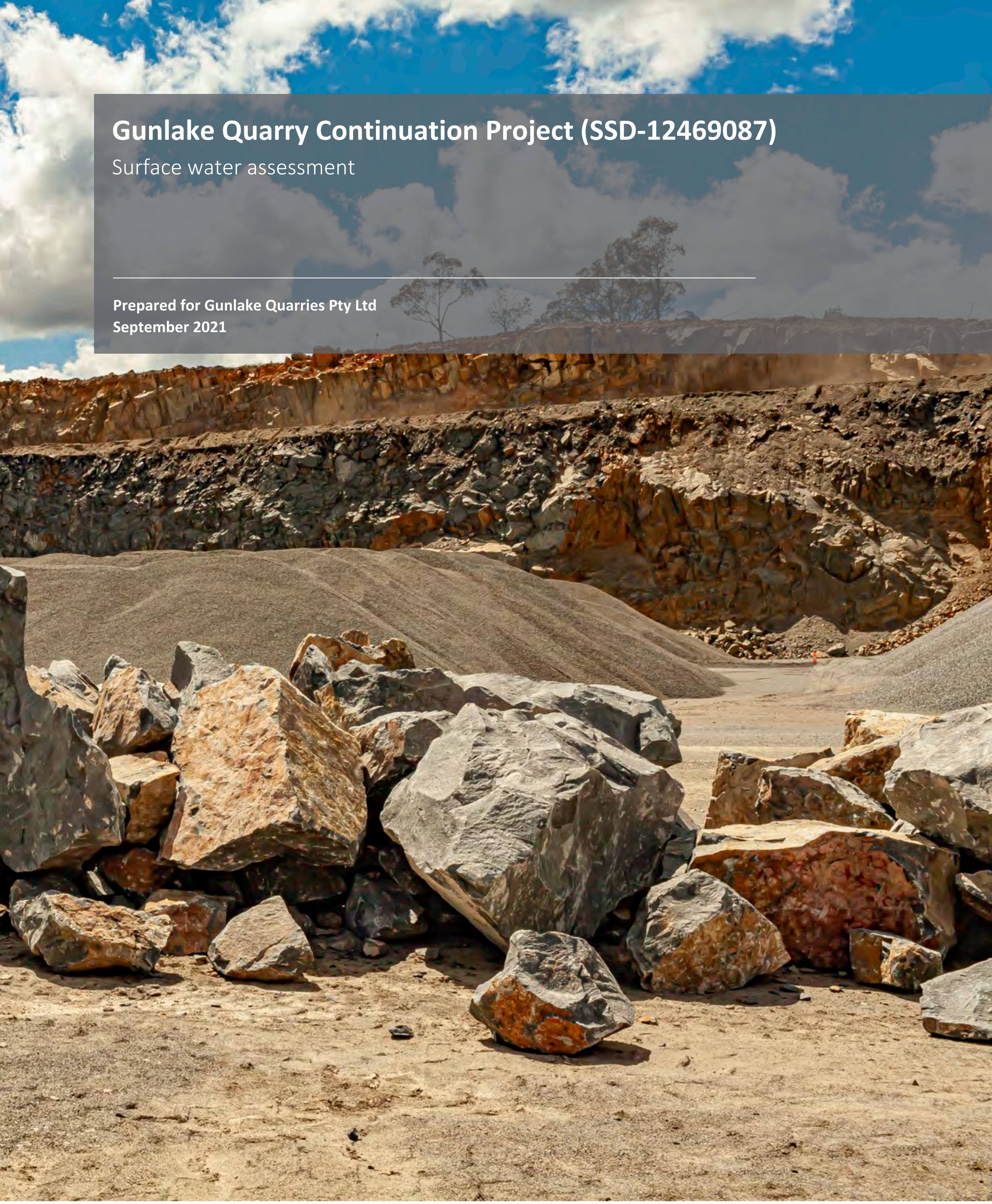
F.6 Surface water assessment

Gunlake Quarry Continuation Project (SSD-12469087)

Surface water assessment

Prepared for Gunlake Quarries Pty Ltd
September 2021



creating opportunities

creating opportunities

Servicing projects throughout Australia and internationally

SYDNEY
Ground Floor, 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE
Level 3, 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE
Level 1, 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

ADELAIDE
Level 4, 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE
Ground Floor, 188 Normanby Road
Southbank VIC 3006
T 03 9993 1905

PERTH
Suite 9.02, Level 9, 109 St Georges Terrace
Perth WA 6000
T 02 9339 3184

CANBERRA
Level 2, Suite 2.04, 15 London Circuit
Canberra City ACT 2601

Gunlake Quarry Continuation Project (SSD-12469087)

Surface water assessment

Report Number

J190263 RP#19

Client

Gunlake Quarries Pty Ltd

Date

10 September 2021

Version

v1 Final

Prepared by

Tess Davies
Senior Water Resources Engineer
10 September 2021

Approved by

Chris Kuczera
Associate Water Resources Engineer
10 September 2021

Executive Summary

ES1 Introduction

Gunlake Quarries Pty Ltd (Gunlake) operates a hard rock quarry (the 'Quarry') located at 715 Brayton Road, Marulan NSW. The Quarry is approximately 7 kilometres (km) north-west of the centre of Marulan in the Goulburn Mulwaree local government area. The land surrounding the Quarry is rural land with a low population density. Gunlake commenced operations in 2009 under project approval 07-0074 granted in September 2008.

Since the Quarry received approval for the Extension Project in 2017 (SSD 7090, NSW Land and Environmental Court Approval 20017/108663), the tonnage of saleable product dispatched by the Quarry has steadily increased and, with an infrastructure boom across the State, Gunlake forecast that demand for products from the Quarry will continue to increase. In response to the increased demand for products from the Quarry, it is proposed to transport more saleable product along the Primary Transport Route. This will require an increase in truck movements than what is currently approved. The additional truck movements will all occur on the recently upgraded Primary Transport Route that has been designed to accommodate comfortably the additional truck movements. The Project is known as the Gunlake Quarry Continuation Project (the 'Continuation Project'). The ignimbrite hard-rock resource will continue to be extracted and processed using the methods currently employed at the Quarry.

The Continuation Project is classified as a State Significant Development (SSD) under Schedule 1, Clause 7 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP). This report accompanies a new SSD application and environmental impact statement (EIS) for the Continuation Project.

ES2 Gunlake Quarry Continuation Project

Gunlake seeks a new development approval for the Continuation Project that allows:

- ongoing Quarry operations;
- a maximum of 375 inbound and 375 outbound daily truck movements with up to 4.2 million tonnes per annum (Mtpa) of Quarry products transported from the site in any calendar year;
- 24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday;
- an extraction depth of 546 metres Australian Hight Datum (mAHD); and
- a 30-year Quarry life (from the date of Continuation Project approval).

ES3 Quarry water management system

Gunlake currently operate the Quarry water management system that was developed as part of the EIS for the Extension Project and is further documented in the Gunlake Quarry Soil and Water Management Plan. The proposed changes to the existing consent relate to increasing production, quarry life and pit depth. No changes to the previously approved disturbance area or water management system are proposed.

ES4 Evaluation of Project

Water balance modelling identified that the Continuation Project will reduce the likelihood and magnitude of overflows occurring from the water management system compared to the overflows predicted for the Extension Project. This is because the process water use associated with higher production will more than offset the increase in predicted groundwater inflows.

As overflows will be reduced, the Continuation Project is assessed to result in a natural to beneficial change to the residual impacts that were assessed as part of the Extension Project EIS.

The Continuation Project is not expected to have any measurable change in flooding regime in downstream waterways as no changes to the previously approved disturbance footprint are proposed.

Table of Contents

Annexures

Tables

Figures

1 Introduction

1.1 Overview

Gunlake Quarries Pty Ltd (Gunlake) operates a hard rock quarry (the 'Quarry') located at 715 Brayton Road, Marulan NSW. The Quarry is approximately 7 kilometres (km) north-west of the centre of Marulan in the Goulburn Mulwaree local government area (Figure 1.1). The land surrounding the Quarry is rural land with a low population density. Gunlake commenced operations in 2009 under project approval 07-0074 granted in September 2008.

Since the Quarry received approval for the Extension Project in 2017 (SSD 7090, NSW Land and Environmental Court Approval 20017/108663), the tonnage of saleable product dispatched by the Quarry has steadily increased and, with an infrastructure boom across the State, Gunlake forecast that demand for products from the Quarry will continue to increase. In response to the increased demand for products from the Quarry, it is proposed to transport more saleable product along the Primary Transport Route. This will require an increase in truck movements than what is currently approved. The additional truck movements will all occur on the recently upgraded Primary Transport Route that has been designed to accommodate comfortably the additional truck movements. The Project is known as the Gunlake Quarry Continuation Project (the 'Continuation Project'). The ignimbrite hard-rock resource will continue to be extracted and processed using the methods currently employed at the Quarry.

The Continuation Project is classified as a State Significant Development (SSD) under Schedule 1, Clause 7 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). This report accompanies a new SSD application and environmental impact statement (EIS) for the Continuation Project.

1.2 Assessment approach and requirements

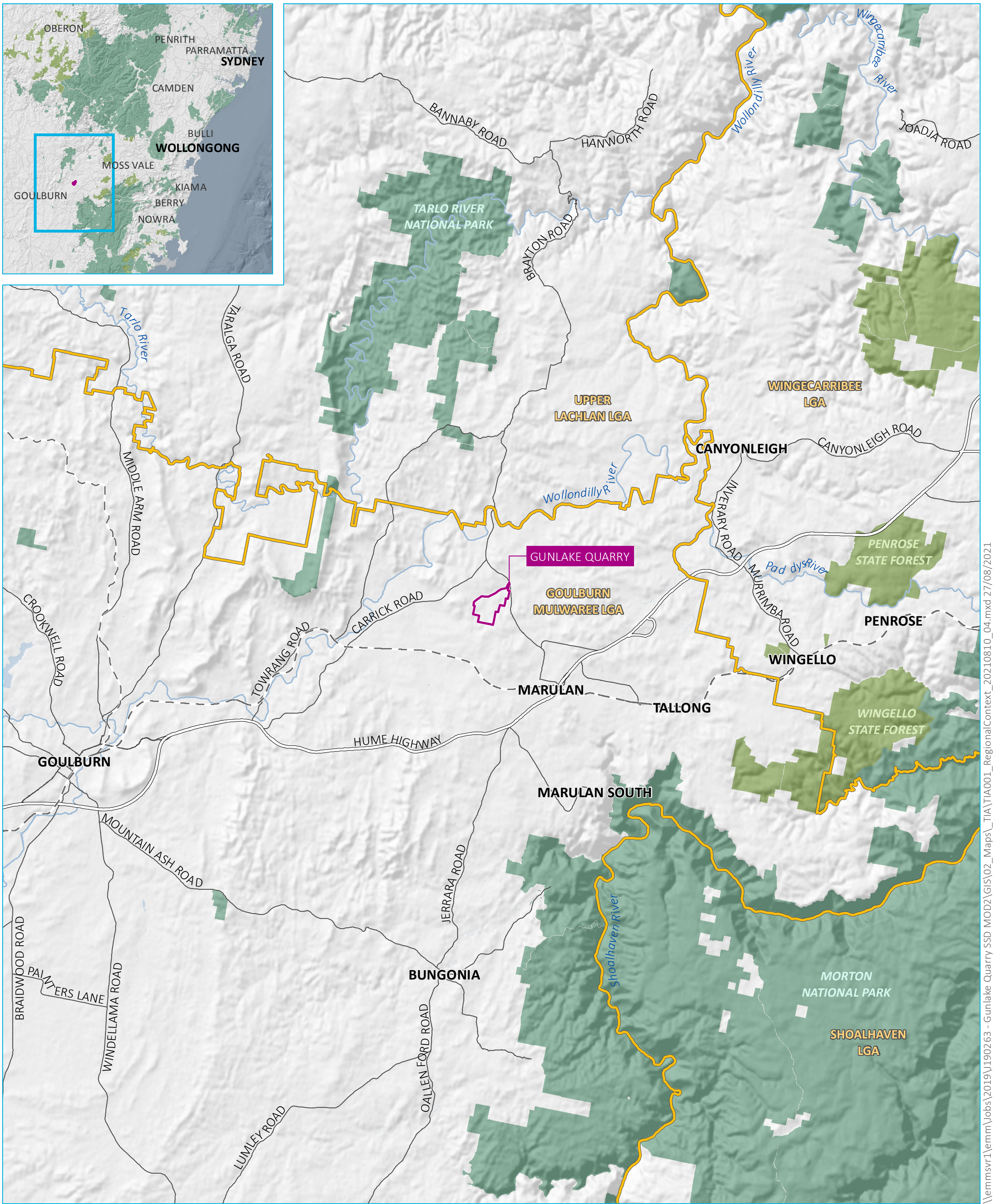
This surface water assessment has been conducted in accordance with NSW regulatory requirements and relevant industry and government guidelines, discussed in Chapter 3. This report comprises of the following sections:

- a description of the Quarry and local setting;
- the assessment requirements and an overview of relevant industry and government guidelines;
- a characterisation of the existing environment at the Quarry site;
- a description of the Quarry's water management strategy;
- residual impacts of the Continuation Project on surface water resources; and
- water licensing requirements.

This surface water assessment has been prepared in accordance with the requirements of the Planning Secretary's Environmental Assessment Requirements (SEARs) for the proposed development, issued on 6 May 2021. The SEARs identify matters which must be addressed in the EIS. The individual requirements relevant to this assessment and where they are addressed in this report are provided in Table 1.1.

Table 1.1 SEARs relating to surface water assessment

Assessment requirement	Where addressed
Detailed site water balance including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures	Section 5.3 Section 5.4 Groundwater make is discussed in Section 7.2.2 of the *Groundwater Assessment* (GWA), EIS Appendix F.5 (EMM 2021)
Identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*	Chapter 7 Groundwater licensing requirements are described in Section 3 of the GWA
Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP)	Chapter 7 Groundwater licensing is described in Section 8.3 of the GWA
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo	Section 5.3 Chapter 7
An assessment of any likely flooding impacts of the development	Section 6.2
An assessment of the likely impacts on the quality and quantity of existing surface and groundwater resources, including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives	Section 5.4 Chapter 6 Groundwater impacts are described in the GWA
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users	Chapter 6 Groundwater impacts are described in Section 7 of the GWA
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts	Section 5.3 Groundwater management and mitigation measures are described in Section 8 of the GWA



Source: EMM (2021); DFSI (2017); GA (2011); ASGC (2006)

0 5 10 km

GDA 1994 MGA Zone 55

N

KEY

- Site boundary
- Local government area
- Rail line
- Highway
- Major road
- River
- Waterbody
- NPWS reserve
- State forest

Regional context

Gunlake Quarry Continuation Project
Surface water assessment
Figure 1.1

EMM
creating opportunities

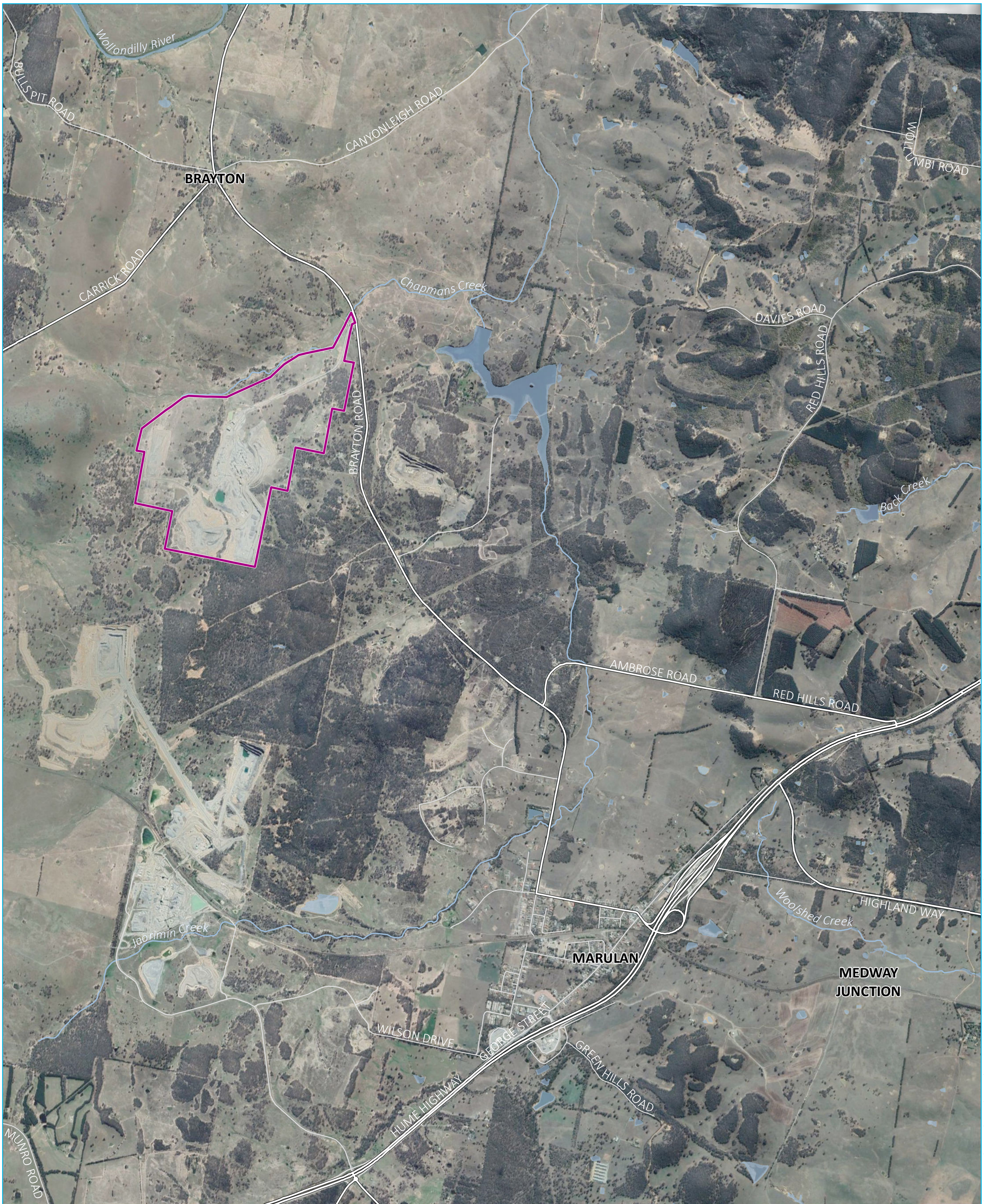
2 Project description and setting

2.1 The site

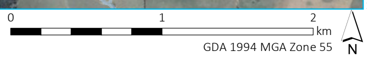
The Quarry is located wholly on Lot 13 DP 1123374 (the 'Quarry site'). There are biodiversity management areas in Lot 13 DP1123374, Lot 12 DP1123374, Lot 271 DP750053 and Lot 1 DP841147. These lots are owned by Gunlake Quarries Pty Ltd.

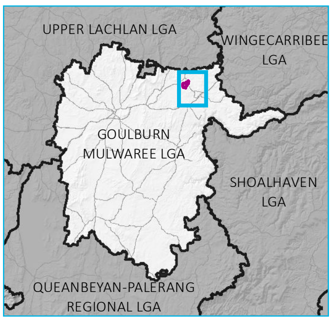
The land surrounding the Quarry is rural with low population density, predominately used for agriculture, generally grazing. Built features immediately surrounding the Quarry include dams, access tracks and fences. There are a small number of residences around the Quarry (Figure 2.1). The nearest town is Marulan, about 7 km south-east of the site boundary.

There are four local operational quarries within approximately 15 km of the Quarry site: Lynwood Quarry; Peppertree Quarry; Marulan South Limestone Mine; and Johnniefelds Quarry. There are two creek systems in the Quarry site, Chapmans Creek and an unnamed tributary of Chapmans Creek. Chapmans Creek is an ephemeral watercourse located on the northern site boundary. Chapmans Creek flows north-east into Joarimin Creek. Joarimin Creek is also ephemeral and drains to Wollondilly River, approximately 8.6 km north-east of the Quarry site.



Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011); ASGC (2006)





KEY
- Site boundary
- Major road
- Minor road
- Named watercourse
- Waterbody

Local context

Gunlake Quarry Continuation Project
Surface water assessment
Figure 2.1

2.2 Continuation Project description

Gunlake seeks a new development approval for the Continuation Project that allows:

- ongoing Quarry operations;
- a maximum of 375 inbound and 375 outbound daily truck movements with up to 4.2 million tonnes per annum (Mtpa) of Quarry products transported from the site in any calendar year;
- 24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday;
- an extraction depth of 546 metres Australian Hight Datum (mAHD); and
- a 30-year Quarry life (from the date of Continuation Project approval).

A summary of the key elements of the approved Extension Project compared to the Continuation Project is provided in Table 2.1.

Table 2.1 Extension Project compared to the Continuation Project

Project element	Approved Extension Project	Proposed Continuation Project
Extraction method	Blasting and excavation.	Blasting and excavation.
Resource	Ignimbrite hard-rock.	Ignimbrite hard-rock.
Extraction	Quarry pit - pit depth of 572 mAHD.	Quarry pit - pit depth of 546 mAHD (ie 26 m deeper than the Extension Project). No change to pit disturbance area.
Operations	Onsite rock processing, including crushing and screening.	Onsite rock processing, including crushing and screening.
Product transport	Transport of up to 2.6 million tonnes per annum (Mtpa) of Quarry products. Truck movements limited to: • a maximum of 295 inbound movements and 295 outbound movements, including no more than 38 outbound truck movements on the Secondary Transport Route, per working day; and • an average of 220 inbound movements and 220 outbound movements, including no more than 25 outbound movements on the Secondary Transport Route, per working day (averaged over the working days in each quarter).	Transport of up to 4.2 Mtpa of quarry products. Total truck movements limited to: • a maximum of 375 inbound movements and 375 outbound movements, including no more than 38 outbound laden movements on the Secondary Transport Route, per working day; • an average of no more than 25 outbound movements on the Secondary Transport Route, per working day (averaged over the working days in each quarter).
General infrastructure	Offices, amenity buildings, processing plant and other minor infrastructure.	Offices, amenity buildings, processing plant and other minor infrastructure.

Table 2.1 Extension Project compared to the Continuation Project

Project element	Approved Extension Project	Proposed Continuation Project
Management of wastes	Overburden[1] is emplaced in designated emplacement areas. Receipt of up to 30,000 tonnes of cured concrete per calendar year for beneficial reuse/recycling. No other classified waste materials to be received on site.	Overburden is emplaced in designated emplacement areas. Receipt of up to 50,000 tonnes of cured concrete per calendar year for beneficial reuse/recycling. No other classified waste materials to be received on site.
Hours of operation	24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday.	24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday.
Blasting	Up to twice weekly, 9 am to 5 pm Monday to Friday.	Up to twice weekly, 9 am to 5 pm Monday to Friday.
Quarry life	To 30 June 2042.	Extension of the Quarry life to 30 years from the date of approval.

Further information on the project is available in the Continuation Project EIS.

2.3 Resource and pit development

Quarry operations extract a hard rock resource from the Devonian Bindook Volcanic Complex. The Complex comprises a north to north-east trending series of volcanics. A resource of 180 million tonnes (Mt) of tuffaceous rhyodacite has been proven to depths in excess of 100 metres (m) below surface. The resource is suitable for use in a range of quarry products including concrete and sealing aggregates, rail ballast, manufactured sand and road base.

The Continuation Project pit will be within the approved Extension Project footprint. It will be extracted in horizontal benches with the quarry floor reaching 546 m AHD over the 30-year quarry lifespan (ie by about 2051).

1 ‘Overburden’: any extracted unsalable material.

3 Assessment framework

3.1 Relevant legislation and policies

3.1.1 *Protection of the Environment Operations Act 1997*

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA). Under the POEO Act, an environment protection licence (EPL) is required for 'scheduled activities', generally activities with potentially significant environmental impacts. Licence conditions may relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

The Quarry is a scheduled premise covered by EPL 13012. There are no licensed discharge points or monitoring requirements that relate to surface water management at the site.

3.1.2 *Water Management Act 2000*

The NSW *Water Management Act 2000* (WM Act) is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WM Act recognises that water management decisions must consider economic, environmental, social, cultural and heritage factors. It recognises that sustainable and efficient use of water delivers economic and social benefits to the state of NSW. The WM Act provides for water sharing between different water users, including environmental, basic landholder rights and licence holders. The licensing provisions of the WM Act apply to those areas where a water sharing plan (WSP) has commenced.

WSPs are statutory documents that apply to one or more water sources. They define the rules for sharing and managing water resources within water source areas. WSPs describe the basis for water sharing and document the water available and how it is shared between environmental, extractive and other uses. The WSPs outline the water available for extractive uses within different categories, such as local water utilities, domestic and stock, basic landholder rights, irrigation and industrial uses.

The WSPs relevant to the Quarry are:

- Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 – the Lower Wollondilly River Management Zone within the Upper Nepean and Upstream Warragamba Water Source applies to the surface water in the vicinity of the site; and
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 – the Goulburn Fractured Rock Groundwater Source applies to groundwater in the Hawkesbury Sandstone and deeper porous rocks in the vicinity of the site.

3.1.3 *Water NSW Act 2014*

The NSW *Water NSW Act 2014* defines the functions and objectives of WaterNSW, which is a State-owned corporation formed in 2015 from the merger of the Sydney Catchment Authority and State Water Corporation. WaterNSW is Australia's largest bulk water supplier and NSW's major supplier of raw water. The principle objectives of WaterNSW under the *Water NSW Act 2014* are:

- to capture, store and release water in an efficient, effective, safe and financially responsible manner;
- to supply water in compliance with appropriate standards of quality;

- to ensure that declared catchment areas and water management works in such areas are managed and protected so as to promote water quality, the protection of public health and public safety and the protection of the environment;
- to provide for the planning, design, modelling and construction of water storages and other water management works; and
- to maintain and operate the works of WaterNSW efficiently and economically and in accordance with sound commercial principles.

The Quarry discharges water within the Wollondilly River catchment, which is part of the Sydney drinking water catchment. The Water NSW Regulation 2013 provides regulatory powers to WaterNSW to manage pollution activities that could impact water quality within the Sydney drinking water catchment.

3.1.4 *State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011*

The aims of the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 (the SEPP) are:

a) to provide for healthy water catchments that will deliver high quality water while permitting development that is compatible with that goal;

b) to provide that a consent authority must not grant consent to a proposed development unless it is satisfied that the proposed development will have a neutral or beneficial effect on water quality; and

c) to support the maintenance or achievement of the water quality objectives for the Sydney drinking water catchment.

The SEPP specifically requires all proposed developments in the Sydney drinking water catchment to demonstrate a neutral or beneficial effect (NorBE) on water quality.

3.2 Relevant guidelines and leading practice

3.2.1 Erosion and sediment control guidelines

Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom 2004) outlines the basic principles for the design, construction and implementation of sediment and erosion control measures to improve stormwater management and mitigate the impacts of land disturbance activities on soils and receiving waters.

Additional guidelines on specific aspects of development and the application of erosion and sediment controls are also available. Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries (DECC 2008) provide specific guidelines, principles and minimum design standards for good management practice in erosion and sediment control during the construction and operation of mines and quarries.

3.2.2 NSW water quality and river flow objectives

The NSW Water Quality and River Flow Objectives (DECCW 2006) provides environmental values and long-term targets for water quality and river flow in each catchment in NSW. The objectives are intended to be considered in assessing and managing the potential impacts of activities associated with waterways.

The water quality objectives for fresh and estuarine surface waters are consistent with the national framework for assessing water quality provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). River flow objectives are the high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

The Quarry is located within the Hawkesbury-Nepean catchment. There are no specified objectives for this catchment.

3.2.3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) provides guidance on monitoring, assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. The guidelines provide a framework for:

- establishing water quality objectives;
- assessing and managing water quality for environmental values; and
- establishing protection levels, water quality indicators and trigger values.

Environmental values associated with the waterways and water sources surrounding the Quarry include primary industry, aquatic ecosystems, recreational users, irrigation and stock watering. Water quality monitoring results have been compared to default guideline values (DGVs) recommended by ANZG (2018) for the protection of aquatic ecosystems. Surface water resources in the vicinity of the Quarry are considered to be 'slightly to moderately disturbed' systems, due to the impact of disturbance in the catchment associated with past and ongoing agriculture and urban development. The site is also classified as a 'upland river' as the elevation of the site is more than 150 m.

DGVs provided by ANZG (2018) for toxicants (including metals) are usually derived from ecotoxicity testing using a species sensitivity distribution of chronic toxicity data. The reliability of the DGVs is classified as very high, high, moderate, low, very low or unknown. Classification is primarily based on the number and type (chronic, acute or a mix of both) of data used to derive the guideline value, as well as the fit of the statistical model (species sensitivity distribution) to the data.

DGVs are provided by ANZG (2018) for 99%, 95%, 90% and 80% species protection. For most toxicants, the level of species protection assigned for slightly to moderately disturbed systems is generally the 95% species protection DGV. For toxicants that potentially bioaccumulate, the level of species protection assigned for slightly to moderately disturbed systems is generally the 99% species protection DGV.

DGVs for slightly to moderately disturbed ecosystems recommended by ANZG (2018) are presented in Table 3.1. DGVs for physical and chemical stressors and nutrients provided by ANZECC (2000) have been used as these parameters as they have not yet been updated by ANZG (2018).

Table 3.1 Default guideline values for the assessment of water quality

Parameter	Units	DGV	Additional information
Physical and chemical stressors			
Electrical conductivity (EC)	µS/cm	30–350	DGV for NSW upland river (Table 3.3.3; ANZECC 2000)
pH	pH units	6.5–8.0	DGV for upland river in south-east Australia (Table 3.3.2; ANZECC 2000)
Turbidity	NTU	2–25	DGV for NSW upland river (Table 3.3.3; ANZECC 2000)

Table 3.1 Default guideline values for the assessment of water quality

Parameter	Units	DGV	Additional information
Nutrients			
Total nitrogen	mg/L	0.25	DGV for upland river in south-east Australia (Table 3.3.2; ANZECC 2000)
Total phosphorus	mg/L	0.02	DGV for upland river in south-east Australia (Table 3.3.2; ANZECC 2000)
Metals			
Aluminium	mg/L	0.055	Low reliability DGV for pH > 6.5
Arsenic	mg/L	0.013	Moderate reliability DGV for As(V)
Cobalt	mg/L	0.0014	Unknown reliability DGV
Copper	mg/L	0.0014	High reliability DGV
Iron	mg/L	0.3	Canadian aesthetically-based guideline as recommended by ANZECC (2000; Section 8.3.7.1)
Manganese	mg/L	1.9	Moderate reliability DGV
Nickel	mg/L	0.011	Low reliability DGV
Zinc	mg/L	0.008	Very high reliability DGV

3.2.4 Neutral or beneficial effect on water quality assessment guideline

Guidelines for the assessment of a NorBE on water quality have been published by WaterNSW (2021) and provide clear direction on what a NorBE means, how to achieve it and how to assess an application. As defined by the guidelines (WaterNSW 2021), a NorBE on water quality is demonstrated when a project:

- has no identifiable potential impact on water quality; or
- will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site; or
- will transfer any water quality impact outside the site to a location where it is treated and disposed of to a standard approved by the consent authority.

The type and complexity of the development determines the type and extent of information needed to demonstrate that a development has a NorBE on water quality.

3.2.5 Guidelines for controlled activities on waterfront land

As the project is categorised as an SSD, a controlled activity approval is not required under section 4.41(1)(g) of the EP&A Act.

3.2.6 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 (DEC 2005); and

- Storing and Handling Liquids: Environmental Protection: Participant's Manual (DECC 2007).

3.3 Previous studies

The following documents have been reviewed and applicable information used in this surface water assessment:

- Gunlake Quarry Extension Project: Surface Water Assessment (RHDHV 2016) – prepared to assess surface water impacts associated with the Extension Project (provided in Annexure A);
- Gunlake Quarry: Soil and Water Management Plan (Gunlake 2020) – plan for the management and monitoring of surface water and groundwater at the Quarry; and
- Gunlake Quarry Extension Project: Soil and Rehabilitation Assessment (EMM 2016) – prepared to assess the land, soils and rehabilitation impacts of the Extension Project.

4 Project setting

4.1 Climate

Patched point climate data was obtained from the Scientific Information for Land Owners (SILO) database hosted by the Science Division of the Queensland Government's Department of Environment and Science. SILO patched point data consist of interpolated estimates based on historically observed data from Bureau of Meteorology (BOM) weather stations. For this assessment, SILO data was obtained for the Marulan (George Street) Station (BOM station 70063), which is located 5.5 km south-east of the Quarry.

Table 4.1 presents key information and statistical data calculated from the SILO patched point data between 1970 and 2020. Figure 4.1 presents the average daily rainfall and evaporation rates on a monthly basis calculated from the SILO data.

Table 4.1 Key climate statistics

Key annual statistic	Rainfall (mm/year)	Evaporation (mm/year)
Average	703	1,280
Minimum	341	1,025
5th percentile	409	1,086
10th percentile	473	1,093
Median	701	1,256
90th percentile	913	1,484
95th percentile	1,021	1,587
Maximum	1,195	1,747

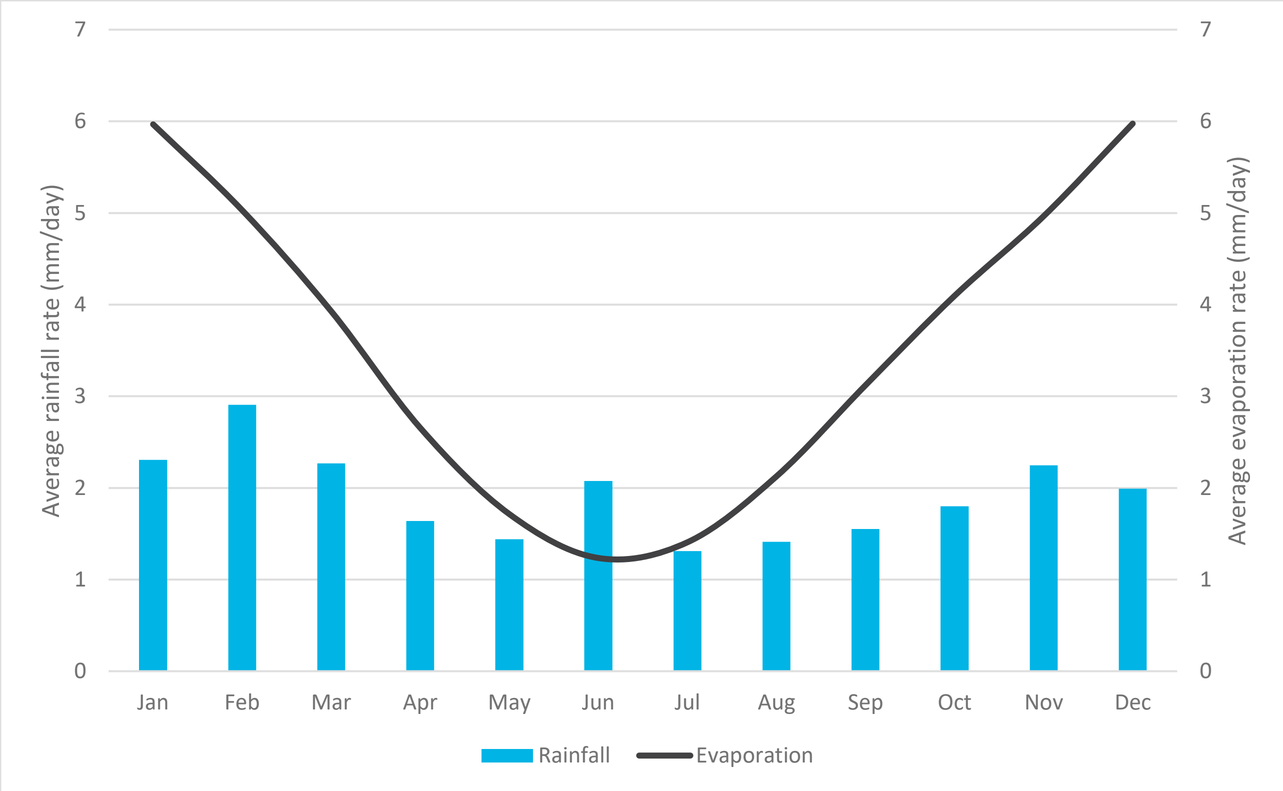


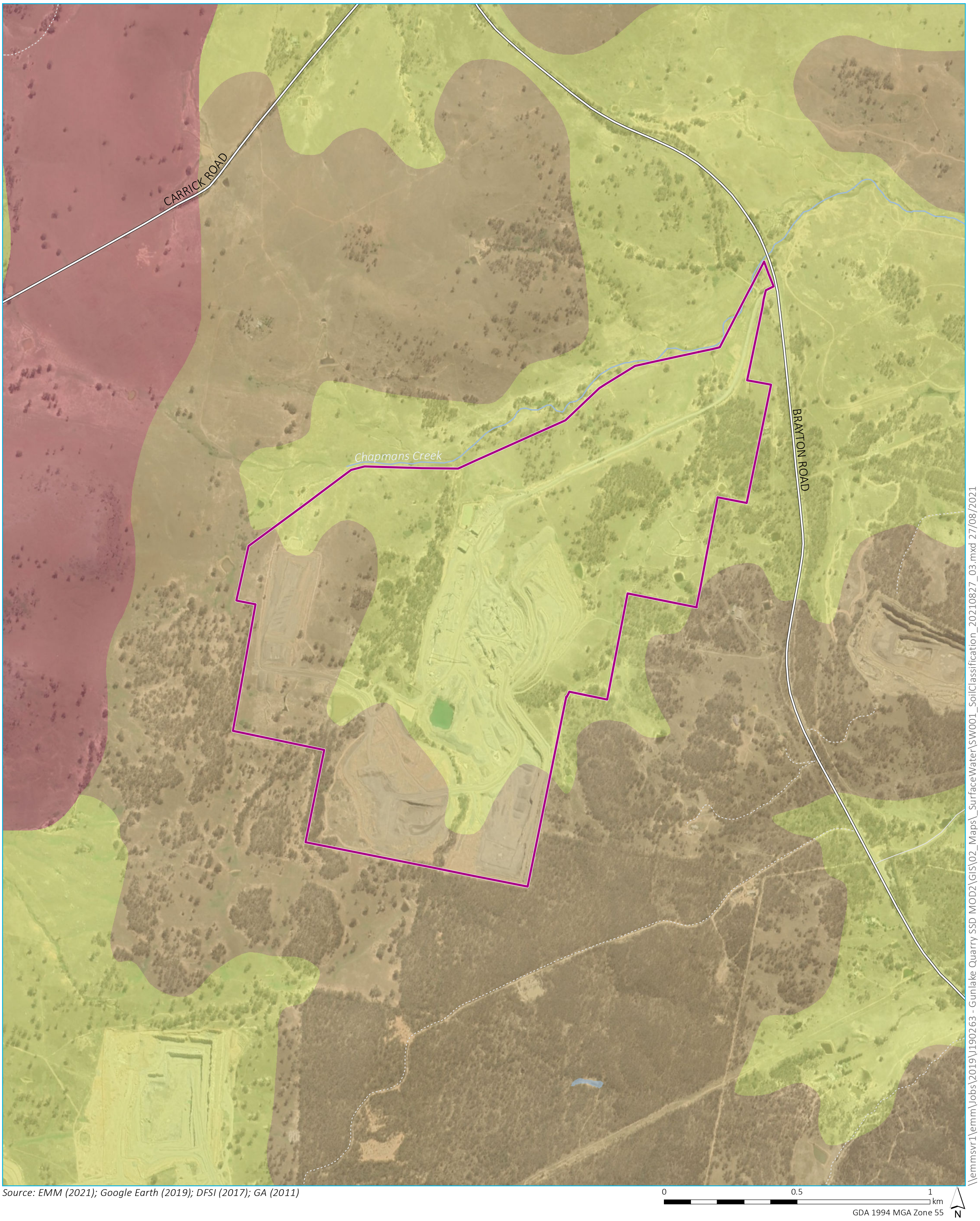
Figure 4.1 Average daily rainfall and evaporation rates

4.2 Soils

The Gunlake Quarry Extension Project: Soil and Rehabilitation Assessment (EMM 2016) identified two soil types in the Quarry site: Kurosol (44.1 ha) and Natric Kurosol (55 ha) soils, as shown in Figure 4.2. The hydrologic soil group mapping in NSW identifies soils at the Quarry as C for Kurosol and D for Natric kurosols:

- Type C – soils having slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission and high runoff rates.

