, it is noted that some of the highest concentrations recorded were in 2007 prior to the commencement of quarry operations. This indicates that the elevated levels are associated with the agricultural land uses.

- Recorded Arsenic and Manganese concentrations were generally below ANZECC trigger values for 95% protection of freshwater species.

The surface water monitoring program has established a database of the existing water quality at the monitoring locations shown in **Plate 3-6**. Should the proposed quarry extension proceed, Gunlake will modify the surface water monitoring program to reflect the expanded footprint and surface water management plan. The revised surface water monitoring program is discussed in **Section 7**.

3.4 Local Soil Conditions

A soil survey was undertaken as part of the original EIS for the quarry (SEEC, 2008). The survey included a number test pits within the project area to establish soil characteristics. The survey concluded that soils within the project area are generally expected to be:

- Type D dispersive soils; and

- Moderately to very highly erodible.

It is also noted that the report recommended that some soils within the project area would not be suitable for use in the construction of water holding embankments.

4 SURFACE WATER MANAGEMENT

The proposed extension project will comprise the expansion of the existing pit to the south and west and the establishment of an additional emplacement area to the west of the proposed pit. Process water use is expected to increase as a result of the increase in the production rate from 0.75 to 2.0 Mtpa. These changes will require additional surface water controls to manage the potential impacts and to provide a reliable supply of water for the quarry operation.

This section documents the surface water management strategy that has been developed for the extension project. This section is structured as follows:

- **Section 4.1** introduces terminology used to describe the surface water management strategy.
- **Section 4.2** conceptually describes the surface water management strategy.
- **Section 4.3** details the methodology and assumptions applied to the development of a site water balance model for the project.
- **Section 4.4** details Surface Water Management Plans (SWMPs) for various stages of the quarry life.
- **Section 4.5** details a water balance model for the final void.

Surface water impacts and water licencing requirements are discussed separately in **Sections 5** and **6** respectively.

4.1 Definitions

Surface water within the quarry site has been differentiated into the following categories based on water quality and intended use:

- **Clean Water** – refers to surface water runoff from catchments that are undisturbed, relatively undisturbed or fully rehabilitated following disturbance. Clean water can be discharged from the site with no treatment.
- **Dirty Water** – refers to surface water runoff from the quarry's pit, haul roads, emplacement and product stockpiles and processing areas. Dirty water is likely to contain elevated suspended sediment levels and requires sedimentation treatment prior to release.
- **Process Water** - refers to water used by the quarry operation for haul road dust suppression and plant water use.
- **Wastewater –** refers to wastewater generated from the onsite amenities such as toilets and showers. Wastewater contains human waste and associated pathogens.
- **Potable Water –** refers to water suitable for drinking.

4.2 Surface Water Management Strategy

This section discusses the surface water management objectives and associated management measures. Detailed SWMPs are provided in **Section 4.4** for various stages of the quarry life.

4.2.1 Surface Water Management Objectives

Table 4-1 summarises the surface water management objectives and associated management measures that have been applied to the development of the surface water management strategy.

***Table 4-1** – Water Management Objectives and Associated Management Measures*

Management Objectives	Management Measures
1. Where practical, separate clean and quarry water circuits to minimise the volume of water that requires treatment.	Where possible, clean water diversion drains will be established up gradient from disturbance areas to reduce the volume of water that enters the quarry's water management system.
2. Provide appropriately sized sedimentation basins for all catchment areas that will be disturbed by the quarry operation.	Sedimentation basins will be established to capture and treat runoff from disturbed areas. The basins will be sized in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008).
3. Establish suitable means to manage excess water that accumulates in the pit.	Water accumulated in the pit will be dewatered (via pumping) to a dedicated pit dewatering dam that will store water for process water use. During periods of water surplus, water will be released from the dam when its water quality is suitable. This process is explained further in **Section 4.2.2**.
4. Minimise the volume and frequency of site discharge.	Water from disturbed areas will be captured in a series of water management dams. Water stored in dams will be used to meet process water demands such and plant and haul road dust suppression. This water use will reduce dam levels and the associated discharge frequencies and volumes.
5. Establish site discharge locations and characteristics.	Site discharge locations have been identified for each stage of the quarry plan.
6. Establish the quarry's operational water demands and identify reliable water sources over the life of the quarry.	Water balance modelling has been undertaken to estimate the project's process water needs and the reliability of supply. The model was used to establish dam storage volumes that will reduce the risk of water shortages and associated need to import externally sourced water.
7. Establish an ongoing monitoring and review program that will enable the surface water management system to be progressively improved overtime.	A conceptual monitoring and review program is provided in **Section 7**. This program will be formalised (in consultation with relevant authorities) post approval as part of the Environmental Management Plan for the expanded operation.

4.2.2 Surface Water Management Strategy

The proposed surface water management strategy is diagrammatically described in **Plate 4-1**. Key aspects of the strategy are discussed below the diagram.

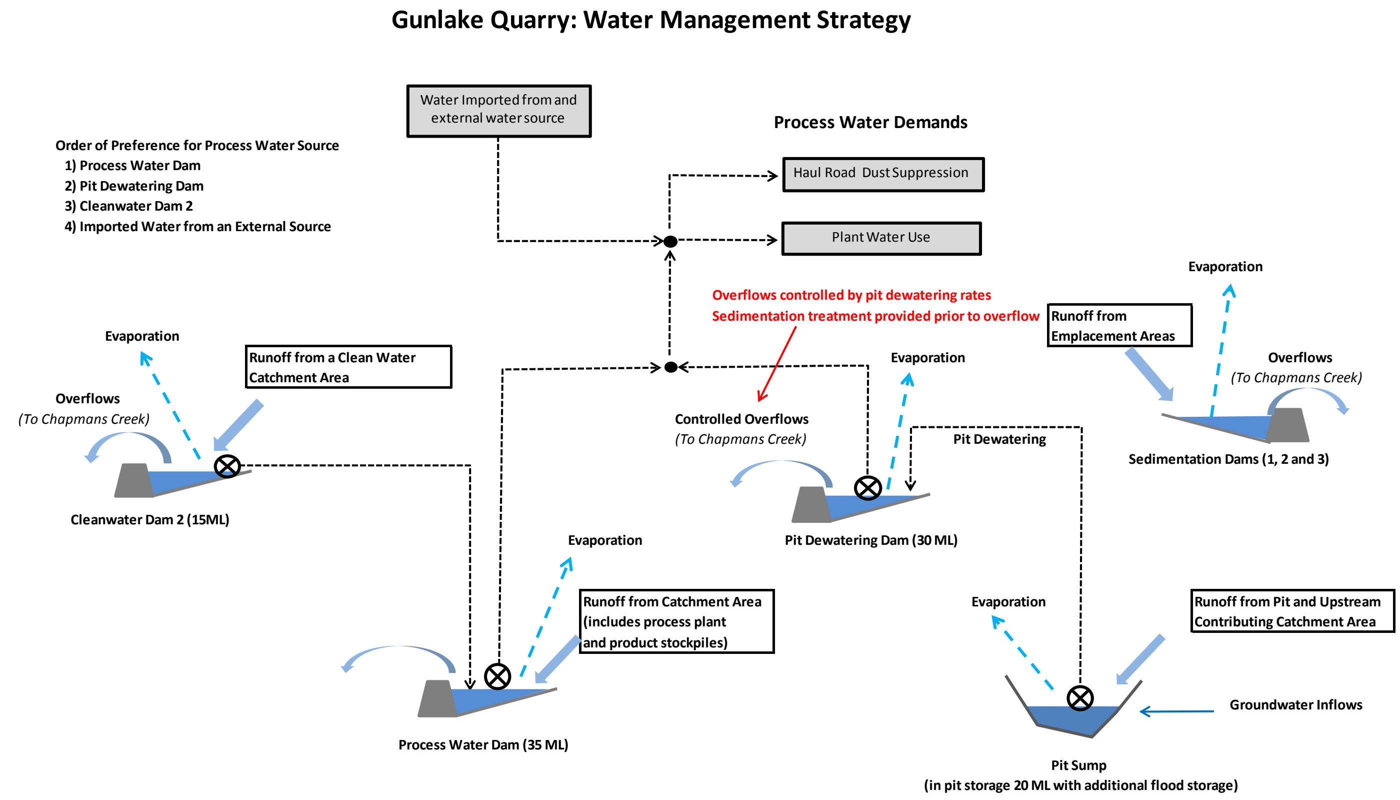


Plate 4-1*- Surface Water Management Strategy*

Managing Runoff from Dirty Water Catchments

Runoff from dirty water catchments will be collected in either the Process Water Dam, or one of the numerous sedimentation dams proposed. All dams will be designed and constructed to provide adequate sedimentation treatment in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008). Refer to the SWMPs presented in **Section 4.4** for the dam locations and contributing catchments at each stage of the quarry life. Sedimentation dam sizing calculations are also provided in **Appendix B** for each stage of the quarry life.

The frequency and volume of overflows from the Process Water Dam and Pit Dewatering Dam will be reduced by the extraction of stored water to meet process water requirements, such as plant and haul road dust suppression.

Managing Pit Water

Water ingress into the pit will occur due to runoff from within the pit footprint and from groundwater inflows. For Quarry Years 10 to 30, the collective contributing catchment area to the pit is estimated to be 53ha. Accordingly, during extended periods of wet weather or following a substantial runoff event, substantial volumes of water will accumulate in the pit, resulting in the need for the pit to be dewatered. The following measures are proposed to manage flood risk to the pit and manage water produced from pit dewatering:

- A pit sump will be progressively maintained throughout the quarry life. Water from the sump will be pumped to a specifically constructed Pit Dewatering Dam. The dam will have a volume of 30 ML and will be constructed as a 'Turkeys Nest' style dam, meaning it will have a minimal catchment area. The Pit Dewatering Dam will provide the following functions:

  - The dam will store water that has been dewatered from the pit for future process water use.
  - During water surplus conditions, controlled release from the Pit Dewatering Dam will be required. All water released will be treated by sedimentation in the dam. Gunlake will monitor the water quality of water released and will provide additional treatment, such as pH adjustment or flocculation if required. As the dam will only receive water from pit dewatering, the release rate can be controlled by the pump dewatering rate (or dam inflow rate) to ensure water quality objectives are achieved.

- Gunlake will be aware of the potential flood risk to the pit and will operate a quarry plan that extracts material from a number of levels within the pit. This will avoid disruptions to the quarry operation if the base of the pit is flooded for a number of months following a substantial runoff event.

Drought Security

The expanded quarry is expected to use 100 to 110 ML (discussed further in **Section 4.3**) of water per year for process water uses such as haul road dust suppression and plant water use. Water balance model results indicate that the quarry's process water requirements will be primarily met by extraction from the proposed water management dams, which receive surface water runoff from a number of dirty and clean water catchment areas as well as groundwater inflows into the pit. As a contingency, if water shortfalls occur for a period of time, Gunlake will either:

- Reduce water usage through the use of chemical dust suppressants;
- Seek an external water source and tanker water to the quarry; or
- Temporarily reduce the scale of the operation to ensure the dust management objectives are being achieved.

Refer to the water balance results presented in **Section 4.3** for further information on the drought security.

Amenities Water Supply

It is understood that a rainwater tank collects runoff from the administration office and maintenance shed roofs. Harvested water is used for non-potable uses such as toilet flushing. The tanks can be filled with imported potable water during periods of water shortages. Drinking water is imported to the site and is provided in all facilities.

Gunlake proposes to continue to operate the current amenities water supply arrangements.

Waste Water Management

The quarry currently operates an onsite waste water treatment and disposal system to manage all waste water produced from the quarry's amenities. Following approval of the expansion project, Gunlake will review the adequacy of this system and will upgrade or replace the system if additional capacity is required due to increased staffing levels associated with the quarry expansion.

4.3 Site Water Balance

A site water balance model was developed for the proposed quarry expansion. The objectives of the water balance are to:

- Quantitatively assess the effectiveness of the surface water management system over the life of the project.
- Quantify the quarry's process water demand and source profiles over the life of the project for a full range of climatic conditions.
- Demonstrate the ability of the proposed surface water management system to manage large volumes of surface water runoff that would occur during periods of prolonged or extreme wet weather.
- Assess the drought security of the operation and identify the risk of process water shortages.
- Assist in the determination of water licensing requirements.

This section details the modelling approach and assumptions. Model results are presented for each SWMP in **Section 4.4**.

4.3.1 Modelling Approach

The water balance model was developed using a Visual-Basics Programme that has been developed independently by RHDHV. The model applies a continuous simulation methodology that simulates the performance of each stage of the SWMP under a range of climatic conditions. The key features of the model are described below:

- The model runs on a daily time-step and requires daily rainfall and evaporation rates as model inputs. The model results are available on a daily time step, but are reported as annual averages to simplify the results presentation.
- The model runs as a continuous simulation and applies a long term (115 year) rainfall record that includes a wide range of embedded dry and wet periods as well as major flood events. The model results are processed to provide a statistical representation of the performance of each SWMP, under a full range of climatic conditions.
- Water demands and sources can be applied at constant rates or through the use of customised dynamic functions.
- Water transfers between storages, demands and sources can be controlled using transfer rules that are based on storage levels, demand requirements and source availability.

A model has been developed for each SWMP discussed in **Section 4**. Results are presented in flow chart format for typical dry (10^{th} Percentile), median (50^{th} Percentile) and wet (90^{th} Percentile) years in **Section 4.4**.

4.3.2 Model Assumptions

This section details the assumptions applied to the water balance model.

Climatic Data

In order to facilitate a comprehensive assessment of a range of climatic conditions, a 115 year simulation period was adopted for the water balance model based on the available rainfall record. This simulation period applies the constructed daily rainfall record that is described in **Section 3.1**. The average monthly evaporation and potential evapotranspiration rates listed in **Table 3-2** were applied to the model.

Calculation of Runoff

The SIMHYD rainfall / runoff model was applied to simulate the rainfall runoff response from the catchments within the quarry's surface water management system. SIMHYD is one of the most commonly used rainfall runoff models in Australia and has been extensively tested using data from across Australia (*Chiew, 2005*). There was no site specific data available to calibrate the rainfall runoff. Accordingly, the SIMHYD model was parametrised to achieve the following long term average volumetric runoff coefficients (C_v), based on typical values for a quarry site:

- **Clean Water Catchments** – C_v 0.1 or 10% or rainfall.
- **Dirty Water Catchments (excluding the pit)** - C_v 0.3 or 30% or rainfall.
- **Pit Area** - C_v 0.43 or 43% or rainfall.

It is noted that SIMHYD calculates runoff on a daily time step, as a function of soil moisture storage. Hence, C_v for any given rainfall event will generally be below the long term average C_v during dry conditions (due to the soils being dry before the event) and above the long term average C_v during wet conditions when the soils are close to saturated before the event. This represents the effects of antecedent soil moisture conditions when calculating daily runoff.

Process Water Demands

The primary process water uses include:

- Water use in the process plant (primarily for dust suppression).
- Water use for haul road dust suppression.

The following sections describe the assumptions and methods applied to calculate process water demands in the water balance model.