- Type D – soils having very slow infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission and very high runoff rates.



Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

KEY

- Site boundary
- Major road
- Minor road
- Vehicular track
- Named watercourse

Australian soil classification

- Ferrosols
- Kurosols
- Kurosols, Natric

Soil types

Gunlake Quarry Continuation Project
Surface water assessment
Figure 4.2

EMM
creating opportunities

4.3 Hydrology

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. The catchment area and riparian zones of Chapmans Creek have been predominantly cleared and are used as grazing land. Observations of Chapmans Creek during routine monitoring undertaken by Gunlake indicate that the upper reaches are predominantly dry and only flow following heavy rainfall events, while the lower section towards Brayton Road at the Quarry property boundary consists largely of unconnected stagnant pools which respond quickly to rainfall events and tend to dry rapidly in periods of dry weather.

Jaorimin Creek flows in a northerly direction to its confluence with the Wollondilly River, approximately 8.6 km downstream of the Quarry. The Wollondilly River is the major river in the region and is one of the key tributaries to Lake Burragorang, which is located 65 km to the north-east of the Quarry. Johnniefelds 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.

There are no identified surface water users upstream of the confluence of Chapmans Creek with Jaorimin Creek, with the exception of farm dam water supplies for stock water supply.

Watercourses in the vicinity of the Quarry are presented in Figure 4.3.

4.4 Hydrogeology

The Continuation Project Groundwater Assessment (EMM 2021; provided as Appendix F.5 to the EIS) characterises the existing groundwater regime, estimates groundwater inflows into the pit and assesses potential risks and impacts to groundwater resources.

4.4.1 Alluvial/colluvial deposits

The poorly developed alluvial/colluvial deposits along the alignment of Chapmans Creek and Jaorimin Creek (and associated drainage channels) host an unconfined, perched water source. The alluvial/colluvial deposits are typically less than 5 m thick with low storage (Dundon 2005). Groundwater residence time is low with rapid recharge and discharge following rainfall. The groundwater flow direction is consistent with the overlying surface water drainage features. The extent of the alluvium/colluvium associated with Chapmans Creek is confined to a narrow band along the creek banks.

The alluvial/colluvial deposits comprise a matrix of fine particles (clay and silt) with minor sand/gravel and have a low permeability. Given the low permeability and limited extent (and therefore storage capacity), the alluvial/colluvial aquifer is a marginal water source for extractive water supply.

4.4.2 Fractured rock water bearing zone

The porphyry rock mass at the Quarry hosts a fractured rock groundwater source with marginal extraction value (ie high salinity and low yield). Regional groundwater flow is towards the north-east, with eventual discharge to the Wollondilly River. On a local scale, the groundwater flows north-east, following a muted reflection of topography. Groundwater flow may also follow structural discontinuities in the rock mass, as shown by seep discharges.

The groundwater systems are recharged via the direct infiltration of rainfall and potentially overlying surface water sources where alluvium is located. Recharge rates to alluvium and low-lying areas are expected to be higher than the fractured rock mass. This is because alluvium has a higher permeability than the porphyry rock mass and low-lying areas receive more inundation with surface water flow. The alluvial/colluvial deposits within the project area along the upper Chapmans Creek are expected to have similar recharge rates to the adjacent fractured rock areas.

Source: EMM (2021); Google Earth (2019); DFSI (2017); DPI (2015); GA (2011)

0 0.5 1 km
GDA 1994 MGA Zone 55
N

\\emmsvr1\emm\Jobs\2019\J190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_SurfaceWater\SW002_Watercourses_20210827_03.mxd 27/08/2021

KEY

- Site boundary
- Major road
- Minor road
- Vehicular track
- Surface elevation (mAHD)

Strahler stream order

- 1st order
- 2nd order
- 3rd order
- 4th order

Watercourses

Gunlake Quarry Continuation Project
Surface water assessment
Figure 4.3

EMM
creating opportunities

4.4.3 Groundwater quality

A groundwater monitoring network was installed at the Quarry site in April 2007. Groundwater quality has been monitored at the Quarry from December 2014 to June 2021. Groundwater in the project area is generally of poor quality. Overall, EC conditions range from fresh to moderately brackish with no distinct trends, although EC conditions are consistently fresh at GM6. Groundwater salinity levels generally exceed the ANZECC (2000) DGV at bores GM13, GM24 and GM36 on numerous occasions. Most groundwater in the fractured volcanic rock is naturally brackish. The exception is the physicochemical results at GM6, ie consistently low salinity groundwater, which again suggests this local area receives direct rainfall recharge.

Average pH conditions are neutral, although there were multiple exceedances of the ANZECC (2000) DGVs, both above and below the guideline range. Acidic and alkaline conditions were observed; however, the pH is mostly neutral at GM6 with the notable exception of pH 9 recorded in May 2015. It is likely that this sampling event for GM6 is compromised and such fluctuations in results are not indicative of regional water quality trends.

Groundwater concentrations of dissolved cadmium, chromium, lead and nickel were greater than the ADWG values. Concentrations of cadmium, copper, nickel and zinc were also greater than the ANZG (2018) DGVs. Elevated concentrations of dissolved metals are natural and are not attributable to quarry activities.

Groundwater ammonia, nitrite, nitrate and phosphorous concentrations frequently exceeded the ANZG (2018) DGVs, often by one order of magnitude. There were only three exceedances of the ADWG values, and this was for ammonia as N. Nutrient concentrations may be attributed to anthropogenic land use practices within the groundwater catchment (eg farming).

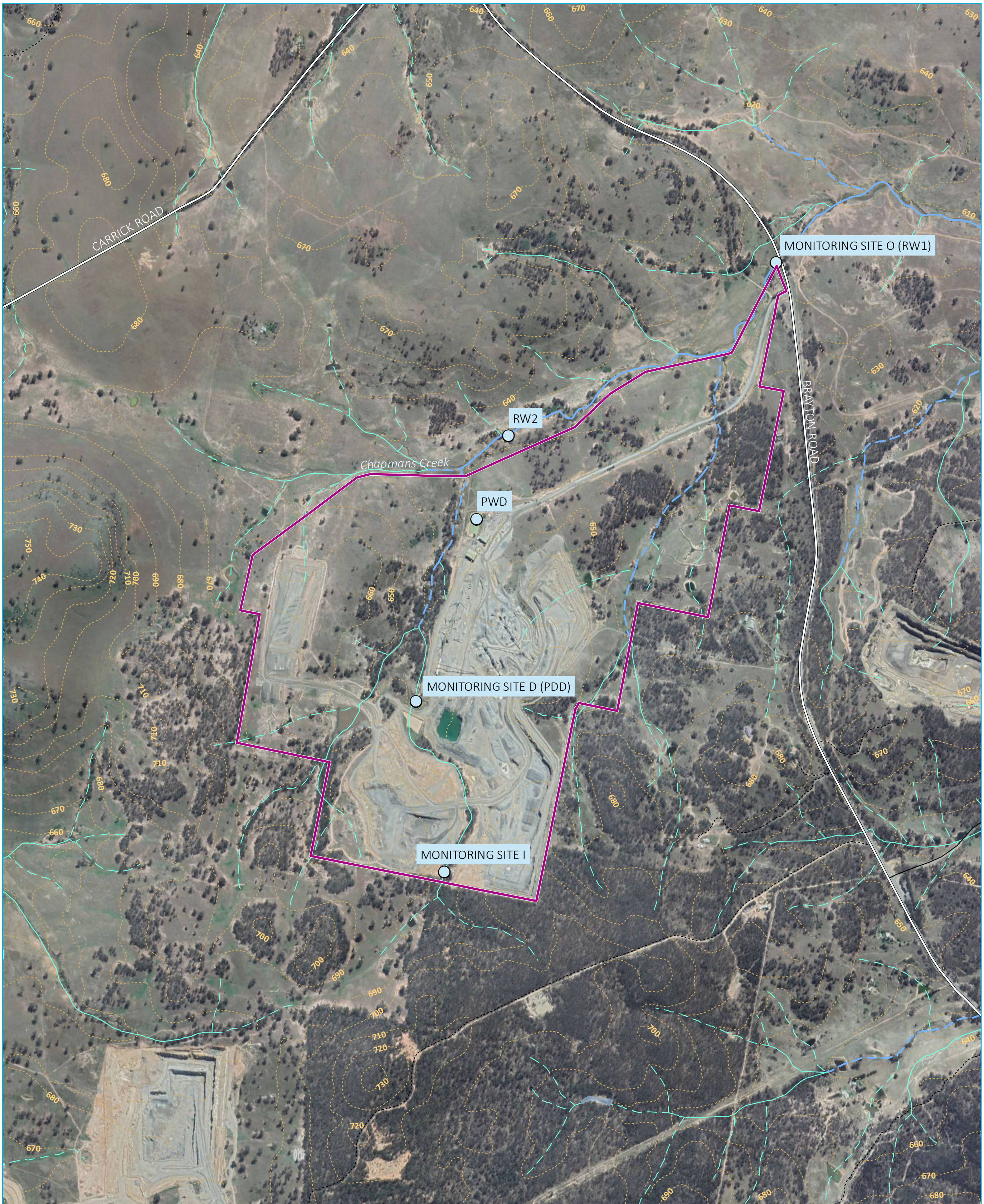
4.5 Surface water quality

4.5.1 Sampling program

Surface water quality monitoring at the Quarry has been undertaken between February 2007 and June 2021 at the following locations, as shown in Figure 4.4:

- upstream/pre-quarrying monitoring sites:
  - monitoring site I – upper reach of Chapmans Creek;
  - monitoring site D – upper reach of Chapmans Creek;
- receiving water monitoring sites:
  - RW1 (previously referred to as monitoring site O);
  - RW2;
- Quarry water management system:
  - PWD – Process Water Dam; and
  - drop cut – in-pit sump.

Monitoring at sites I and D ceased in 2018 following the extension of the quarry pit through the upper reaches of Chapmans Creek. Monitoring of sites RW2, PWD and drop cut commenced in 2018.



Source: EMM (2021); Google Earth (2019); DFSI (2017); DPI (2015); GA (2011)

0 0.5 1 km
GDA 1994 MGA Zone 55
N

KEY

- Site boundary
- Surface water monitoring location
- Major road
- Minor road
- Vehicular track
- Surface elevation (mAHD)

Strahler stream order

- 1st order
- 2nd order
- 3rd order
- 4th order

Surface water quality monitoring locations

Gunlake Quarry Continuation Project
Surface water assessment
Figure 4.4

EMM
creating opportunities

4.5.2 Monitoring results

A summary of median water quality results is presented in Table 4.2. All monitoring data is presented in Annexure B. Where an analytical result was below the detection limit, then the numerical value of the limit of reporting was used in the analysis. Results are compared to DGVs recommended by ANZG (2018) (refer Section 3.2.3). Results that exceed the relevant DGV are highlighted in orange.

A limited number of monitoring results were available for the majority of parameters, particularly for monitoring site I which was dry during most sampling events.

Key results are summarised as follows:

- Background water quality is highly variable, which is a result of the highly intermittent flow regime of Chapmans Creek.
- There is generally an increasing trend in pH, EC, sodium and chloride downstream within Chapmans Creek, while nitrogen, phosphorus, iron and manganese tend to decrease downstream.
- Recorded EC was generally significantly higher at monitoring site RW1 (downstream of the Chapmans Creek weir) than sites D and RW2 (adjacent to the Quarry). Higher EC levels were generally associated with dry conditions following periods of runoff. The elevated EC at RW1 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.
- Recorded total suspended solids (TSS) concentrations at site RW1 were generally below 20 milligrams per litre (mg/L) following rainfall events, indicating that the Quarry operation is not contributing sediment-laden water to downstream receiving waters.
- Recorded nutrients (total nitrogen and total phosphorus) were consistently five to ten times greater than the DGVs recommended by ANZG (2018). It is noted that some of the highest concentration recorded were in 2007 prior to the commencement of quarry operations in 2009. This indicates that the elevated levels are associated with agricultural land use.
- Recorded arsenic, cobalt, manganese, nickel and zinc concentrations were generally below the DGVs (ANZG 2018).

Table 4.2 Summary of surface water quality monitoring results

Parameter	Units	DGV[1]	Upstream/pre-mining monitoring				Receiving waters monitoring				Quarry water management system			
			Monitoring site I		Monitoring site D		RW1[2]		RW2		PWD		Drop cut	
			Count	Median	Count	Median	Count	Median	Count	Median	Count	Median	Count	Median
Physical and chemical stressors														
Dissolved oxygen	mg/L				14	9.0	26	8.8	9	9.4	12	9.3	10	9.6
EC	µS/cm	30–350	18	136	60	110	67	930	9	1,530	12	683	10	825
pH	pH units	6.5–8.0	18	6.4	60	7.1	67	8.0	9	8.0	12	8.1	10	7.8
TDS	mg/L		14	248	29	117	41	480	9	852	12	420	10	536
TSS	mg/L		4	14	32	11	38	8	9	9	12	30	10	15
Turbidity	NTU	2–25					12	10	9	7	12	29	10	15
Major ions														
Calcium	mg/L						12	35	9	37	8	15	10	28
Chloride	mg/L		14	20	28	11	40	91	9	289	8	66	10	147
Magnesium	mg/L						12	45	9	55	8	15	10	26
Potassium	mg/L						12	5	9	6	8	5	10	5
Sodium	mg/L		13	11	28	6	40	45	9	156	8	86	10	82
Nutrients														
Total nitrogen	mg/L	0.25	16	2.0	41	2.4	47	1.2	9	2.3	11	6.1	9	8.0
Total phosphorus	mg/L	0.02	15	0.13	29	0.14	40	0.03	9	0.02	12	0.02	10	0.01
Metals														
Total aluminium	mg/L	0.055					2	8.30	1	3.15	2	6.96	1	1.12

Table 4.2 Summary of surface water quality monitoring results

Parameter	Units	DGV[1]	Upstream/pre-mining monitoring				Receiving waters monitoring				Quarry water management system			
			Monitoring site I		Monitoring site D		RW1[2]		RW2		PWD		Drop cut	
			Count	Median	Count	Median	Count	Median	Count	Median	Count	Median	Count	Median
Total arsenic	mg/L	0.013	14	0.001	30	0.001	42	0.001	9	0.001	12	0.001	10	0.001
Total cobalt	mg/L	0.0014					12	0.001	9	0.001	12	0.001	10	0.001
Total copper	mg/L	0.0014					12	0.002	9	0.001	12	0.003	10	0.002
Dissolved iron	mg/L	0.3	14	4.39	30	1.52	30	0.42						
Total iron	mg/L	0.3					12	0.32	9	0.24	12	1.76	10	0.49
Total manganese	mg/L	1.9	14	0.211	30	0.116	42	0.032	9	0.053	12	0.061	10	0.021
Total nickel	mg/L	0.011					12	0.001	9	0.001	12	0.002	10	0.001
Total zinc	mg/L	0.008					12	0.005	9	0.005	12	0.008	10	0.005

1. DGV – default guideline value recommended by ANZG (2018) (refer Section 3.2.3).
2. RW1 was previously referred to as monitoring site O.

5 Water management

5.1 Overview

A Surface Water Assessment (RHDHV 2016; provided in Annexure A) was prepared as part of the Extension Project EIS. This described the management of surface water associated with the expansion of the pit to the south and west and the establishment of the emplacement area to the west of the pit. Following approval of the Extension Project, the *Gunlake Quarry Soil and Water Management Plan* (Gunlake 2020) was updated with the approved surface water management strategy.

There are no changes to the previously approved disturbance footprint or the approved water management approach proposed as part of the Continuation Project. However, the water balance modelling has been updated to incorporate:

- updated groundwater inflow estimates (EMM 2021); and
- an increase in process water use due to the higher production rates.

This chapter describes the approved surface water management strategy for the Quarry and updated water balance model results.

5.2 Definitions

Surface water and groundwater described in this report has been categorised as follows based on water quality and intended use:

- clean water – surface water runoff from undisturbed or fully rehabilitated catchments;
- dirty water – surface water runoff from disturbed areas, such as the Quarry pit, haul roads, emplacement and product stockpiles and processing areas, which is likely to contain suspended sediment;
- process water – water that has been used for haul road dust suppression and within the processing plant;
- groundwater – groundwater inflows into the Quarry pit that are predicted to occur once the groundwater table is intercepted (second bench of the Quarry);
- potable water – water suitable for drinking; and
- wastewater – water produced by on-site amenities (ie sewage).

5.3 Water management strategy

This section describes the Quarry's water management strategy using information reproduced from the surface water assessment prepared for the Extension Project (RHDHV 2016). The strategy was developed as part of the Extension Project and has been applied by Gunlake for several years.

5.3.1 Objectives

Table 5.1 reproduces the water management objectives and approaches that were applied to establish the water management strategy (RHDHV 2016).

Table 5.1 Water management objectives and approach

Water management objectives	Applied approach (RHDHV 2016)
1 Where practical, separate clean and quarry water circuits to minimise the volume of water that requires treatment.	Where possible, clean water diversion drains were established up gradient of disturbance areas to reduce the volume of water that enters the water management system.
2 Provide appropriately sized sedimentation basins for all catchment areas that will be disturbed by the Quarry operation.	Sedimentation basins were established to capture and treat runoff from disturbed areas. The basins were sized in accordance with the methods recommended by *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 is dewatered via pumping from in pit storages to the Process Water Dam, where it is stored for process water use. During periods of water surplus, it is proposed to release water from the dam when its water quality is suitable. However, this has not been necessary since the implementation of the Extension Project.
4 Minimise the volume and frequency of site discharge.	Water from disturbed areas is captured in a series of water management dams. Water stored in dams is used to meet process water demands and plant and haul road dust suppression. This water use reduces dam levels and the potential discharge frequencies and volumes.
5 Establish site discharge locations and characteristics.	Site discharge locations have been established for the Quarry.
6 Establish the Quarry's operational water demands and identify reliable water sources over the life of the Quarry.	Water balance modelling was undertaken to estimate the Quarry'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 program that will enable the surface water management system to be improved over time.	A monitoring program is provided as part of the *Gunlake Quarry Soil and Water Management Plan* (Gunlake 2020). No changes to the monitoring program are proposed as part of the Continuation Project.

The approved surface water management system for the Quarry is presented in Figure 5.1. The key water management strategy adopted across the site is containment and management of potentially sediment-laden runoff from disturbed areas and reuse where feasible. Key aspects of the strategy are discussed below.

5.3.2 Clean water management

A clean water diversion system has been constructed to divert runoff from a clean water catchment that is located to the south of the pit. The system has been constructed along the southern and western edges of the final pit extent. Due to topographic constraints, the channel has been established on one of the upper benches within the Quarry and will permanently divert clean water around the pit.

5.3.3 Dirty water management

Runoff from dirty water catchments is collected within the Process Water Dam, the Pit Dewatering Dam (to be constructed once the groundwater table is intercepted), pit sump or one of the numerous sedimentation dams on site. All dams are designed and constructed to provide adequate sedimentation treatment in accordance with the methods recommended by Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries (DECC 2008).

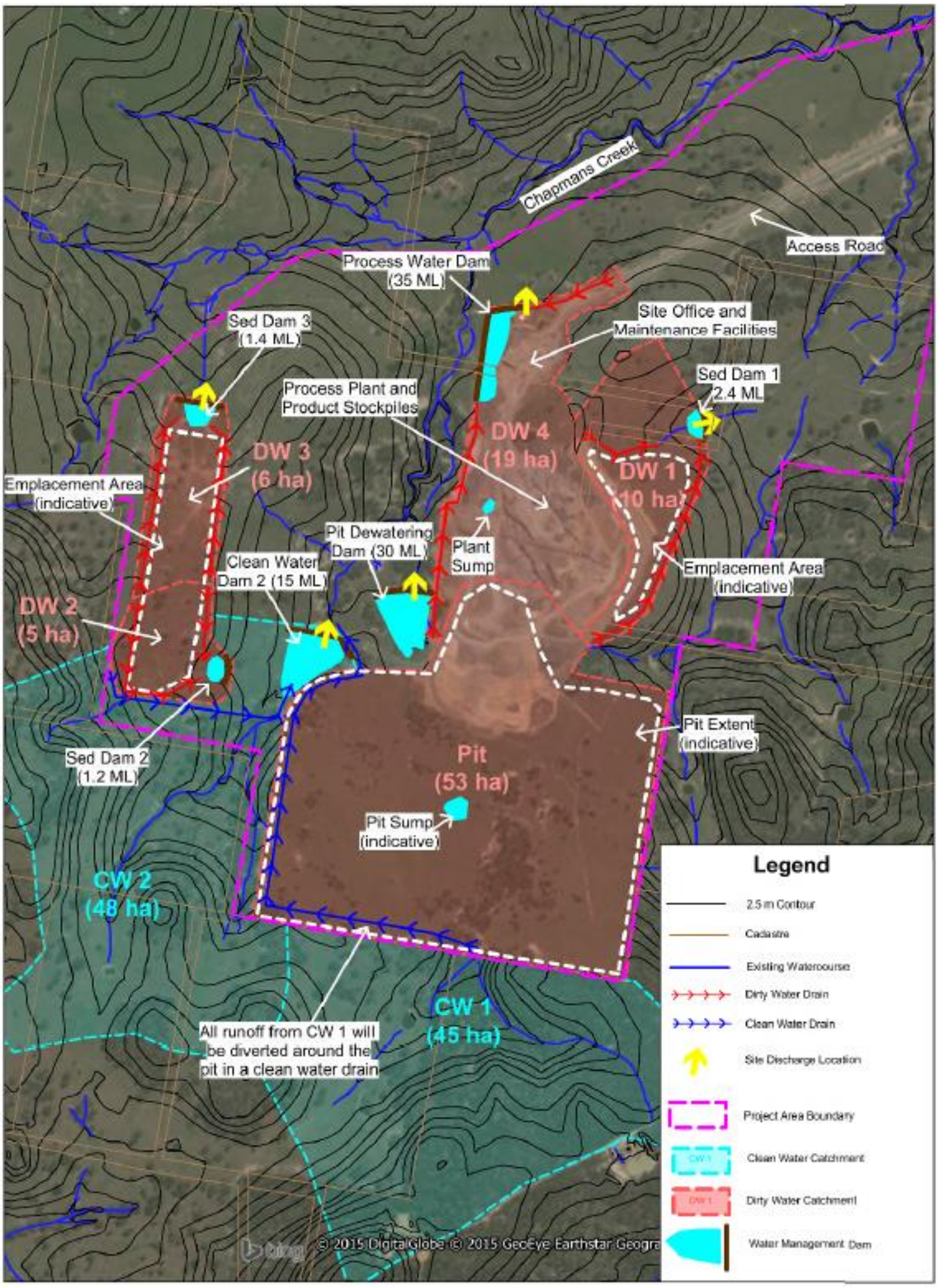


Figure 5.1 Surface water management strategy (RHDHV 2016)

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

Table 5.2 summarises the features of the dirty water management storages in place at the Quarry.

Table 5.2 Water management storages

Storage	Description/function	Catchment	Volume	Outflows
Pit sump (drop cut)	Captures runoff from within the pit footprint and from groundwater inflows.	53 ha	80 ML	Water is extracted to supply plant water use and haul road dust suppression. Dewatered to the Pit Dewatering Dam (once constructed).
Process Water Dam	Captures runoff from the northern infrastructure area (catchment DW4) and receives water pumped from Clean Water Dam 2.	19 ha	25 ML	Water is extracted to supply plant water use and haul road dust suppression. Overflows to Chapmans Creek.
Sediment Dam 1	Captures runoff from the overburden emplacement area (catchment DW1).	10 ha	2.4 ML	Overflows to Chapmans Creek.
Sediment Dam 2	Captures runoff from the southern extent of the western emplacement area (catchment DW2).	5 ha	1.2 ML	Overflows to Clean Water Dam 2.
Sediment Dam 3	Captures runoff from the northern extent of the western emplacement area (catchment DW3).	6 ha	1.4 ML	Overflows to Chapmans Creek.
Clean Water Dam 2	Captures runoff from the upstream clean water catchment (catchment CW2) and overflows from Sediment Dam 2.	48 ha	15 ML	Pumped transfers to Process Water Dam. Overflows to Chapmans Creek.
Pit Dewatering Dam	Turkey's nest dam that is yet to be constructed. Designed to store water that has been dewatered from the pit.	N/A	30 ML	Water is extracted to supply plant water use and haul road dust suppression. Overflows to Chapmans Creek.

5.3.4 Groundwater inflows

As extraction progresses below the water table, a hydraulic gradient will be created directing groundwater flow towards the depressurised strata and into the pit (groundwater inflow). Groundwater inflow predictions have been revised for the Continuation Project (EMM 2021), with the average modelled groundwater flux to the Quarry area once quarrying is below the water table (ie from January 2027 to January 2052) is 68 ML/year. Seepage into the Quarry pit at the end of quarrying is estimated to be 50 ML/year, decreasing to 28 ML/year long-term.

5.3.5 Water use

Water used in the process plant is primarily used for dust suppression. Flow meter data indicates that the net water use in the plant is 18.2 L per tonne processed, which is consistent with typical values for a hard rock quarry (RHDHV 2016).

Haul road dust suppression is required on non-rainy days to mitigate dust produced from the operation of trucks and other equipment on haul roads. Required application rates on any given day are a function of the active haul road area and the prevailing climatic conditions. Dust suppression is required over approximately 8 ha of haul roads.

Process water demands for the process plant and haul road dust suppression is supplied from the following sources (in order of preference):

- Process Water Dam;
- pit sump (drop cut);
- Clean Water Dam 2;
- Pit Dewatering Dam (to be constructed); and
- Sediment Dams 1, 2 and 3.

5.3.6 Amenities and wastewater systems

Rainwater tanks capture runoff from the administration office and maintenance shed roofs. Harvested water is used for non-potable uses in the bathrooms and kitchen facilities. The tanks can be filled with imported potable water during periods of water shortages. Bottled drinking water is imported to the site and provided in all facilities.

An onsite septic system is used for all wastewater produced from the Quarry's amenities. The system includes a primary collection tank followed by an absorption trench system which consists of aggregate covered by topsoil and grass. The trench is fed via a distribution box which evenly conveys clarified effluent from the primary collection tank. The septic system is maintained annually by an external contractor.

5.4 Water balance

5.4.1 Model approach

A water balance model of the Quarry was prepared for the Extension Project (RHDHV 2016). The model was prepared using standard industry methods and was applied to assess the effectiveness of the Quarry's water management system, estimate discharges and determine water licensing requirements. The model was provided by RHDHV to EMM for use in the Continuation Project and was updated to incorporate the revised groundwater inflow estimates and an increase in plant water use due to the higher production rates. No other changes to the model were made.

Table 5.3 describes the scenarios assessed, the reference model presented by RHDHV (2016) and changes that were made to the reference model. Refer to RHDHV (2016) (which is reproduced in Annexure A) for descriptions of the model approach and assumptions.

Table 5.3 Water balance scenarios

Scenario	Context	Reference model[1]	Summary of changes
Scenario 1 (2022 to 2026)	• Pit excavation above the groundwater table • Approx. 2.2–4.2 Mtpa production	Quarry year 5	• Groundwater inflows into the pit reduced from 23 ML/year to 0 ML/year in the updated model (EMM 2021). • Water use in the process plant is has been predicted to increase from 37 ML/year to 40 ML/year [2] due to the increase in production rates to 2.2 Mtpa (this would increase for higher production rates).

Table 5.3 Water balance scenarios

Scenario	Context	Reference model[1]	Summary of changes
Scenario 2 (2027 to 2051)	• Pit excavation below the groundwater table • Up to 4.2 Mtpa production	Quarry years 10 to 30	• Groundwater inflows into the pit increased from 34 ML/year to 68 ML/year in the updated model (EMM 2021). • Water use in the process plant was increased from 36 ML/year to 80 ML/year [2] due to the increase in production rates from 2.0 Mtpa to 4.2 Mtpa.
Post closure scenario	• The Quarry will be rehabilitated and a pit lake allowed to form.	Final void model	• The peak groundwater inflows into the pit increased from 34 ML/year to 54 ML/year in the updated model (EMM 2021).

Notes: 1. Refers to the water balance model scenario presented by RHDHV (2016) that was modified for use in this project.
2. Plant water use was calculated using the 18.2 L/tonne processed material established in RHDHV (2016).

5.4.2 Results

Water balance results for Scenarios 1 and 2 are presented in flow chart form for typical dry (10th percentile), median (50th percentile) and wet (90th percentile) rainfall years. The flow chart results are annualised, which means they show the total water movement over the simulated year.

i Scenario 1

The Scenario 1 results relate to the proposed Quarry operation between 2022 to 2026, ie pit excavation above the groundwater table. Water balance results are presented for dry (Figure 5.2), median (Figure 5.3) and wet (Figure 5.4) years. A summary of changes to the results from the reference model is provided below the charts.

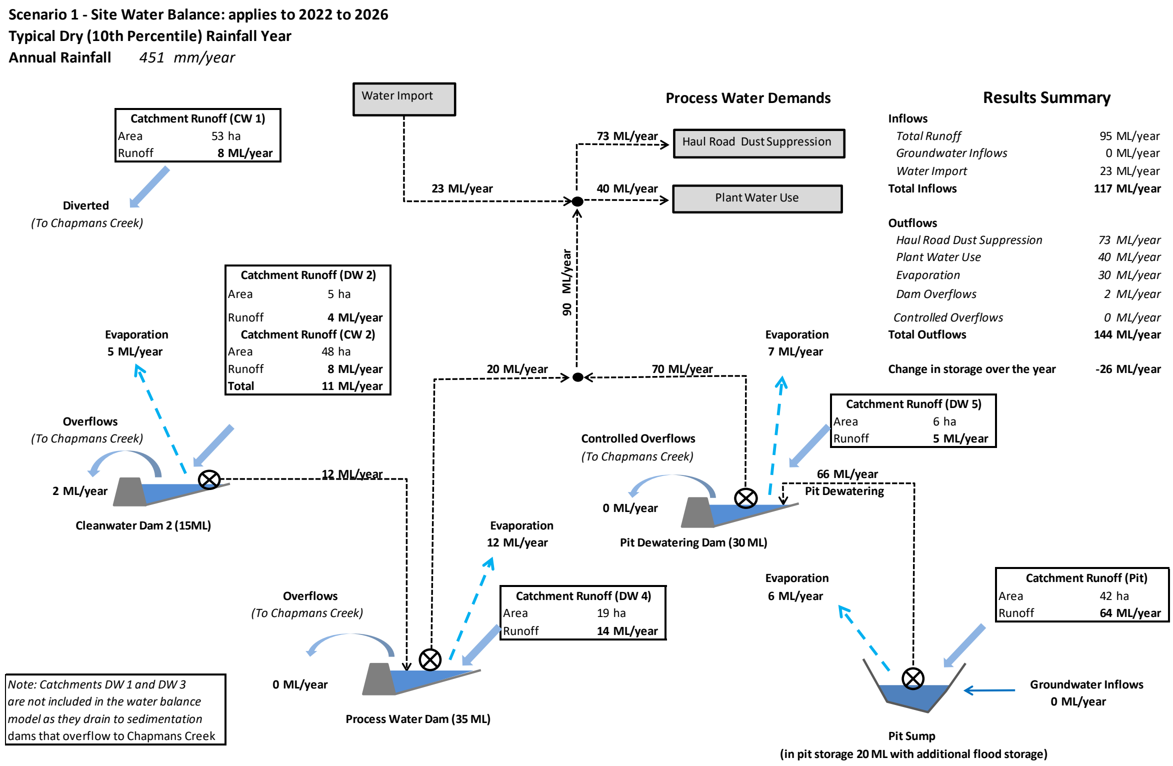


Figure 5.2 Scenario 1 water balance results – typical dry year

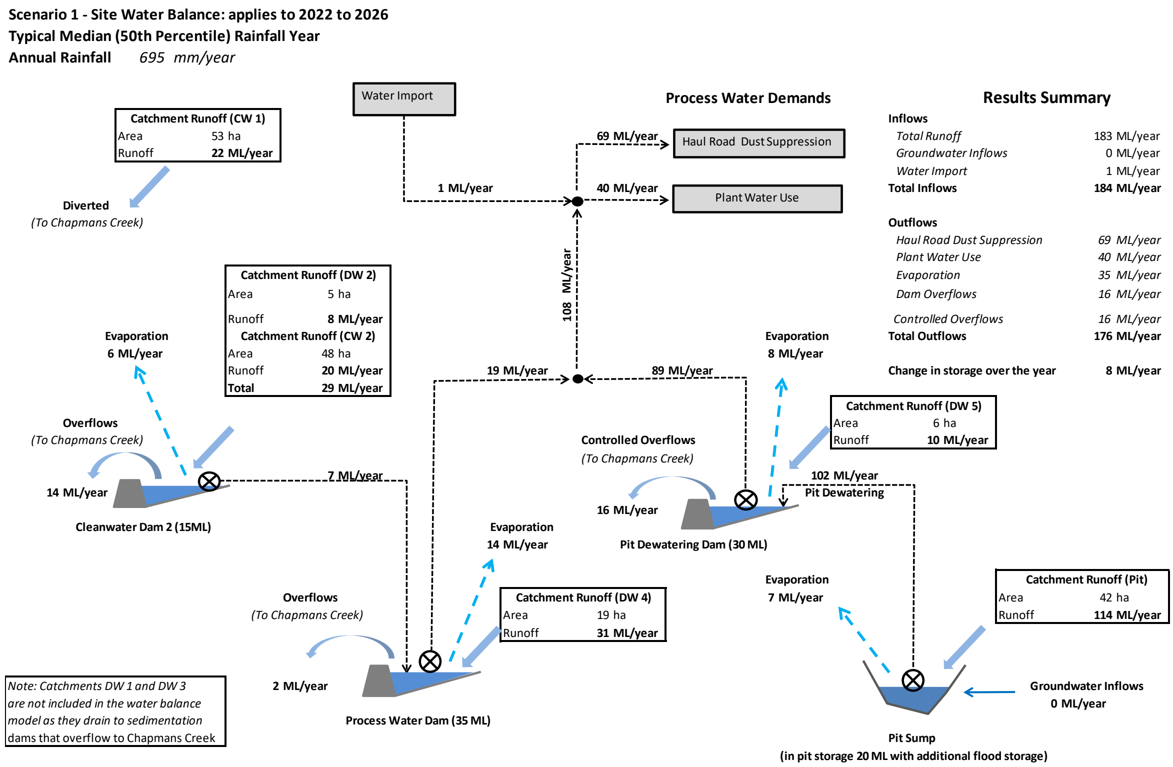


Figure 5.3 Scenario 1 water balance results – typical median rainfall year

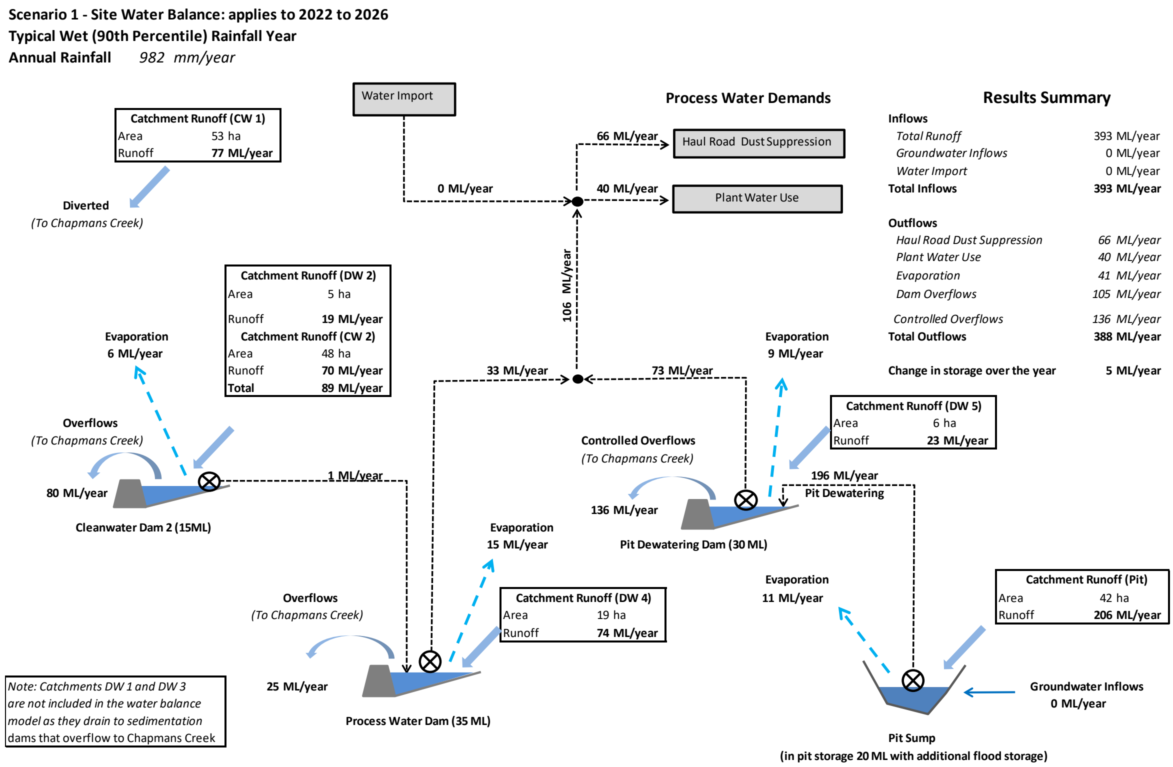


Figure 5.4 Scenario 1 water balance results – typical wet year

The Scenario 1 water balance applied a reduction in groundwater inflows into the pit and an increase in plant water use (see Table 5.3). Collectively these changes reduce assumed inflows and increase assumed outflows (via process water use) from the water management system. In general terms, these changes will increase the need for water imports and reduce system overflows. Table 5.4 provides a summary of changes (relative to the reference model) to the predicted water imports and system overflows for dry, median and wet years. The results show a moderate increase in the need for/likelihood of water imports during dry conditions and a moderate reduction in system overflows during all conditions should they occur over the 5-year Scenario 1 period. If water stored on site at the start of a dry period is insufficient to meet all water requirements, operations may need to be scaled accordingly.

Table 5.4 Summary of changes – Scenario 1

	Water import			Overflows		
	RHDHV (2016)	This assessment	Change	RHDHV (2016)	This assessment	Change
Dry year	2 ML/year	23 ML/year	+21 ML/year	3 ML/year	2 ML /year	-1 ML/year
Median year	0 ML/year	1 ML/year	+1 ML/year	54 ML/year	32 ML/year	-22 ML/year
Wet year	0 ML/year	0 ML/year	No change	265 ML/year	241 ML/year	-24 ML/year

ii Scenario 2

The Scenario 2 results relate to the proposed Quarry operation between 2027 to 2051, pit excavation below the groundwater table. Water balance results are presented for dry (Figure 5.5), median (Figure 5.6) and wet (Figure 5.7) years. A summary of changes to the results from the reference model is provided below the charts.

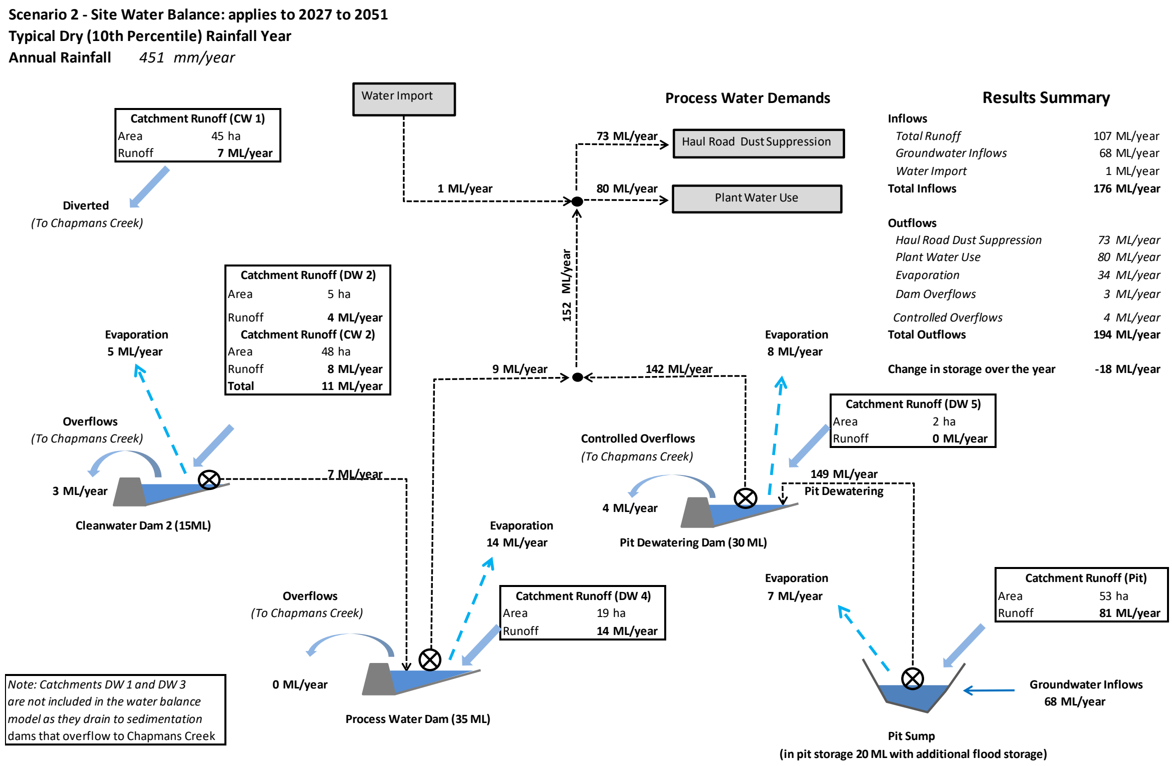


Figure 5.5 Scenario 2 water balance results – typical dry year

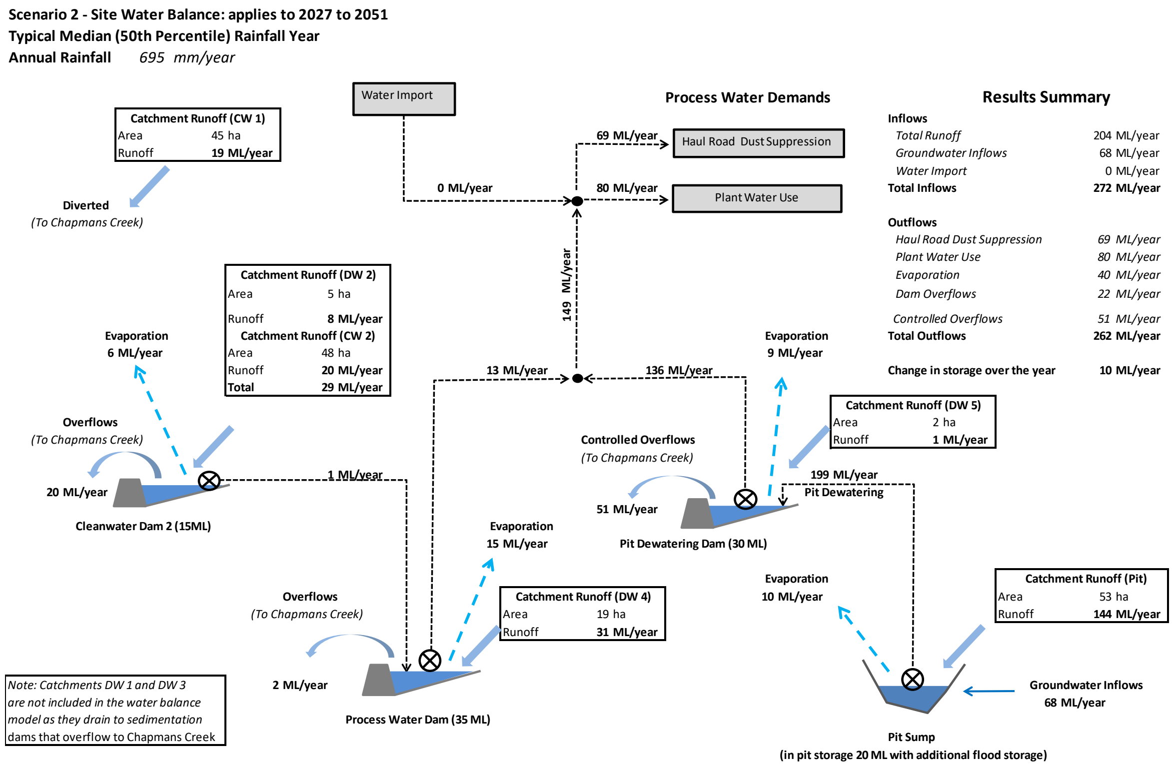


Figure 5.6 Scenario 2 water balance results – typical median year

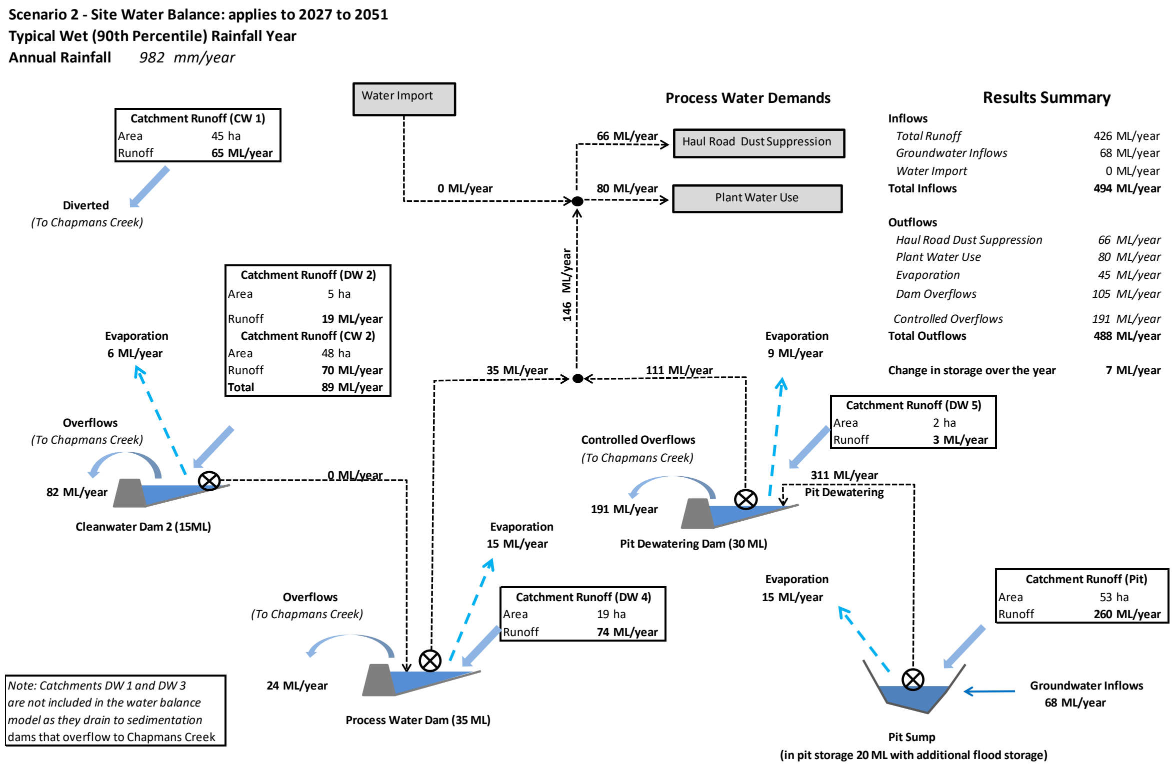


Figure 5.7 Scenario 2 water balance results – typical wet year

The Scenario 2 water balance applied an increase in both groundwater inflows into the pit and plant water use (see Table 5.3). These changes increase both the assumed inflows and outflows from the water management system by a similar amount and will therefore result in a minimal overall change to the water balance. Table 5.5 provides a summary of changes (relative to the reference model) to the predicted water imports and system overflows for dry, median and wet years. The results show there is no change to the need for/likelihood of water imports during dry conditions and a minor reduction in system overflows during all conditions.

Table 5.5 Summary of changes – Scenario 2

	Water import			Overflows		
	RHDHV (2016)	This assessment	Change	RHDHV (2016)	This assessment	Change
Dry year	0 ML/year	0 ML/year	No change	10 ML/year	7 ML/year	-3 ML/year
Median year	0 ML/year	0 ML/year	No change	85 ML/year	73 ML/year	-12 ML/year
Wet year	0 ML/year	0 ML/year	No change	307 ML/year	296 ML/year	-11 ML/year

iii Post closure scenario

The post closure scenario documented by RHDHV (2016) was updated to incorporate a higher peak groundwater inflow estimate (see Table 5.3). The simulated pit lake volumes from the 2016 and current assessments are shown in Figure 5.8. The results indicate that the moderate increase in the assumed post closure groundwater inflow rate would result in a minimal change to the pit lake water level regime. This is because direct rainfall to the pit lake, surface water runoff from the catchment area to the pit lake and evaporation losses are the primary processes that will influence the pit lake levels.

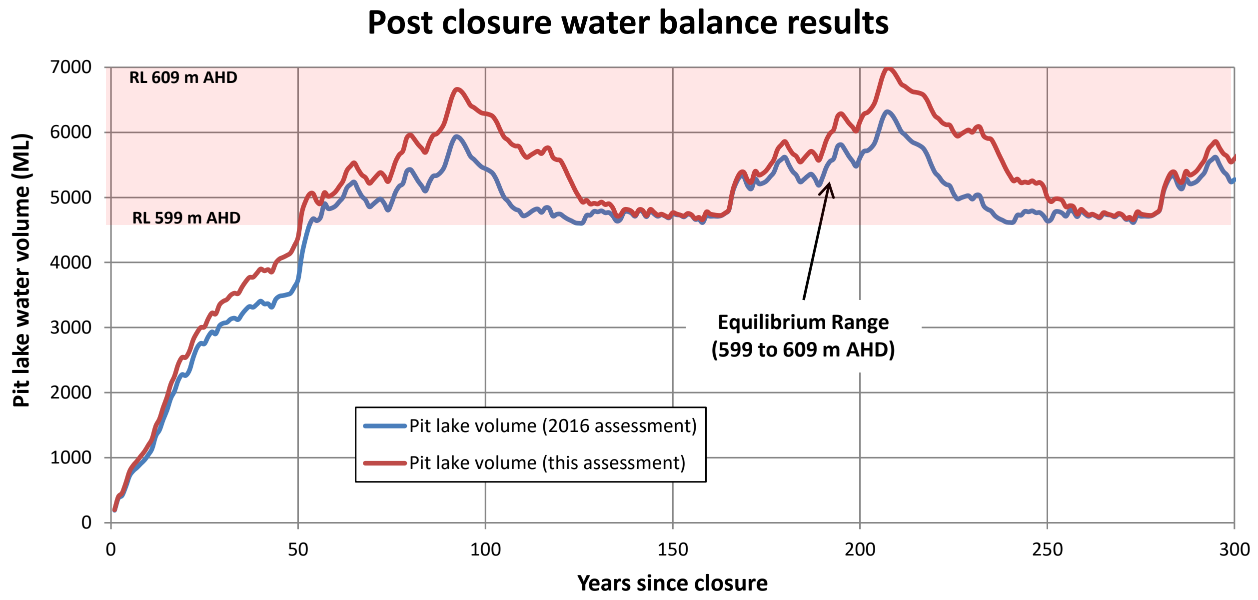


Figure 5.8 Post closure water balance results

6 Residual impacts

6.1 Water management system overflows

Gunlake currently operate the Quarry water management system that was developed as part of the EIS for the Extension Project and is further documented in the Soil and Water Management Plan (Gunlake 2020). The proposed changes to the existing consent (Section 2.2) relate to increasing production, quarry life and pit depth. No changes to the previously approved disturbance footprint or water management system are proposed. Water balance modelling (Section 5.4) found that the proposed changes will reduce the likelihood and magnitude of overflows occurring from the water management system. This is because the process water use associated with higher production will more than offset the increase in predicted groundwater inflows.

As overflows will be reduced, the Continuation Project is not predicted to result in a negative impact to water quality in the downstream catchments relative to the approved Quarry. It is therefore classified as having a neutral or beneficial effect (NorBE) on downstream water quality within the Sydney Drinking Water Catchment area in accordance with the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011.

6.2 Flooding

The Continuation Project is not expected to have any measurable change in flooding regime in downstream waterways as no changes to the previously approved disturbance footprint are proposed.

7 Water licensing

7.1 Approvals

Clause 4.41(1)(g) of the EP&A Act exempts an SSD authorised by a development consent from requiring a water use approval under section 89, a water management work approval under section 90, or an activity approval (other than an aquifer interference approval) under section 91 of the WM Act. These exemptions apply to the project as it has been declared an SSD and, therefore, there is no requirement to obtain approvals under the WM Act, including water use, water management work or controlled activity approvals.

7.2 Excluded works exemption

Dams that are solely for the capture, containment or recirculation of drainage, consistent with best management practice to prevent the contamination of a water source, that are located on a minor stream are considered to be excluded works under Schedule 1, item 3 of the NSW Water Management (General) Regulation 2018. The current and future storages that form the dirty water management system (refer Section 5.3.3) are considered to be excluded works under this definition as the primary use of the storages are for water quality control by capturing sediment-laden runoff and retaining sediment to prevent pollution of the downstream receiving environment. All storages are located on minor streams (ie first or second order watercourses).

Water stored within the dirty water management system is reused for dust suppression activities and to supply the processing plant. The take of water from the dirty water management system is exempt from requiring a licence under Schedule 4, item 12 of the NSW Water Management (General) Regulation 2018.

7.3 Harvestable rights

Under Section 53 of the WM Act, owners or occupiers of a landholding are entitled to collect a proportion of the runoff from their property in one or more dams located on a minor stream or unmapped stream and use the water without the need for a licence or water supply work or water use approvals. Harvestable Rights Orders are published in the NSW Government Gazette and specify the rules relating to harvestable rights.

In the Central and Eastern Divisions of NSW (where the Quarry is located), landholders may capture, store and use up to 10% of the average regional runoff for their property. Dams that are solely for the capture, containment or recirculation of drainage, consistent with best management practice to prevent the contamination of a water source, that are located on a minor stream are not included in harvestable rights calculations.

Gunlake's current landholding that is within or adjacent to the project site is 227 ha. The Maximum Harvestable Right Calculator provided by WaterNSW was used to determine the maximum harvestable right for the site of 17 ML (Annexure C).

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.

Clean Water Dam 2 is the only storage at the Quarry that captures clean water runoff, which has a volume of 15 ML. As this volume is within the calculated maximum harvestable rights, there is no licensing required for the capture or use of clean runoff at the site.

7.4 Groundwater inflows

Licensing requirements associated with groundwater inflows into the Quarry pit are addressed by the Continuation Project Groundwater Assessment (EMM 2021).

References

ANZECC 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Governments and Australian state and territory governments, http://www.waterquality.gov.au/anz-guidelines/.

DEC 2004, *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales*, NSW Department of Environment and Conservation.

DEC 2005, *Liquid Chemical Storage, Handling and Spill Management: Review of Best Practice Regulation*, NSW Department of Environment and Conservation.

DECC 2007, *Storing and Handling Liquids: Environmental Protection: Participant's Manual*, NSW Department of Environment and Climate Change.

DECC 2008, *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries*, NSW Department of Environment and Climate Change.

DECCW 2006, *NSW Water Quality and River Flow Objectives*, NSW Department of Environment, Climate Change and Water, http://www.environment.nsw.gov.au/ieo/.

Dundon 2005, *Proposed Lynwood Quarry: Marulan Groundwater Impact Assessment*, prepared as Appendix 7 for the Umwelt Pty Ltd Lynwood Quarry Environmental Impact Assessment, Peter Dundon & Associates.

EMM 2015, *Groundwater Assessment: Gunlake Extension Project*, prepared as Appendix H for Gunlake Quarry Extension Project Environmental Impact Statement.

EMM 2016, *Gunlake Quarry Extension Project: Soil and Rehabilitation Assessment: Gunlake Extension Project*, prepared as Appendix F for Gunlake Quarry Extension Project Environmental Impact Statement.

EMM 2021, *Groundwater Assessment: Gunlake Quarry Continuation Project*, prepared as Appendix F.5 for Gunlake Quarry Continuation Project Environmental Impact Statement.

Gunlake 2020, *Gunlake Quarry: Soil and Water Management Plan*.

Landcom 2004, *Managing Urban Stormwater: Soils and Construction – Volume 1*, 4th edition.

NHMRC 2018, *National Water Quality Management Strategy: Australian drinking water guidelines 6 2011*, version 3.5 updated August 2018, National Health and Medical Research Council.

NRAR 2018, *Guidelines for controlled activities on waterfront land*, NSW Natural Resources Access Regulator.

RHDHV 2016, *Gunlake Quarry Extension Project: Surface Water Assessment*, prepared as Appendix G for Gunlake Quarry Extension Project Environmental Impact Statement.

WaterNSW 2021, *Neutral or Beneficial Effect on Water Quality Assessment Guideline*, https://www.waternsw.com.au/__data/assets/pdf_file/0004/165775/NorBE-Assessment-Guideline-2021.pdf.

Abbreviations

ADWG	Australian drinking water guidelines
AHD	Australian Height Datum
BOM	Bureau of Meteorology
Continuation Project	Gunlake Quarry Continuation Project
DGV	default guideline value
EC	electrical conductivity
EIS	environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPL	environment protection licence
Extension Project	Gunlake Quarry Extension Project
Gunlake	Gunlake Quarries Pty Ltd
GWA	*Groundwater Assessment*, EIS Appendix F.5
NorBE	neutral or beneficial effect
NRAR	Natural Resources Access Regulator
POEO Act	*Protection of the Environment Operations Act 1997*
Quarry	Gunlake Quarry
SEARs	Secretary's environmental assessment requirements
SILO	Scientific Information for Land Owners
SSD	State significant development
TDS	total dissolved solids
TSS	total suspended solids
WM Act	*Water Management Act 2000*
WSP	water sharing plan

Annexure A

Gunlake Quarry Extension Project: surface water assessment (RHDHV 2016)

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.

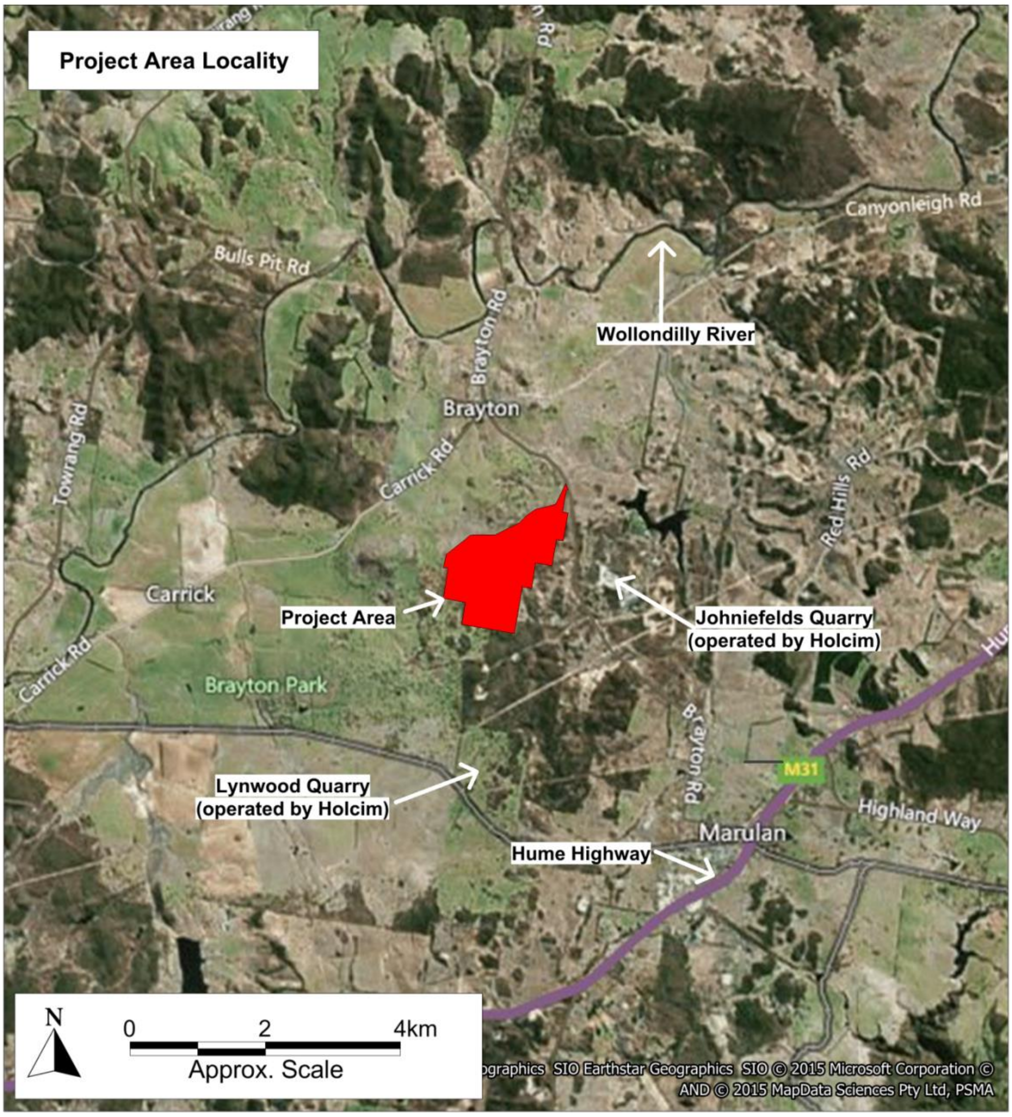


***Plate 1-1** – Site Locality*

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**.

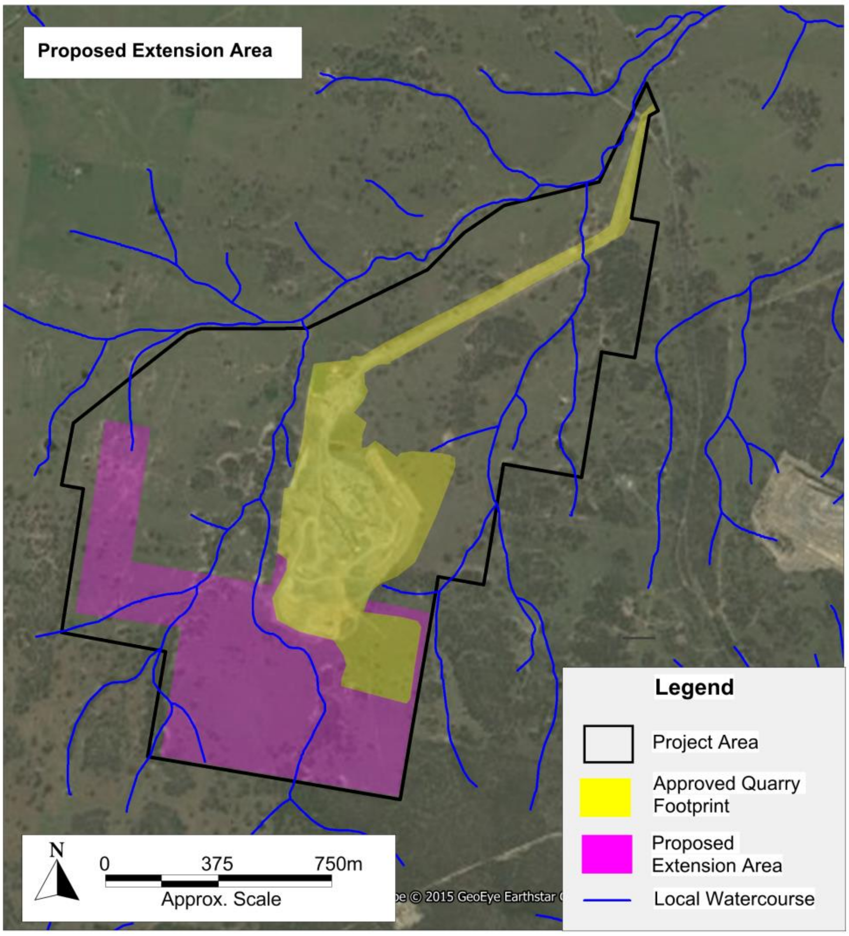


***Plate 1-2** – Proposed Extension Area*

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**.

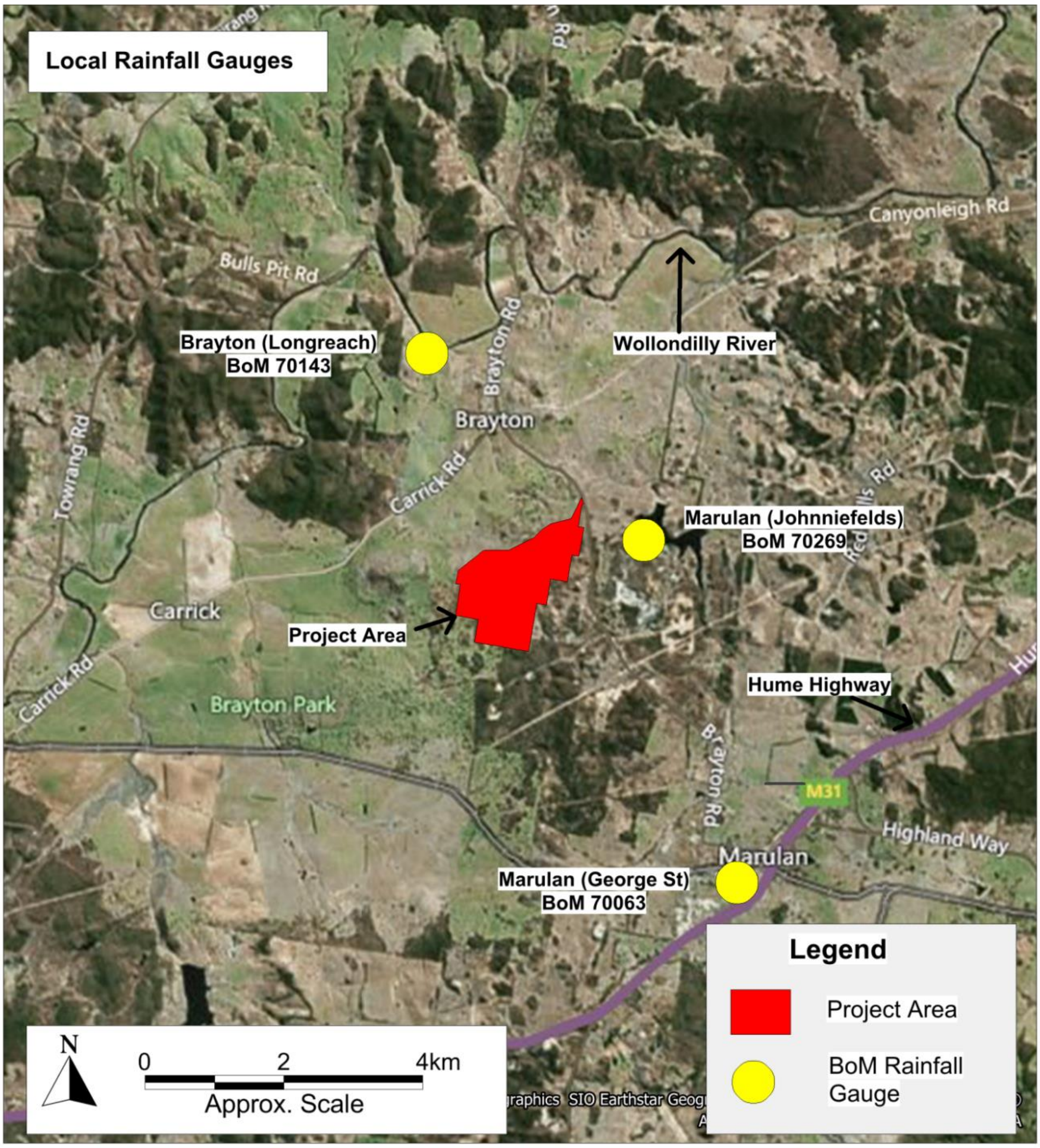


Plate 3-1 – *Local Rainfall Gauges*

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**.

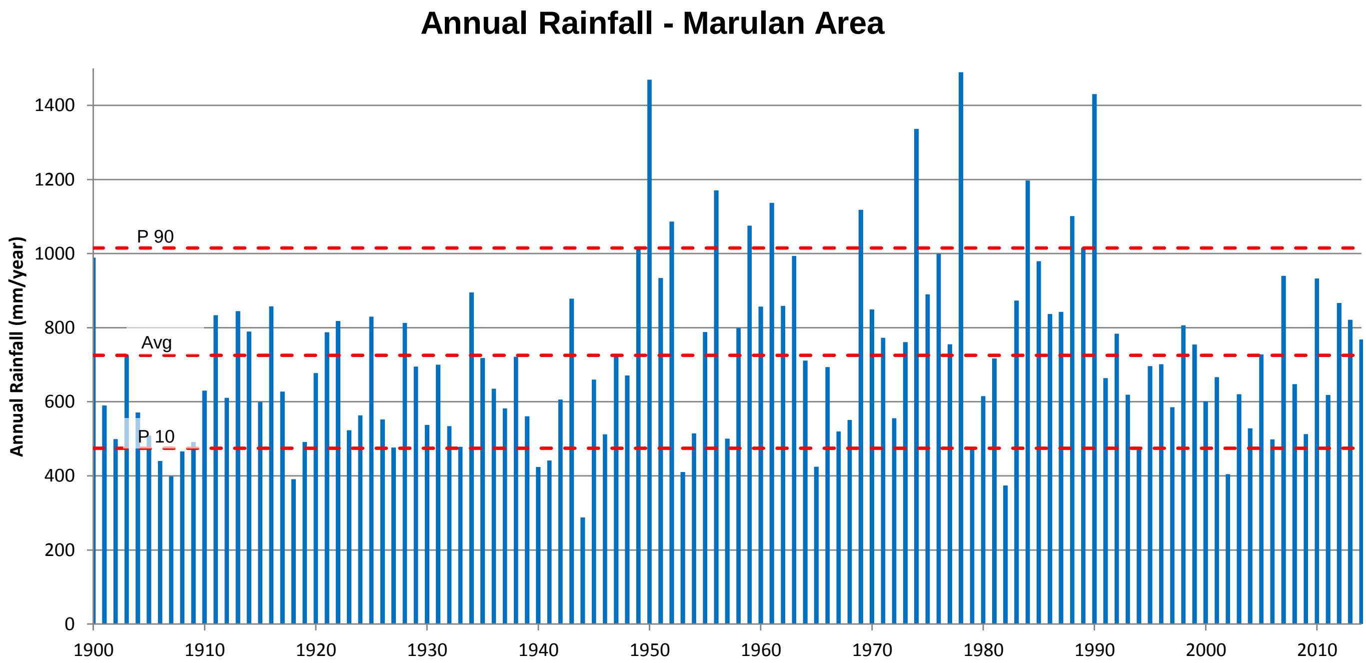


***Plate 3-2** – Annual rainfall totals for the Marulan Area*

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.

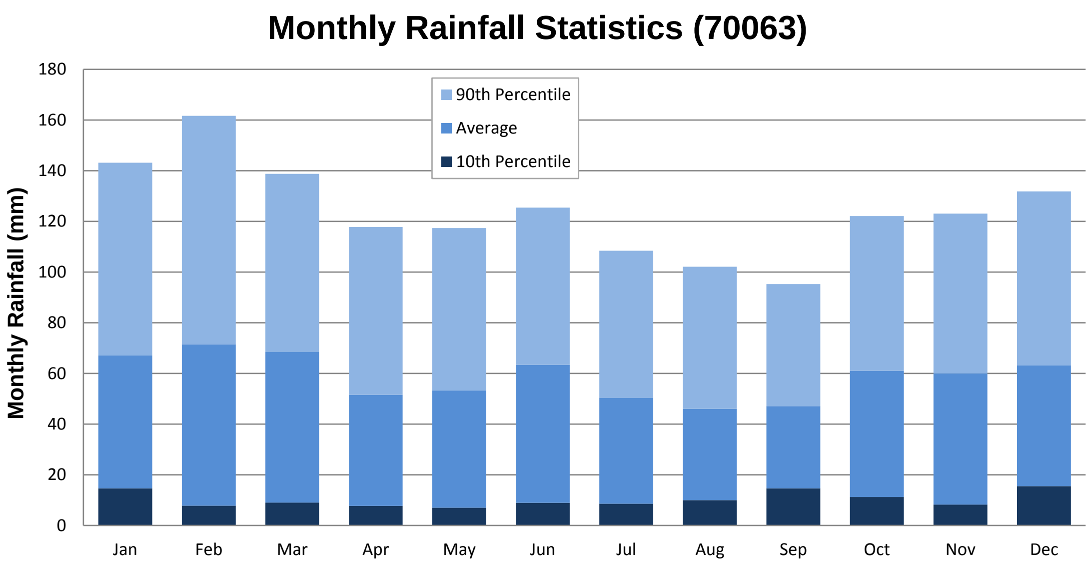


***Plate 3-3** – Monthly rainfall statistics at Marulan (George Street) – 70063 (Source: BoM)*

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.

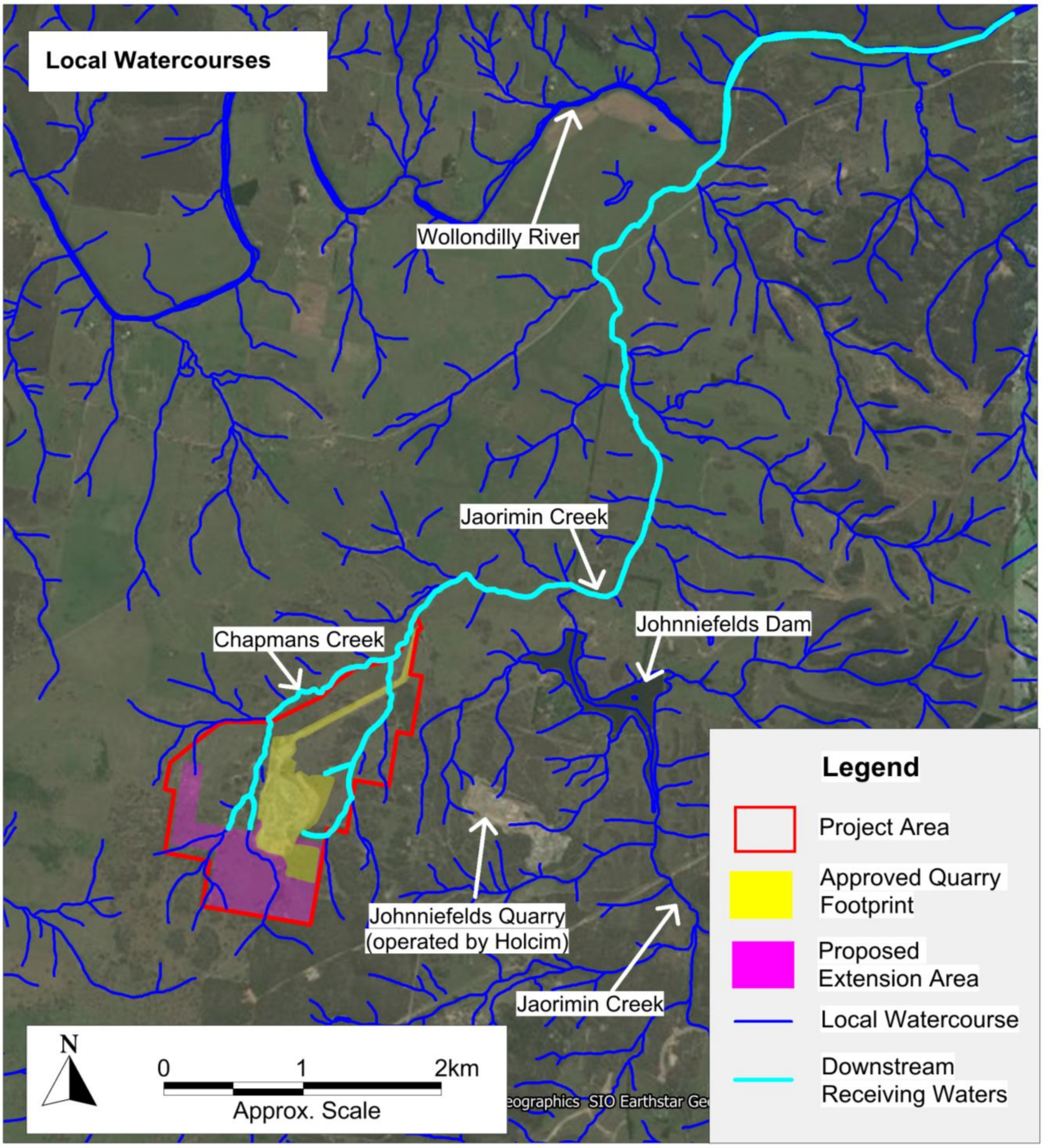


***Plate 3-4** – Local Watercourses*

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.