Plant Water Use

Water use in the process plant is primarily used for dust suppression. Flow meter data provided by Gunlake indicates that the net water use in the plant is 18.2 L per tonne processed. This is consistent with typical values for a hard rock quarry. The following annual plant water use rates have been adopted for water balance modelling:

- **Approved Quarry Operation** (0.75 Mtpa) – 13.7 ML/year
- **Expanded Quarry Operation** (2 Mtpa) – 36.4 ML/year

Haul Road Dust Suppression

Haul road dust suppression is required on non-rainy days to mitigate dust produced from the operation of trucks and other equipment on the haul roads. Required application rates on any given day are a function of the active haul road area and the prevailing climatic conditions. Accordingly, water usage requirements have been calculated within the water balance model by applying the following equation at each model time step:

$$(\ ) = \quad (\ 0((, \quad (\ ) \times \qquad) - \qquad (\quad) \ ) \times \ 0 \ 1 \ ) \qquad \times \ 0 \ .$$

Where:

DSupp(t) = Daily water use for haul road dust suppression (ML/day)

Evap(t) = Daily pan evaporation (mm/day)

PanCoeff = Evaporation adjustment coefficient

Rain(t) = Daily rainfall (mm/day)

HRArea = Area of active haul road (ha)

An evaporation adjustment coefficient (PanCoeff, as outlined in the equation above) of 0.72 was adopted based on the outcomes of previous water balance projects completed by RHDHV. This achieves an annualised average application rate of **2.3 L/m^2/day**, which is within the range of typical values (1.3 to 3 L/m^2/day) published in an Australian Coal Association Research Program (ACARP) commissioned study titled *Understanding Leading Practice in Water Management* (Project C16035, 2008).

Plate 4-2 plots the predicted monthly average and 10th and 90th Percentile application rates that have been calculated using the methods described above. These results demonstrate the seasonal variation in application rates achieved by the modelling approach.

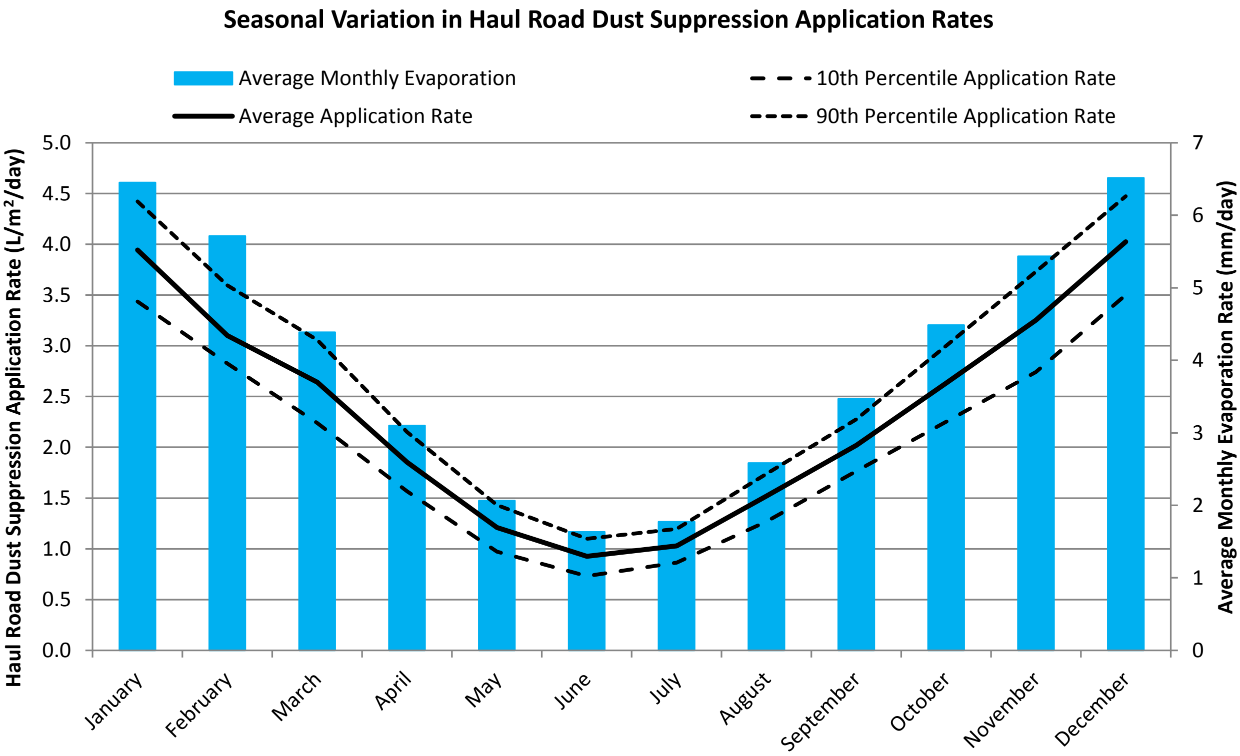


***Plate 4-2** – Seasonal Variation in Haul Road Dust Suppression*

Net haul road dust suppression water use was calculated for each SWMP using the above methods and the following total haul road area:

- **Approved Quarry Operation** (0.75 Mtpa) – 5 ha of haul road. This was the adopted haul road area in the surface water assessment prepared for the quarries expansion to 0.75 Mtpa (Cardno, 2014).
- **Expanded Quarry Operation** (2 Mtpa) – 8 ha of haul road. This area was estimated based on the relative increase in the quarry footprint.

Table 4-2 presents the estimated 10th, 50th and 90th Percentile annual water use for haul road dust suppression for the approved and expanded quarry operation. 10th Percentile use rates are indicative of use rates during wet years when rainfall is higher and 90th Percentile rates are indicative of use rates during dry years, when rainfall is lower.

Table 4-2 – *Estimated Haul Road Dust Suppression Water Use Rates*

Stage of Mine Plan	Area of Haul Road	Estimated Water Usage for Haul Road Dust Suppression		
		10th Percentile	50th Percentile	90th Percentile
	(ha)	(ML/year)	(ML/year)	(ML/year)
Approved Quarry	5.0[1]	41	43	45
Expanded Quarry	8.0	66	69	73

Note 1: Adopted haul road area from Gunlake Quarry Marulan: Water Assessment (Cardno, 2014)

Water Management Dams

Relevant water management dams were included in the model for each SWMP. Evaporation losses will occur from all water storages. The model calculates evaporation losses on a daily time step as a function of:

- **Evaporation Rates** - the average monthly evaporation rates provided in **Table 3-2** were applied to the water balance model. A Pan Coefficient of 0.7 was applied to all evaporation loss calculations from water management dams.

- **Dam Surface Area -** is a function of the dam stage (or level) and the stage / volume properties of the storage. The water balance model calculates the surface area at each daily time step based on the dam stage and assumed stage / volume properties of each storage. The assumed maximum storage and average depth of each dam is provided in the model assumption sheet provided in **Appendix B** for each SWMP.

Groundwater Inflows

Groundwater inflows into the pit are expected to occur at varying rates over the life of the quarry as a result of depressurising the local groundwater system. **Table 4-3** provides estimated inflow rates that were established as part of the Groundwater Impact Assessment (EMM, 2015).

Table 4-3 – *Groundwater Inflow Rates*

Quarry Year	Average Pit Seepage Rates
	(ML/year)
1-5	0
5-10	23
10-20	37
20-30	34

Note: Groundwater inflow rates sourced from the Groundwater Impact Assessment (EMM, 2015)

4.4 Surface Water Management Plans

This section documents Surface Water Management Plans (SWMPs) and site water balance results for the following stages of the quarry operation:

- **Approved Operation**: A SWMP for the currently approved quarry operation has been prepared to enable the impacts of the proposed quarry expansion to be assessed relative to the approved operation.

- **Expanded Operation:** SWMPs have been prepared for Quarry Years 1, 5 and 10 to 30. It is noted that the pit will be developed to its ultimate footprint by Quarry Year 10, with the pit progressively becoming deeper over the remaining 20 year quarry life. As the pit footprint will not change between Quarry Years 10 to 30, a common SWMP has been developed for this period.

- **Final Void:** Water balance modelling for the final void has been undertaken to establish its long term hydrologic regime, following the completion of quarrying operations. Final void water balance results are discussed in **Section 4.5**.

For each of the above SWMPs, the following information is provided:

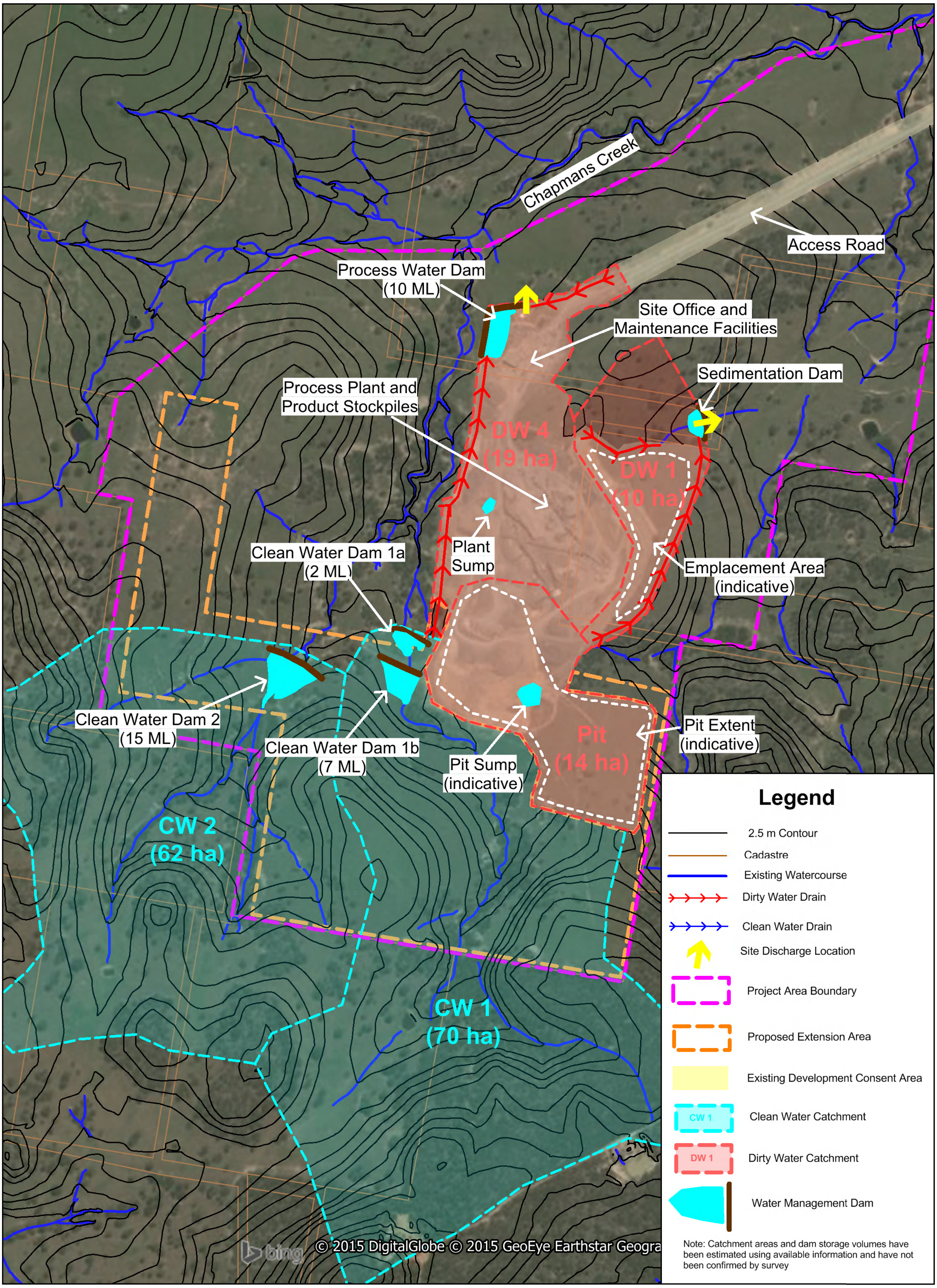
- A SWMP figure has been prepared that depicts key catchment areas, water management dam locations and sizes, clean and dirty water drains and site discharge locations.
- Water balance results are presented in flow chart form for typical dry (10th Percentile), median (50th Percentile) and wet (90th Percentile) rainfall years. The flow charts show total water movements over the year.
- Water balance summary sheets are provided in **Appendix B**. Each sheet includes the following information:
  - A summary of key water balance assumptions applicable to the SWMP.
  - The above-mentioned flow charts at full page scale.
  - A sedimentation dam calculation sheet.

4.4.1 SWMP for Approved Operation

As outlined earlier, a SWMP for the approved quarry operation has been prepared to enable the impacts of the proposed quarry expansion to be assessed relative to the approved operation. The SWMP was developed based on information provided in *Gunlake Quarry: Water Assessment* (Cardno, 2014). The water balance model was developed to reflect the SWMP. The model methodologies and assumptions described in **Section 4.3** of this report were applied to enable the results to be directly compared to the quarry expansion scenario results.

It is noted that catchment areas and dam storage volumes have been estimated using available data and have not been confirmed by survey.

Figure 1 shows the SWMP for the approved operation. Water balance results are presented in **Plates 4-3**, **4-4** and **4-5** for dry, median and wet rainfall years respectively.



Royal HaskoningDHV
Enhancing Society Together

Figure 1 **Approved Operation: Surface Water Management Plan**

NORTH

0 100 200m
Approx. Scale

SCALE 1:10,000 PAGE SIZE A4

FILEPATH I:\Projects\PA1052 - Gunlake Quarry -EIS\E - Technical Data\E13 GIS

Gunlake Quarry: Site Water Balance: Approved Operation: Surface Water Management Plan
Typical Dry (10th Percentile) Rainfall Year
Annual Rainfall *451 mm/year*

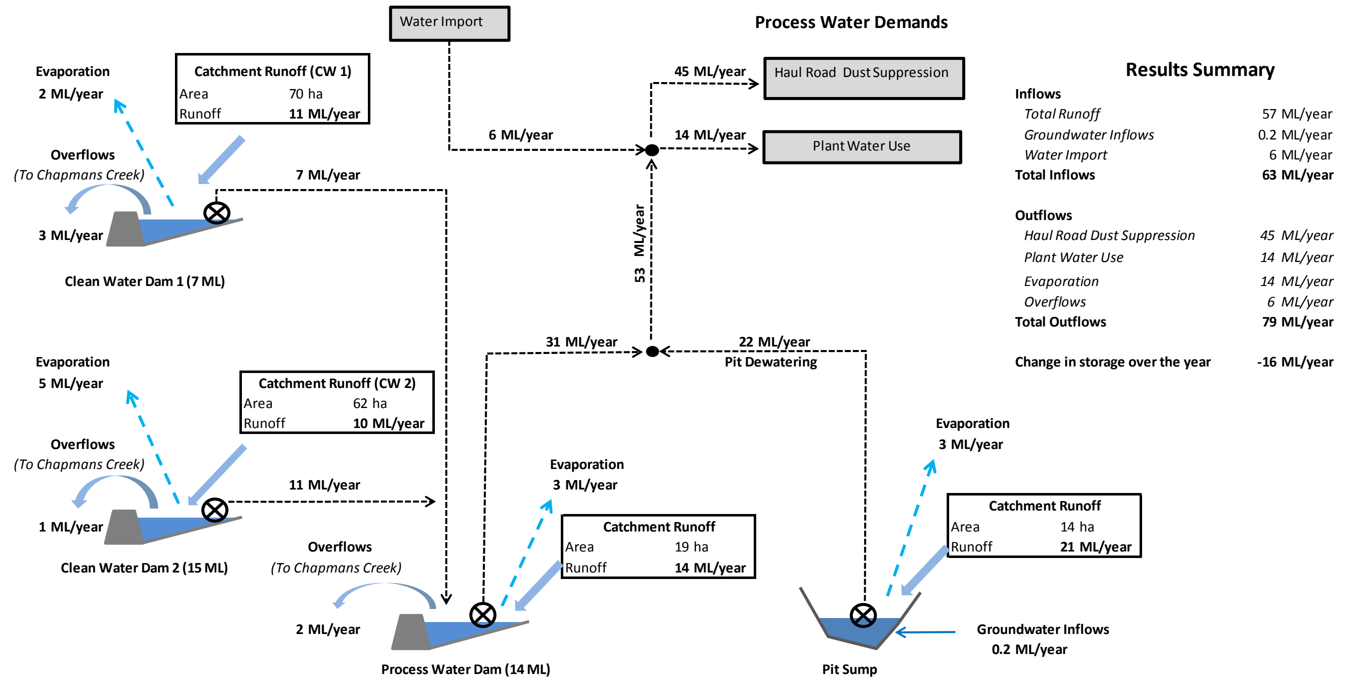


***Plate 4-3** – Approved Operation: Water Balance Results for a Typical Dry Rainfall Year*

Gunlake Quarry: Site Water Balance: Approved Operation: Surface Water Management Plan
Typical Median (50th Percentile) Rainfall Year
Annual Rainfall *695 mm/year*

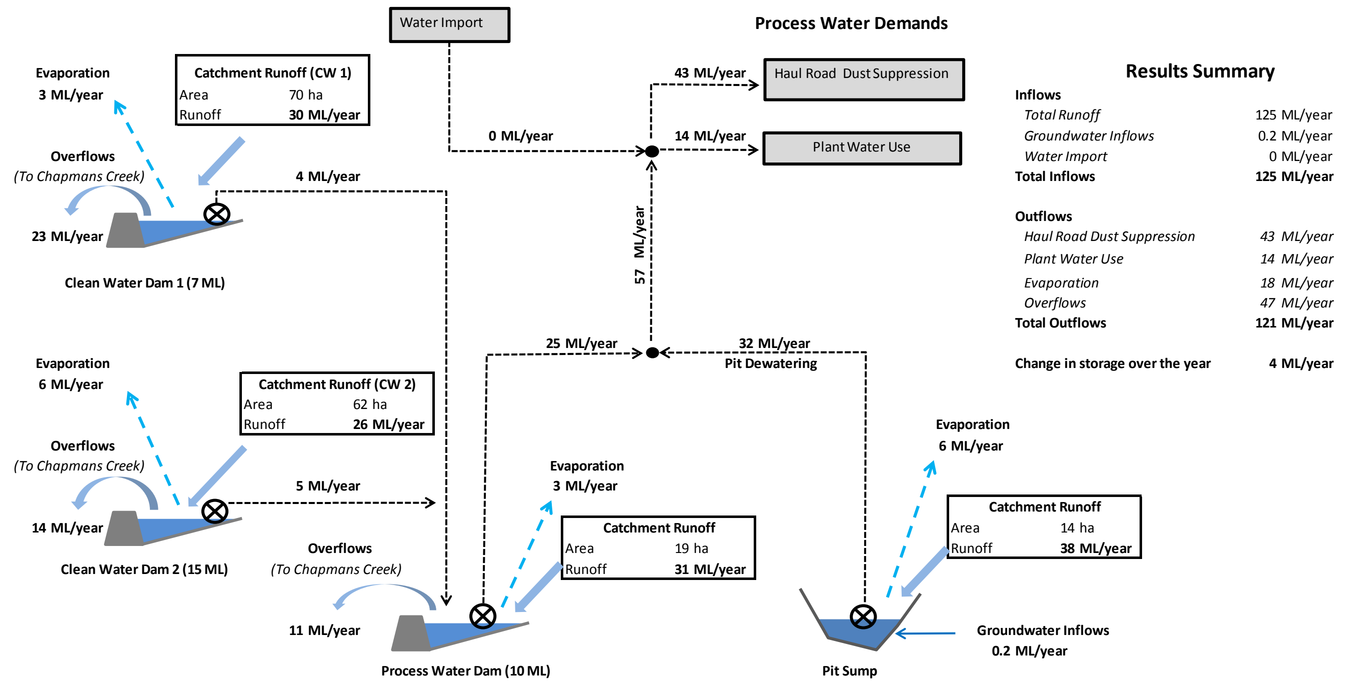


***Plate 4-4** – Approved Operation: Water Balance Results for a Typical Median Rainfall Year*

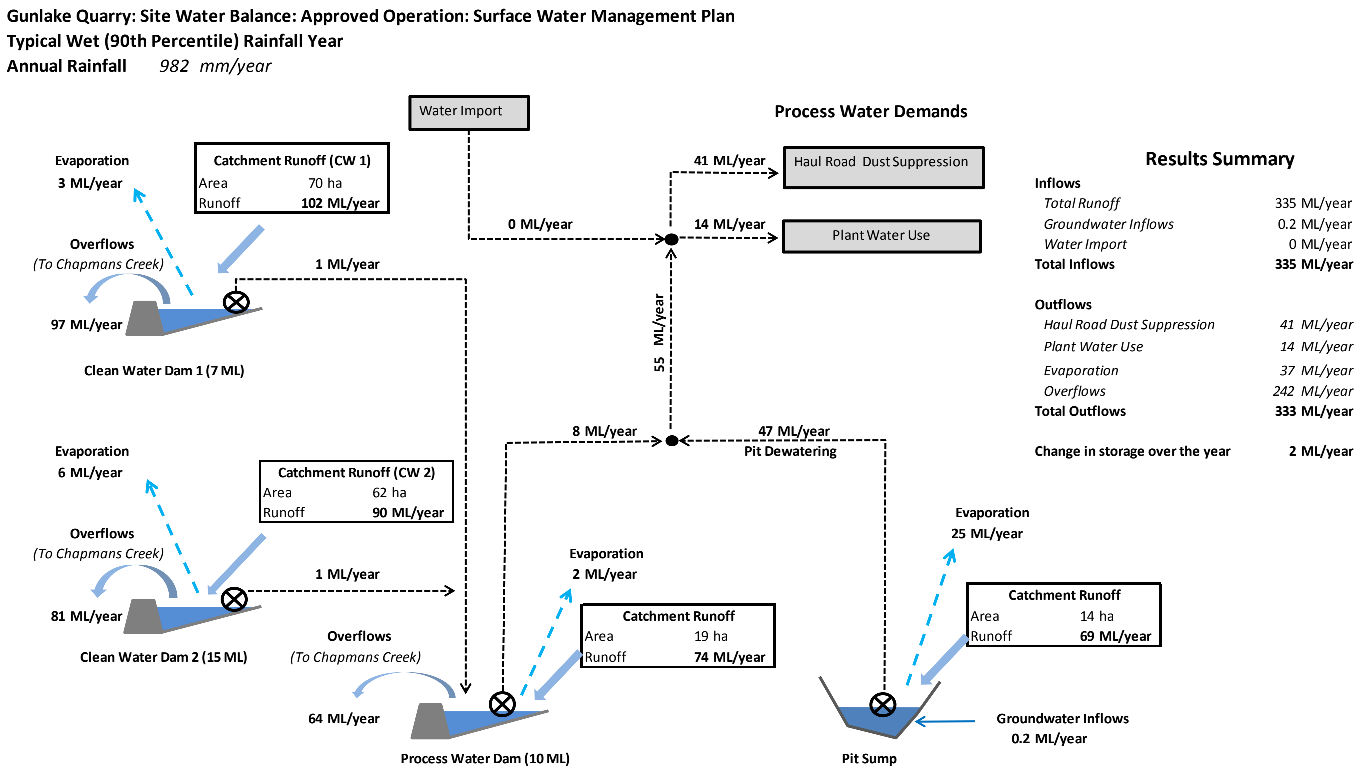


***Plate 4-5** – Approved Operation: Water Balance Results for a Typical Wet Rainfall Year*

The water balance results for the approved operation indicate that:

- Runoff volumes from the dirty water catchments DW-1 and the Pit exceed the process water use volumes in median and wet years. This results in overflows from the Process Water Dam.
- During median and dry years, water is harvested from Cleanwater Dams 1 and 2 to supplement process water supply from the pit sump and Process Water Dam. Model results indicated that during dry years, there will be periods of water shortages and externally soured water is likely to be required to supplement process water demand.

4.4.2 SWMPs for the Quarry Extension Project

The proposed quarry extension project will comprise the expansion of the existing pit to the south and west and the establishment of an additional emplacement area to the west of Cleanwater Dam 2. The pit will be progressively developed to its final footprint by Quarry Year 10. Process water use is expected to increase as a result of the increased in the production rate from 0.75 to 2.0 Mtpa.

The following surface water controls are proposed to manage the potential impacts associated with the expansion project and provide a reliable supply of water for the quarry operation:

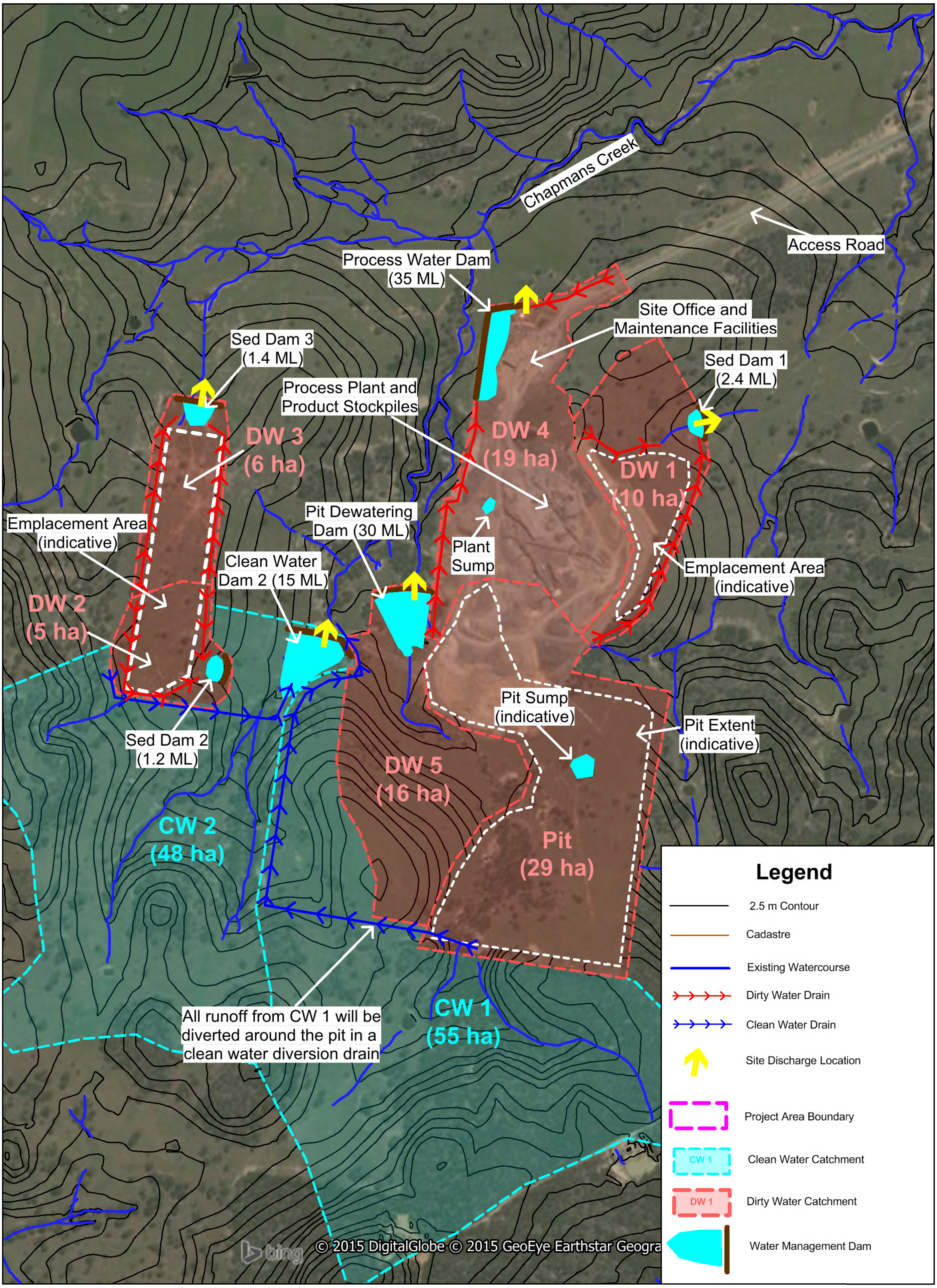
- A clean water diversion channel will be constructed to divert runoff from a clean water catchment that is located to the south of the pit. The channel will be constructed along the southern and western edges of the final pit extent. Due to topographic constraints, the channel will need to be excavated to depths of up to 10 m to drain freely under gravity. When the pit is established to its final extent, the channel will be established on one of the upper benches within the quarry and will permanently divert clean water around the pit.

- Cleanwater Dams 1a and 1b will be removed and a 30 ML Pit Dewatering Dam will be constructed at the Cleanwater Dam 1a location. This dam will initially provide the following two functions:
  - Management of water that has been dewatered from the pit (as described in **Section 4.2**); and
  - Sedimentation treatment for runoff from upstream areas that will be disturbed by pre-stripping activities. The contributing catchment area to the Pit Dewatering Dam will progressively decrease as the pit development progresses. The dam will have a minimal catchment area by Quarry Year 10, when the pit has been developed to its ultimate footprint. Sedimentation dam calculations are provided in **Appendix B**.
- The Process Water Dam will be expanded from 10 ML to 35 ML. This will be achieved by raising the existing embankment by approximately 2 m and excavation of additional storage to the south of the existing storage.
- Two sedimentation dams (referred to as Sedimentation Dams 2 and 3) will be constructed to treat runoff from the proposed emplacement area. Sedimentation dam calculations are provided in **Appendix B**.
- Clean Water Dam 2 will continue to operate. This dam will receive runoff from an upstream clean water catchment (CW-2) as well as treated overflows from Sedimentation Dam 2.

The following sections present the SWMP and water balance results for Quarry Years 1, 5 and 10 to 30. This is followed by a results summary.

Quarry Year 1 SWMP and Water Balance Results

The SWMP for Quarry Year 1 is provided in **Figure 2**. Water balance results are presented in **Plates 4-6**, **4-7** and **4-8** for dry, median and wet rainfall years respectively. **Appendix B** contains a water balance summary sheet which includes applicable assumptions, water balance results (presented on a full page scale) and sedimentation dam calculations.