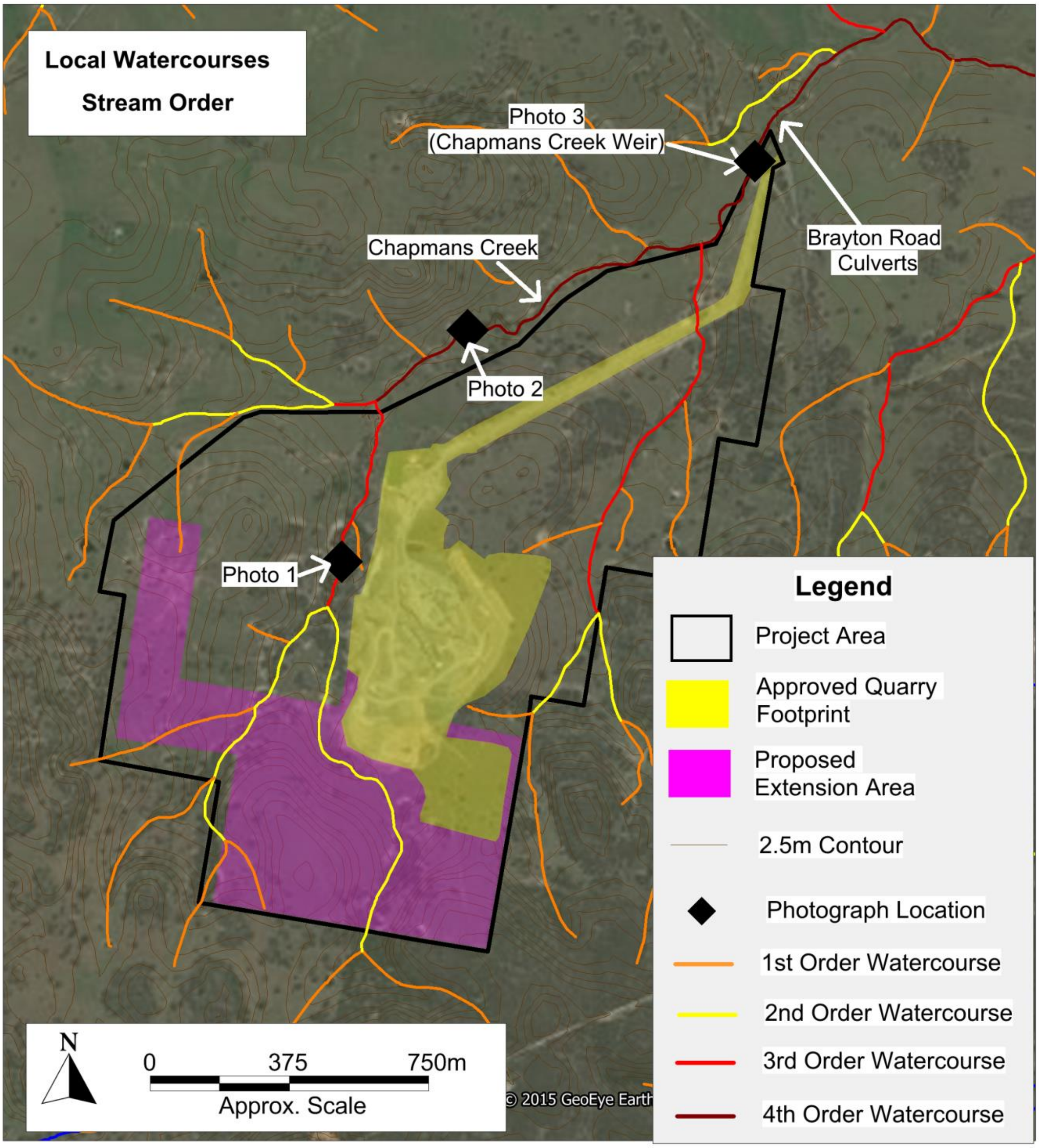


Plate 3-5 *– Location and Stream Order of Local Watercourses*

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)

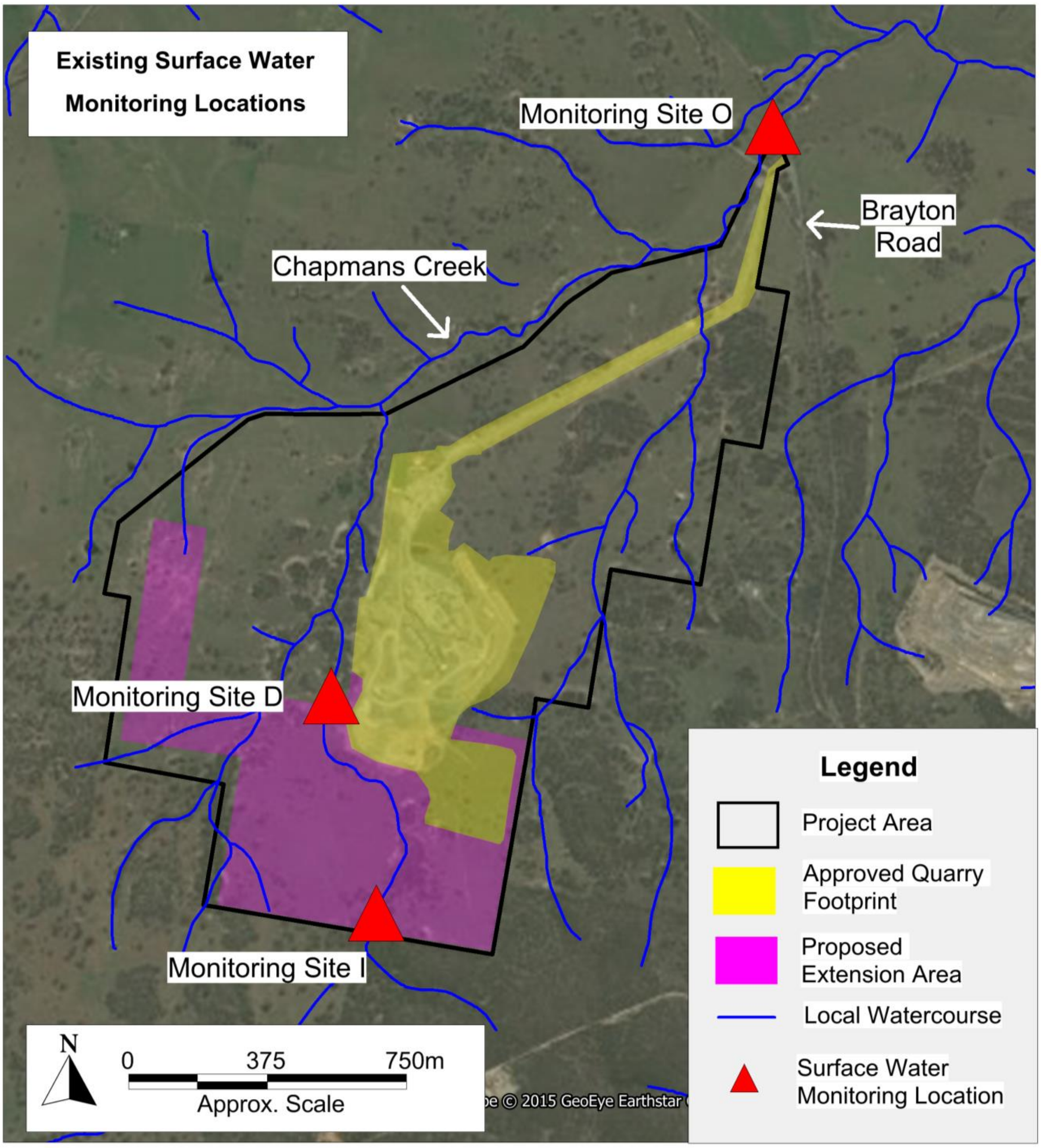


***Plate 3-6** – Existing Surface Water Monitoring Locations*

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.

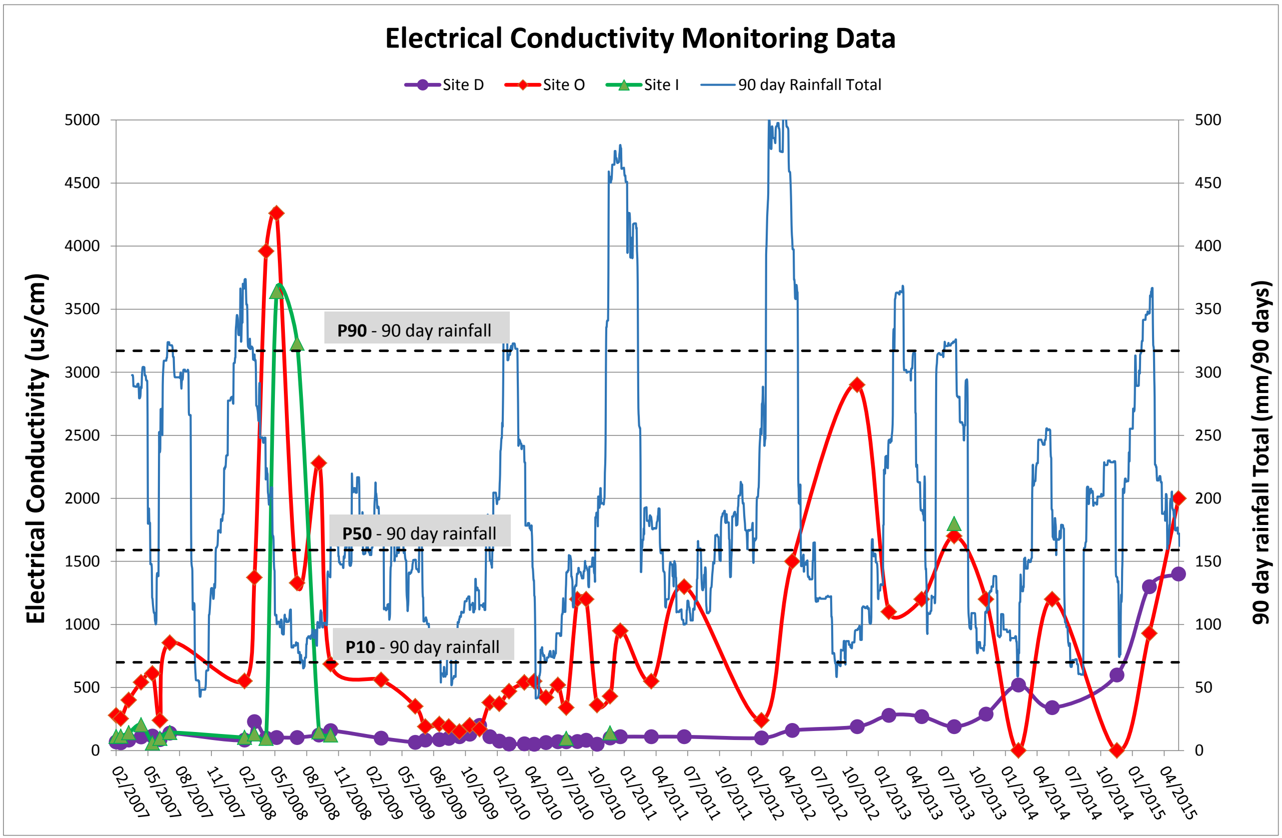


***Plate 3-7** – Recorded Electrical Conductivity (EC)*

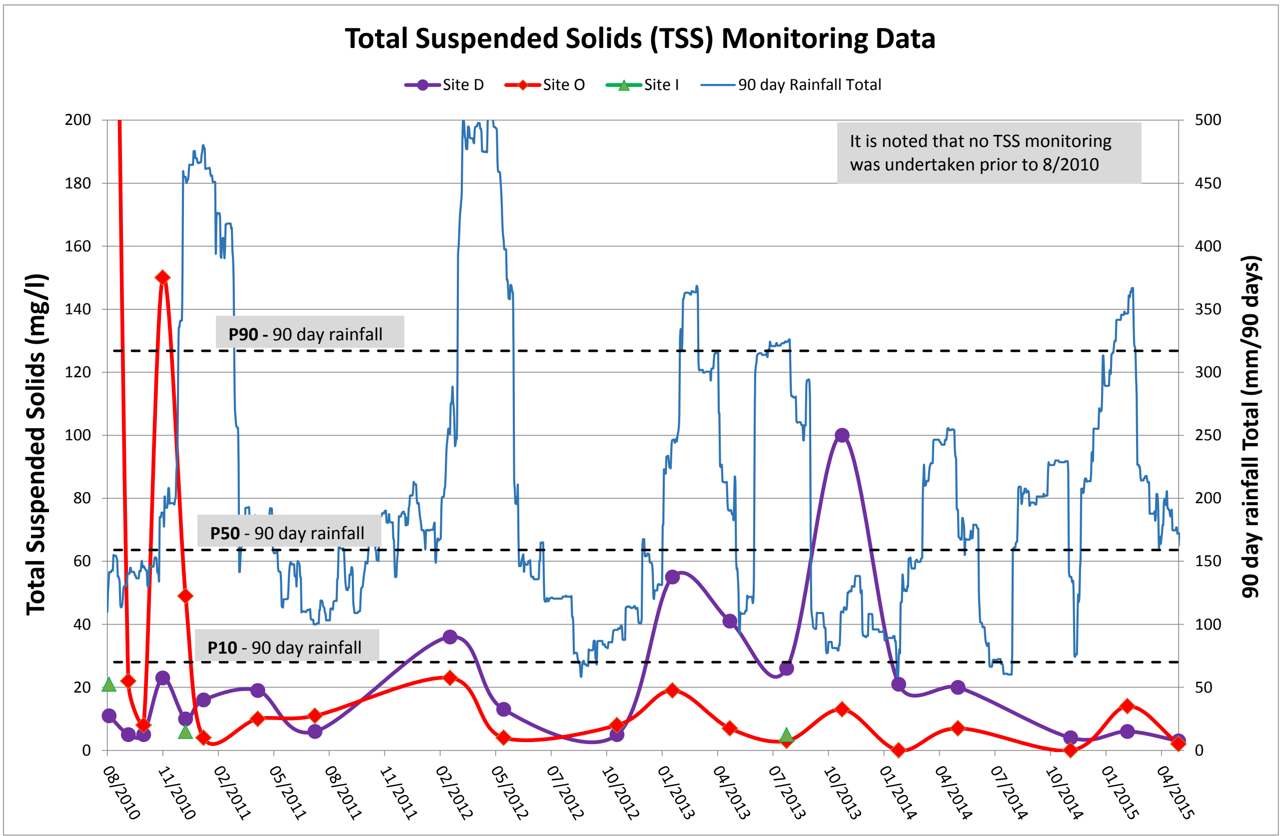


Plate 3-8 – *Recorded Total Suspended Solids (TSS)*

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.

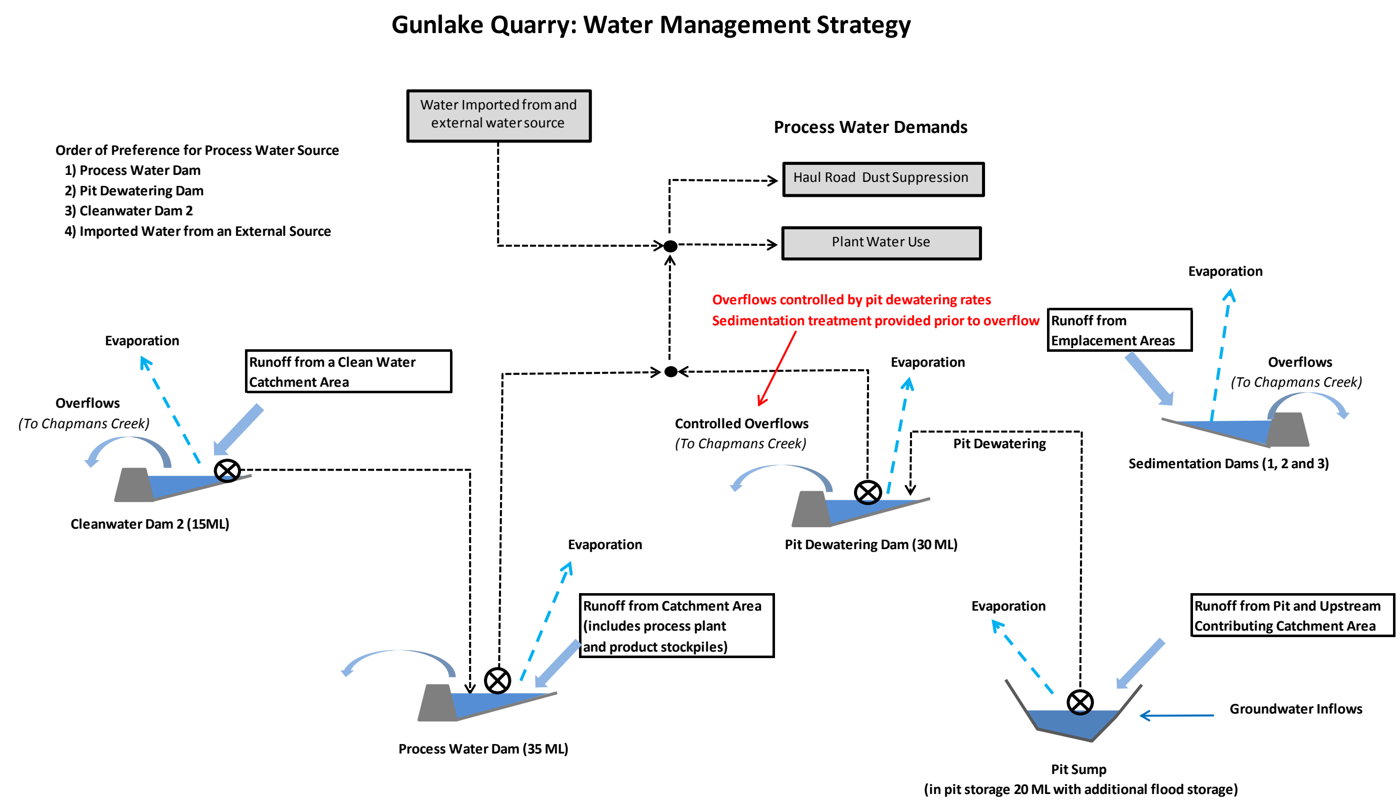


***Plate 4-1**- Surface Water Management Strategy*

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:

$$DSupp(t) = Max(0, ((Evap(t) \times PanCoeff) - Rain(t)) \times HRArea \times 0.01)$$

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.

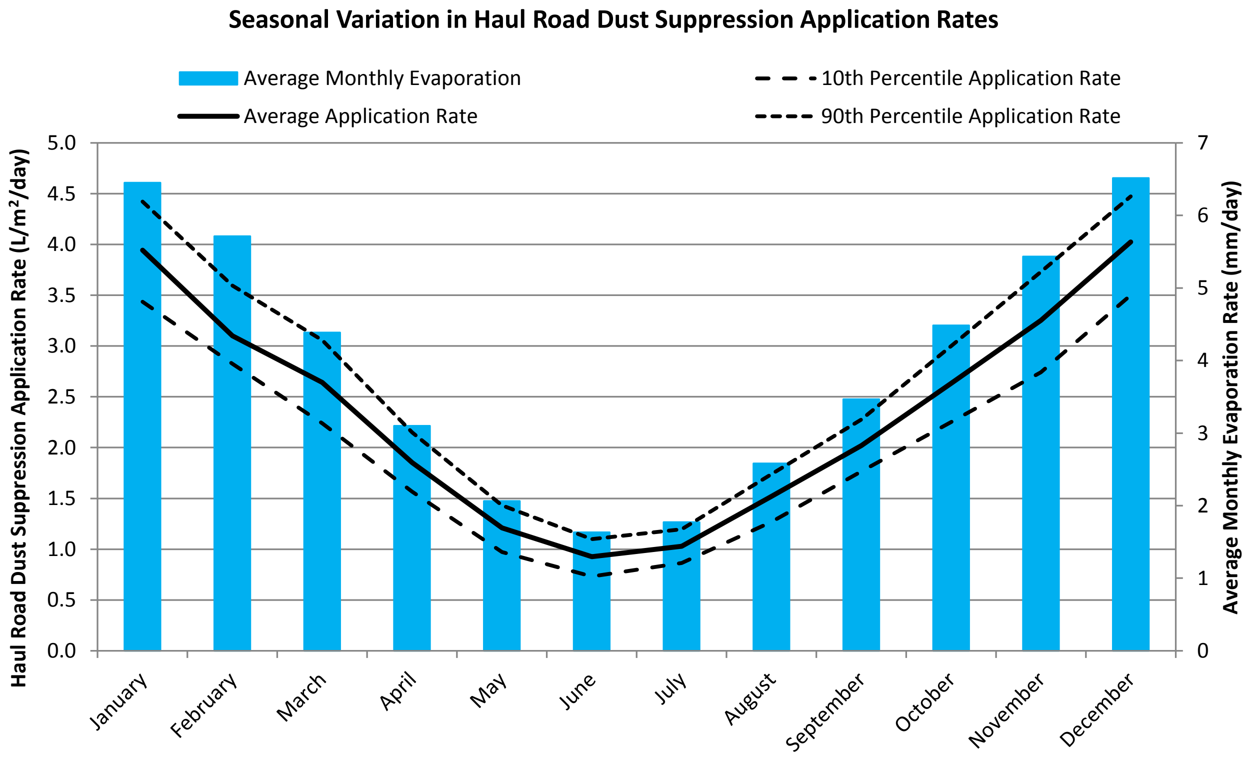


***Plate 4-2** – Seasonal Variation in Haul Road Dust Suppression*

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 10^{th}, 50^{th} and 90^{th} Percentile annual water use for haul road dust suppression for the approved and expanded quarry operation. 10^{th} Percentile use rates are indicative of use rates during wet years when rainfall is higher and 90^{th} 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		
		10^{th} Percentile	50^{th} Percentile	90^{th} 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:

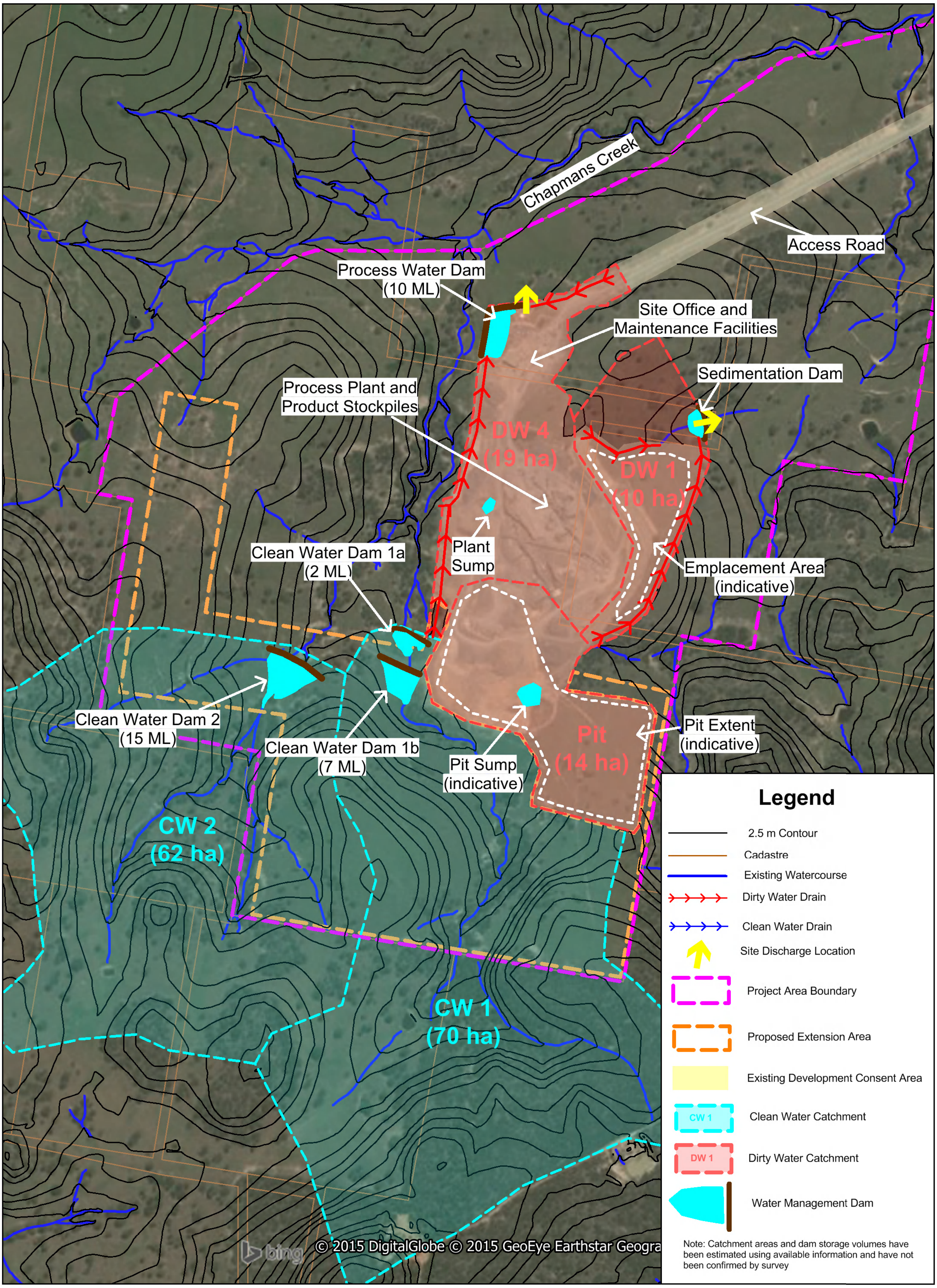
- A SWMP figure has been prepared that depicts key catchment areas, water management dam locations and sizes, clean and dirty water drains and site discharge locations.
- Water balance results are presented in flow chart form for typical dry (10th Percentile), median (50th Percentile) and wet (90th Percentile) 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*

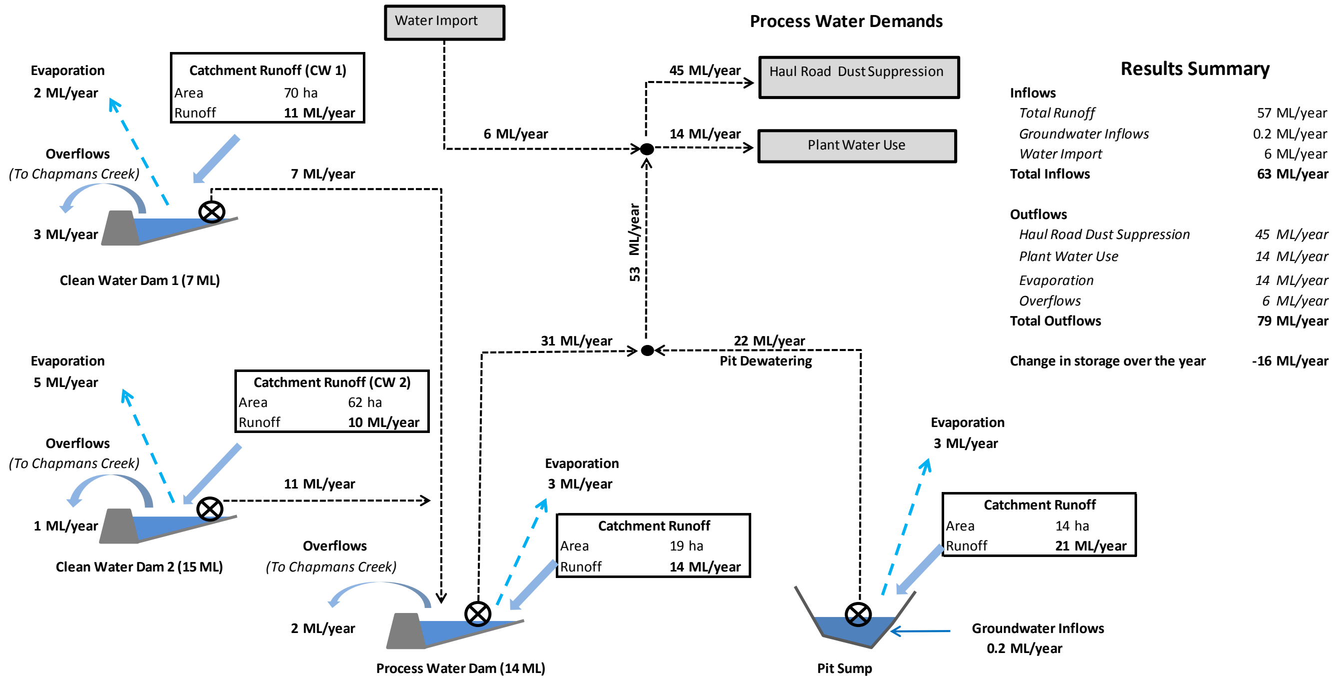


***Plate 4-3** – Approved Operation: Water Balance Results for a Typical Dry Rainfall Year*

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

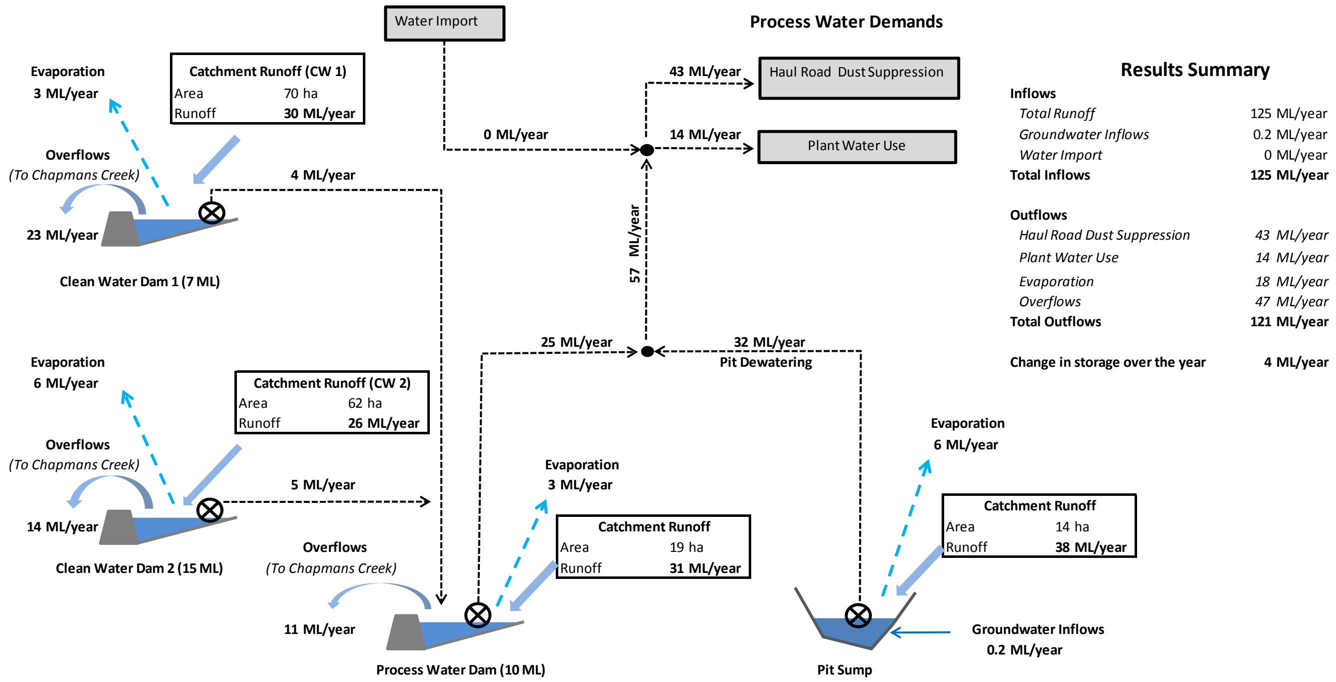


***Plate 4-4** – Approved Operation: Water Balance Results for a Typical Median Rainfall Year*

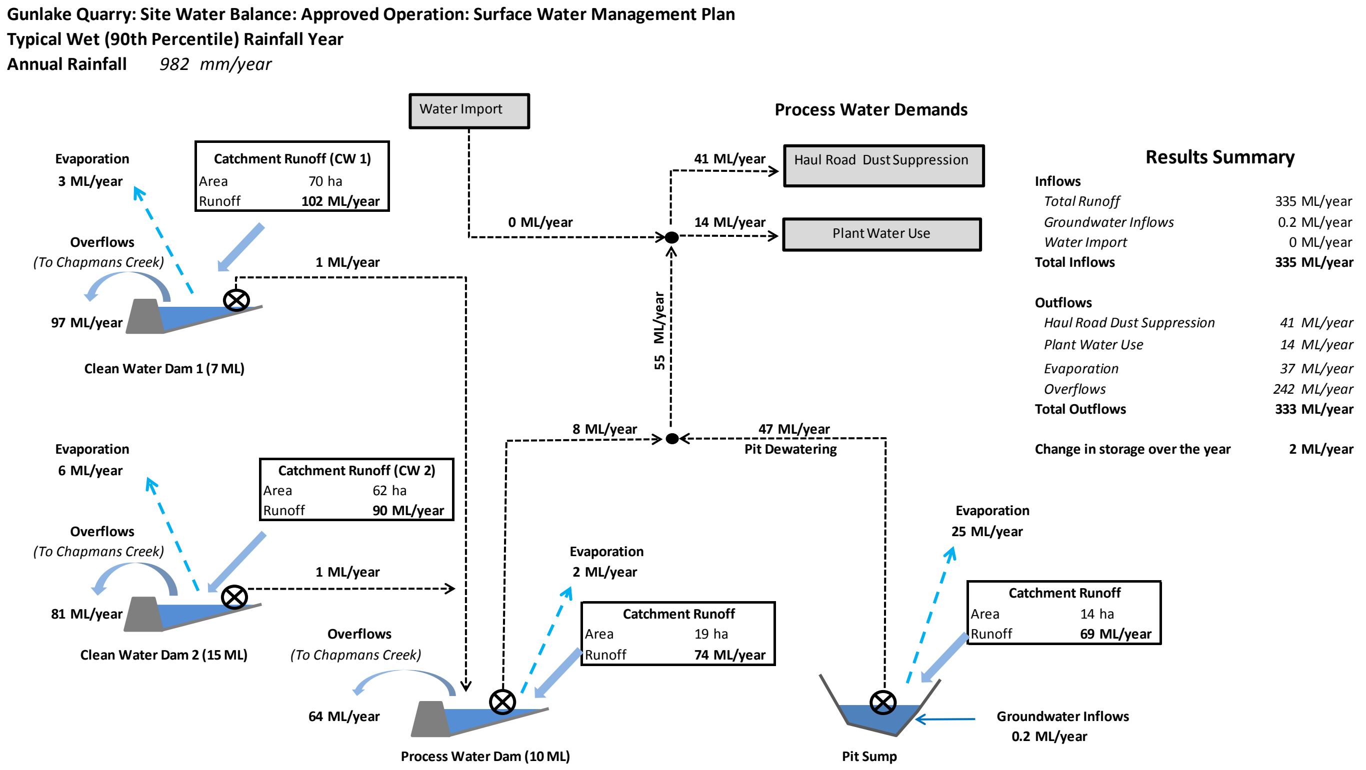


***Plate 4-5** – Approved Operation: Water Balance Results for a Typical Wet Rainfall Year*

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:

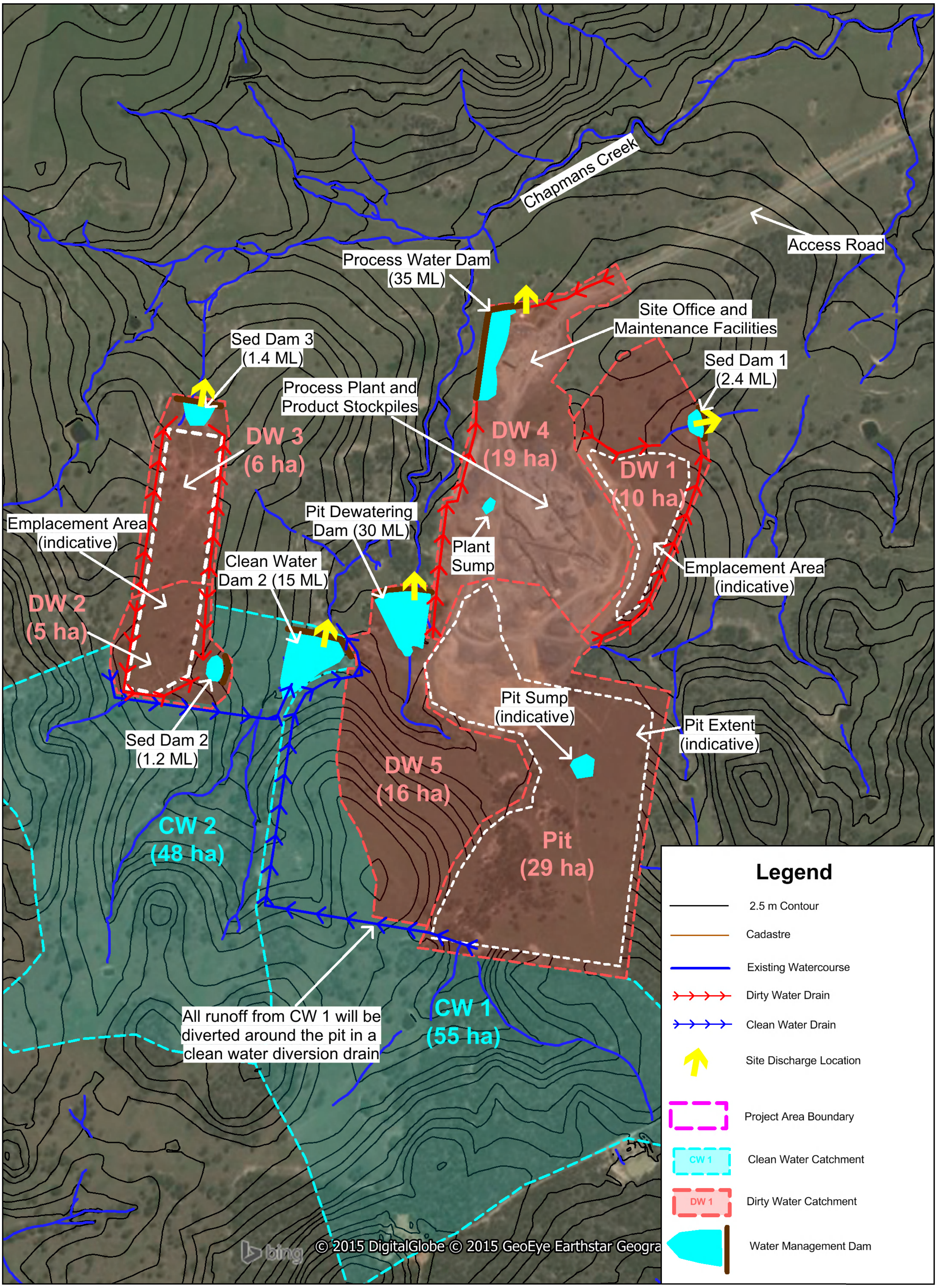
- A clean water diversion channel will be constructed to divert runoff from a clean water catchment that is located to the south of the pit. The channel will be constructed along the southern and western edges of the final pit extent. Due to topographic constraints, the channel will need to be excavated 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

Gunlake Quarry: Site Water Balance: Quarry Year 1: Surface Water Management Plan
Typical Dry (10th Percentile) Rainfall Year
Annual Rainfall *451 mm/year*