Royal HaskoningDHV
Enhancing Society Together

Figure 2 Quarry Year 1: Surface Water Management Plan

NORTH

0 100 200m
Approx. Scale

SCALE 1:10,000

PAGE SIZE A4

FILEPATH I:\Projects\PA1052 - Gunlake Quarry -EIS\E - Technical Data\E13 GIS

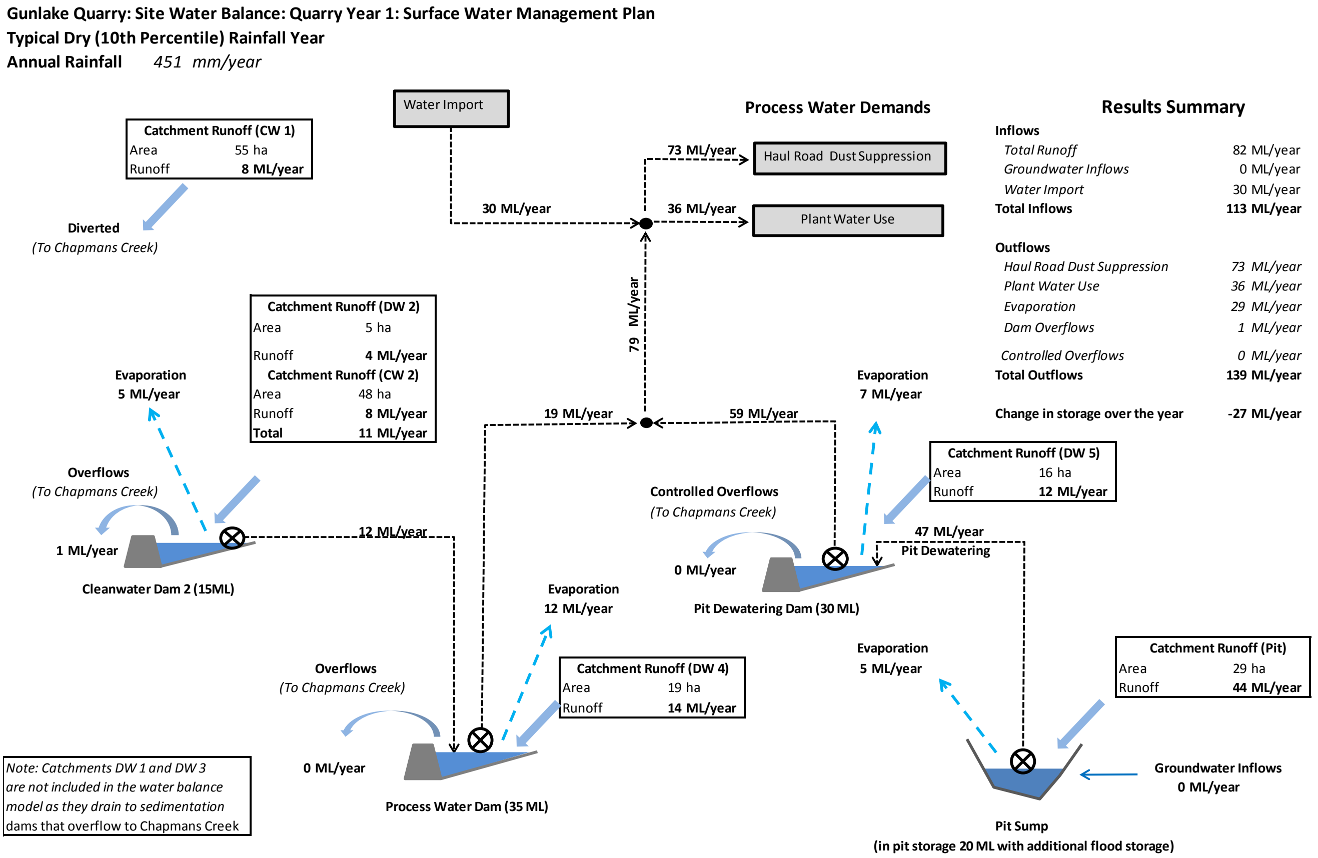


***Plate 4-6** – Quarry Year 1: Water Balance Results for a Typical Dry Rainfall Year*

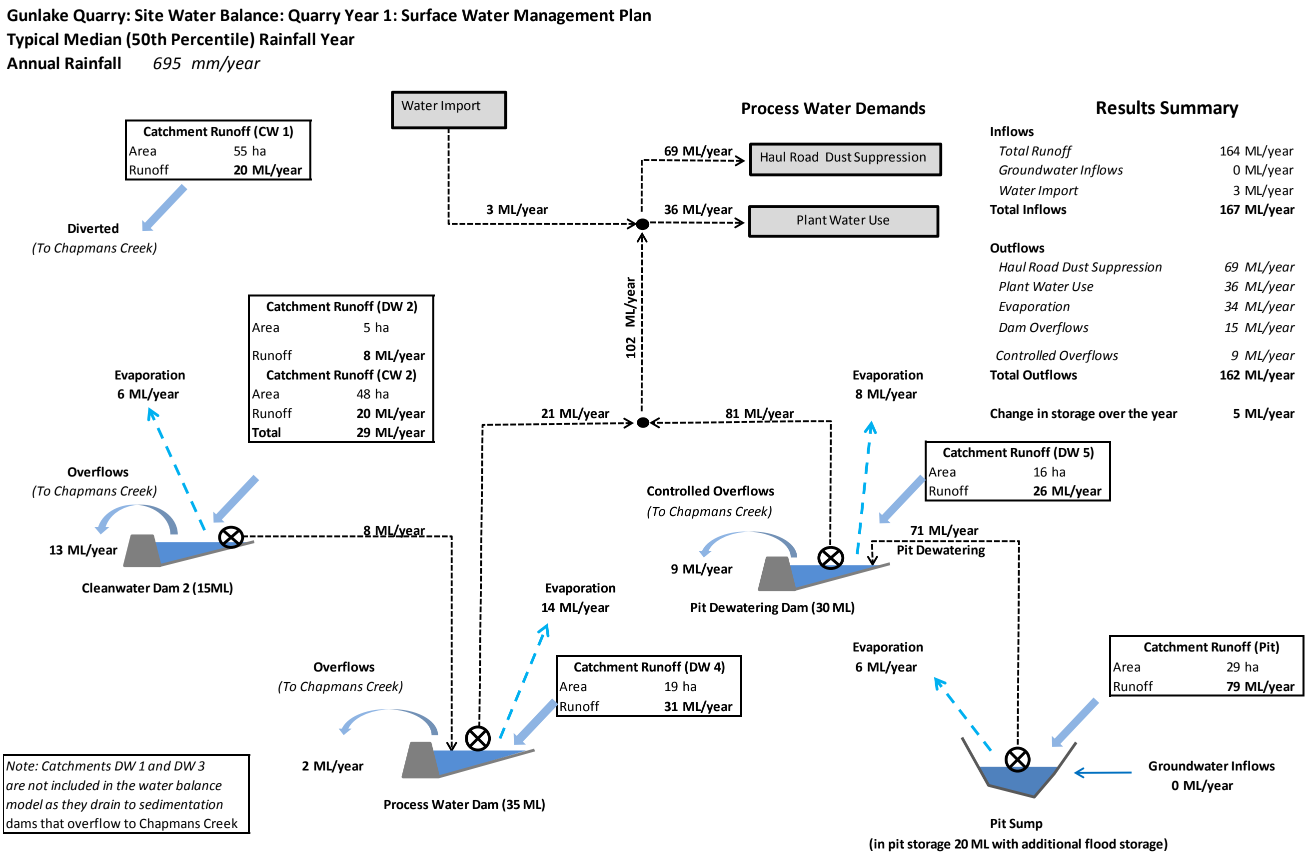


Plate 4-7 – *Quarry Year 1: Water Balance Results for a Typical Median Rainfall Year*

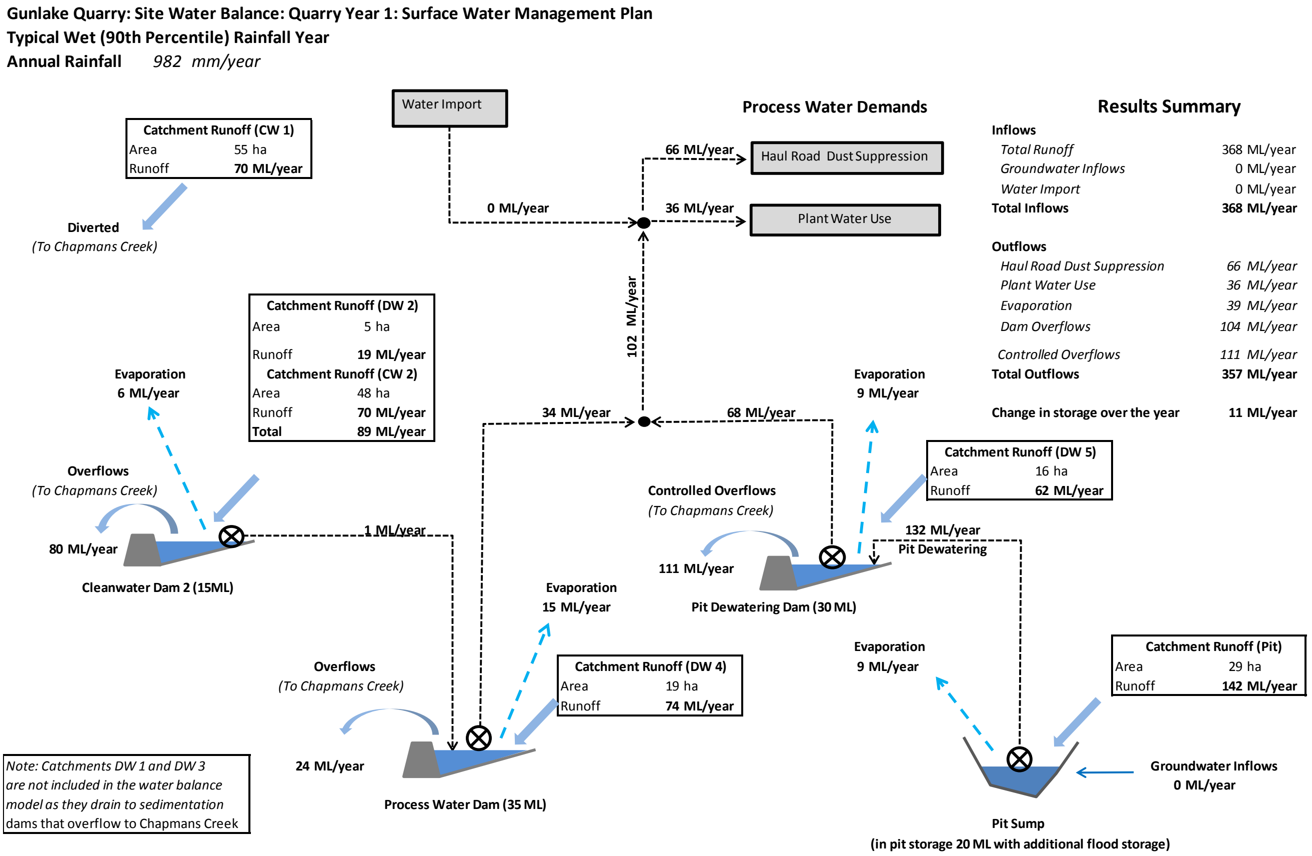
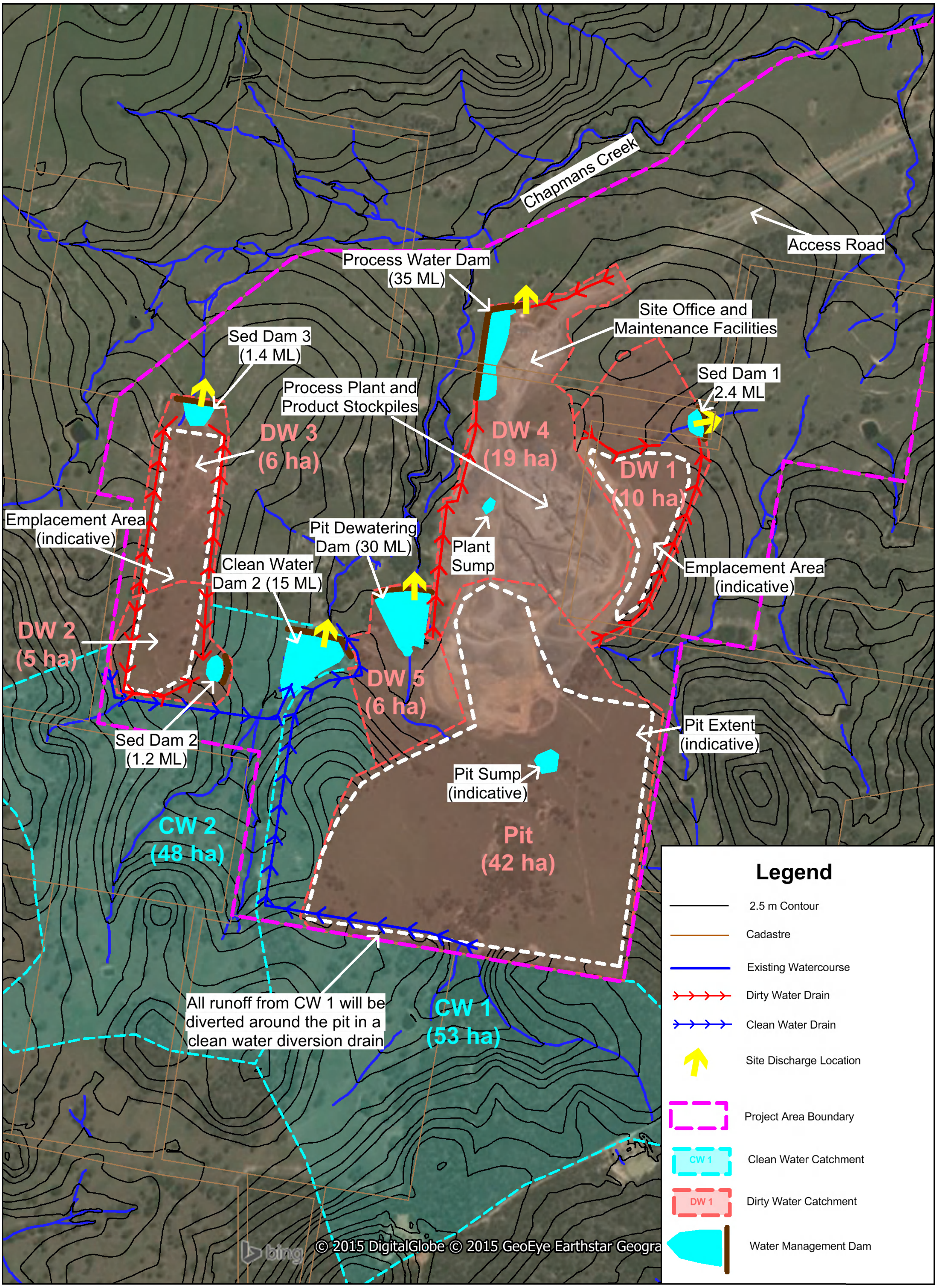


Plate 4-8 *– Quarry Year 1: Water Balance Results for a Typical Wet Rainfall Year*

Water balance results are summarised at the end of this section.

Quarry Year 5 SWMP and Water Balance Results

The SWMP for Quarry Year 5 is provided in **Figure 3**. Water balance results are presented in **Plates 4-9**, **4-10** and **4-11** for dry, median and wet rainfall years respectively. **Appendix B** contains a water balance summary sheet which includes applicable assumptions, water balance results presented on a full page scale and sedimentation dam calculations.



Royal HaskoningDHV
Enhancing Society Together

Figure 3 Quarry Year 5: Surface Water Management Plan

NORTH

0 100 200m
Approx. Scale

SCALE 1:10,000

PAGE SIZE A4

FILEPATH I:\Projects\PA1052 - Gunlake Quarry -EIS\E - Technical Data\E13 GIS

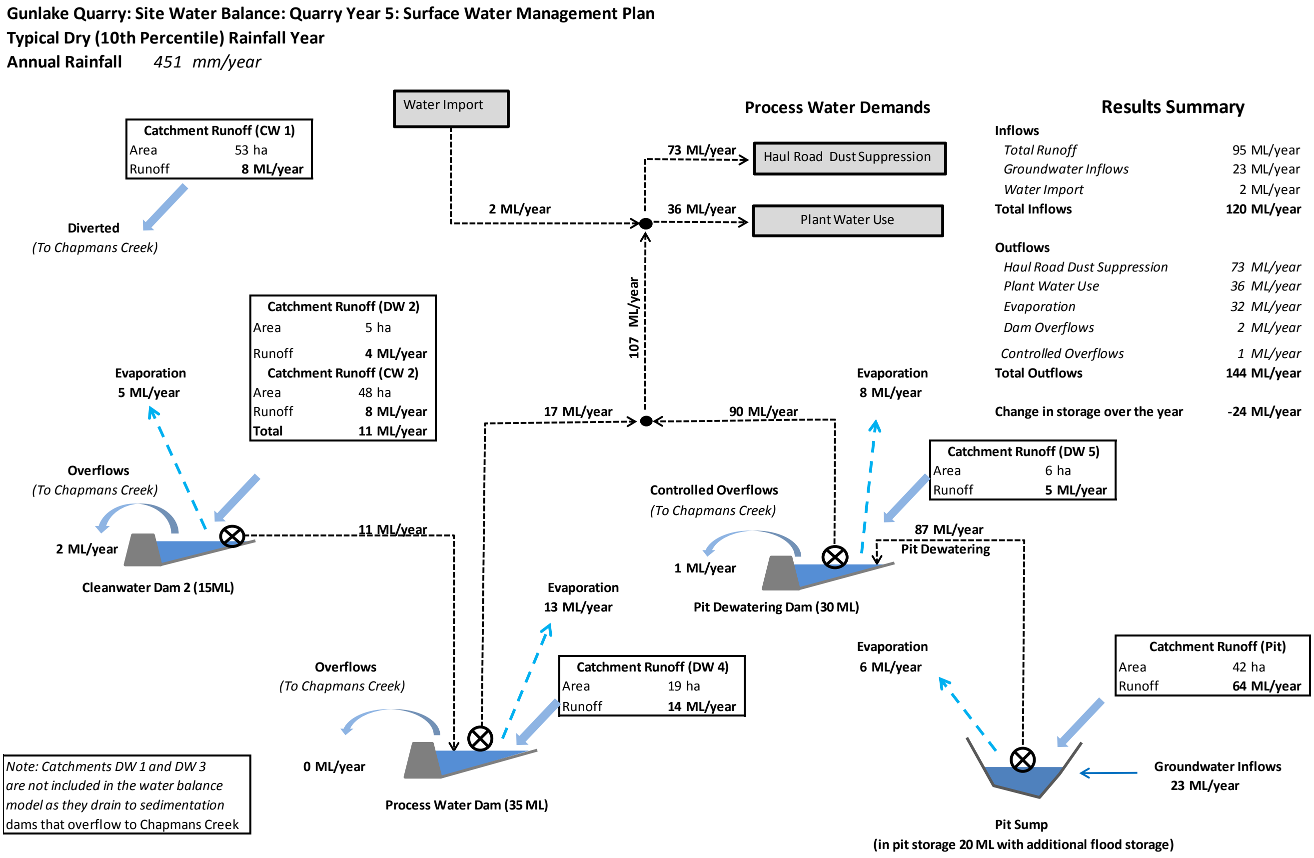


***Plate 4-9** – Quarry Year 5: Water Balance Results for a Typical Dry Rainfall Year*

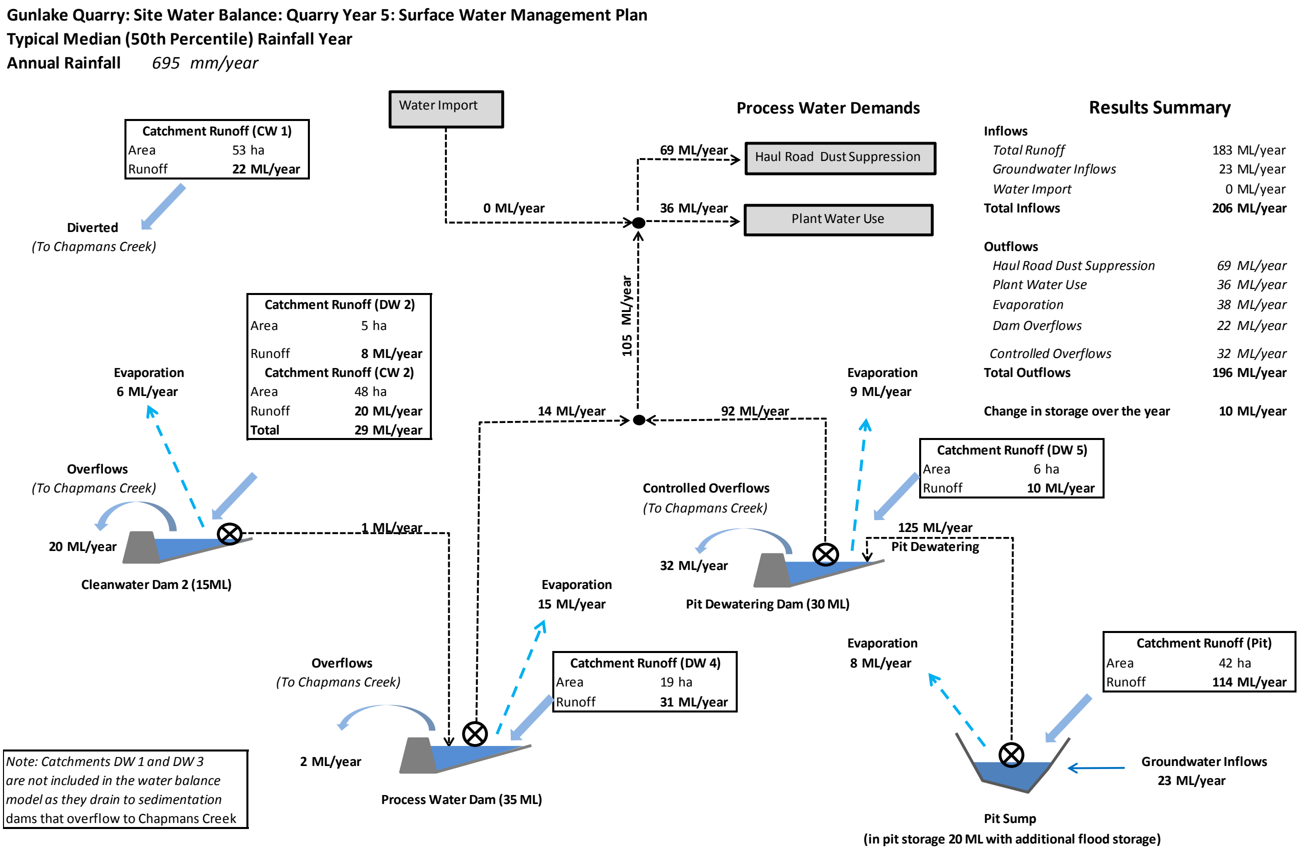


Plate 4-10 – *Quarry Year 5: Water Balance Results for a Typical Median Rainfall Year*

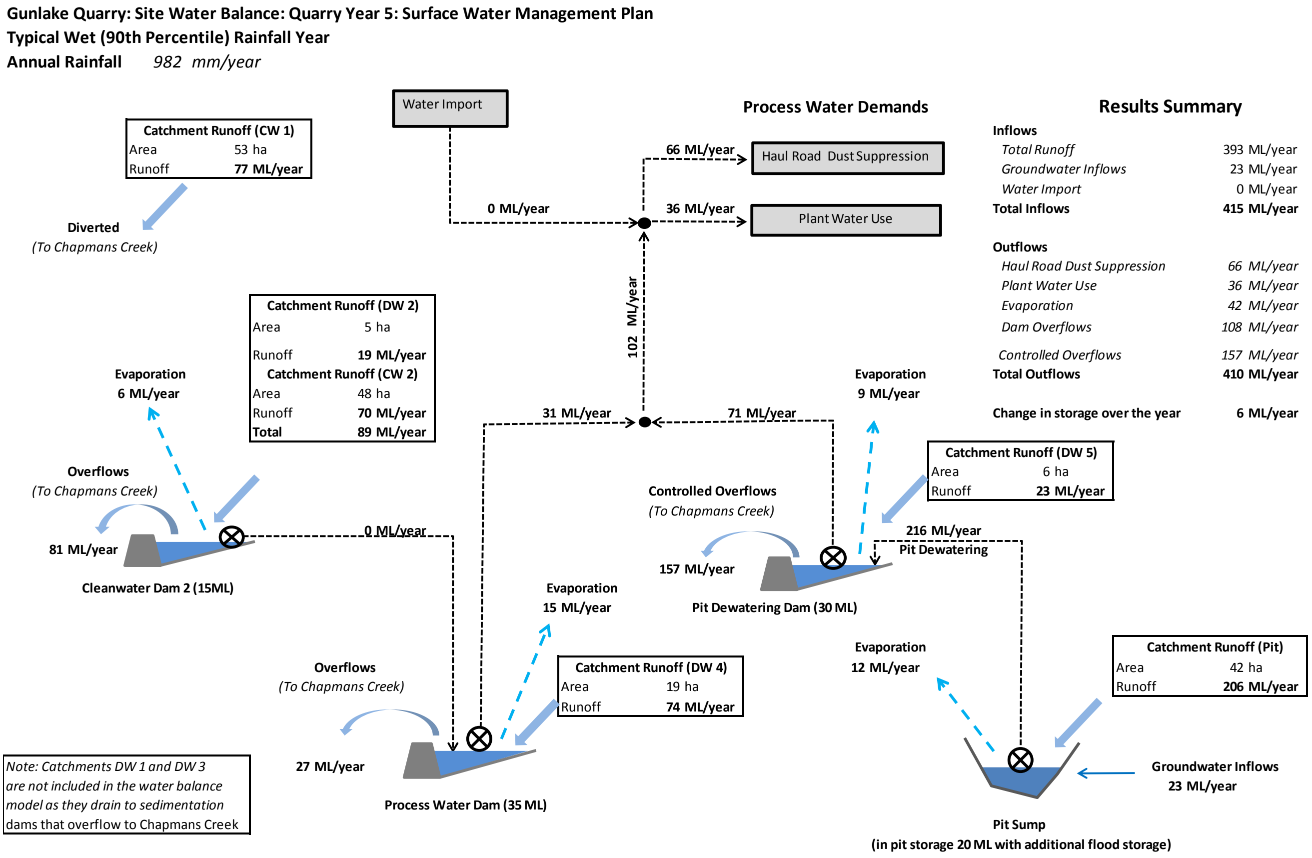
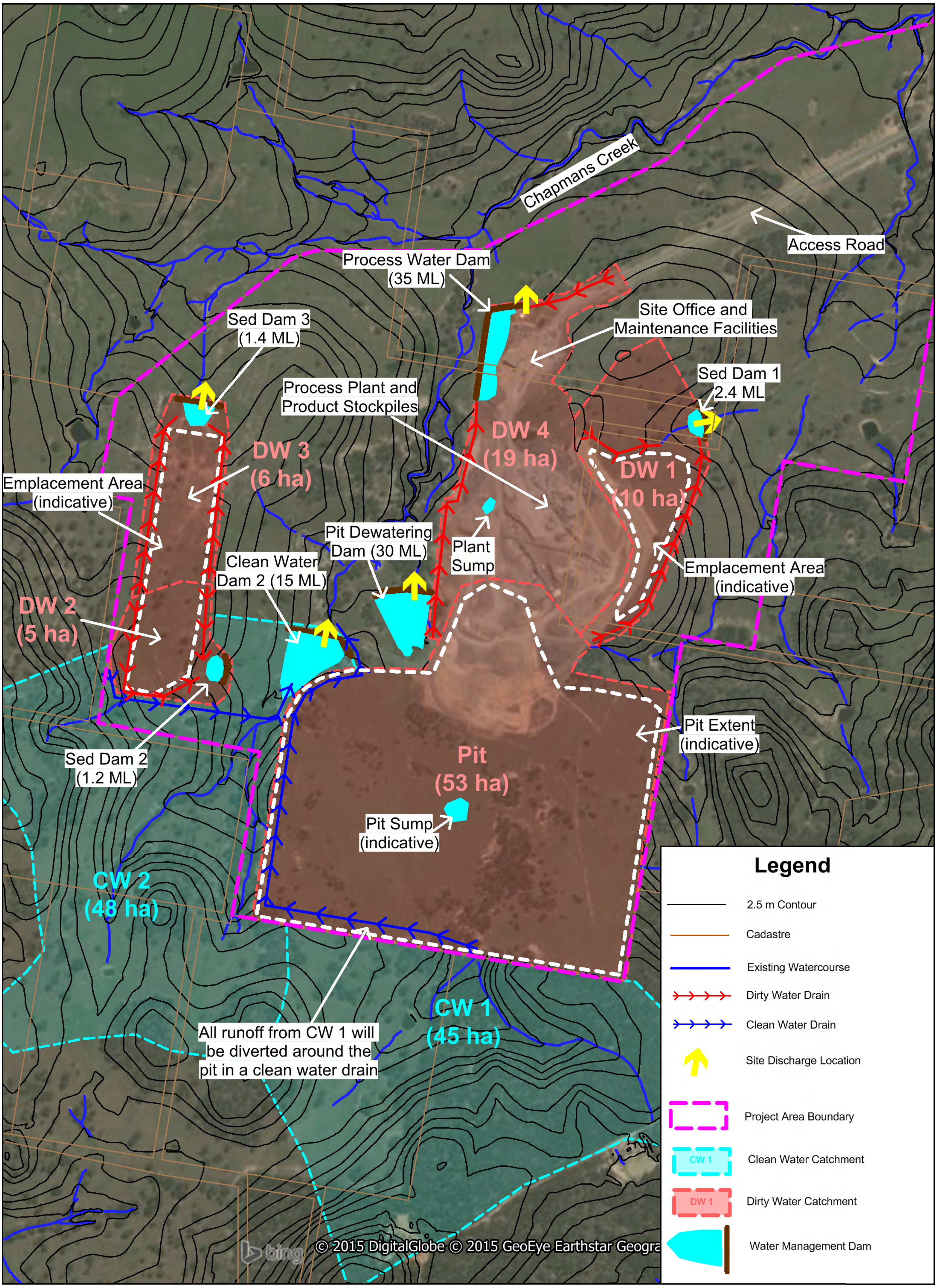


***Plate 4-11** – Quarry Year 5: Water Balance Results for a Typical Wet Rainfall Year*

Water balance results are summarised at the end of this section.

Quarry Years 10 to 30 SWMP and Water Balance Results

The SWMP for Quarry Years 10 to 30 is provided in **Figure 4**. Water balance results are presented in **Plates 4-12**, **4-13** and **4-14** for dry, median and wet rainfall years respectively. **Appendix B** contains a water balance summary sheet which includes applicable assumptions, water balance results presented on a full page scale and sedimentation dam calculations.