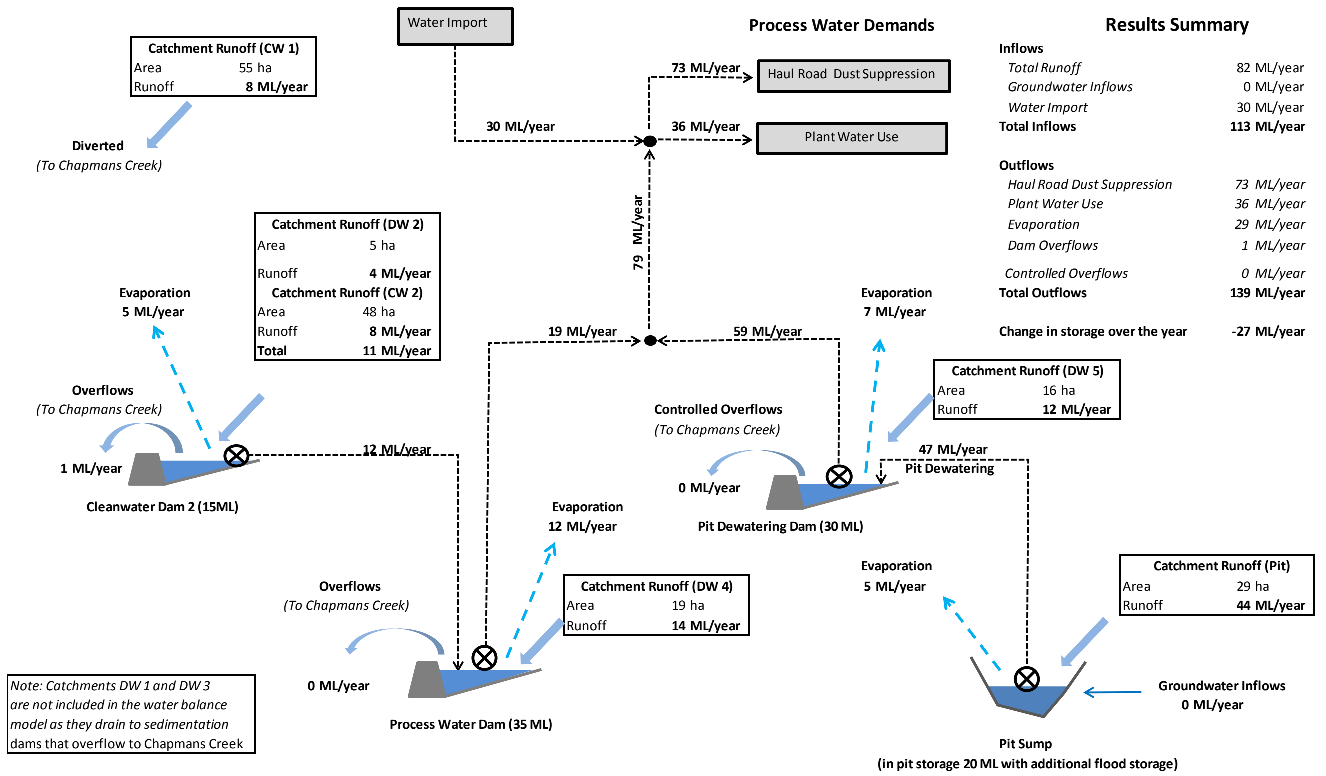


***Plate 4-6** – Quarry Year 1: Water Balance Results for a Typical Dry Rainfall Year*

Gunlake Quarry: Site Water Balance: Quarry Year 1: Surface Water Management Plan
Typical Median (50th Percentile) Rainfall Year
Annual Rainfall *695 mm/year*

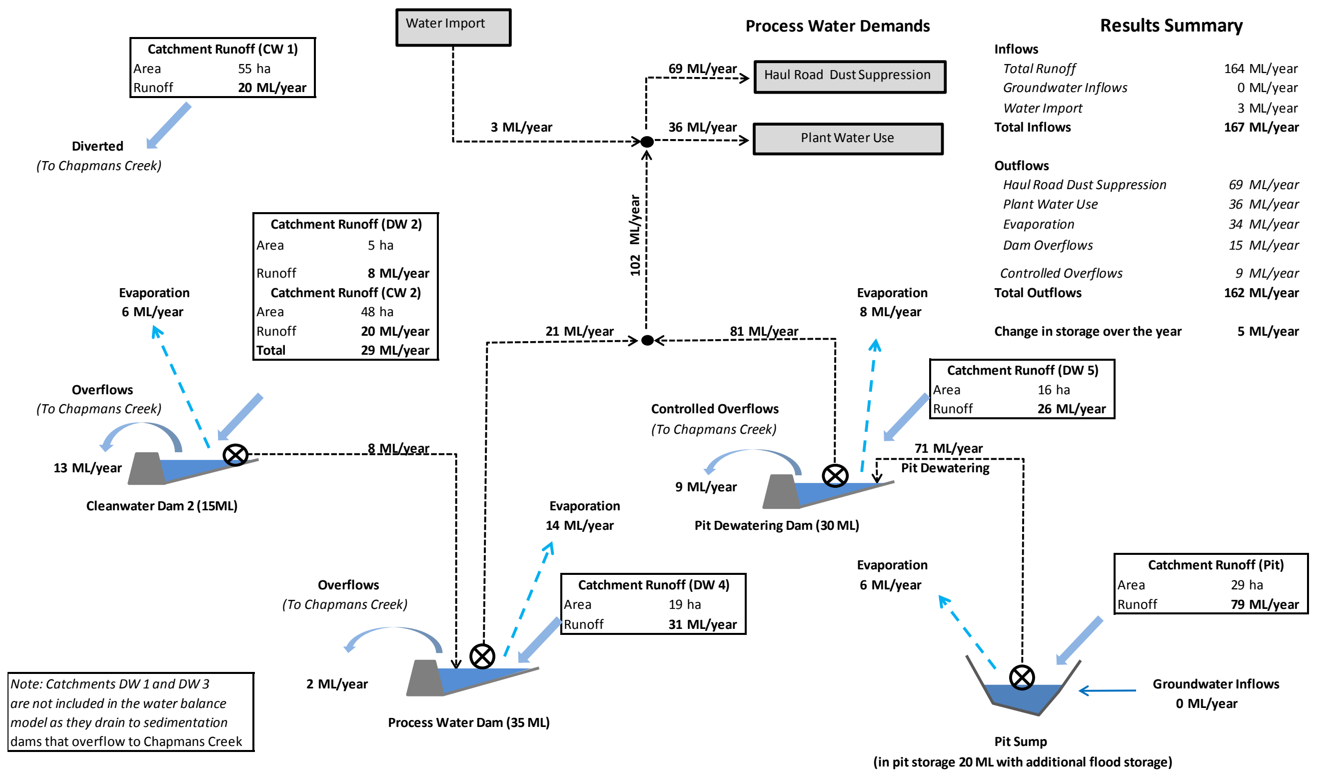


Plate 4-7 – *Quarry Year 1: Water Balance Results for a Typical Median Rainfall Year*

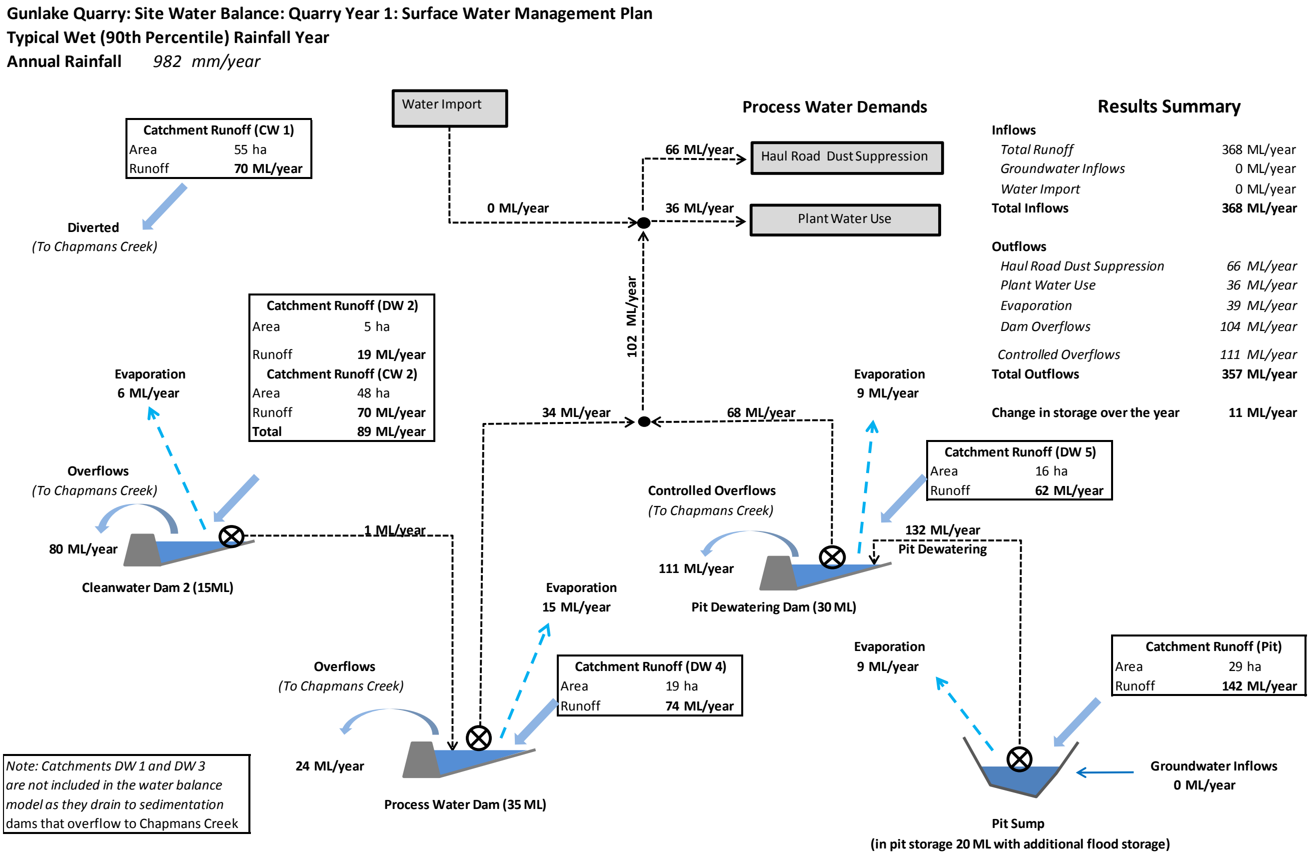
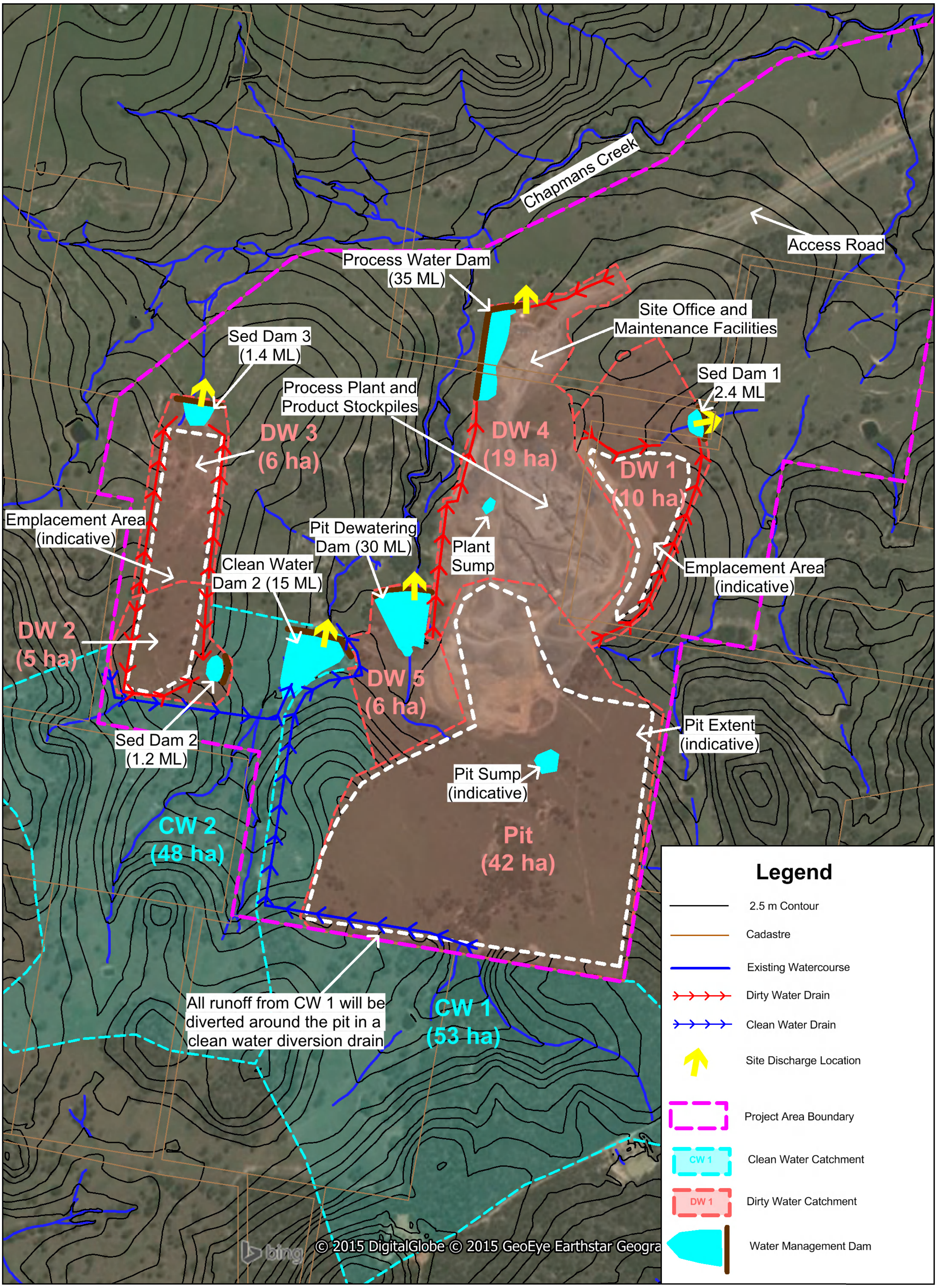


***Plate 4-8** – Quarry Year 1: Water Balance Results for a Typical Wet Rainfall Year*

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

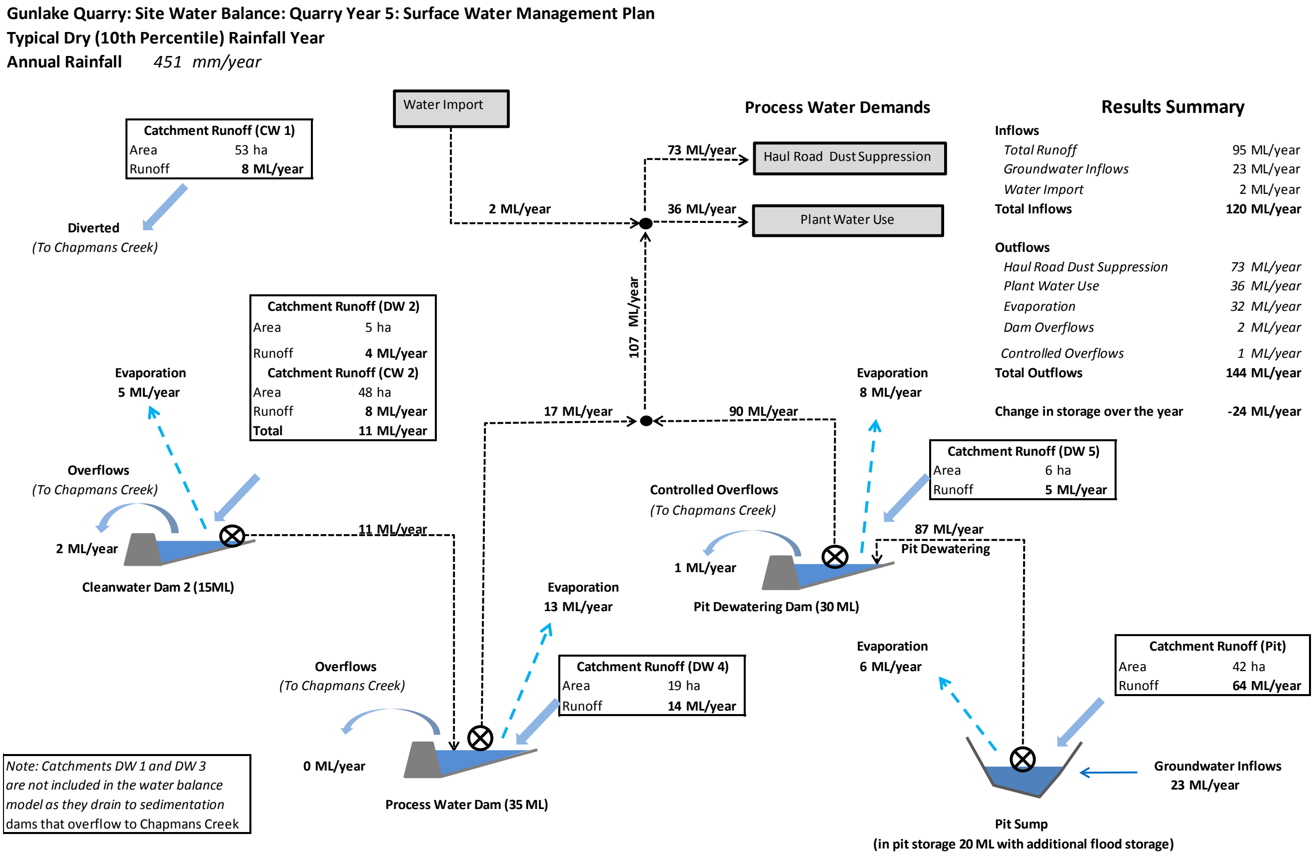


Plate 4-9 – *Quarry Year 5: Water Balance Results for a Typical Dry Rainfall Year*

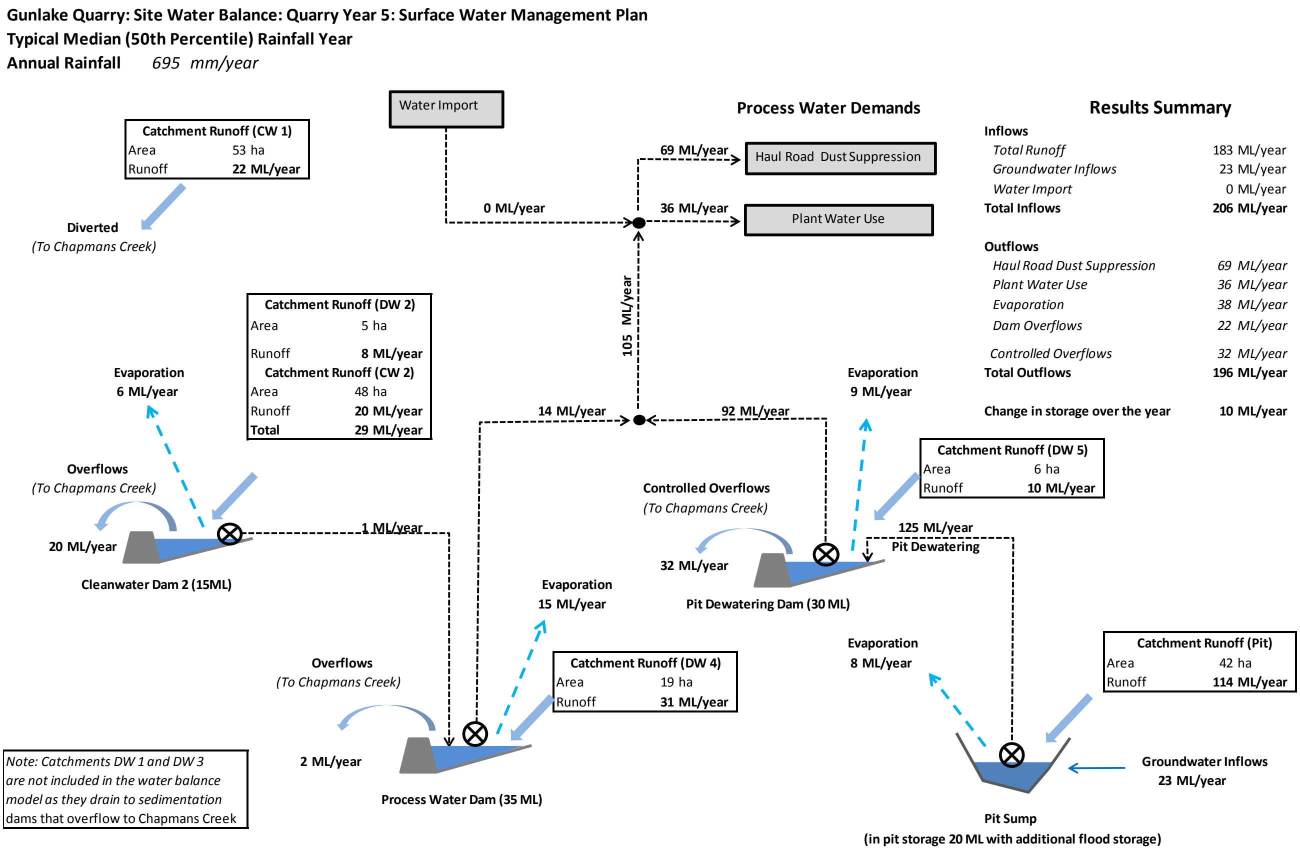


Plate 4-10 – *Quarry Year 5: Water Balance Results for a Typical Median Rainfall Year*

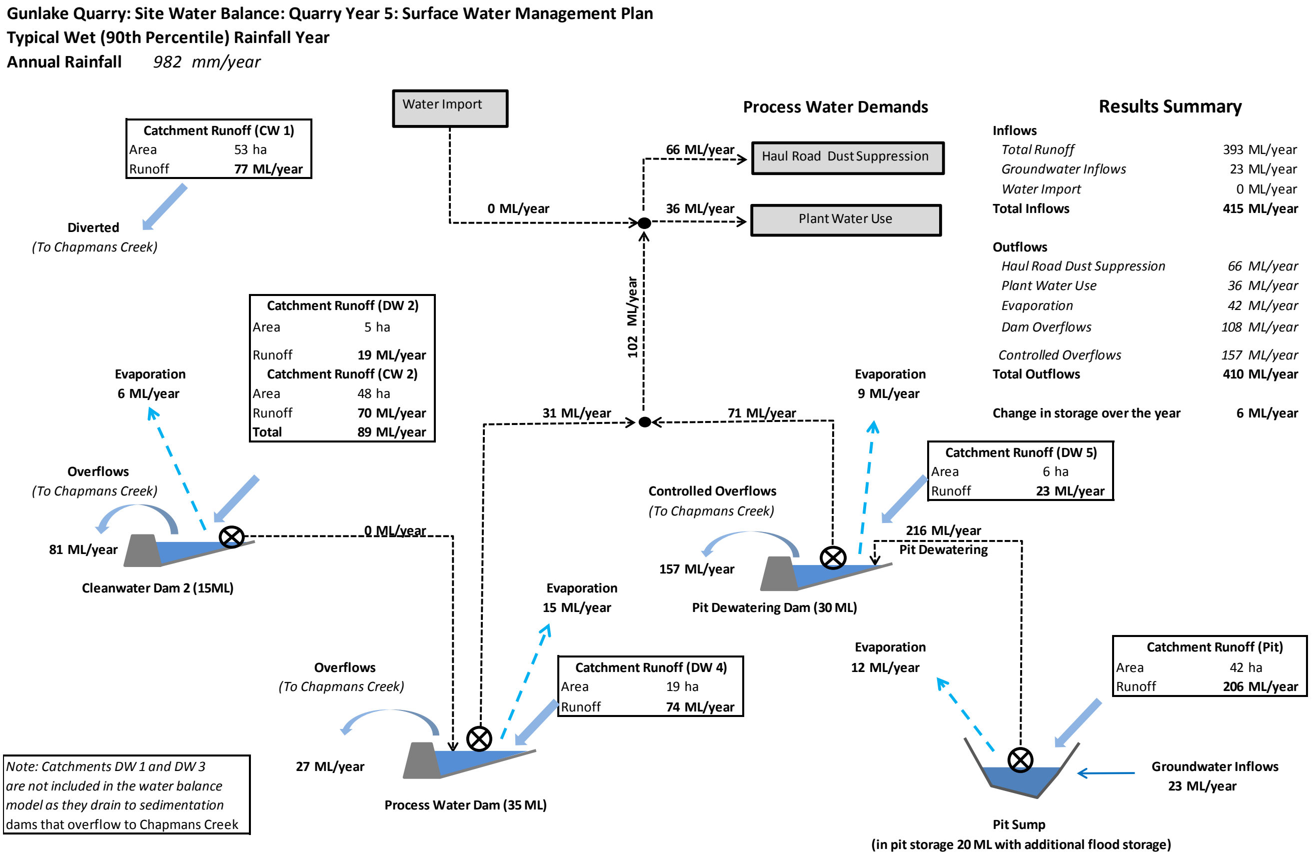
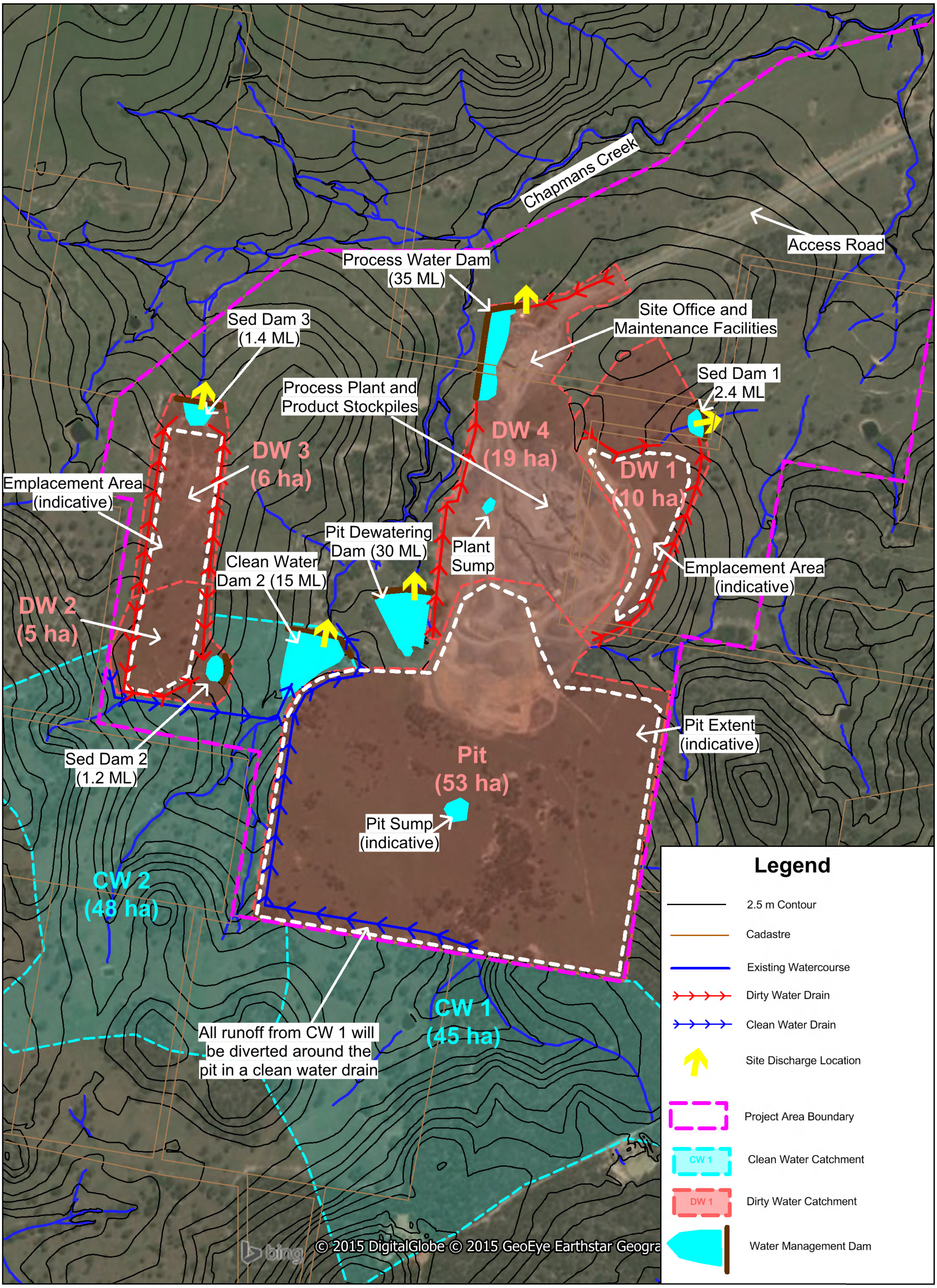


***Plate 4-11** – Quarry Year 5: Water Balance Results for a Typical Wet Rainfall Year*

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

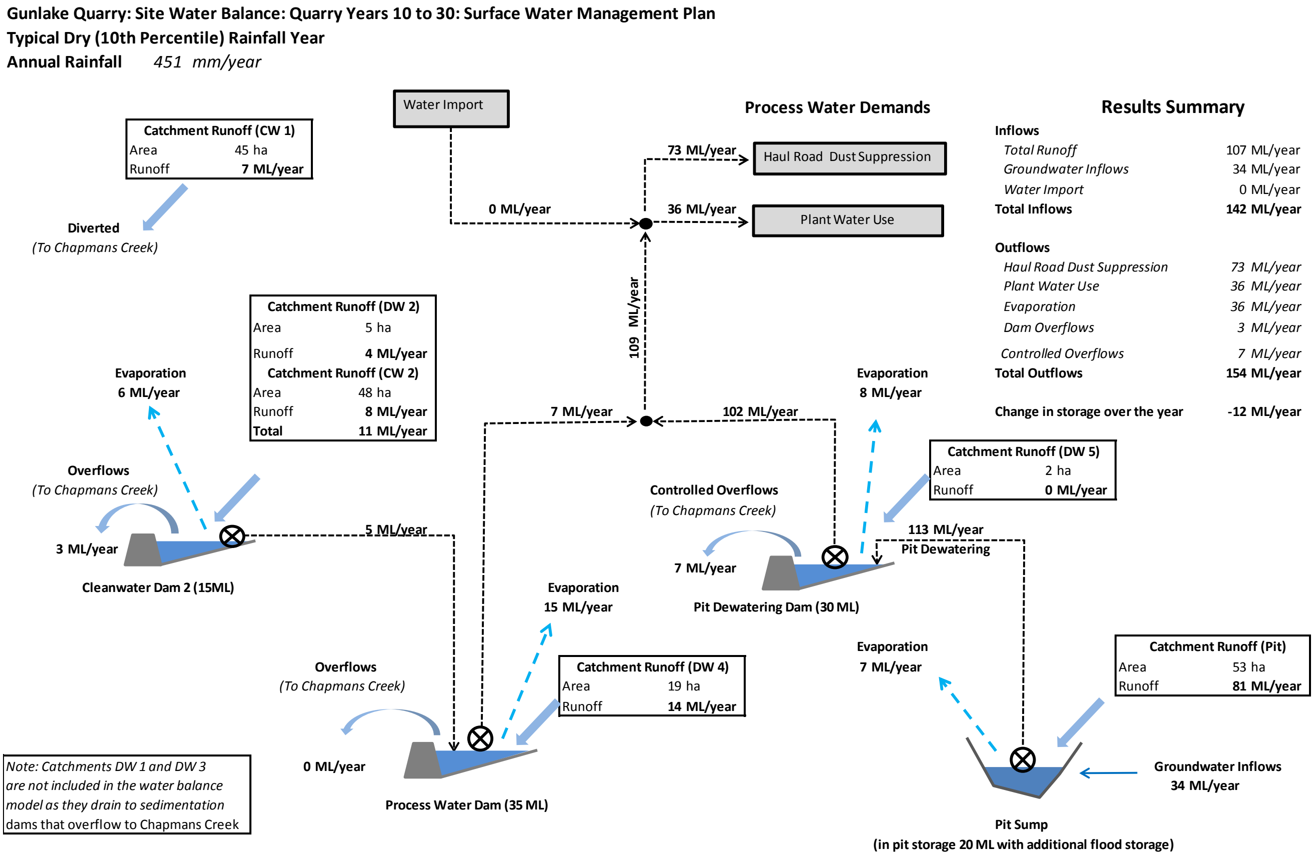


Plate 4-12 – *Quarry Years 10 to 30: Water Balance Results for a Typical Dry Rainfall Year*

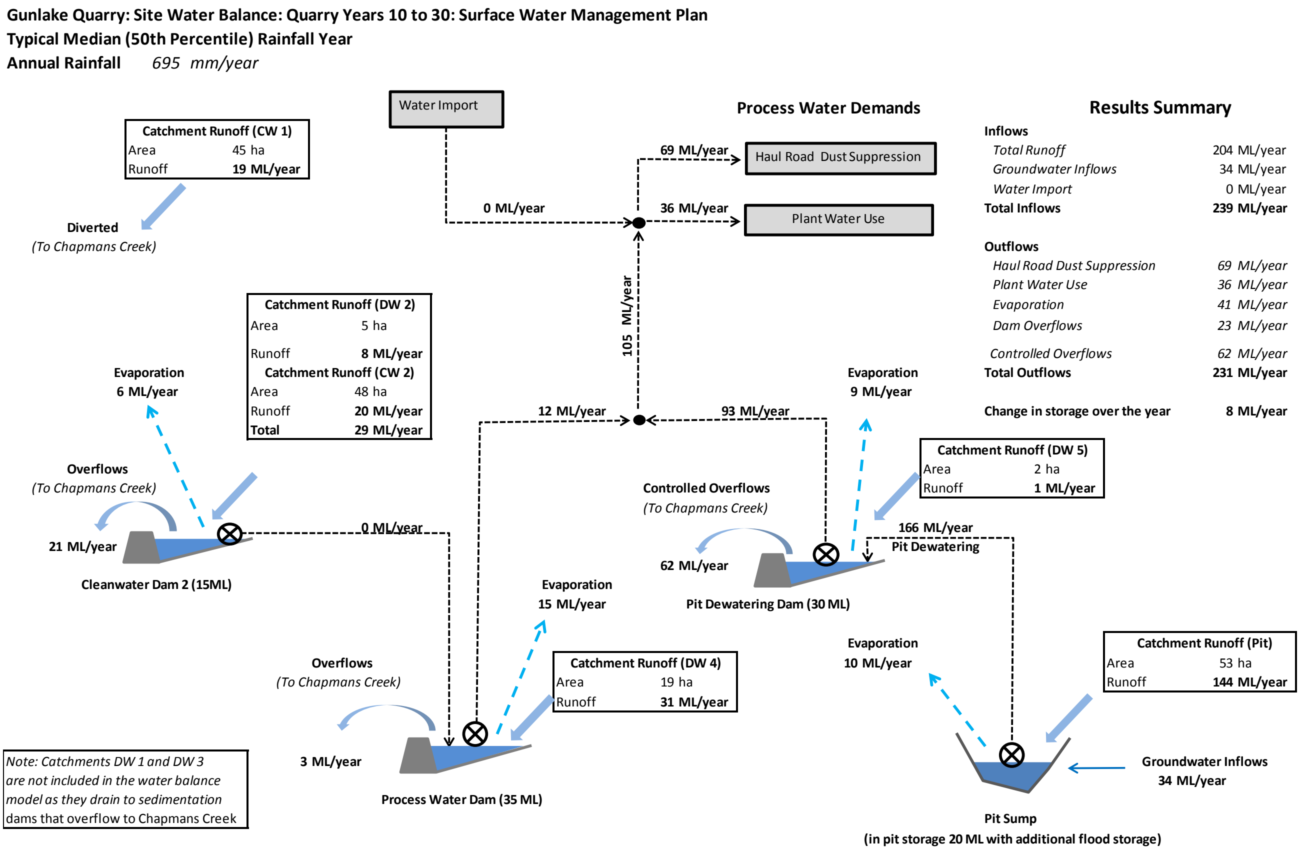


Plate 4-13 – *Quarry Years 10 to 30: Water Balance Results for a Typical Median Rainfall Year*

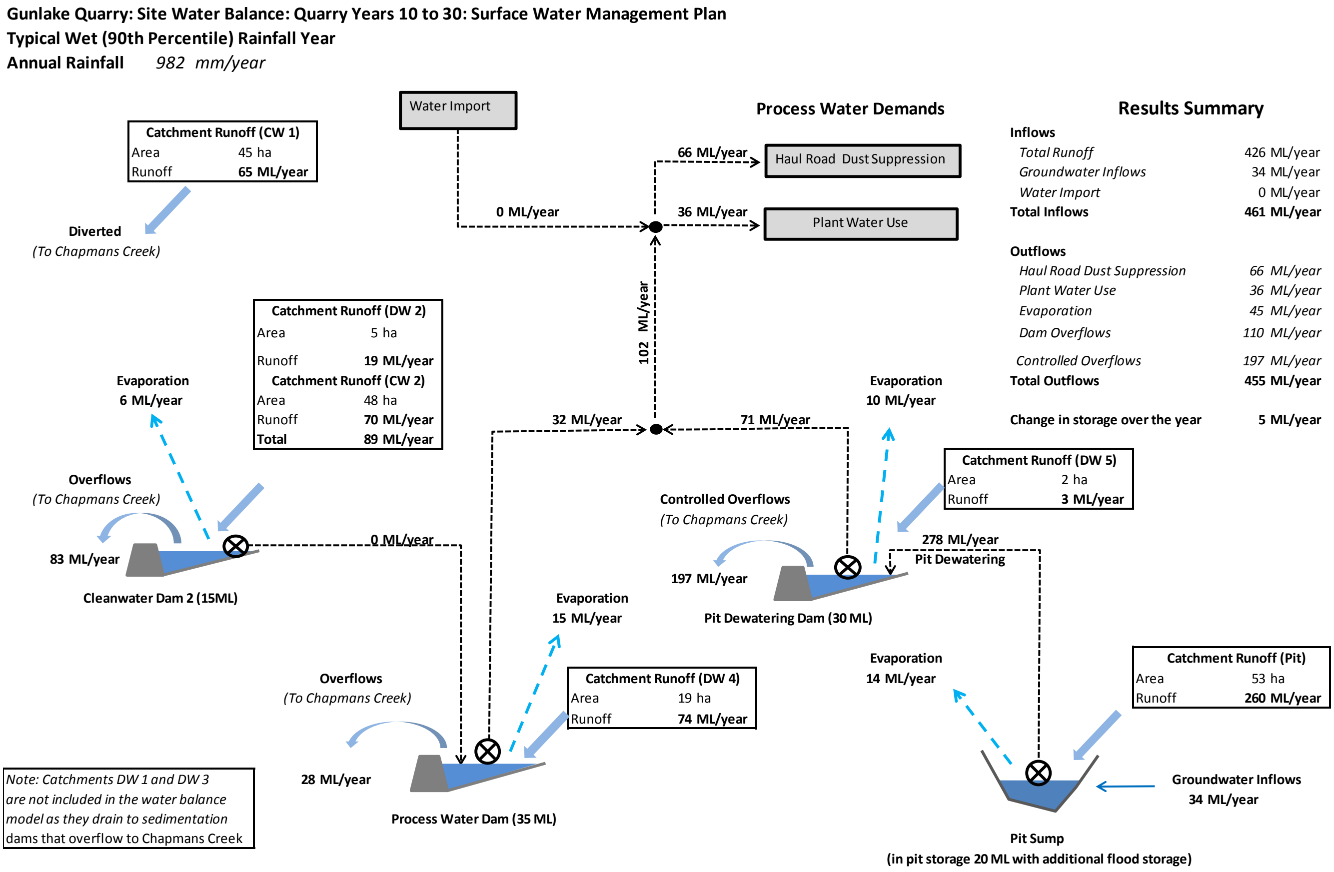


***Plate 4-14** – Quarry Years 10 to 30: Water Balance Results for a Typical Wet Rainfall Year*

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.

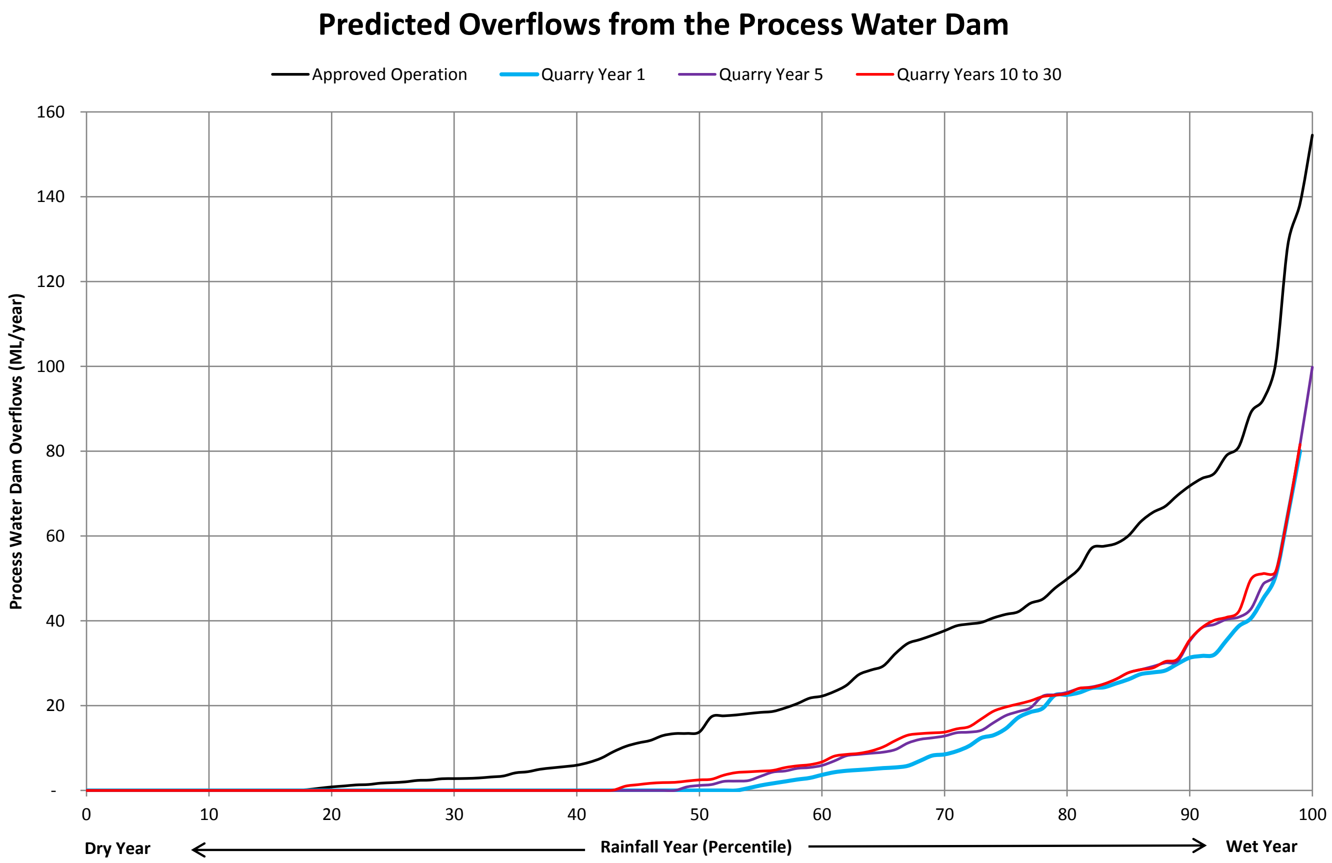


***Plate 4-15** – Predicted overflows from the Process Water Dam*

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).

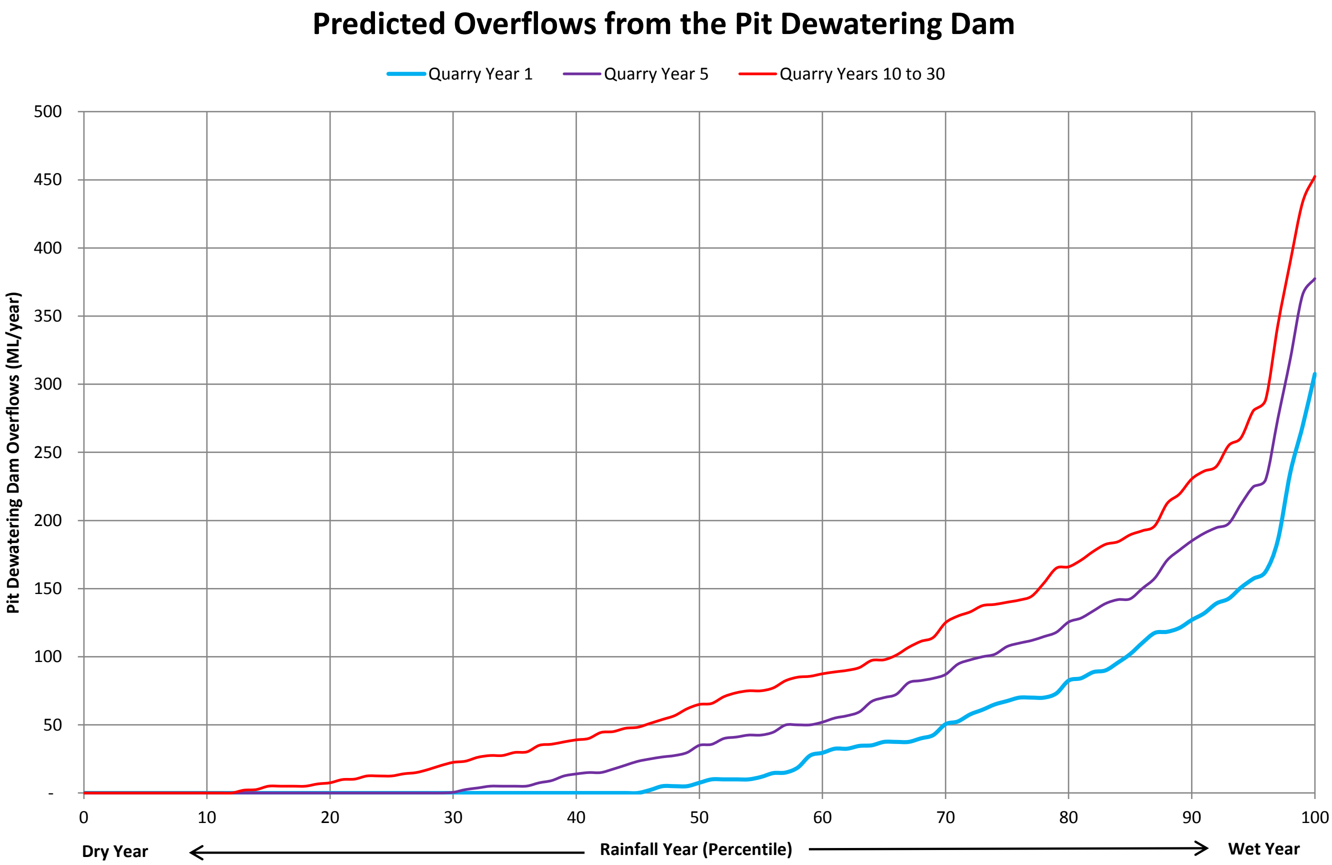


__Plate 4-16__ – Predicted overflows from the Pit Dewatering Dam

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.

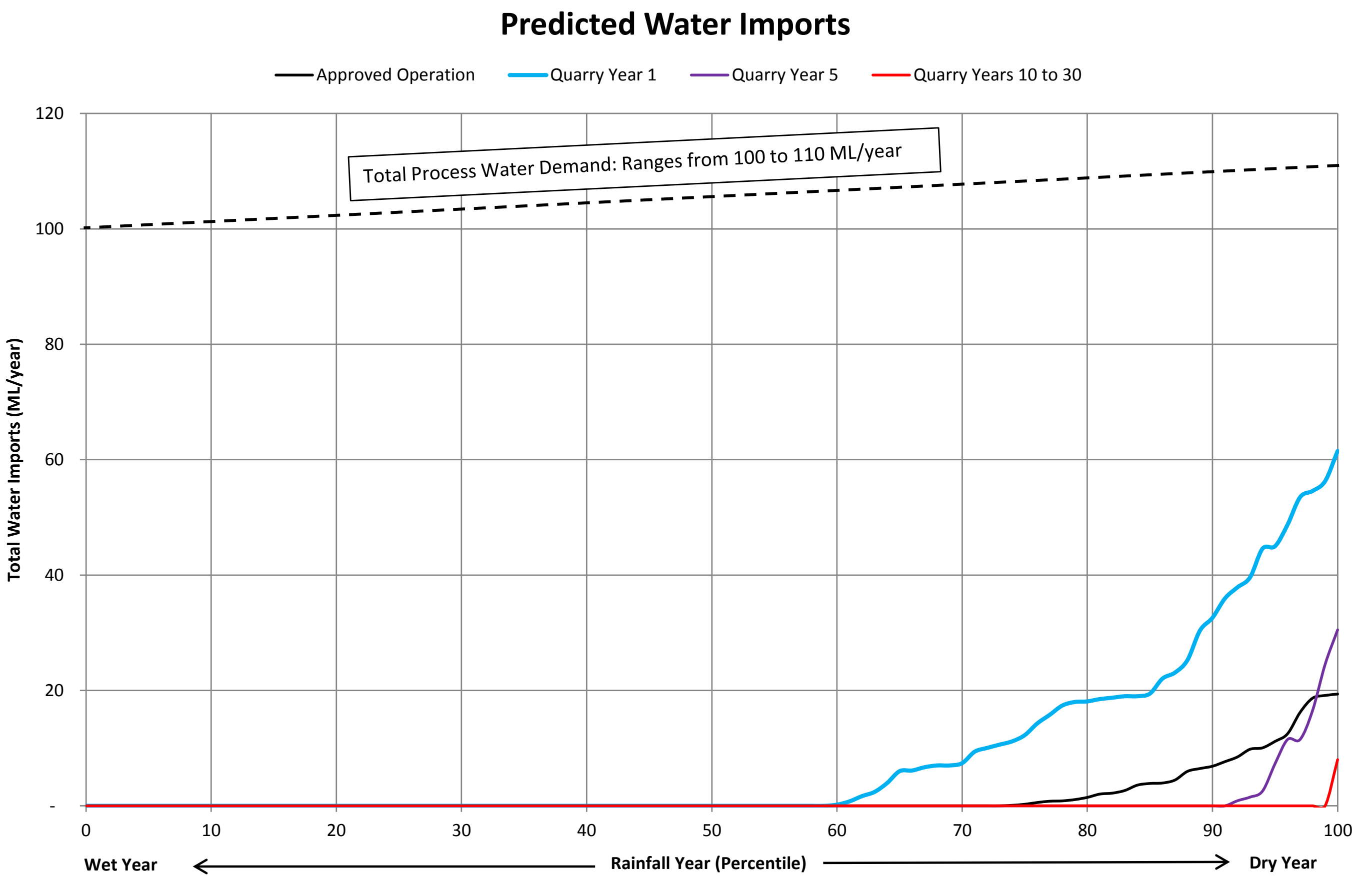


Plate 4-17 *– Predicted water import volumes*

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.

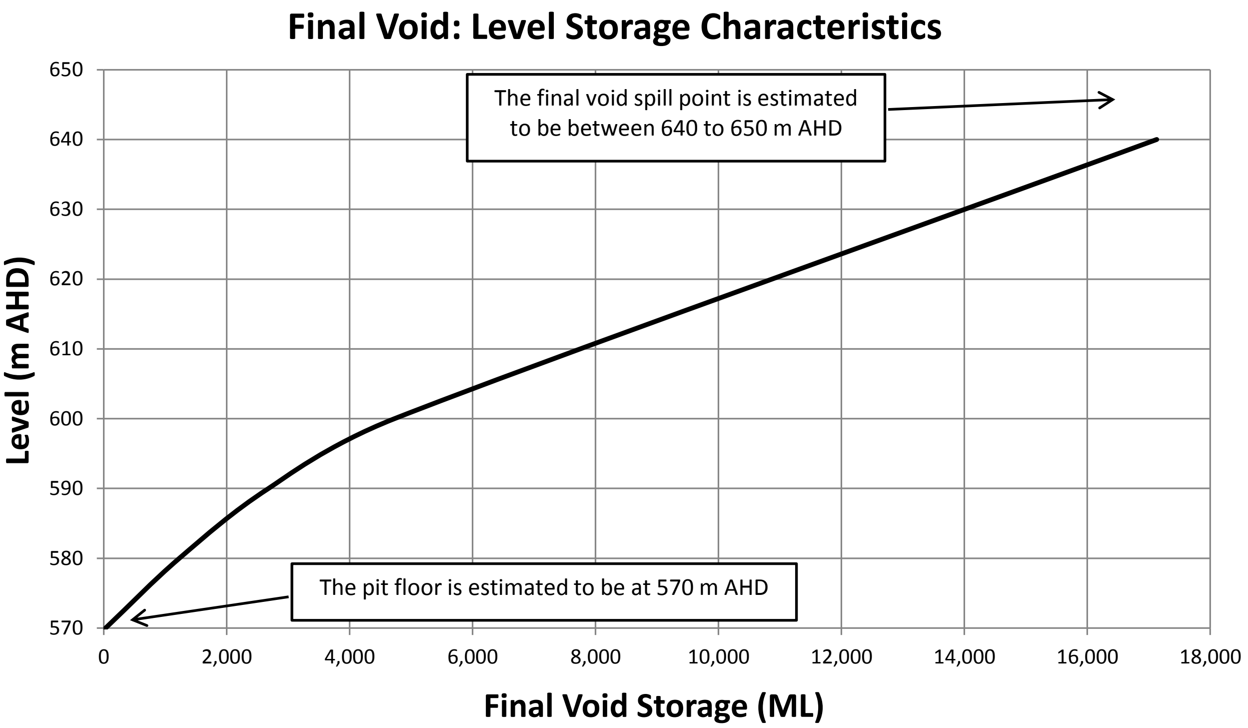


***Plate 4-18** – Final Void: Level Storage Curve*

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**.

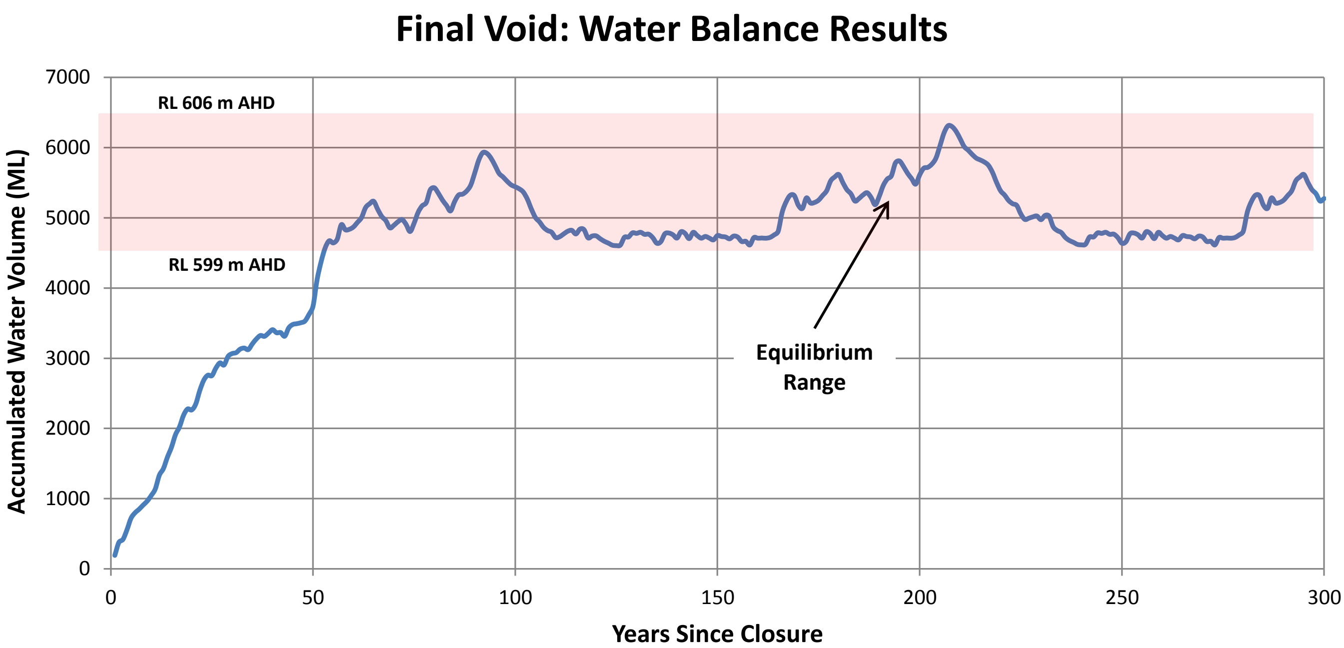


***Plate 4-19**: Final Void Water Balance Results*

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**.

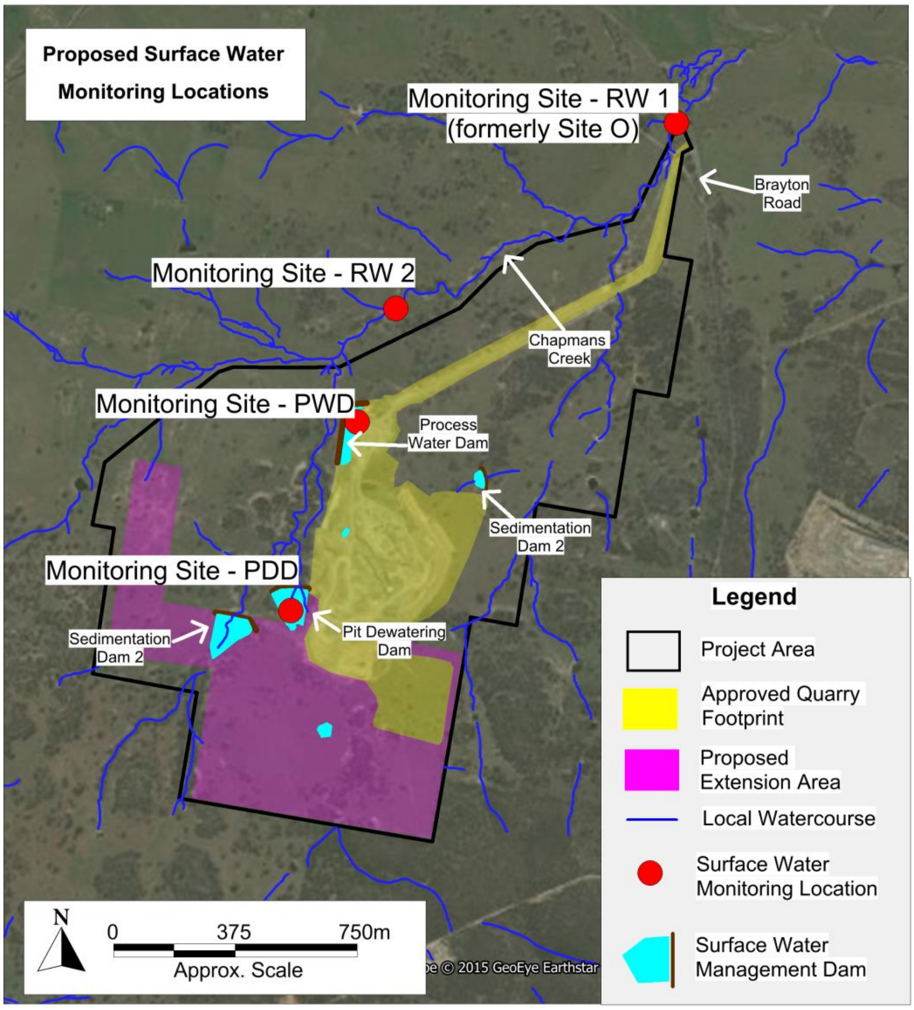


Plate 7-1 – *Proposed Monitoring Locations*

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'*

APPENDIX A – SURFACE WATER QUALITY MONITORING RESULTS

	Site D Monitoring Results											
	pH	Dissolved Oxygen	Electrical Conductivity	Total Suspended Solids (TSS)	Total Dissolved Solids (TDS)	Chloride	Sodium	Arsenic	Manganese	Dissolved Iron	Total Nitrogen	Total Phosphorus
Unit		mg/L	µS/cm k 25.00C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Limit of Reporting	0.1		1	< 2	1	1	1	0.001	0.001	0.05	0.1	0.01
ANZECC Trigger Values for physical & chemical stressors for south-east Australia for slightly disturbed ecosystems (Upland River)	6.5 - 8		30 - 350								0.25	0.02
ANZECC Trigger Values - Freshwater Ecosystems												
99% Level of Species Protection								< LOR	1.2			
95% Level of Species Protection								0.013	1.9			
90% Level of Species Protection								0.042	2.5			
80% Level of Species Protection								0.14	3.6			
Australian Drinking Water Guidelines												
Health								0.01	0.5			
Aesthetic	6.5 - 8.5	> 85%			600	250	180		0.1	0.3		
14/02/2007	6.4		69		111	4.8	4	< 0.001	0.111	1.54	4.2	3.15
27/02/2007	6.3		62		112	4.4	2	< 0.001	0.433	1.49	2.3	0.15
22/03/2007	6.6		84		77	3.9	4	< 0.001	0.417	1.93	2.9	0.22
26/04/2007	6.7		109		128	4.2	3	0.004	0.972	4.74	3.7	0.26
28/05/2007	7		115		118	4.4	4	0.002	0.94	7.82	6.3	0.46
18/06/2007	6.2		87		149	19.2	9	< 0.001	0.105	1.77	1.5	0.04
16/07/2007	6.1		138		129	23.4	13	< 0.001	0.257	1.57	2.4	0.2
13/02/2008	6.2		83		130	9	6	< 0.001	0.112	2.22	2	0.1
12/03/2008	6.4		230		79	16.3	7	< 0.001	0.156	1.94	1.7	0.16
14/04/2008	6.9		98		107	17.2	7	< 0.001	0.143	1.69	2	0.07
14/05/2008	6.5		103		86	6.1	7	0.002	0.125	1.67	3.4	0.18
11/07/2008	7.1		104		99	16.6	7	< 0.001	0.082	1.83	2.8	0.27
11/09/2008	6.7		124		120	17		0.001	0.296	2.59	2.7	0.17
14/10/2008	6.5		158		128	7	4	0.001	0.161	3.29	1.8	0.2
6/03/2009	6.7	8.2	98		116.4	9.7	7.2	< 0.001	0.066	0.69		
11/06/2009	6.3	10.4	66		117	12	6.6	< 0.001	0.058	0.95		
9/07/2009	6.1	8.8	83		110	12	6.5	< 0.001	0.031	0.76		
18/08/2009	6.8	10.7	87		120	13	6.9	< 0.001	0.097	0.79		
14/09/2009	7.1	10.2	96		130	14	6.8	< 0.001	0.21	1.1		
14/10/2009	8.3	10.8	110		130	15	7.9	0.001	0.47	2.1		
12/11/2009	7.5	6.4	130		120	18	8.7	0.001	0.12	1.4		
10/12/2009	8.3	10.8	200		160	23	10	0.001	0.061	0.26		
8/01/2010	5.9	5.8	110		220	12	5.9	0.001	0.56	2.1		
4/02/2010	6	8.9	76		450	6.6	4.1	0.001	0.12	0.72		
4/03/2010	6.9	7.9	52		80	7	3.6	0.001	0.11	0.97		
16/04/2010	10	9.1	53		58	7.7	3.8	0.001	0.009	0.41		
14/05/2010	6		50	26	66		4	0.001	0.033	0.27	1.9	0.14
16/06/2010	5.1	11.8	63		100	9	4.5	0.001	0.016	0.4		
20/07/2010	6.9	7.3	71		77	9.2	4.9	0.001	0.052	0.61		
13/08/2010	6.7		70	11								
13/09/2010	7.2		72	5								
8/10/2010	7.1		82	5								
8/11/2010	6.6		51	23							1.6	0.14
15/12/2010	6.7		100	10								
13/01/2011	7.1		110	16								
11/04/2011	6.7		110	19							1.7	0.09
13/07/2011	7.3		110	6				0.001	0.011	0.43	1.6	0.04
17/02/2012	6.2		100	36							2.5	0.18
14/05/2012	7		160	13							2.6	0.1
14/11/2012	6.8		190	5							2.1	0.07
12/02/2013	7.1		280	55							4.1	0.18
16/05/2013	7.5		270	41							1.9	0.09
16/08/2013	7.3		190	26							2.8	0.08
14/11/2013	7.9		290	100							2.7	0.15
14/02/2014	9.2		520	21							3	0.12
21/05/2014	7.4		340	20							2.3	0.13
20/11/2014	8		600	4							4.1	0.03
20/02/2015	8.2		1300	6							9.9	0.02

Site O Monitoring Results

	pH	Dissolved Oxygen	Electrical Conductivity	Total Suspended Solids (TSS)	Total Dissolved Solids (TDS)	Chloride	Sodium	Arsenic	Manganese	Dissolved Iron	Total Nitrogen	Total Phosphorus
Unit		mg/L	µS/cm k 25.00C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Limit of Reporting	0.1		1	< 2	1	1	1	0.001	0.001	0.05	0.1	0.01
ANZECC Trigger Values for physical & chemical stressors for south-east Australia for slightly disturbed ecosystems (Upland River)	6.5 - 8		30 - 350								0.25	0.02
ANZECC Trigger Values - Freshwater Ecosystems												
99% Level of Species Protection								< LOR	1.2			
95% Level of Species Protection								0.013	1.9			
90% Level of Species Protection								0.042	2.5			
80% Level of Species Protection								0.14	3.6			
Australian Drinking Water Guidelines												
Health								0.01	0.5			
Aesthetic	6.5 - 8.5	> 85%			600	250	180		0.1	0.3		
14/02/2007	6.5		279		207	51.2	22	< 0.001	0.03	1.76	4.1	0.26
27/02/2007	7.7		253		190	34.1	14	0.002	0.044	0.91	2.5	0.1
22/03/2007	7.5		400		252	47.6	26	0.002	0.104	0.91	1.7	0.07
26/04/2007	8.1		542		364	82.1	42	< 0.001	0.08	0.44	1.7	0.05
28/05/2007	8		611		332	90.2	47	< 0.001	0.164	0.36	1.9	0.12
18/06/2007	7		240		193	42.5	20	< 0.001	0.025	1.43	3.6	0.22
16/07/2007	7.2		855		480	183	66	< 0.001	0.028	0.34	1.2	0.07
13/02/2008	7.2		552		446	91.2	43	< 0.001	0.094	1.17	1.6	0.01
12/03/2008	7.7		1372		894	401	118	< 0.001	0.103	0.32	1.2	0.03
14/04/2008	8.2		3960		2780	1220	357	< 0.001	0.071	1.02	0.8	0.01
14/05/2008	8.2		4260		2360	1180	430	0.001	0.013	0.05	0.8	0.01
11/07/2008	8.2		1329		808	373	112	< 0.001	0.011	0.19	0.9	0.37
11/09/2008	8.3		2280		1350	641		< 0.001	0.034	0.27	0.8	0.01
14/10/2008	7.6		686		468	144	61	< 0.001	0.062	2.08	0.7	0.08
6/03/2009	8.3	9.5	560		340	87	38	< 0.001	0.004	0.2		
11/06/2009	7.8	10.3	350		241	62	31	< 0.001	0.003	0.19		
9/07/2009	6.6	6.7	190		330	35	16	< 0.001	0.004	0.79		
18/08/2009	6.9	8.8	210		380	36	18	< 0.001	0.017	0.7		
14/09/2009	6.5	3	190		1100	28	16	< 0.001	0.011	0.62		
14/10/2009	7.3	9.7	150		1400	19	30	0.001	0.007	1.5		
12/11/2009	7.5	3.3	200		920	23	24	0.001	0.086	0.85		
10/12/2009	6	1.3	170		940	23	17	0.001	0.19	0.54		
8/01/2010	6.9	7.2	380		260	55	25	0.001	0.08	0.39		
4/02/2010	6.3	1.4	370		370	56	26	0.002	0.53	0.7		
4/03/2010	8	8	470		320	73	39	0.001	0.003	0.13		
16/04/2010	8.5	9.3	540		340	87	46	0.001	0.003	0.06		
14/05/2010	8.5		550		350		49	0.001	0.004	0.03	1.3	0.05
16/06/2010	5.8	8.4	420		520	80	42	0.001	0.013	0.29		
20/07/2010	7.4	9.3	520		350	110	50	0.001	0.008	0.1		
13/08/2010	7.7		340	470								
13/09/2010	8.3		1200	22								
8/10/2010	8.5		1200	8								
8/11/2010	7.9		360	150							1.5	0.16
15/12/2010	7.8		430	49								
13/01/2011	8.4		950	4								
11/04/2011	8		550	10							1.3	0.05
13/07/2011	8.3		1300	11				0.001	0.012	0.05	0.8	0.02
17/02/2012	6.6		240	23							2.2	0.10
14/05/2012	8.3		1500	4							0.8	0.01
14/11/2012	8.1		2900	8							0.7	0.02
12/02/2013	7.8		1100	19							1.5	0.08
16/05/2013	8.3		1200	7							0.8	0.02
16/08/2013	8.1		1700	3							0.8	0.01
14/11/2013	8.1		1200	13							0.6	0.02
14/02/2014												
21/05/2014	8.5		1200	7							1.8	0.06
20/11/2014												
20/02/2015	8.2		930	14							0.94	0.02
14/05/2015	8.5		2000	2							0.57	0.01

Site I Monitoring Results												
	pH	Dissolved Oxygen	Electrical Conductivity	Total Suspended Solids (TSS)	Total Dissolved Solids (TDS)	Chloride	Sodium	Arsenic	Manganese	Dissolved Iron	Total Nitrogen	Total Phosphorus
Unit		mg/L	µS/cm k 25.00C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Limit of Reporting	0.1		1	< 2	1	1	1	0.001	0.001	0.05	0.1	0.01
ANZECC Trigger Values for physical & chemical stressors for south-east Australia for slightly disturbed ecosystems (Upland River)	6.5 - 8		30 - 350								0.25	0.02
ANZECC Trigger Values - Freshwater Ecosystems												
99% Level of Species Protection								< LOR	1.2			
95% Level of Species Protection								0.013	1.9			
90% Level of Species Protection								0.042	2.5			
80% Level of Species Protection								0.14	3.6			
Australian Drinking Water Guidelines												
Health								0.01	0.5			
Aesthetic	6.5 - 8.5	> 85%			600	250	180		0.1	0.3		
14/02/2007	6.8		111		110	17.5	11	< 0.001	0.189	8.8	4.7	5.55
27/02/2007	6.2		114		209	11.5	7	< 0.001	0.062	4.09	2.1	0.22
22/03/2007	6.6		142		213	7.3	8	0.003	0.832	5.57	2.5	0.12
26/04/2007	7		205		800	20.4	14	0.007	1.7	28.6	8.8	1.22
28/05/2007	6.5		61		91	6.2	9	< 0.001	0.023	2.52	1.6	0.04
18/06/2007	6.2		96		167	22.3	11	< 0.001	0.032	1.69	1.2	0.03
16/07/2007	5.9		143		142	25.7	14	0.001	0.128	0.98	2	0.13
13/02/2008	6.3		105		282	10.3	10	0.001	0.232	4.68	2	0.08
12/03/2008	6.4		132		286	19.8	8	0.003	0.682	18.6	3.3	0.3
14/04/2008	5.9		96		147	20.8	8	< 0.001	0.26	2.97	2.2	0.21
14/05/2008	8.2		3640		1950	846	376	< 0.001	0.025	0.08	1.8	0.91
11/07/2008	8.3		3230		2060	822	306	0.002	0.012	0.05	1.4	0.13
11/09/2008	5.7		149		398	27		< 0.001	0.312	6.21	0.9	0.18
14/10/2008	6.2		123		407	19	11	0.002	0.52	12.6	1.4	0.06
6/03/2009												
11/06/2009												
9/07/2009												
18/08/2009												
14/09/2009												
14/10/2009												
12/11/2009												
10/12/2009												
8/01/2010												
4/02/2010												
4/03/2010												
16/04/2010												
14/05/2010												
16/06/2010												
20/07/2010												
13/08/2010	6.4		97	21								
13/09/2010												
8/10/2010												
8/11/2010												
15/12/2010	6.3		140	6								
13/01/2011												
11/04/2011												
13/07/2011												
17/02/2012												
14/05/2012												
14/11/2012												
12/02/2013												
16/05/2013												
16/08/2013	8		1800	5							0.55	0.01
14/11/2013												
14/02/2014												
21/05/2014												
20/11/2014												
20/02/2015												
14/05/2015												

APPENDIX B – WATER BALANCE SUMMARY SHEETS

Gunlake Quarry: Site Water Balance
Model Assumptions: Approved Operation (0.75 Mtpa)

Storage Assumptions

Storage Name	Surface Area (m^2)	Average Depth (m)	Volume (ML)	Contributing Catchments	Overflows	Function
Process Water Dam	*4500*	*2.2*	*10*	*DW -1 (19ha)*	*to Chapmans Creek*	*Captures runoff from DW-1 for process water use*
Pit Sump	*1500*	*3*	*5 plus flood storage*	*Pit (14ha)*	*no overflows*	*Captures runoff from the pit for process water use*
Clean Water Dam 1	*3500*	*2*	*7*	*CW -1 (70ha)*	*to Chapmans Creek*	*Captures runoff from CW-1 for process water use*
Clean Water Dam 2	*6000*	*2.5*	*15*	*CW -2 (62ha)*	*to Chapmans Creek*	*Captures runoff from CW-2 for process water use*

Note: Storage volumes have been estimated using available information and have not been confirmed by survey

Demand Assumptions

Haul Road Dust Suppression

Water use for haul road dust suppression is calculated as a function of the haul road area and prevailing climatic conditions using the following formulae

$$DSupp(t) = Max(0, ((Evap(t) \times PanCoeff) - Rain(t)) \times HRArea \times 0.01)$$

Where:

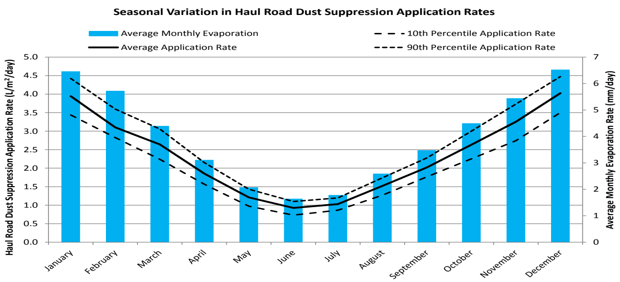
DSupp(t) = Daily water use for haul road dust suppression (ML/day)

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

PanCoeff = Evaporation adjustment coefficient

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

HRArea = Area of active haul road (ha)



The following haul road area and Pan Coeff were adopted

Haul Road Area 5ha

Pan Coeff 0.72 *(This equates to an average annual application rate of 3L/m^2 per day)*

The calculated annual demand varies between **41** to **45 ML/year**, depending on rainfall over the year.
The demand varies seasonally inline with evaporation rates as shown in the above chart.