Royal HaskoningDHV
Enhancing Society Together

Figure 4 Quarry Years 10 to 30: Surface Water Management Plan

NORTH

0 100 200m
Approx. Scale

SCALE 1:10,000 PAGE SIZE A4

FILEPATH I:\Projects\PA1052 - Gunlake Quarry -EIS\E - Technical Data\E13 GIS

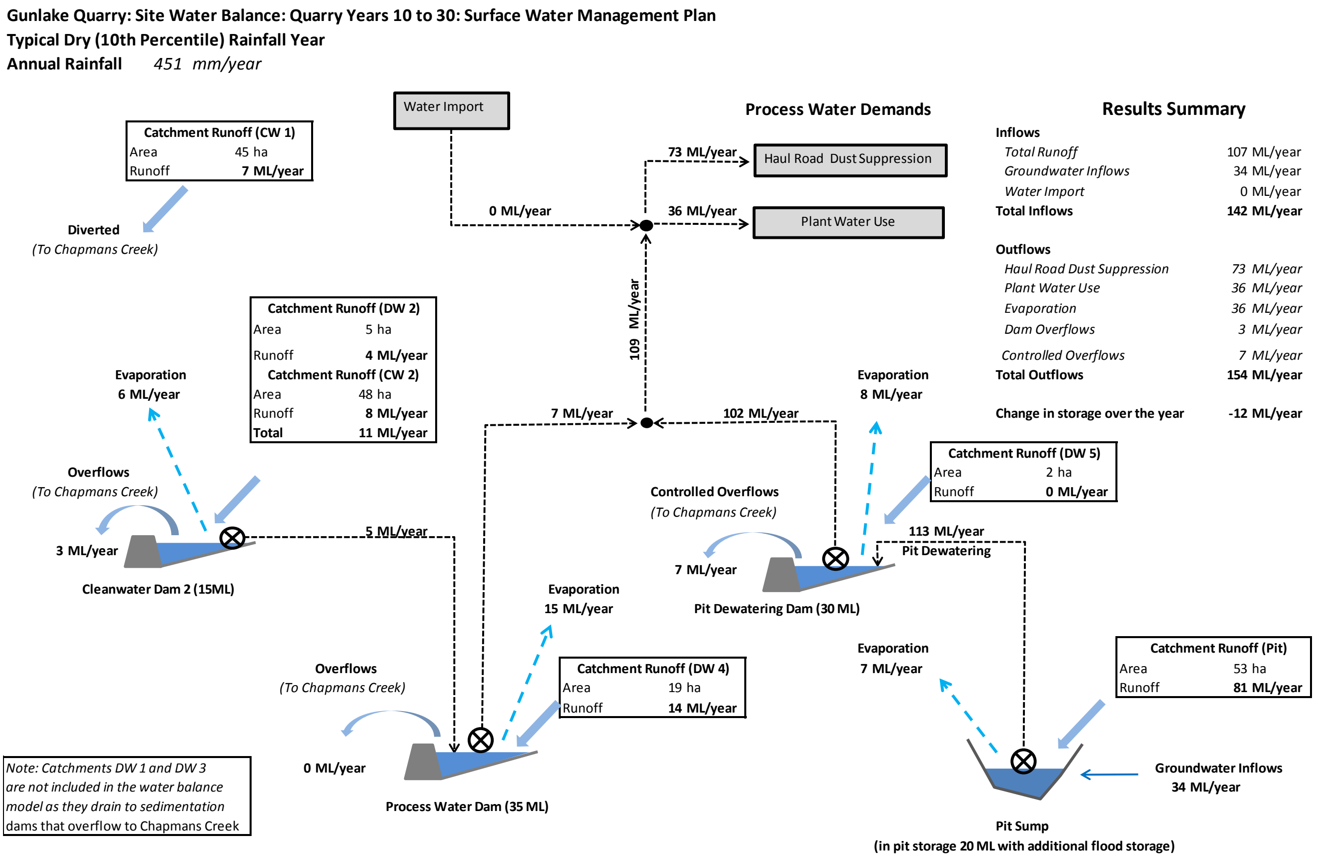


Plate 4-12 – *Quarry Years 10 to 30: Water Balance Results for a Typical Dry Rainfall Year*

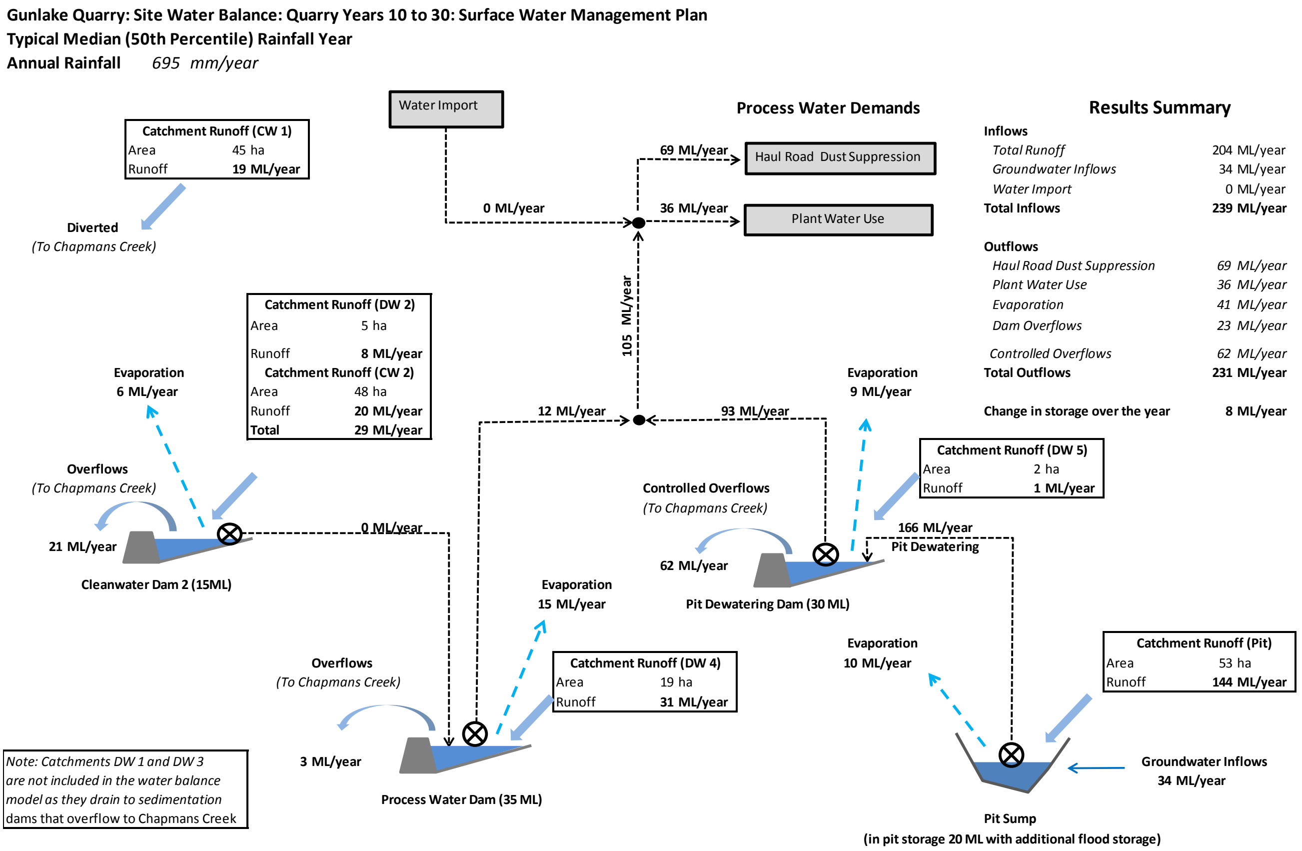


Plate 4-13 – *Quarry Years 10 to 30: Water Balance Results for a Typical Median Rainfall Year*

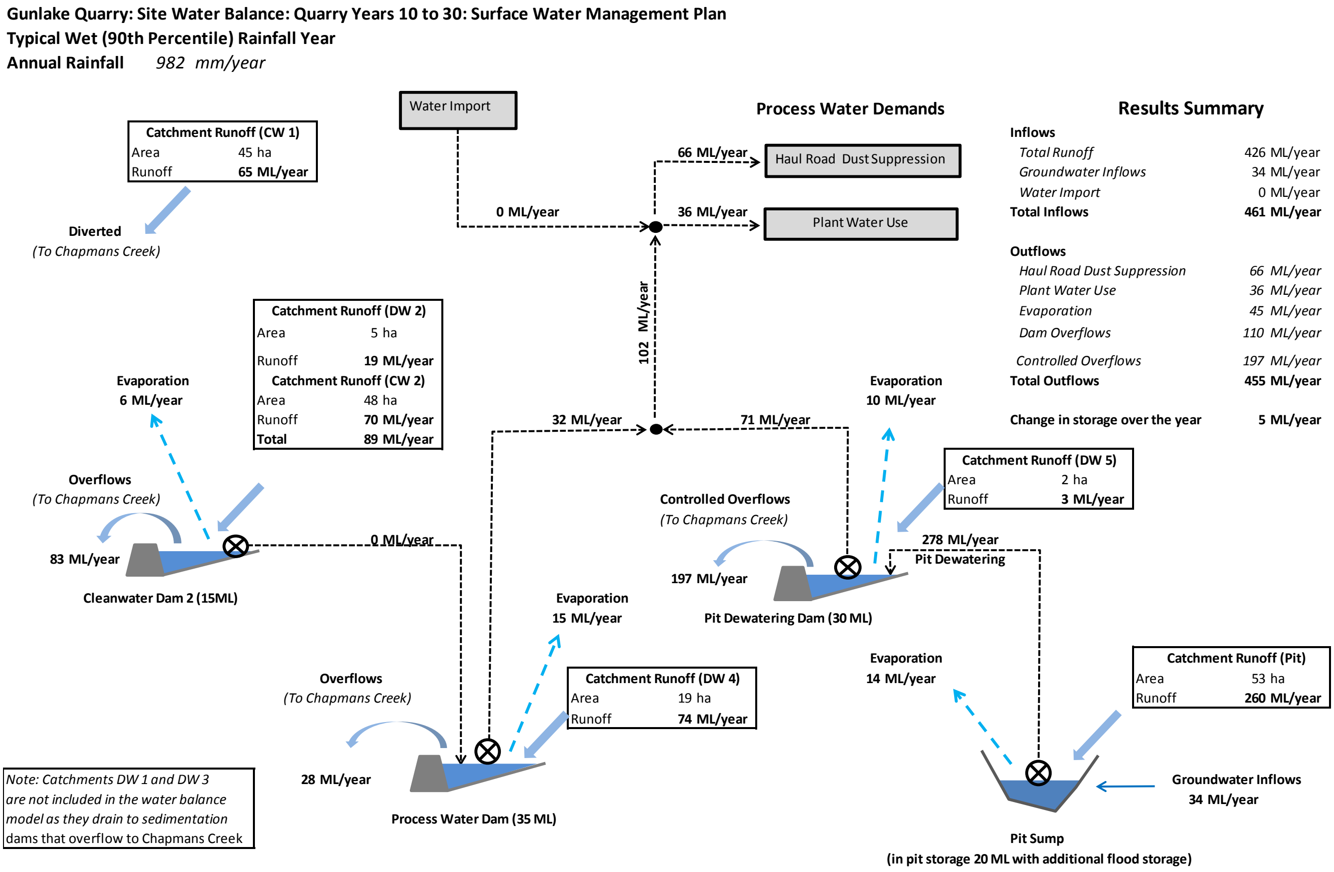


***Plate 4-14** – Quarry Years 10 to 30: Water Balance Results for a Typical Wet Rainfall Year*

Water balance results are summarised at the end of this section.

Water Balance Results Summary

This section provides a summary of the water balance results. The following charts compare the results from the approved operation and the three extension project SWMPs:

- **Plate 4-15** compares the predicted annual overflow volumes from the Process Water Dam.
- **Plate 4-16** compares the predicted annual overflow volumes from the Pit Dewatering Dam.
- **Plate 4-17** compares the predicted annual water import volumes.

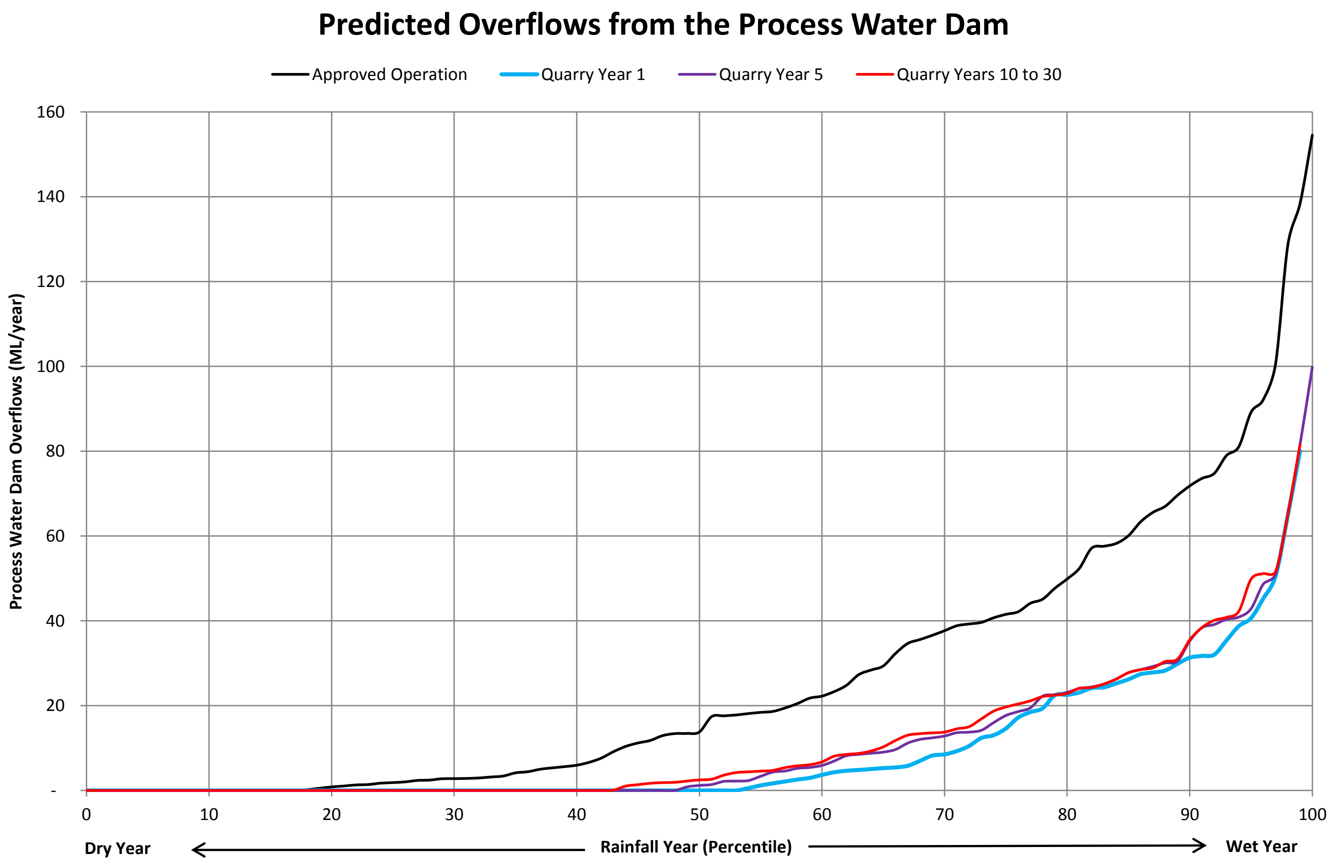


***Plate 4-15** – Predicted overflows from the Process Water Dam*

Water balance model results presented in **Plate 4-15** indicate that both the frequency and volume of overflows from the Process Water Dam will significantly reduce following the expansion of the quarry. This is due to the Process Water Dam being expanded from a 10 to 35 ML storage volume and the expected higher rate of process water extraction from the dam.

During overflow conditions, the Process Water Dam will provide sedimentation treatment to all runoff that passes through the dam. The sedimentation dam calculations provided in **Appendix B** establish that for the dam's contributing 19ha catchment area, a 4.6 ML sedimentation treatment volume would provide adequate sedimentation treatment. The proposed dam volume of 35 ML will provide more than 7 times the calculated treatment volume and is therefore expected to outperform the minimum standards for sedimentation treatment as recommended in the *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008).