Plant Water Use

Plant water use is calculated as a function of the plant throughput and a water use rate

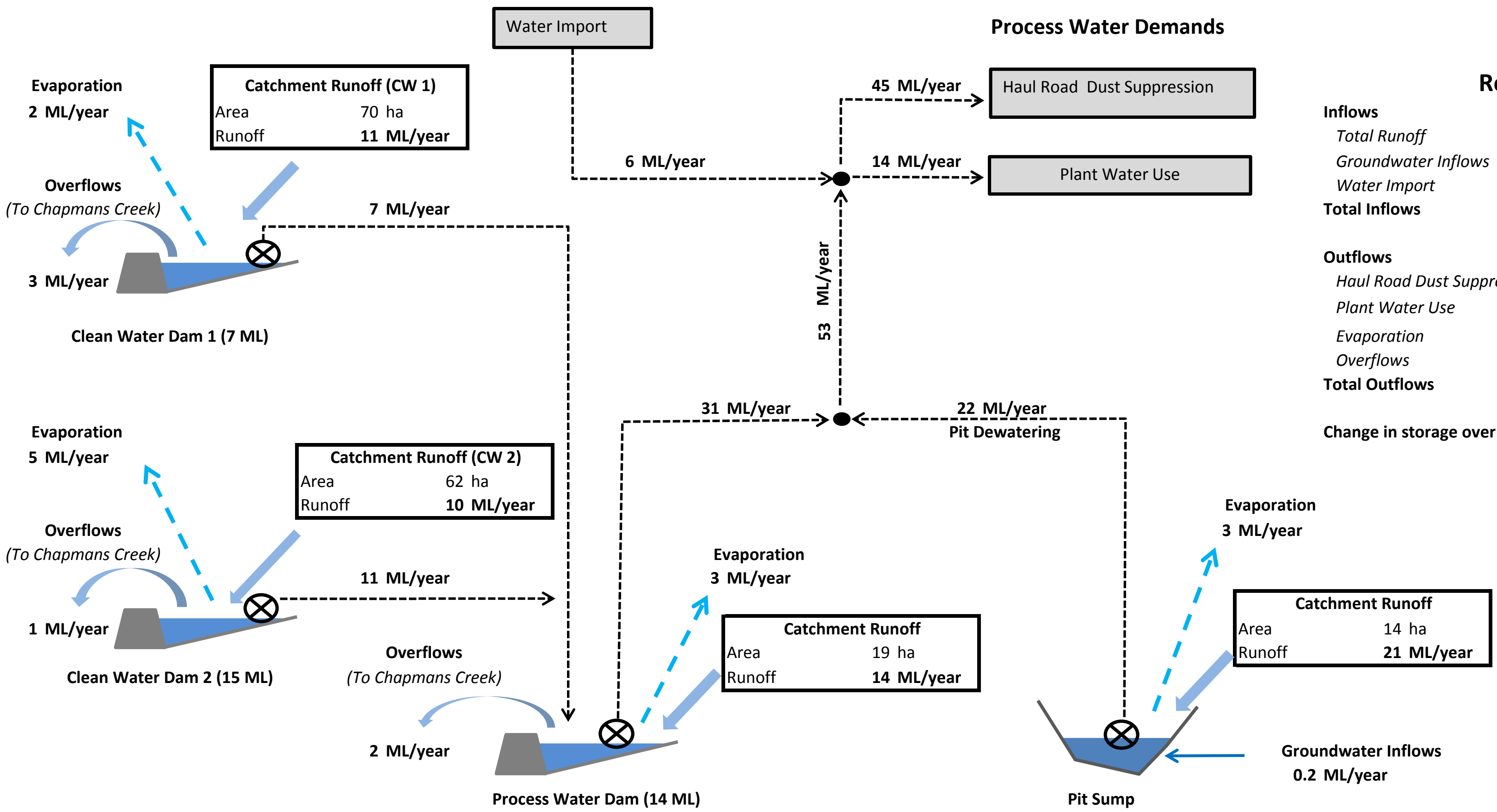
Plant Throughput 0.75 Mtpa
Water use rate 18.2 L/t *(Calculated from metered data provided by Gunlake)*
Annual Water Use **13.7 ML/year**

Process Water Use Order of Preference

The water balance model preferentially sources water to meet process water demands as follows:

1st preference: *Water stored in the pit*
2st preference: *Water stored in the process water dam*
3rd preference: *Water stored in Clean water dams*
4th preference: *Water imported to site via tankers*

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

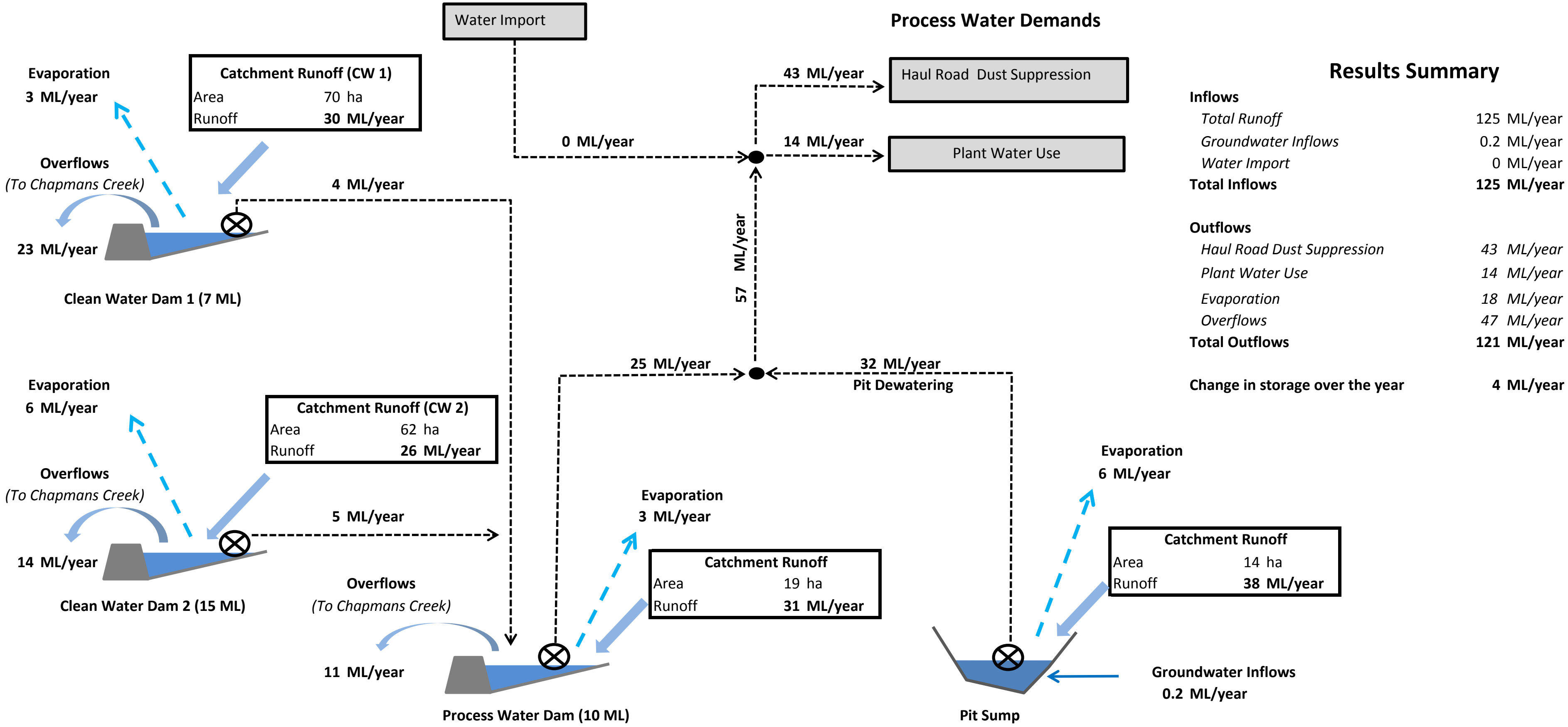


Results Summary

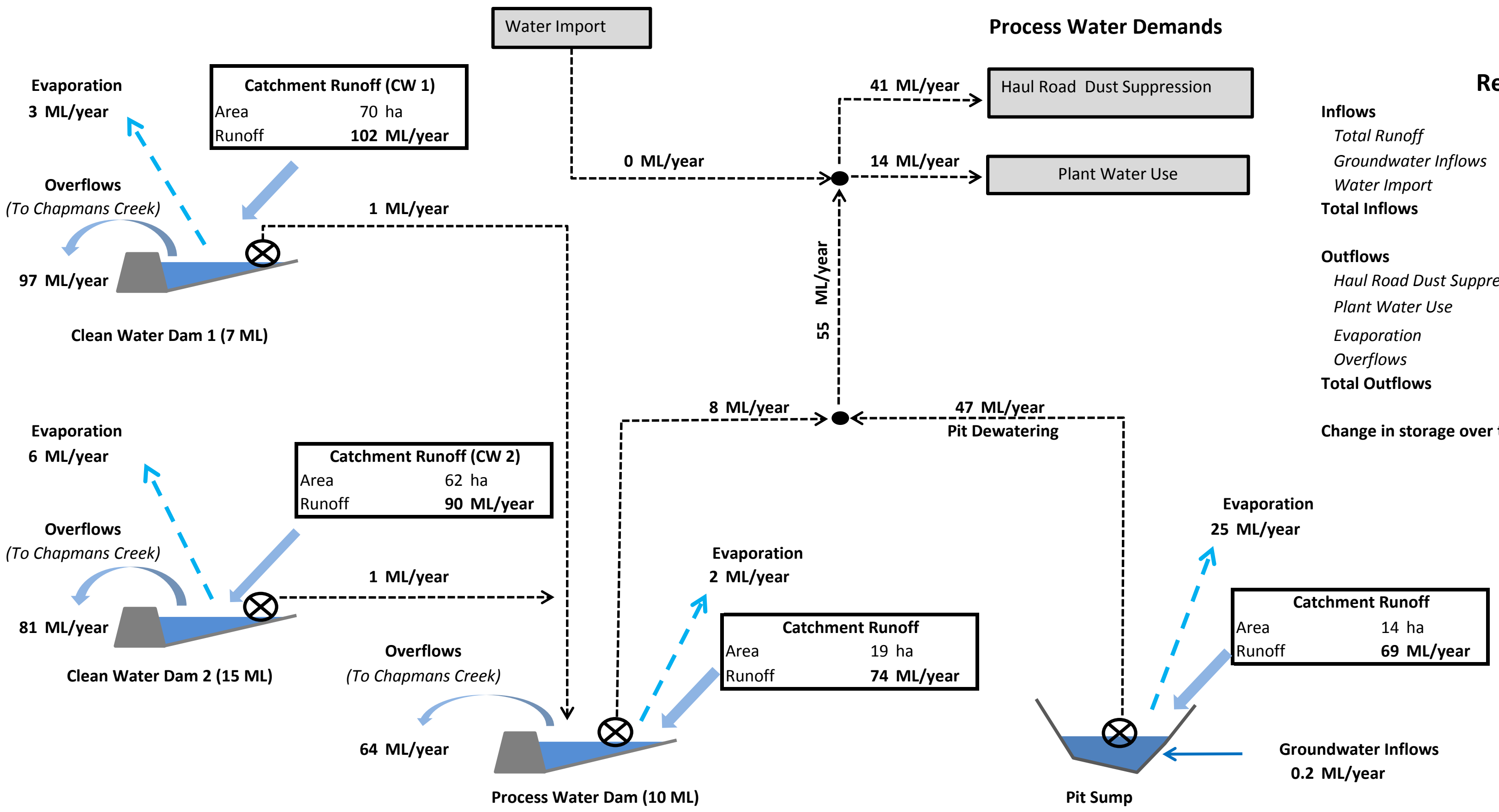
Inflows	
Total Runoff	57 ML/year
Groundwater Inflows	0.2 ML/year
Water Import	6 ML/year
Total Inflows	**63 ML/year**
Outflows	
Haul Road Dust Suppression	*45 ML/year*
Plant Water Use	*14 ML/year*
Evaporation	*14 ML/year*
Overflows	*6 ML/year*
Total Outflows	**79 ML/year**
Change in storage over the year	**-16 ML/year**

Royal HaskoningDHV
Enhancing Society Together

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



Gunlake Quarry: Site Water Balance: Approved Operation: Surface Water Management Plan
Typical Wet (90th Percentile) Rainfall Year
Annual Rainfall *982 mm/year*



Results Summary

Inflows		
Total Runoff	335	ML/year
Groundwater Inflows	0.2	ML/year
Water Import	0	ML/year
Total Inflows	**335**	**ML/year**
Outflows		
Haul Road Dust Suppression	*41*	*ML/year*
Plant Water Use	*14*	*ML/year*
Evaporation	*37*	*ML/year*
Overflows	*242*	*ML/year*
Total Outflows	**333**	**ML/year**
Change in storage over the year	**2**	**ML/year**

Gunlake Quarry: Site Water Balance
Model Assumptions: Quarry Year 1: Surface Water Management Plan

Storage Assumptions

Storage Name	Surface Area (m^2)	Average Depth (m)	Volume (ML)	Contributing Catchments	Overflows	Function
Process Water Dam	*7500*	*5*	*35*	*DW -4 (19ha)*	*to Chapmans Creek*	*Captures runoff from DW-4 for process water use*
Pit Sump	*+7000*	*+3*	*20 plus flood storage*	*Pit (29ha)*	*no overflows*	*Captures runoff from the pit*
Clean Water Dam 2	*6500*	*2.3*	*15*	*CW -2 (48ha) + DW-2 (5ha)*	*to Chapmans Creek*	*Sedimentation dam for emplacement area. Water stored for process water use*
Pit Dewatering Dam	*10000*	*3*	*30*	*DW 5 (16ha)*	*to Chapmans Creek*	*Treats water dewatered from the pit. Water stored for process water use*

Demand Assumptions

Haul Road Dust Suppression

Water use for haul road dust suppression is calculated as a function of the haul road area and prevailing climatic conditions using the following formulae

$$DSupp(t) = Max(0, ((Evap(t) \times PanCoeff) - Rain(t)) \times HRArea \times 0.01)$$

Where:

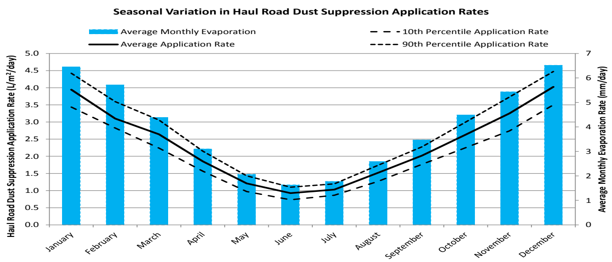
DSupp(t) = Daily water use for haul road dust suppression (ML/day)

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

PanCoeff = Evaporation adjustment coefficient

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

HRArea = Area of active haul road (ha)



The following haul road area and Pan Coeff were adopted

Haul Road Area	8ha	
Pan Coeff	0.72	*(This equates to an average annual application rate of 2.3L/m^2 per day)*

The calculated annual demand varies between **66** to **74 ML/year**, depending on rainfall over the year.
The demand varies seasonally inline with evaporation rates as shown in the above chart.

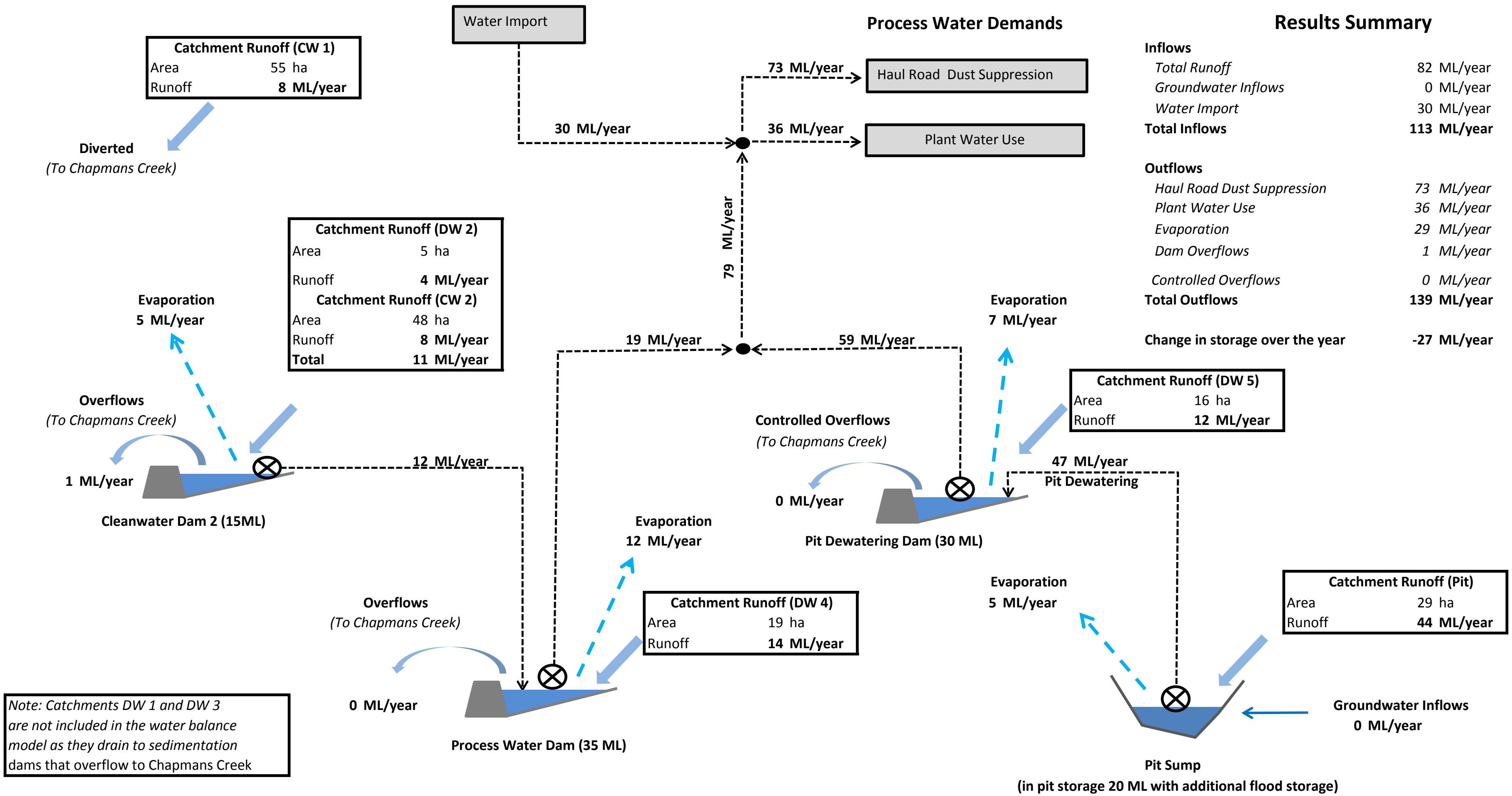
Plant Water Use
Plant water use is calculated as a function of the plant throughput and a water use rate

Plant Throughput	2.0 Mtpa	
Water use rate	18.2 L/t	*(Calculated from metered data provided by Gunlake)*
Annual Water Use	**36.4 ML/year**	

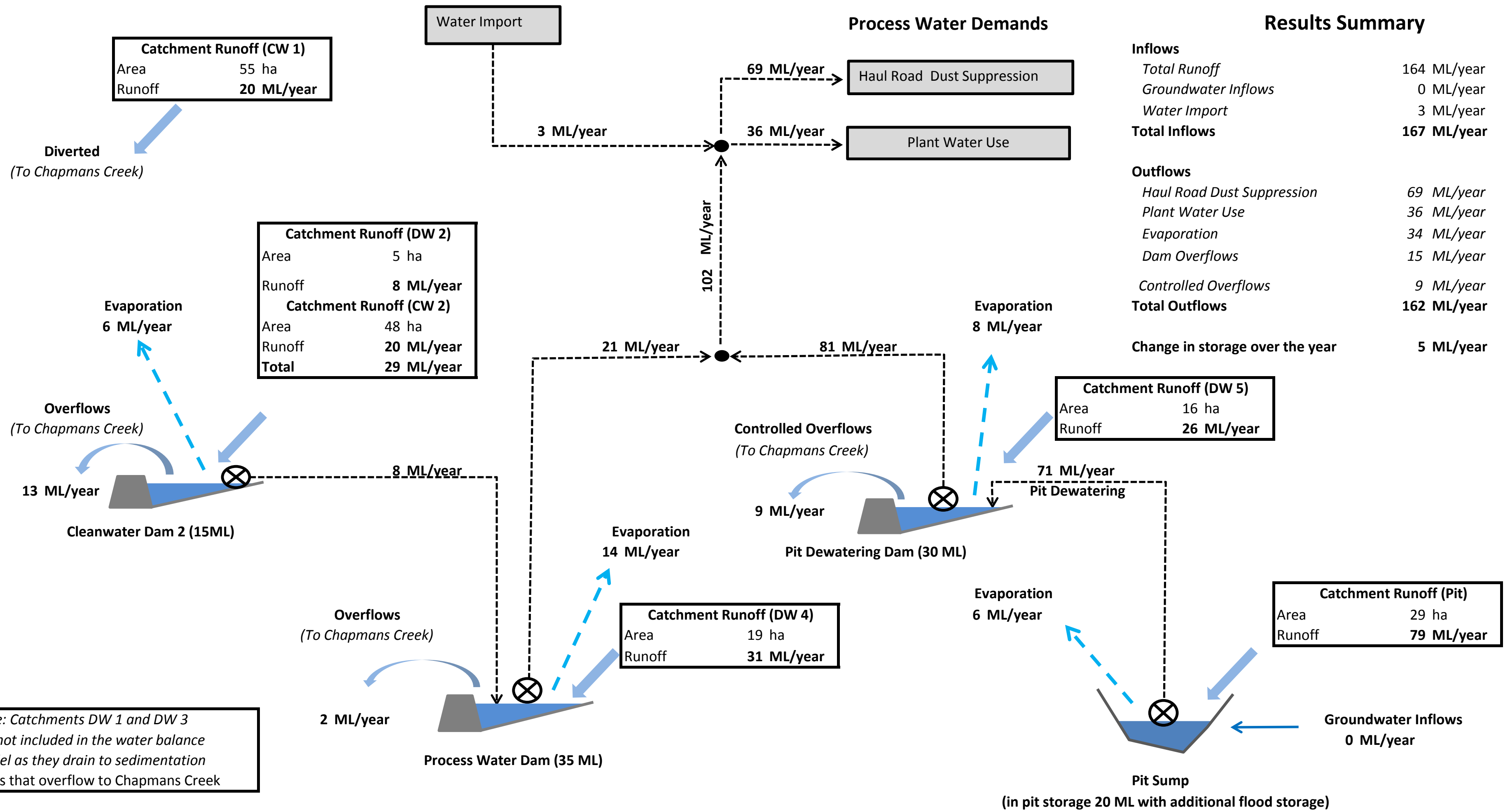
Process Water Use Order of Preference

The water balance model preferentially sources water to meet process water demands as follows:
- ***1st preference:*** *Water stored in the process water dam*
- ***2st preference:*** *Water stored in the Pit Dewatering Dam*
- ***3rd preference:*** *Water stored in the Sed Dam 2*
- ***4th preference:*** *Water imported to site via tankers*

Gunlake Quarry: Site Water Balance: Quarry Year 1: Surface Water Management Plan
Typical Dry (10th Percentile) Rainfall Year
Annual Rainfall *451 mm/year*

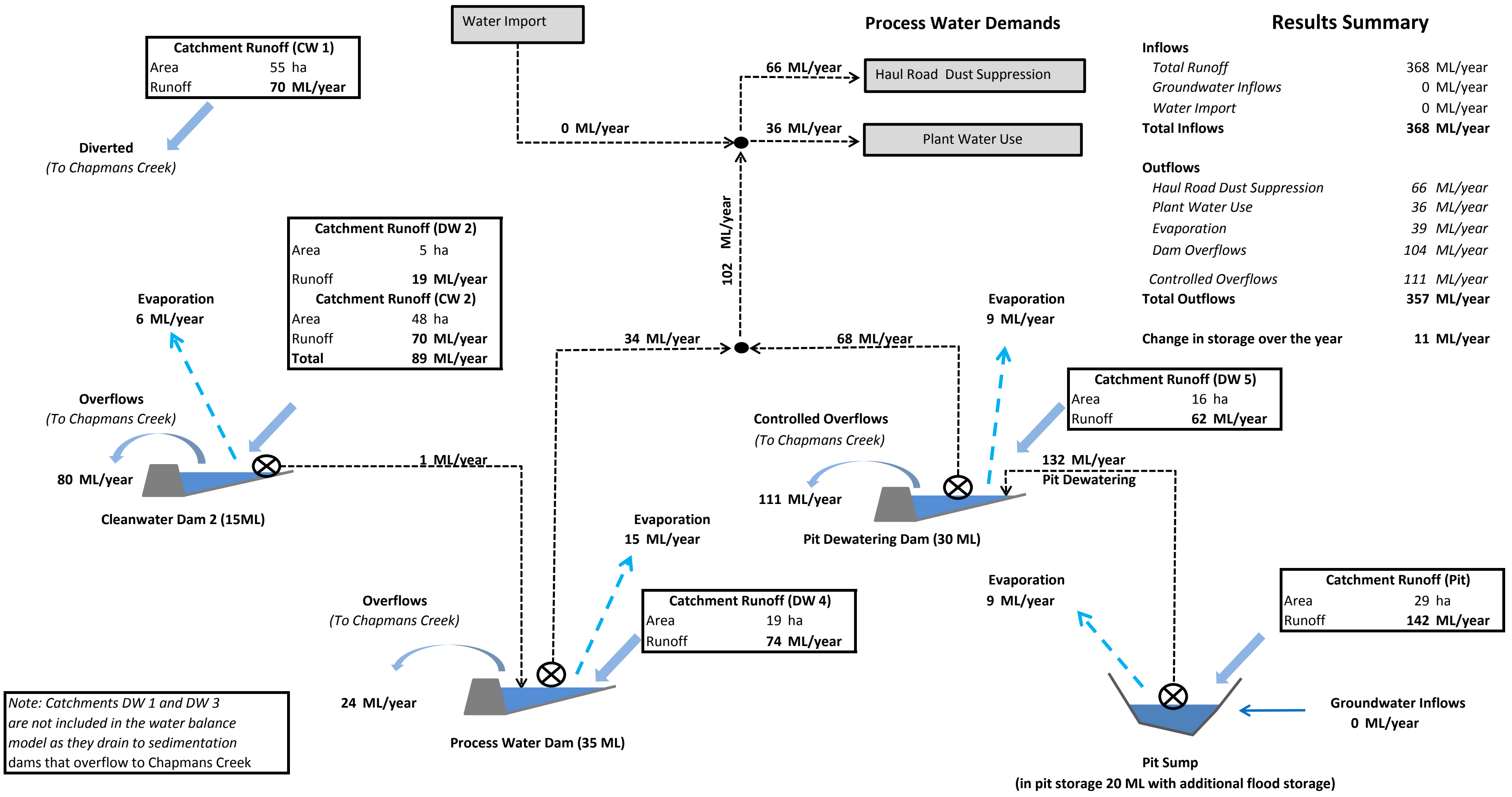


Gunlake Quarry: Site Water Balance: Quarry Year 1: Surface Water Management Plan
Typical Median (50th Percentile) Rainfall Year
Annual Rainfall *695 mm/year*



Note: Catchments DW 1 and DW 3 are not included in the water balance model as they drain to sedimentation dams that overflow to Chapmans Creek

Gunlake Quarry: Site Water Balance: Quarry Year 1: Surface Water Management Plan
Typical Wet (90th Percentile) Rainfall Year
Annual Rainfall *982 mm/year*



Gunlake Quarry: Sedimentation Dam Calculations
Model Assumptions: Quarry Year 1: Surface Water Management Plan

Calculation Assumptions

Sedimentation dam volumes have been calculated in accordance with the methods provided in *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008). The following sizing methods have been adopted:

- The sedimentation dam sizing method for Type F and D soils has been adopted.
- Treatment volumes have been calculated based on the 90th Percentile 5 day rainfall event. This is in accordance with Table 6.1 *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008) for a dam that operates form more than 3 years and overflows to a non-sensitive receiving water.
- A sediment storage volume equivalent to 50% of the treatment volume has been adopted.

Key assumptions are provided in the following table.

Assumption	Adopted Value	Source
90th Percentile Rainfall Depth	28.6 mm	Table 6.3a Vol. 1 (Location Goulburn)
Soil Hydrologic Group	D – high runoff potential	Appendix F Vol. 1

Calculated Dam Sizes

	Units	Dam Name				
		Process Water Dam	Sed Dam 1	Sed Dam 2	Sed Dam 3	Pit Dewatering Dam
Catchment Area (ha)	*(ha)*	19	10	5	6	16
5 day Rainfall Depth	*(mm)*	28.6	28.6	28.6	28.6	28.6
Runoff Coefficient (Cv)[1]	-	0.56	0.56	0.56	0.56	0.56
Sedimentation Dam Volume	*(ML)*	3.0	1.6	0.8	1.0	2.6
Calculated Sediment Storage	*(ML)*	1.5	0.8	0.4	0.5	1.3
Total Dam Volume	*(ML)*	4.6	2.4	1.2	1.4	3.8
Proposed Dam Volume[2]	*(ML)*	35.0	2.4	1.2	1.4	30
Exceeds Minimum Requirements	-	Yes	Yes	Yes	Yes	Yes

Note 1: From Table F2 Vol. 1

Note 2: Some dam volumes exceed minimum requirement as they are sized to store water for process water use

Gunlake Quarry: Site Water Balance

Model Assumptions: Quarry Year 5: Surface Water Management Plan

Storage Assumptions

Storage Name	Surface Area (m^2)	Average Depth (m)	Volume (ML)	Contributing Catchments	Overflows	Function
Process Water Dam	*7500*	*5*	*35*	*DW -4 (19ha)*	*to Chapmans Creek*	*Captures runoff from DW-4 for process water use*
Pit Sump	*+7000*	*+3*	*20 plus flood storage*	*Pit (29ha)*	*no overflows*	*Captures runoff from the pit*
Clean Water Dam 2	*6500*	*2.3*	*15*	*CW -2 (48ha) + DW-2 (5ha)*	*to Chapmans Creek*	*Sedimentation dam for emplacement area. Water stored for process water use*
Pit Dewatering Dam	*10000*	*3*	*30*	*DW 5 (6ha)*	*to Chapmans Creek*	*Treats water dewatered from the pit. Water stored for process water use*

Demand Assumptions

Haul Road Dust Suppression

Water use for haul road dust suppression is calculated as a function of the haul road area and prevailing climatic conditions using the following formulae

$$DSupp(t) = Max(0, ((Evap(t) \times PanCoeff) - Rain(t)) \times HRArea \times 0.01)$$

Where:

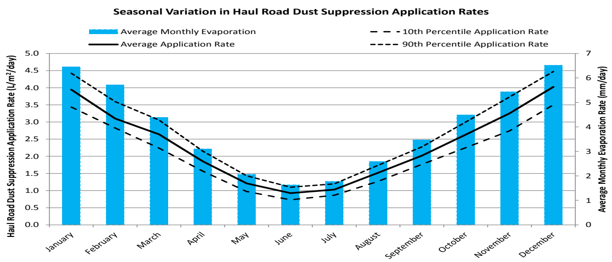
DSupp(t) = Daily water use for haul road dust suppression (ML/day)

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

PanCoeff = Evaporation adjustment coefficient

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

HRArea = Area of active haul road (ha)



The following haul road area and Pan Coeff were adopted

Haul Road Area 8ha

Pan Coeff 0.72 *(This equates to an average annual application rate of 2.3L/m^2 per day)*

The calculated annual demand varies between **66** to **74 ML/year**, depending on rainfall over the year.
The demand varies seasonally inline with evaporation rates as shown in the above chart.

Plant Water Use

Plant water use is calculated as a function of the plant throughput and a water use rate

Plant Throughput 2.0 Mtpa

Water use rate 18.2 L/t *(Calculated from metered data provided by Gunlake)*

Annual Water Use **36.4 ML/year**

Process Water Use Order of Preference

The water balance model preferentially sources water to meet process water demands as follows:

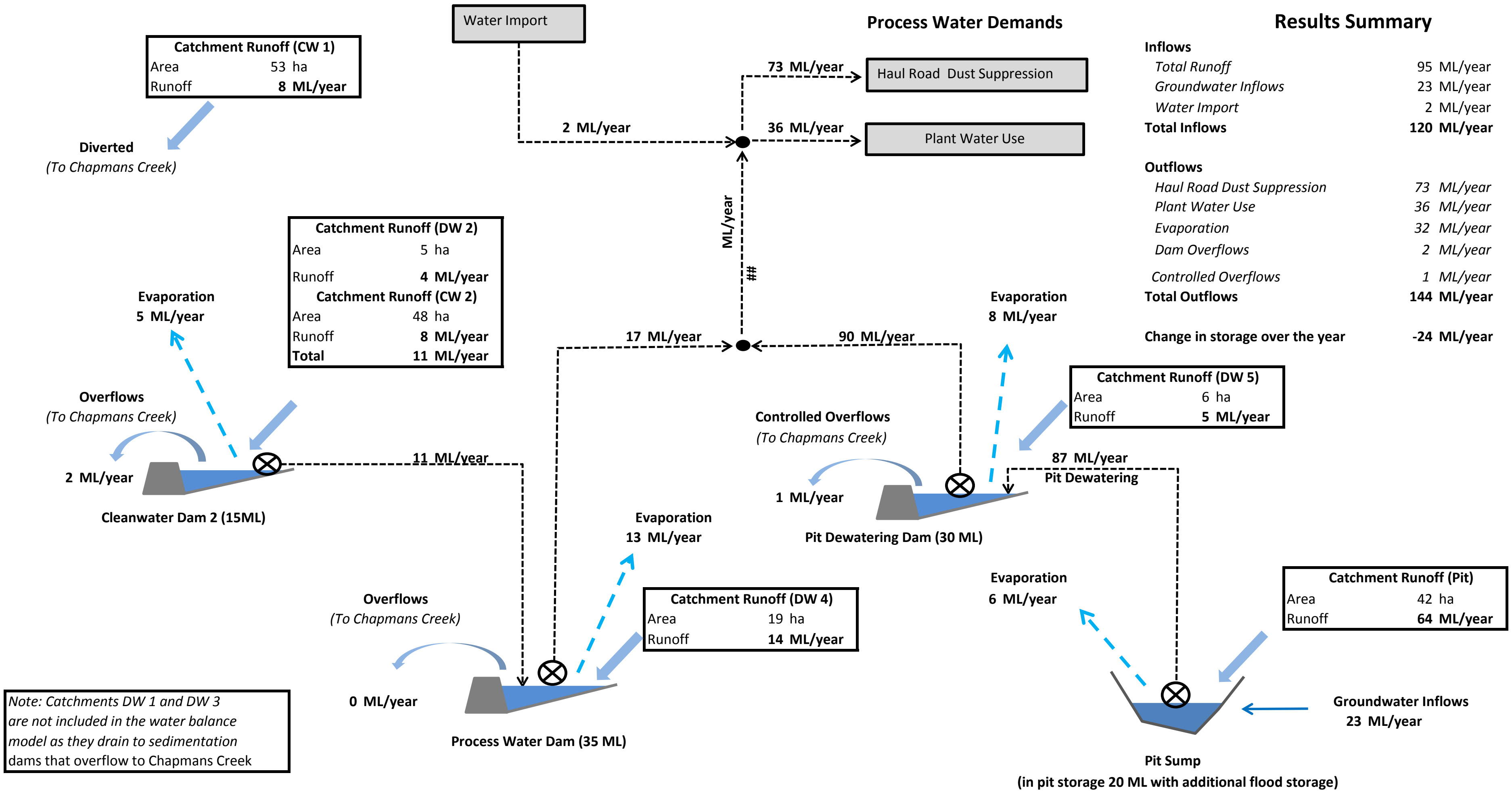
1st preference: *Water stored in the process water dam*

2st preference: *Water stored in the Pit Dewatering Dam*

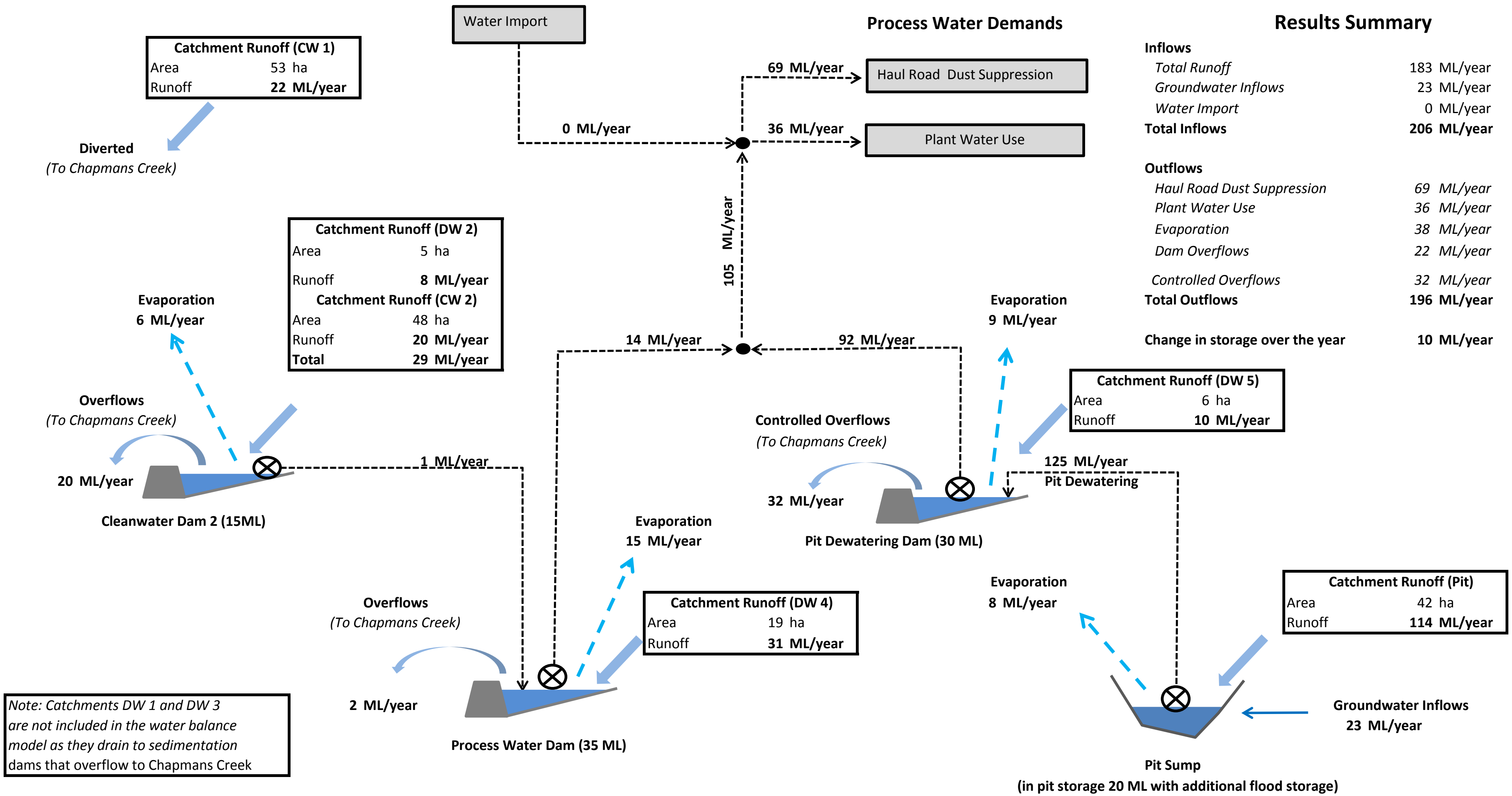
3rd preference: *Water stored in the Sed Dam 2*

4th preference: *Water imported to site via tankers*

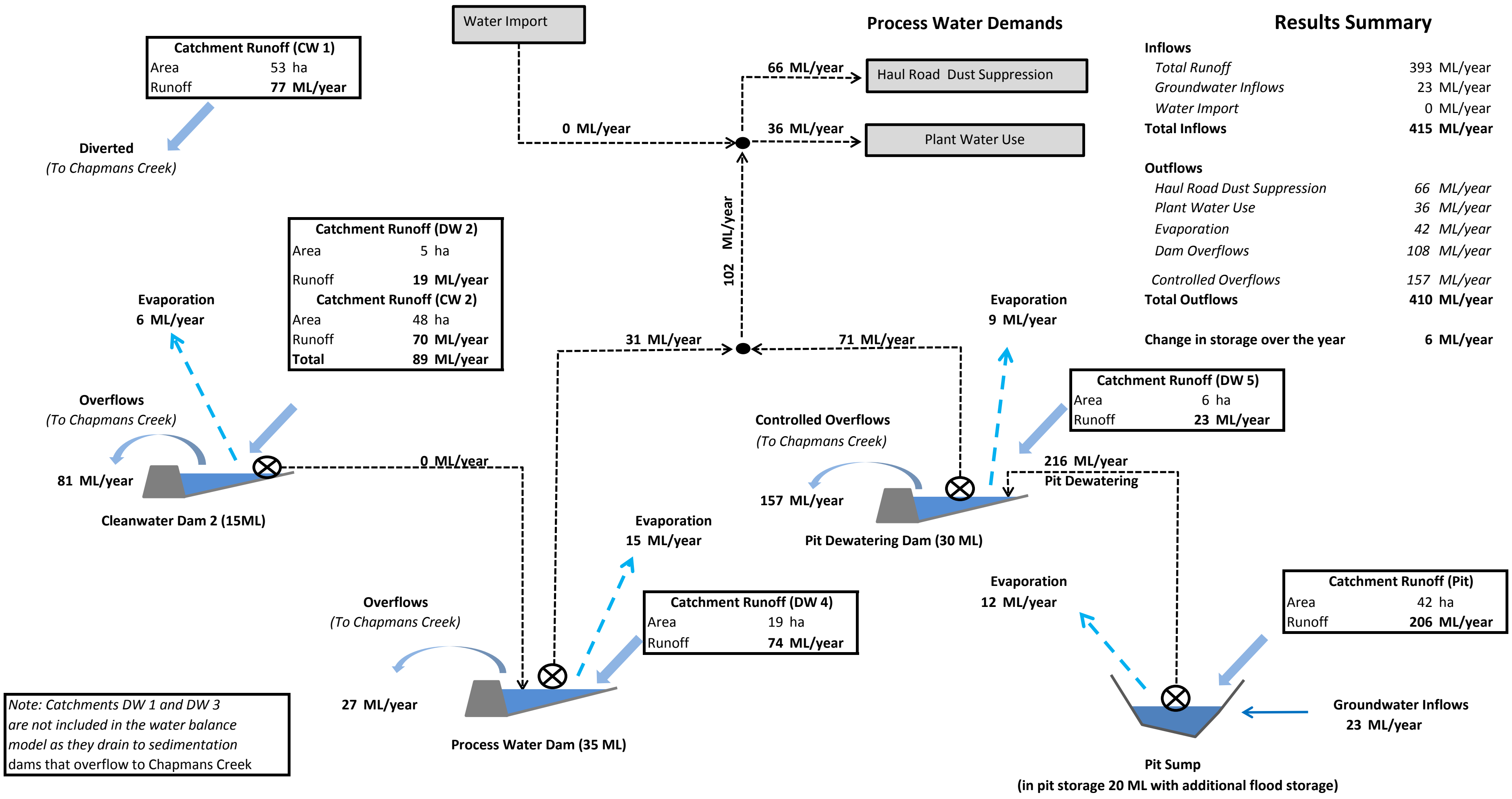
Gunlake Quarry: Site Water Balance: Quarry Year 5: Surface Water Management Plan
Typical Dry (10th Percentile) Rainfall Year
Annual Rainfall *451 mm/year*



Gunlake Quarry: Site Water Balance: Quarry Year 5: Surface Water Management Plan
Typical Median (50th Percentile) Rainfall Year
Annual Rainfall *695 mm/year*



Gunlake Quarry: Site Water Balance: Quarry Year 5: Surface Water Management Plan
Typical Wet (90th Percentile) Rainfall Year
Annual Rainfall *982 mm/year*



Gunlake Quarry: Sedimentation Dam Calculations
Model Assumptions: Quarry Year 5: Surface Water Management Plan

Calculation Assumptions

Sedimentation dam volumes have been calculated in accordance with the methods provided in *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008). The following sizing methods have been adopted:

- The sedimentation dam sizing method for Type F and D soils has been adopted.
- Treatment volumes have been calculated based on the 90th Percentile 5 day rainfall event. This is in accordance with Table 6.1 *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008) for a dam that operates form more than 3 years and overflows to a non-sensitive receiving water.
- A sediment storage volume equivalent to 50% of the treatment volume has been adopted.