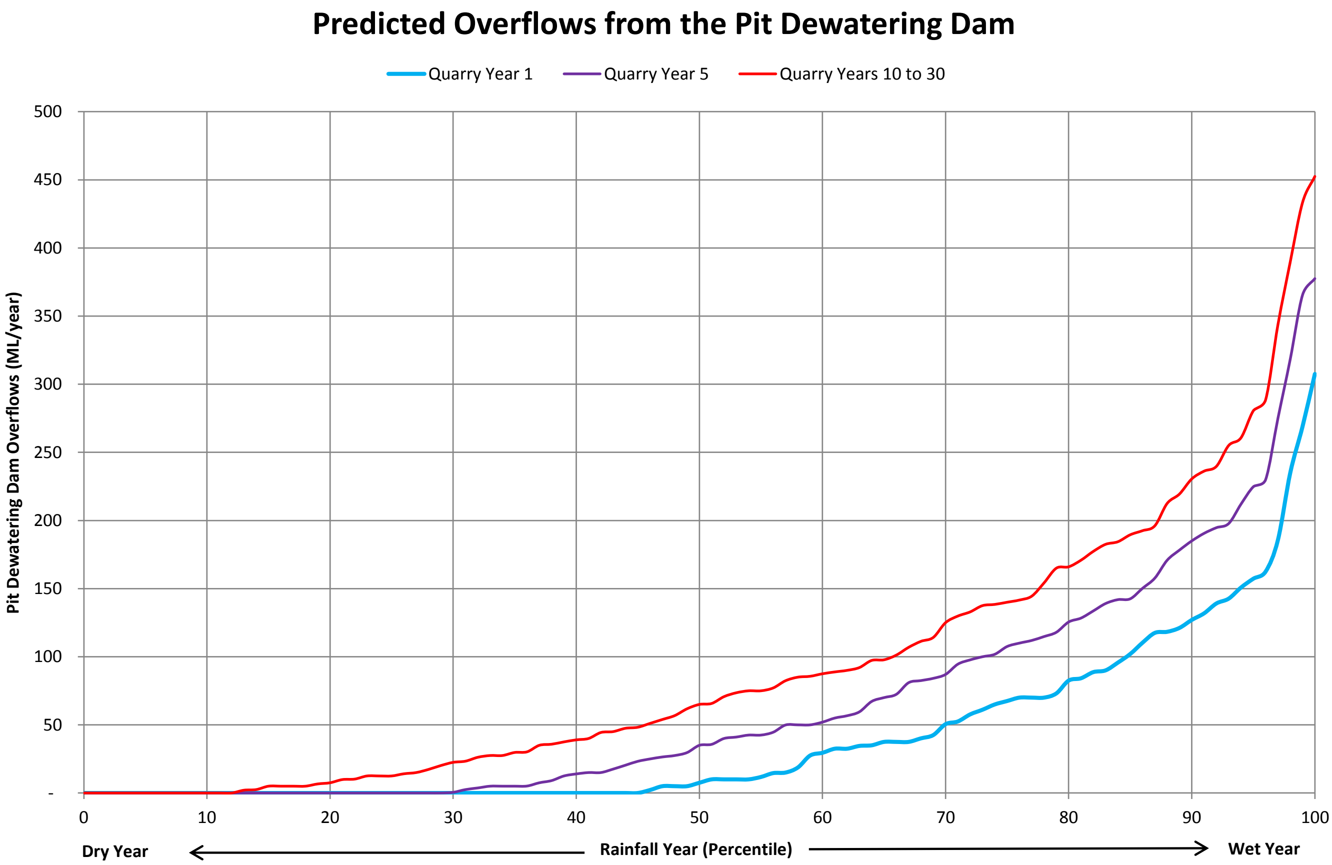


Plate 4-16 *– Predicted overflows from the Pit Dewatering Dam*

As discussed in **Section 4.2**, a 30ML Pit Dewatering Dam will be constructed to receive water that is dewatered from the pit. The dam will also provide a sedimentation dam function during the initial 5 years of the quarry plan.

The Pit Dewatering Dam will store water that is dewatered from the pit for future process water use and will therefore be kept full for the majority of the time. During water surplus conditions, controlled release from the dam will be required. The water balance model results presented in **Plate 4-16** compare the frequency and volume of dam releases over the 115 year water balance model timeframe. The results indicate that:

- Dam releases will be required in 55 to 85% of years, depending on the stage of the quarry plan.
- The frequency and volume of dam releases will increase as the quarry plan progresses. This is due to the pit footprint increasing, resulting in higher runoff volumes accumulating in the pit sump.

As discussed in **Section 4.2**, all water released from the pit dewatering dam will be treated for sedimentation in the dam. Gunlake will monitor the quality of water released and will provide additional treatment, such as pH adjustment and / or flocculation if required. As the dam will only receive water from pit dewatering, the release rate can be controlled by the pit dewatering rate (or dam inflow rate) to ensure water quality objectives are achieved.

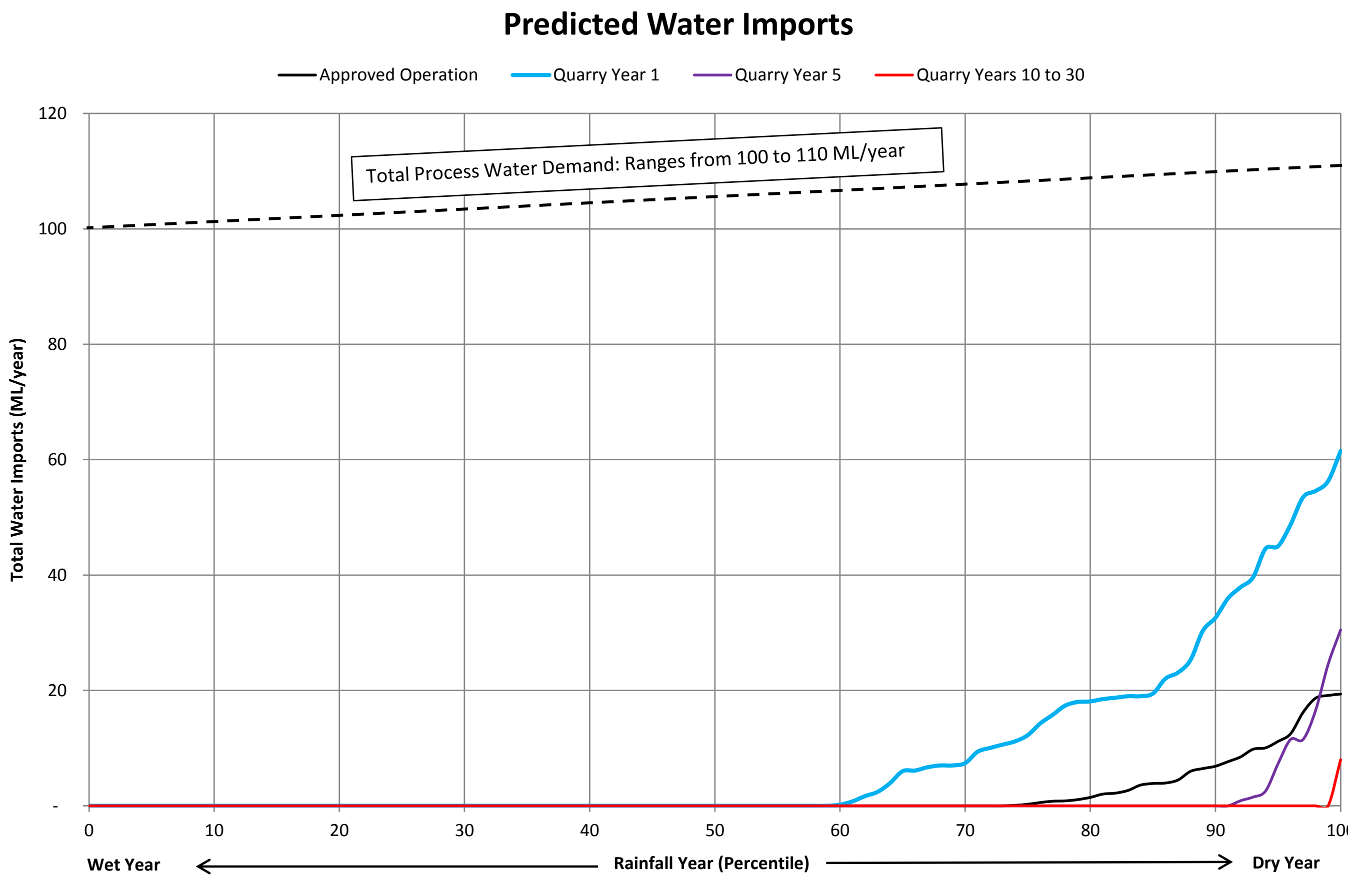


***Plate 4-17** – Predicted water import volumes*

Gunlake proposes to source process water from water stored in the Process Water Dam (35 ML), the Pit Dewatering Dam (30 ML), pit sump (20 ML) and Cleanwater Dam 2 (15 ML). Collectively, these storages (when full) will provide 100 ML of storage. When accounting for evaporation losses, the storages will provide 7 to 8 months of process water supply.

The water balance model was applied to assess the effectiveness of the surface water management system in providing a reliable supply of process water to the quarry operation. **Plate 4-17** plots the frequency and volume of predicted water imports (or shortages) over the 115 year water balance model timeframe. The results indicate that:

- During the initial year of the quarry plan, the operation will be vulnerable to water shortages, with water imports predicted if below average rainfall conditions occur. This is due to the process water demand increasing in line with the production increase and the catchment area of the pit being limited to 29 ha (compared to 53 ha once fully developed). In addition, no groundwater inflows into the pit are predicted in Quarry Year 1.

- The risk of water shortages will decline significantly as the pit is developed to its ultimate footprint and groundwater inflows increase. Results indicating shortages are unlikely to occur post Quarry Year 10.

In summary, water balance model results indicate that the quarry’s process water requirements will be primarily met by extraction from the proposed water management dams. As a contingency, if water shortfalls occur for a period of time, Gunlake will either:

- Reduce water usage through the use of chemical dust suppressants;

- Seek an external water source and tanker water to the quarry; or
- Temporarily reduce the scale of the operation to ensure the dust management objectives are being achieved.

4.5 Final Void Water Balance Model

Following completion of the quarry operation, the pit (referred to as the final void in this section) is expected to have a 53ha footprint and a depth of approximately 100m. The final void will receive runoff from direct rainfall over the pit extent as well as groundwater inflows. Water loss from the void will occur solely through evaporation. It is expected that the void will initially accumulate water as inflow volumes will exceed evaporation losses. As a result a final void lake will form in the base of the pit. As the lake volume increases, the surface area and associated evaporation losses from the lake will increase, and the lake's water levels will reach an equilibrium range, where long term evaporation losses are similar to long-term inflow volumes.

A water balance model was developed to estimate the long term water level regime of the final void lake. The following assumptions were applied to the model:

- Runoff volumes from the 53ha contributing catchment area were calculated using the following assumptions:
  - The final void lake was assumed to inundate 50% of the pit area. Rainfall was applied to this portion of final void with no loss.
  - The remaining 50% of the final void area was assumed to be above the final void lake. The SIMHYD model developed for pit areas that (described in **Section 4.3.2**) was applied to calculate runoff from this portion of the final void.
- The level / storage characteristics of the final void were estimated from indicative final pit contours provided by Gunlake. The adopted level / storage curve is shown in **Plate 4-18**.
- Groundwater inflows of 34 ML/year were applied based on the Quarry Year 30 estimates presented in **Table 4-3**. It is noted that these inflows are expected to be conservative as groundwater inflows are expected to decline overtime as the final void lake forms.
- Evaporation losses were calculated as a function of the calculated final void lake area and the average monthly evaporation rates provided in **Table 3-2**. A Pan Coefficient of 0.7 was applied.

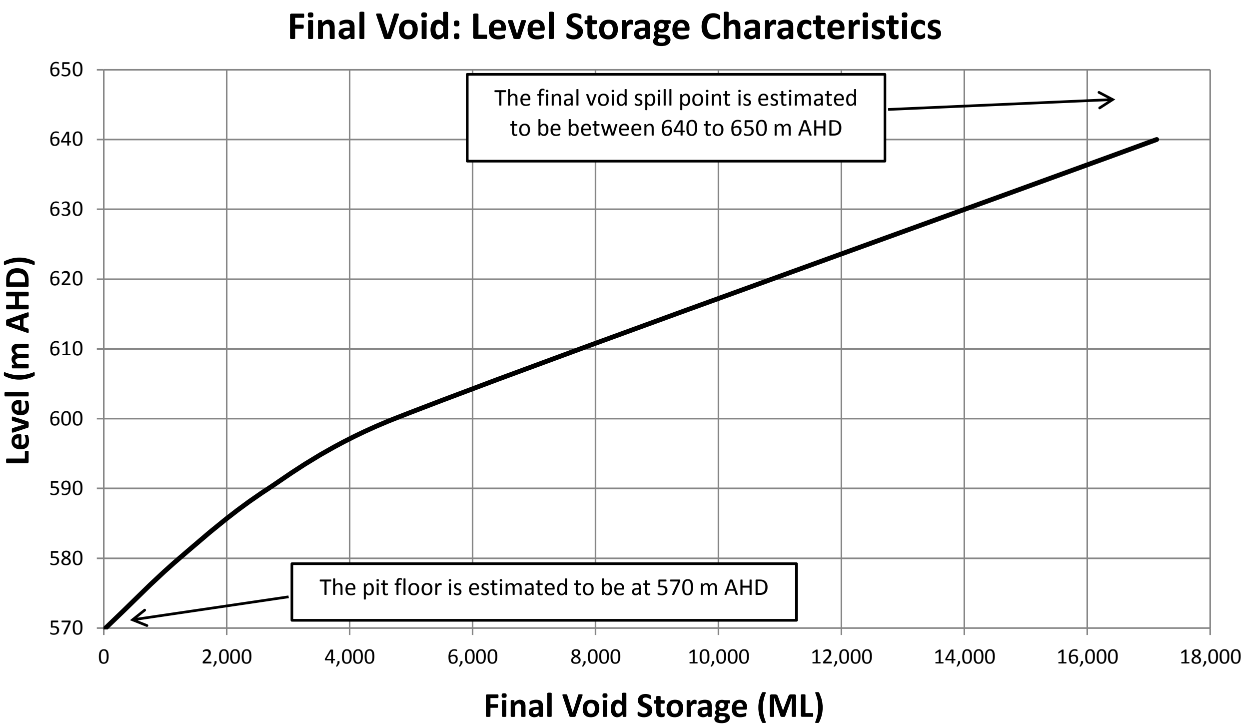


***Plate 4-18** – Final Void: Level Storage Curve*

The model was applied to simulate the final void lake volumes over a 300 year period. This was done by looping the 115 year rainfall record. The simulated lake storage levels are shown in **Plate 4-19**.

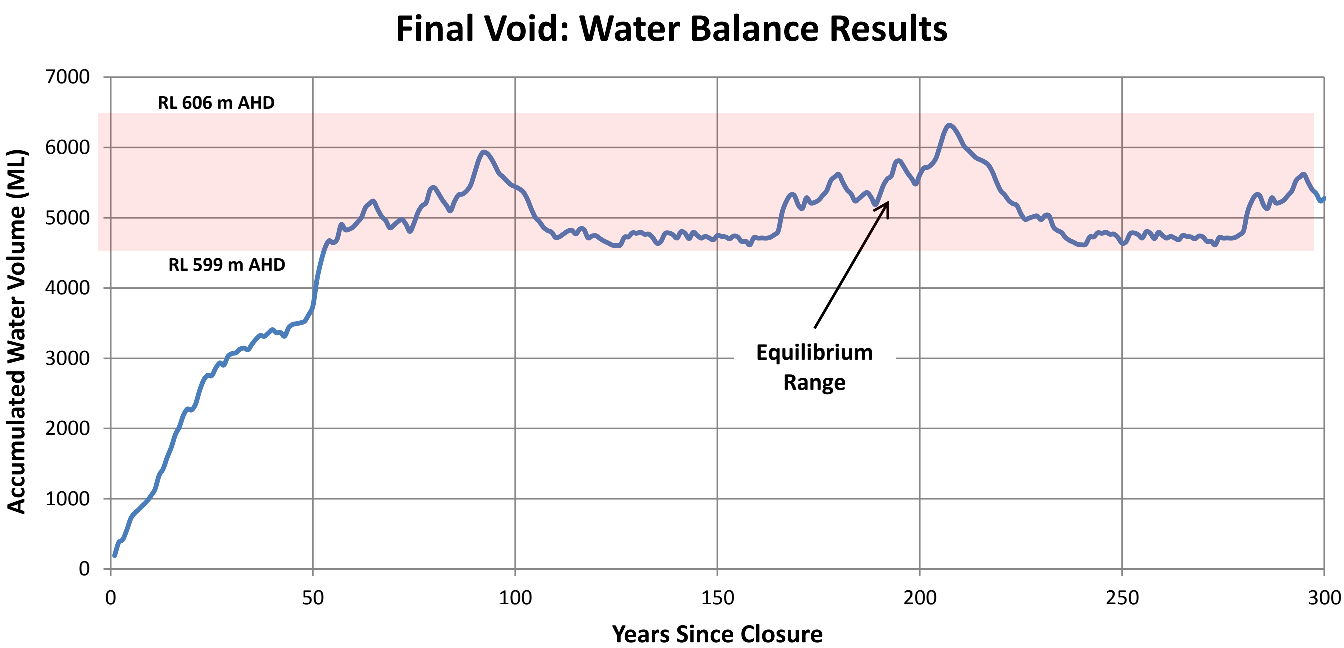


***Plate 4-19**: Final Void Water Balance Results*

The results presented in **Plate 4-19** indicate that the final void is expected to slowly accumulate water for the initial 60 to 70 years following closure of the quarry operation. Equilibrium between long term evaporation losses and runoff inflows is expected to be achieved when the lake level reaches the RL 599 to RL 606 m AHD range, approximately 40 to 45 m above the pit floor. The equilibrium level is at least 35 m below the final void spill point (estimated to be between 640 and 650 m AHD), indicating that the final void lake is unlikely to ever spill to receiving waters.

5 SUMMARY OF PREDICTED IMPACTS AND MANAGEMENT MEASURES

Table 5-1 (on the following page) summaries potential surface water impacts, associated management measures and predicted impacts.

***Table 5-1** – Summary of potential impacts, associated management measures and predicted impacts.*

Potential Impact	Management Measures	Predicted Impacts
Water Quantity Impacts associated with the reduction in streamflow due the capture of surface water runoff in the quarry's water management dams.	• Runoff from Clean Water Catchment 1 will be diverted around the pit. • Stream flow reductions will be offset by overflows from the Process Water Dam and sedimentation dams and controlled releases from the Pit Dewatering Dam. • Gunlake will acquire any necessary Water Access Licences (WALs) required by the Water Management Act 2000. Water licensing requirements are discussed in **Section 6**.	The extension project will unavoidably result in some changes to the hydrologic regime of Chapmans Creek. These impacts will vary depending on the climatic conditions. The impacts are expected to be negligible downstream of the confluence of Chapmans and Jaorimin Creek, due to the size of the quarry's surface water management system footprint (135 ha) relative to the contributing catchment areas of Chapmans and Jaorimin Creeks, which have a collective area of 4,100 ha. DPI has advised that there are no licensed surface water users in the immediate receiving waters downstream of the quarry site. Hence, no impacts to existing surface water users are expected.
Water Quality Impacts to downstream receiving waters due to overflows and controlled releases from the water management dams.	• Sedimentation treatment volumes for the Process Water Dam, Pit Dewatering Dam and Sedimentation Dams 1, 2 and 3 have been calculated using the methods recommended in relevant guidelines to treat sediment laden runoff from a quarry site. The Process Water Dam and Pit Dewatering Dam volumes substantially exceed the calculated treatment volume and are therefore expected to outperform the minimum standards for sedimentation treatment. • The Pit Dewatering Dam is expected to provide effective sedimentation treatment for all water released to Chapmans Creek. • 100 to 110 ML/year of process water will be extracted from the quarry's water management dams. This will reduce both the frequency and volume of overflows and controlled releases.	The proposed water quality management measures are expected to be effective in mitigating the potential water quality impacts. Gunlake will implement a Surface Water Monitoring Program and will progressively improve the surface water management system to mitigate any underperformances identified by the monitoring.
Post Closure Impacts associated with the potential spillage of water accumulated in the final void.	• Runoff from Clean Water Catchment 1 will be permanently diverted around the pit. • Water balance modelling results presented in **Section 4.5** estimated that water will accumulate in the final void to an equilibrium level that is at least 35 m below the final void spill level. Accordingly, the final void lake is unlikely to ever spill to receiving waters.	Runoff from the 53 ha pit footprint will be permanently captured within the final void, resulting in a permanent reduction in stream flows in the downstream waterways. No water quality impacts are expected as no spillage from the final void to receiving waters is likely to occur.

6 WATER LICENSING AND ACCOUNTING

This section addresses the water licensing requirements for the extension project by applying the water balance results reported in **Section 4** to the applicable Water Sharing Plans and Acts.

6.1 Water Licencing Framework

Water licensing for the extension project will be regulated by the *Water Management Act 2000*. Water Access Licenses (WALs) in the project area are administered by the *Water Sharing Plan for the Greater Metropolitan Unregulated Water Sources (2011)*, which is a legal instrument of the *Water Management Act 2000*. The Water Sharing Plan is administered on the basis of catchment scale water sources. The project area is located within the Upper Nepean and Upstream of Warragamba Water Source. For the extension project, water take from the following surface sources will be regulated by the *Water Management Act 2000*:

- **Clean Water Capture** – refers to runoff from clean water catchment areas that are captured in water management dams.
- **Sedimentation Dam Capture** – refers to water captured in the sedimentation dams.
- **Pit Dewatering (surface runoff) –** refers to water dewatered from the pit that originated from surface water runoff from within the pit's contributing catchment area.

Table 6-1 describes the licensing requirements for the abovementioned water sources and offsets with consideration given to excluded works in the NSW Water Management (General) Regulation 2011.

Table 6-1- *Licensing requirements for water sources and offsets*

Water Source / Offset	Licensing Requirements
Pit Dewatering (surface water runoff)	Excluded works under the *Water Management (General) Regulation 2011*[1]
Dirty Water Captured in Sedimentation Dams	Excluded works under the *Water Management (General) Regulation 2011*[1]
Clean Water Captured in Water Management Dams	Clean water captured in water management dams will be licensed in accordance with the *Water Management Act 2000* with consideration given to excluded works in the *NSW Water Management (General) Regulation 2011* and the proponent's harvestable rights (refer to Section 6.2).

Note 1: The proposed Pit Dewatering Dam, Process Water Dam and sedimentation dams are considered to be excluded works under *Water Management (General) Regulation 2011, Schedule 1, item 3* (dams solely for the capture, containment or recirculation of drainage).

The water licensing requirements are discussed in **Section 6.3**.

6.2 Available Harvestable Rights

Under *Section 53 of the Water Management Act 2000*, an owner or occupier of a landholding is entitled without the need for access licence, water supply work approval or water use approval, to construct and use a dam for the purpose of capturing and storing rainwater runoff and using this water in accordance with the harvestable rights order. The order specifies that a landholder has the right to capture 10% of the average runoff from the land by the means of a dam or dams having not more than the total capacity calculated by multiplying the area of the landholding in hectares by the multiplier corresponding to the location of the land shown on the Maximum Harvestable Right Dam Capacity Map (Department of Primary Industries Website website). The map specifies the multiplier relevant to the project area is 0.075 ML/ha.

The available harvestable rights for Gunlake's landholding can calculated based on the landholding of 227 ha (which is referred to the project area in all report figures) and the harvestable rights multiplier of 0.075 ML/ha. This equates to a harvestable rights allocation of 17 ML/year.

There are three existing small farm dams located within Gunlake's landholding. These dams are estimated to have a collective volume of less than 1 ML. Hence, the available harvestable rights allocation is 16 ML/year.

6.3 Water Licencing Requirements

The water licensing requirements presented in **Table 6-1** have established that the only water source that will be subject to water licencing is the capture of clean water runoff (from CW 2) into Cleanwater Dam 2. All runoff from dirty water catchments is considered to be excluded works under *Water Management (General) Regulation 2011, Schedule 1, item 3 (dams solely for the capture, containment or recirculation of drainag*e).

The proposed volume of Cleanwater Dam 2 is 15 ML. Hence, capture of runoff from this catchment is considered to be within Gunlake's harvestable rights allocation of 16 ML and no WALs will be required for the surface water management system.

It is noted that water balance results presented in **Section 4** indicate that Gunlake may need to import water during extended dry periods. If water imports are required, Gunlake will seek appropriate water licences (if required) once the preferred external water source has been identified.

7 MONITORING AND CONTINGENCY MEASURES

7.1 Surface Water Monitoring Plan

Gunlake proposes to modify the existing surface water monitoring program to reflect the changes to the quarry's footprint and surface water management strategy. The modified program will comprise monitoring at the following locations:

- Two receiving water sites that are located on Chapmans Creek, downstream of the quarry; and
- The Process Water Dam and Pit Dewatering Dam.

Proposed monitoring locations are indicated in **Plate 7-1**.

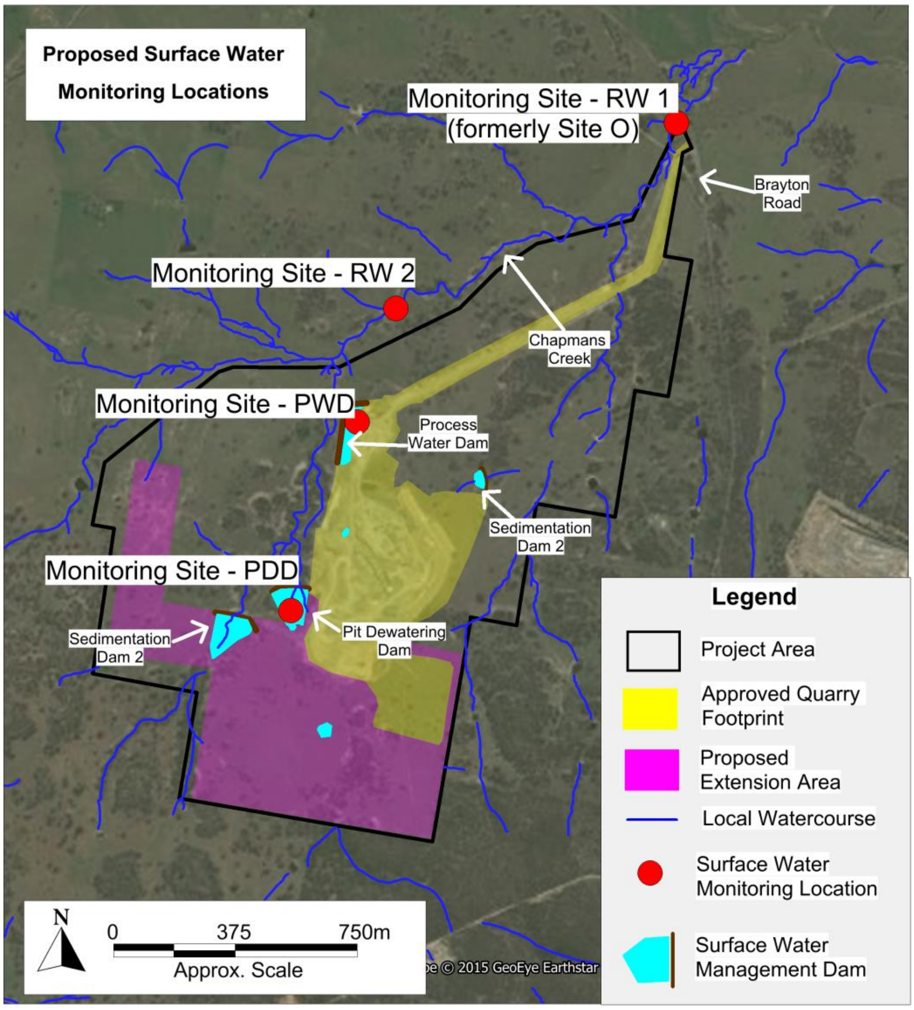


Plate 7-1 – *Proposed Monitoring Locations*

Table 7-1 describes the framework of the monitoring plan and **Table 7-2** details the proposed analytes that will be monitored. A Surface Water Monitoring Plan will be prepared post approval, as part of the Environmental Management Plan for the project.

Table 7-1 – *Proposed Surface Water Monitoring Plan Framework*

Aspect	Objective	Monitoring Locations	Monitoring Description
Receiving Waters	To determine water quality trends and identify water quality impacts associated with the quarry operation.	• Receiving Water 1 (RW 1) • Receiving Water 2 (RW 2)	Quarterly analysis. Refer to **Table 7-2** for a description of the proposed analytes.
On-site Storages	To determine water quality trends in discharges from the on-site storages.	• Process Water Dam (PWD) • Pit Dewatering Dam (PDD)	Quarterly analysis of discharge from the on-site storages. Refer to **Table 7-2** for a description of the proposed analytes.
Water Quantity Monitoring	To monitor the quarry's process water use.	• Cumulative flow meters will be installed to monitor process water use.	

Table 7-2 **–** *Surface Water Monitoring Plan: Analytes Proposed*

	Analytes Proposed
Physical Parameters	• Electrical Conductivity (EC) • Total Suspended Solids (TSS) • Total Dissolved Solids (TDS) • Dissolved Oxygen (DO) • Turbidity
Chemical Parameters	• pH • Sodium • Chloride • Total Nitrogen (TN) • Total Phosphorus (TP) • Metals (Al, As, Co, Cu, Mn, Ni, Zn, Mg, Na, K, Ca, Cl, Fe) • Total Oil and Grease (visual inspection only)

7.2 Summary of Additional Investigations and Contingency Measures

Table 7-3 provides a summary of additional investigations and **Table 7-4** contingency measures that have been proposed in this report.

***Table 7-3** – Summary of Additional Investigations*

Item	Trigger / Timing	Outcomes
Detailed design of the Surface Water Management System	During the ongoing design of the extension project.	Determine the optimum configuration of the various water management facilities such as dams, drainage and pipe networks, dewatering infrastructure and discharge structures.
Surface Water Monitoring Plan	To be developed post approval as part of the suite of Environmental Management Plans. To be updated during the life of the quarry after any significant changes to the quarry plan or further regulatory requirements	A detailed description of the Surface Water Monitoring Plan and proposed trigger levels.
Surface Water Management Plan	To be developed post approval as part of the suite of Environmental Management Plans. To be updated during the life of the quarry to accommodate any significant changes to the quarry plan or further regulatory requirements	A detailed description of the Surface Water Management Plan and operating procedures.

Table 7-4 – *Summary of Contingency Measures*

Item	Trigger / Timing	Outcomes
Surface water quality	If water quality monitoring indicates that the quarry is adversely affecting the water quality in Chapmans Creek.	Gunlake will undertake an investigation to establish the likely cause of the underperformance of the water management system and will implement necessary measures to mitigate the identified underperformance.
Process water shortages	Water balance modelling results presented in **Section 4** indicate that process water shortages are possible during extended dry periods	If process water shortfalls occur, Gunlake will either: • Seek an external water source and tanker water to the quarry; • Temporarily reduce the scale of the operation to ensure the dust management objectives are being achieved; or • Reduce water usage through the use of chemical dust suppressants.

8 REFERENCES

1) Australian Coal Association Research Project (2008), Project C16035, *'Understanding Leading Practice in Water Management'*
2) *Cardno (2014), 'Gunlake Quarry Marulan: Water Assessment'*
3) *Chiew, F.H.S and Siriwardena, L (2005), 'Estimation of SIMHYD Parameter Values for Application in Ungauged Catchments'*
4) Department of Environment and Conservation NSW (2005), *'Environmental Compliance Report: Liquid Chemical Storage, Handling and Spill Management: Part B Review of Best Practice and Regulation'*
5) Department of Environment and Climate Change NSW (2008), *'Managing Urban Stormwater: Soils and Construction Volume 2E Mines and Quarries'*
6) Department of Environment and Climate Change NSW (2007), *'Storing and Handling Liquids: Environmental Protection: Participant's Manual'*
7) EMM (2015), *'Gunlake Quarry Extension Project: Groundwater Assessment'*
8) Olsen Consulting Group (2009), *'Water Management Plan: Environmental Management Systems: Gunlake Quarries'*
9) Institution of Engineers Australia (1987), '*Australian Rainfall and Runoff – A Guide to Flood Estimation'*
10) Landcom (2004), '*Managing Urban Stormwater: Soils and Construction Volume 1 4th Edition'.*
11) SEEC Morse Mcvey (2008), *'Managing Soil and Water: Proposed Gunlake Quarry Project and Haul Road: Brayton Road Marulan'*