Key assumptions are provided in the following table.

Assumption	Adopted Value	Source
90th Percentile Rainfall Depth	28.6 mm	Table 6.3a Vol. 1 (Location Goulburn)
Soil Hydrologic Group	D – high runoff potential	Appendix F Vol. 1

Calculated Dam Sizes

	Units	Dam Name				
		Process Water Dam	Sed Dam 1	Sed Dam 2	Sed Dam 3	Pit Dewatering Dam
Catchment Area (ha)	*(ha)*	19	10	5	6	5
5 day Rainfall Depth	*(mm)*	28.6	28.6	28.6	28.6	28.6
Runoff Coefficient (Cv)[1]	-	0.56	0.56	0.56	0.56	0.56
Sedimentation Dam Volume	*(ML)*	3.0	1.6	0.8	1.0	0.8
Calculated Sediment Storage	*(ML)*	1.5	0.8	0.4	0.5	0.4
Total Dam Volume	*(ML)*	4.6	2.4	1.2	1.4	1.2
Proposed Dam Volume[2]	*(ML)*	35.0	2.4	1.2	1.4	30
Exceeds Minimum Requirements	-	Yes	Yes	Yes	Yes	Yes

Note 1: From Table F2 Vol. 1

Note 2: Some dam volumes exceed minimum requirement as they are sized to store water for process water use

Gunlake Quarry: Site Water Balance

Model Assumptions: Quarry Years 10 to 30: Surface Water Management Plan

Storage Assumptions

Storage Name	Surface Area (m^2)	Average Depth (m)	Volume (ML)	Contributing Catchments	Overflows	Function
Process Water Dam	*7500*	*5*	*35*	*DW -4 (19ha)*	*to Chapmans Creek*	*Captures runoff from DW-4 for process water use*
Pit Sump	*+7000*	*+3*	*20 plus flood storage*	*Pit (53ha)*	*no overflows*	*Captures runoff from the pit*
Clean Water Dam 2	*6500*	*2.3*	*15*	*CW -2 (48ha) + DW-2 (5ha)*	*to Chapmans Creek*	*Sedimentation dam for emplacement area. Water stored for process water use*
Pit Dewatering Dam	*10000*	*3*	*30*	*DW - 5 (2ha)*	*to Chapmans Creek*	*Treats water dewatered from the pit. Water stored for process water use*

Demand Assumptions

Haul Road Dust Suppression

Water use for haul road dust suppression is calculated as a function of the haul road area and prevailing climatic conditions using the following formulae

$$DSupp(t) = Max(0, ((Evap(t) \times PanCoeff) - Rain(t)) \times HRArea \times 0.01)$$

Where:

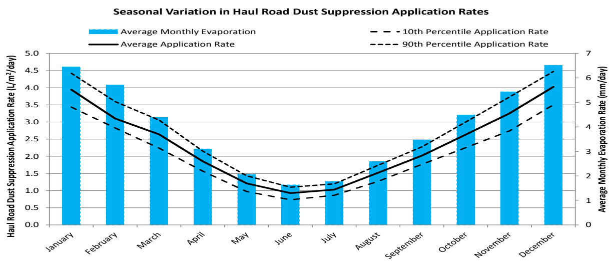
DSupp(t) = Daily water use for haul road dust suppression (ML/day)

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

PanCoeff = Evaporation adjustment coefficient

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

HRArea = Area of active haul road (ha)



The following haul road area and Pan Coeff were adopted

Haul Road Area 8ha

Pan Coeff 0.72 *(This equates to an average annual application rate of 2.3L/m^2 per day)*

The calculated annual demand varies between **66** to **74 ML/year**, depending on rainfall over the year.
The demand varies seasonally inline with evaporation rates as shown in the above chart.

Plant Water Use

Plant water use is calculated as a function of the plant throughput and a water use rate

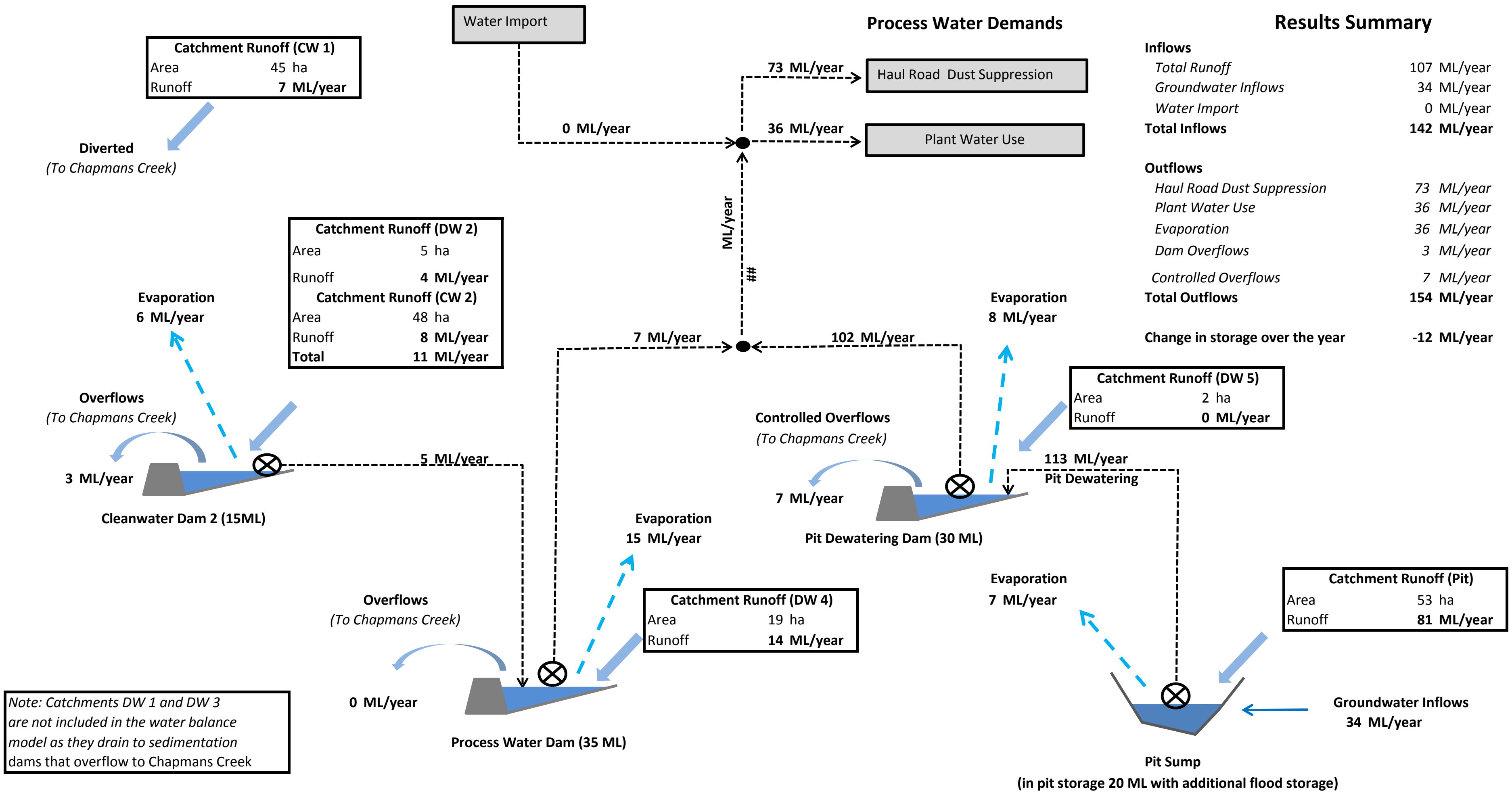
Plant Throughput	2.0 Mtpa	
Water use rate	18.2 L/t	*(Calculated from metered data provided by Gunlake)*
Annual Water Use	**36.4 ML/year**	

Process Water Use Order of Preference

The water balance model preferentially sources water to meet process water demands as follows:

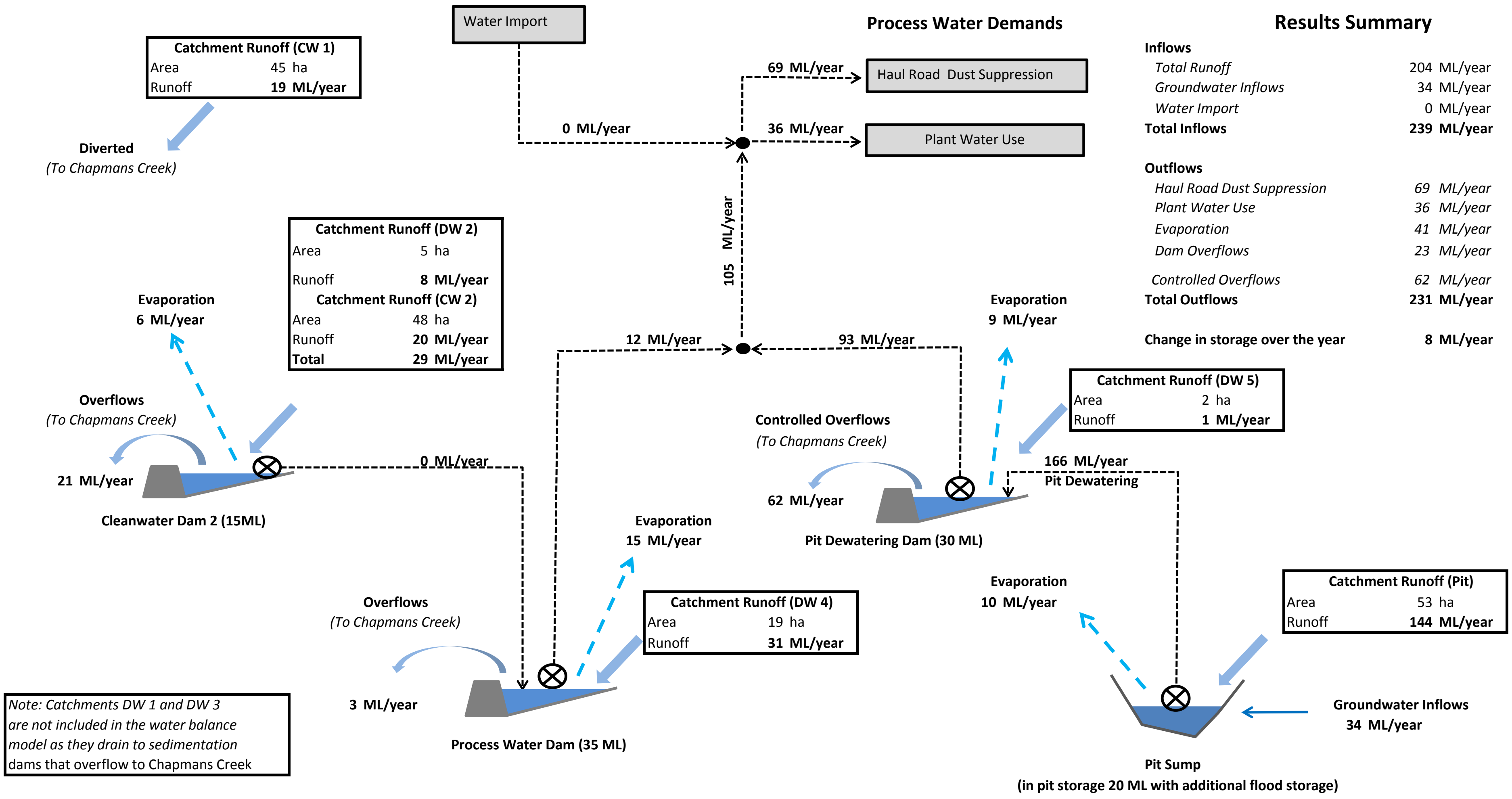
1st preference: *Water stored in the process water dam*
2st preference: *Water stored in the Pit Dewatering Dam*
3rd preference: *Water stored in the Sed Dam 2*
4th preference: *Water imported to site via tankers*

Gunlake Quarry: Site Water Balance: Quarry Years 10 to 30: Surface Water Management Plan
Typical Dry (10th Percentile) Rainfall Year
Annual Rainfall *451 mm/year*

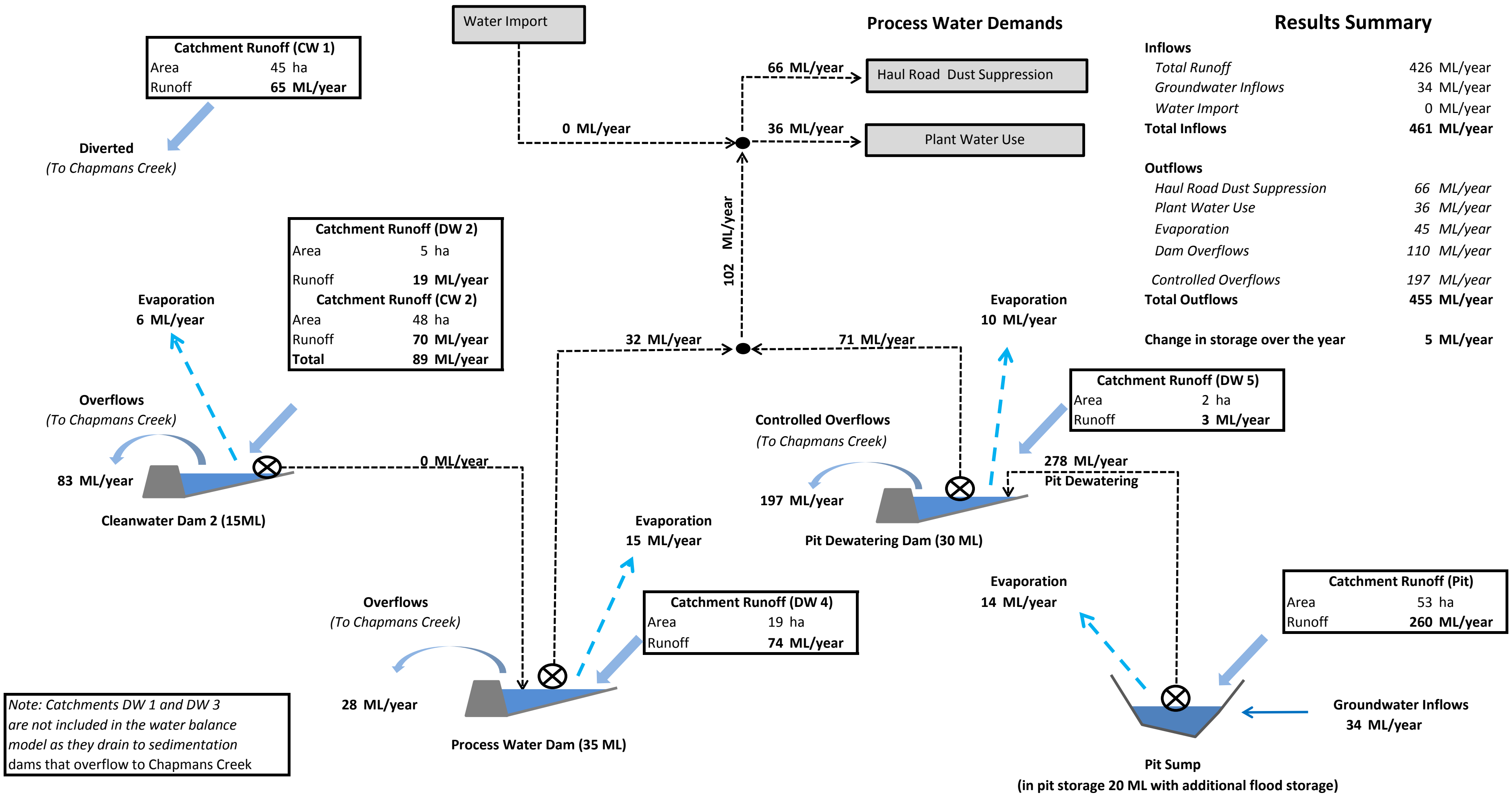


Royal HaskoningDHV

Gunlake Quarry: Site Water Balance: Quarry Years 10 to 30: Surface Water Management Plan
Typical Median (50th Percentile) Rainfall Year
Annual Rainfall *695 mm/year*



Gunlake Quarry: Site Water Balance: Quarry Years 10 to 30: Surface Water Management Plan
Typical Wet (90th Percentile) Rainfall Year
Annual Rainfall *982 mm/year*



Gunlake Quarry: Sedimentation Dam Calculations
Model Assumptions: Quarry Years 10 to 30: Surface Water Management Plan

Calculation Assumptions

Sedimentation dam volumes have been calculated in accordance with the methods provided in *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008). The following sizing methods have been adopted:

- The sedimentation dam sizing method for Type F and D soils has been adopted.
- Treatment volumes have been calculated based on the 90th Percentile 5 day rainfall event. This is in accordance with Table 6.1 *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries* (DECC, 2008) for a dam that operates form more than 3 years and overflows to a non-sensitive receiving water.
- A sediment storage volume equivalent to 50% of the treatment volume has been adopted.

Key assumptions are provided in the following table.

Assumption	Adopted Value	Source
90th Percentile Rainfall Depth	28.6 mm	Table 6.3a Vol. 1 (Location Goulburn)
Soil Hydrologic Group	D – high runoff potential	Appendix F Vol. 1

Calculated Dam Sizes

	Units	Dam Name				
		Process Water Dam	Sed Dam 1	Sed Dam 2	Sed Dam 3	Pit Dewatering Dam
Catchment Area (ha)	*(ha)*	19	10	5	6	2
5 day Rainfall Depth	*(mm)*	28.6	28.6	28.6	28.6	28.6
Runoff Coefficient (Cv)[1]	-	0.56	0.56	0.56	0.56	0.56
Sedimentation Dam Volume	*(ML)*	3.0	1.6	0.8	1.0	0.3
Calculated Sediment Storage	*(ML)*	1.5	0.8	0.4	0.5	0.2
Total Dam Volume	*(ML)*	4.6	2.4	1.2	1.4	0.5
Proposed Dam Volume[2]	*(ML)*	35.0	2.4	1.2	1.4	30
Exceeds Minimum Requirements	-	Yes	Yes	Yes	Yes	Yes

Note 1: From Table F2 Vol. 1

Note 2: Some dam volumes exceed minimum requirement as they are sized to store water for process water use

Annexure B

Water quality monitoring results

Table B.1 Water quality results – Chapmans Creek Monitoring Site I

	pH	EC	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
Units	pH units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DGV	6.5–8.0	30–350			0.25	0.02			0.013	1.9	0.3
14/02/2007	6.8	111	110		4.7	5.55	17.5	11	<0.001	0.189	8.8
27/02/2007	6.2	114	209		2.1	0.22	11.5	7	<0.001	0.062	4.09
22/03/2007	6.6	142	213		2.5	0.12	7.3	8	0.003	0.832	5.57
26/04/2007	7	205	800		8.8	1.22	20.4	14	0.007	1.7	28.6
28/05/2007	6.5	61	91		1.6	0.04	6.2	9	<0.001	0.023	2.52
18/06/2007	6.2	96	167		1.2	0.03	22.3	11	<0.001	0.032	1.69
16/07/2007	5.9	143	142		2.0	0.13	25.7	14	0.001	0.128	0.98
13/02/2008	6.3	105	282		2.0	0.08	10.3	10	0.001	0.232	4.68
12/03/2008	6.4	132	286		3.3	0.30	19.8	8	0.003	0.682	18.6
14/04/2008	5.9	96	147		2.2	0.21	20.8	8	<0.001	0.26	2.97
14/05/2008	8.2	3,640	1,950		1.8	0.91	846	376	<0.001	0.025	0.08
11/07/2008	8.3	3,230	2,060		1.4	0.13	822	306	0.002	0.012	0.05
11/09/2008	5.7	149	398		0.9	0.18	27		<0.001	0.312	6.21
14/10/2008	6.2	123	407		1.4	0.06	19	11	0.002	0.520	12.6
6/03/2009											
11/06/2009											
9/07/2009											

Table B.1 Water quality results – Chapmans Creek Monitoring Site I

	pH	EC	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
18/08/2009											
14/09/2009											
14/10/2009											
12/11/2009											
10/12/2009											
8/01/2010											
4/02/2010											
4/03/2010											
16/04/2010											
14/05/2010											
16/06/2010											
20/07/2010											
13/08/2010	6.4	97		21							
13/09/2010											
8/10/2010											
8/11/2010											
15/12/2010	6.3	140		6							
13/01/2011											
11/04/2011											

Table B.1 Water quality results – Chapmans Creek Monitoring Site I

	pH	EC	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
13/07/2011											
17/02/2012											
14/05/2012											
14/11/2012											
12/02/2013											
16/05/2013											
16/08/2013	8.0	1,800		5	0.55	0.01					
14/11/2013											
14/02/2014											
21/05/2014											
20/11/2014											
20/02/2015											
14/05/2015											
14/05/2015											
20/08/2015	8.9	723		40	19.8						
18/11/2015											
25/02/2016											
20/05/2016											
18/08/2016											

Table B.1 Water quality results – Chapmans Creek Monitoring Site I

	pH	EC	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
15/11/2016											
17/02/2017											
19/05/2017											
17/11/2017											
8/02/2018											
24/05/2018											

Table B.2 Water quality results – Chapmans Creek Monitoring Site D

	pH	EC	Dissolved oxygen	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
Units	pH units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DGV	6.5–8.0	30–350				0.25	0.02			0.013	1.9	0.3
14/02/2007	6.4	69		111		4.2	3.15	4.8	4	<0.001	0.111	1.54
27/02/2007	6.3	62		112		2.3	0.15	4.4	2	<0.001	0.433	1.49
22/03/2007	6.6	84		77		2.9	0.22	3.9	4	<0.001	0.417	1.93
26/04/2007	6.7	109		128		3.7	0.26	4.2	3	0.004	0.972	4.74
28/05/2007	7.0	115		118		6.3	0.46	4.4	4	0.002	0.940	7.82
18/06/2007	6.2	87		149		1.5	0.04	19.2	9	<0.001	0.105	1.77
16/07/2007	6.1	138		129		2.4	0.20	23.4	13	<0.001	0.257	1.57
13/02/2008	6.2	83		130		2.0	0.10	9.0	6	<0.001	0.112	2.22
12/03/2008	6.4	230		79		1.7	0.16	16.3	7	<0.001	0.156	1.94
14/04/2008	6.9	98		107		2.0	0.07	17.2	7	<0.001	0.143	1.69
14/05/2008	6.5	103		86		3.4	0.18	6.1	7	0.002	0.125	1.67
11/07/2008	7.1	104		99		2.8	0.27	16.6	7	<0.001	0.082	1.83
11/09/2008	6.7	124		120		2.7	0.17	17.0		0.001	0.296	2.59
14/10/2008	6.5	158		128		1.8	0.20	7.0	4	0.001	0.161	3.29
6/03/2009	6.7	98	8.2	116				9.7	7.2	<0.001	0.066	0.69
11/06/2009	6.3	66	10.4	117				12	6.6	<0.001	0.058	0.95
9/07/2009	6.1	83	8.8	110				12	6.5	<0.001	0.031	0.76

Table B.2 Water quality results – Chapmans Creek Monitoring Site D

	pH	EC	Dissolved oxygen	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
18/08/2009	6.8	87	10.7	120				13	6.9	<0.001	0.097	0.79
14/09/2009	7.1	96	10.2	130				14	6.8	<0.001	0.210	1.1
14/10/2009	8.3	110	10.8	130				15	7.9	0.001	0.470	2.1
12/11/2009	7.5	130	6.4	120				18	8.7	0.001	0.120	1.4
10/12/2009	8.3	200	10.8	160				23	10	0.001	0.061	0.26
8/01/2010	5.9	110	5.8	220				12	5.9	0.001	0.560	2.1
4/02/2010	6.0	76	8.9	450				6.6	4.1	0.001	0.120	0.72
4/03/2010	6.9	52	7.9	80				7	3.6	0.001	0.110	0.97
16/04/2010	10.0	53	9.1	58				7.7	3.8	0.001	0.009	0.41
14/05/2010	6.0	50		66	26	1.9	0.14		4	0.001	0.033	0.27
16/06/2010	5.1	63	11.8	100				9	4.5	0.001	0.016	0.4
20/07/2010	6.9	71	7.3	77				9.2	4.9	0.001	0.052	0.61
13/08/2010	6.7	70			11							
13/09/2010	7.2	72			5							
8/10/2010	7.1	82			5							
8/11/2010	6.6	51			23	1.6	0.14					
15/12/2010	6.7	100			10							
13/01/2011	7.1	110			16							
11/04/2011	6.7	110			19	1.7	0.09					

Table B.2 Water quality results – Chapmans Creek Monitoring Site D

	pH	EC	Dissolved oxygen	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
13/07/2011	7.3	110			6	1.6	0.04			0.001	0.011	0.43
17/02/2012	6.2	100			36	2.5	0.18					
14/05/2012	7.0	160			13	2.6	0.10					
14/11/2012	6.8	190			5	2.1	0.07					
12/02/2013	7.1	280			55	4.1	0.18					
16/05/2013	7.5	270			41	1.9	0.09					
16/08/2013	7.3	190			26	2.8	0.08					
14/11/2013	7.9	290			100	2.7	0.15					
14/02/2014	9.2	520			21	3.0	0.12					
21/05/2014	7.4	340			20	2.3	0.13					
20/11/2014	8.0	600			4	4.1	0.03					
20/02/2015	8.2	1,300			6	9.9	0.02					
14/05/2015	8.2	1,400			3	5.1						
20/08/2015	8.06	1,280			4	10.8						
18/11/2015	8.39	1,480			7	15.8						
25/02/2016	9.42	1,240			6	1.43						
20/05/2016	8.43	1,460			11	1.48						
18/08/2016	7.95	624			<2	0.88						
15/11/2016	8.97	573			3	0.99						

Table B.2 Water quality results – Chapmans Creek Monitoring Site D

	pH	EC	Dissolved oxygen	TDS	TSS	Total nitrogen	Total phosphorus	Chloride	Sodium	Total arsenic	Total manganese	Dissolved iron
17/02/2017	9.11	754			5	1.21						
19/05/2017	8.91	990			2	6.65						
17/11/2017	9.05	964			16	1.14						
8/02/2018	9.18	1,530			56	3.13						
24/05/2018	8.29	1,270			12	1.79						

Table B.3 Water quality results – Chapmans Creek Monitoring Site RW1 (previously known as Monitoring Site O)

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Dissolved iron	Oil and grease
Units	pH units	µS/cm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
DGV	6.5–8.0	30–350				2–25	0.25	0.02						0.055	0.013	0.0014	0.0014	1.9	0.011	0.008	0.3	0.3	
14/02/2007	6.5	279		207			4.1	0.26	51.2			22			<0.001			0.03				1.76	
27/02/2007	7.7	253		190			2.5	0.1	34.1			14			0.002			0.044				0.91	
22/03/2007	7.5	400		252			1.7	0.07	47.6			26			0.002			0.104				0.91	
26/04/2007	8.1	542		364			1.7	0.05	82.1			42			<0.001			0.08				0.44	
28/05/2007	8.0	611		332			1.9	0.12	90.2			47			<0.001			0.164				0.36	
18/06/2007	7.0	240		193			3.6	0.22	42.5			20			<0.001			0.025				1.43	
16/07/2007	7.2	855		480			1.2	0.07	183			66			<0.001			0.028				0.34	
13/02/2008	7.2	552		446			1.6	0.01	91.2			43			<0.001			0.094				1.17	
12/03/2008	7.7	1,372		894			1.2	0.03	401			118			<0.001			0.103				0.32	
14/04/2008	8.2	3,960		2,780			0.8	0.01	1,220			357			<0.001			0.071				1.02	
14/05/2008	8.2	4,260		2,360			0.8	0.01	1,180			430			0.001			0.013				0.05	
11/07/2008	8.2	1,329		808			0.9	0.37	373			112			<0.001			0.011				0.19	
11/09/2008	8.3	2,280		1,350			0.8	0.01	641						<0.001			0.034				0.27	
14/10/2008	7.6	686		468			0.7	0.08	144			61			<0.001			0.062				2.08	
6/03/2009	8.3	560	9.5	340					87			38			<0.001			0.004				0.2	
11/06/2009	7.8	350	10.3	241					62			31			<0.001			0.003				0.19	
9/07/2009	6.6	190	6.7	330					35			16			<0.001			0.004				0.79	
18/08/2009	6.9	210	8.8	380					36			18			<0.001			0.017				0.7	
14/09/2009	6.5	190	3	1,100					28			16			<0.001			0.011				0.62	
14/10/2009	7.3	150	9.7	1,400					19			30			0.001			0.007				1.5	

Table B.3 Water quality results – Chapmans Creek Monitoring Site RW1 (previously known as Monitoring Site O)

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Dissolved iron	Oil and grease
12/11/2009	7.5	200	3.3	920					23			24			0.001			0.086				0.85	
10/12/2009	6.0	170	1.3	940					23			17			0.001			0.19				0.54	
8/01/2010	6.9	380	7.2	260					55			25			0.001			0.08				0.39	
4/02/2010	6.3	370	1.4	370					56			26			0.002			0.53				0.7	
4/03/2010	8.0	470	8	320					73			39			0.001			0.003				0.13	
16/04/2010	8.5	540	9.3	340					87			46			0.001			0.003				0.06	
14/05/2010	8.5	550		350			1.3	0.05				49			0.001			0.004				0.03	
16/06/2010	5.8	420	8.4	520					80			42			0.001			0.013				0.29	
20/07/2010	7.4	520	9.3	350					110			50			0.001			0.008				0.1	
13/08/2010	7.7	340			470																		
13/09/2010	8.3	1,200			22																		
8/10/2010	8.5	1,200			8																		
8/11/2010	7.9	360			150		1.5	0.16															
15/12/2010	7.8	430			49																		
13/01/2011	8.4	950			4																		
11/04/2011	8.0	550			10		1.3	0.05															
13/07/2011	8.3	1,300			11		0.8	0.02							0.001			0.012				0.05	
17/02/2012	6.6	240			23		2.2	0.1															
14/05/2012	8.3	1,500			4		0.8	0.01															
14/11/2012	8.1	2,900			8		0.7	0.02															
12/02/2013	7.8	1,100			19		1.5	0.08															
16/05/2013	8.3	1,200			7		0.8	0.02															
16/08/2013	8.1	1,700			3		0.8	0.01															

Table B.3 Water quality results – Chapmans Creek Monitoring Site RW1 (previously known as Monitoring Site O)

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Dissolved iron	Oil and grease
14/11/2013	8.1	1,200			13		0.6	0.02															
14/02/2014																							
21/05/2014	8.5	1,200			7		1.8	0.06															
20/11/2014																							
20/02/2015	8.2	930			14		0.94	0.02															
14/05/2015	8.5	2,000			2		0.57																
14/05/2015	8.5	2,000			2		0.57	0.01															
20/08/2015	8.36	2,050			3		0.56																
18/11/2015																							
25/02/2016	8.52	1,330			4		0.89																
20/05/2016	8.52	1,200			3		0.63																
18/08/2016	8.37	1,250			6		1.49																
15/11/2016	8.37	1,360			10		0.98																
17/02/2017																							
19/05/2017	8.59	1,410			3		8.12																
17/11/2017	8.11	2,990			5		1.39																
8/02/2018																							
24/05/2018																							
21/06/2018	7.52	787	9.6	512	53	76.1	1.1	<0.01	180	27	27	72	4		<0.001	<0.001	0.002	0.058	0.002	0.014	1.92		None visible
27/09/2018	7.81	537	7.7	349	68	74.2	1.1	<0.01	92	22	17	44	4	1.79	<0.001	<0.001	0.003	0.116	<0.001	0.01	1.28		None visible
29/11/2018	7.53	850	9.2	552	194	312	1.8	0.14	259	23	33	84	5	14.8	0.002	0.005	0.01	0.224	0.007	0.027	11.3		None visible

Table B.3 Water quality results – Chapmans Creek Monitoring Site RW1 (previously known as Monitoring Site O)

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Dissolved iron	Oil and grease
2/04/2019	7.73	248	6.3	161	20	32.7	0.9	0.09	39	13	9	24	5		<0.001	<0.001	<0.001	0.051	0.001	0.007	1.26		None visible
2/07/2019	8.34	1,760	12	1,140	14	3.9		0.01	481	50	68	185	5		<0.001	<0.001	0.002	0.011	<0.001	<0.005	0.16		None visible
26/09/2019	7.31	1,170	9.6	760	<5	1.1	7	0.01	304	39	41	101	5		<0.001	<0.001	<0.001	0.004	<0.001	<0.005	<0.05		None visible
10/12/2019	7.94	2,160	8.7	1,400	18	14.1	1	0.01	638	56	88	226	9		0.002	<0.001	0.002	0.130	0.001	<0.005	0.07		None visible
10/03/2020	8.03	1,520	8.6	988	6	4.3	4.2	0.01	405	40	59	192	5		<0.001	0.001	<0.001	0.029	0.001	<0.005	0.17		None visible
9/06/2020	8.03	2,990	9.8	628	<5	10.7	4.6	0.03	212	29	35	112	6		<0.001	0.001	0.003	0.026	0.001	0.005	0.46		None visible
15/12/2020	8.37	1,340	8.9	871	7	2.7	1.2	<0.01	297	33	49	151	6		<0.001	<0.001	<0.001	0.048	<0.001	<0.005	0.16		None visible
16/03/2021	8.28	1,360	8.6	884	10	9.6	0.6	0.05	294	36	53	161	6		<0.001	<0.001	<0.001	0.046	0.001	<0.005	0.61		None visible
15/06/2021	7.98	1,370	10.2	890	<5	6.7	2.3	0.02	302	43	58	144	5		<0.001	<0.001	<0.001	0.038	<0.001	0.007	0.06		None visible

Table B.4 Water quality results – Chapmans Creek monitoring site RW2

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Oil and grease
Units	pH units	µS/cm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
DGV	6.5–8.0	30–350				2–25	0.25	0.02						0.055	0.013	0.0014	0.0014	1.9	0.011	0.008	0.3	
21/06/2018																						
27/09/2018																						
29/11/2018	7.79	1,530	9.4	994	30	59.5	2.2	0.07	480	39	64	156	5	3.15	<0.001	0.001	0.003	0.115	0.002	0.006	2.26	None visible
2/04/2019	7.95	4,730	7.4	3,070	10	1.1	0.6	<0.01	1,200	107	172	428	8		<0.001	<0.001	<0.001	0.136	0.001	<0.005	0.17	None visible
2/07/2019	7.98	2,860	11.3	1,860	15	0.9		<0.01	733	67	112	315	6		<0.001	0.001	0.005	0.006	<0.001	<0.005	0.05	None visible
26/09/2019	7.91	1,010	9.9	656	20	9	15	0.03	208	27	37	133	6		<0.001	0.002	0.001	0.024	<0.001	<0.005	0.24	None visible
10/12/2019																						
10/03/2020	7.76	1,200	8.5	780	7	11.3	2.2	0.04	289	28	42	148	4		<0.001	0.002	<0.001	0.075	0.001	0.006	0.34	None visible
9/06/2020	7.88	2,620	10.4	575	6	9.5	5.8	0.02	179	22	32	107	6		<0.001	0.001	0.002	0.034	<0.001	0.006	0.38	None visible
15/12/2020	8.48	1,310	8.9	852	6	2.6	0.8	<0.01	266	28	51	157	6		<0.001	<0.001	<0.001	0.053	<0.001	<0.005	0.16	None visible
16/03/2021	8.15	1,670	8.7	1,080	9	7.3	2.3	0.02	380	43	65	197	7		<0.001	<0.001	<0.001	0.109	0.001	<0.005	0.47	None visible
15/06/2021	7.97	1,280	10.3	832	<5	7.3	4.6	<0.01	268	37	55	142	6		<0.001	<0.001	<0.001	0.03	0.001	0.006	0.06	None visible

Table B.5 Water quality results – Quarry water management system monitoring site PWD

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Oil and grease
Units	pH units	µS/cm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
DGV	6.5–8.0	30–350				2–25	0.25	0.02						0.055	0.013	0.0014	0.0014	1.9	0.011	0.008	0.3	
21/06/2018	7.86	563	10.3	366	50	72.5	3.5	<0.01	70	16	15	67	5		<0.001	0.002	0.003	0.115	0.002	0.009	2.77	None visible
27/09/2018	9.17	856	9.3	556	32	29.3	3.8	<0.01	154	18	25	106	7	1.31	<0.001	<0.001	0.004	0.083	<0.001	<0.005	10.5	None visible
29/11/2018	8.39	374	9.3	243	150	347	4.3	0.08	54	9	8	53	3	12.6	0.002	0.005	0.007	0.232	0.005	0.034	10.7	None visible
2/04/2019	8.21	518	8.6	337	91	118	6.1	0.09	56	13	12	75	4		<0.001	0.001	<0.001	0.071	0.002	0.014	4.66	None visible
2/07/2019	8.01	360	11.3	234	98	218		0.09	44	9	8	54	3		0.001	0.004	0.006	0.202	0.003	0.03	8.01	None visible
26/09/2019	7.83	2,220	8.7	1,440	11	3.1	0.7	0.04	683	49	85	215	5		<0.001	<0.001	0.002	0.051	0.002	<0.005	0.08	None visible
10/12/2019	8.18	1,360	9.5	884	10	6	2.1	<0.01	368	39	55	144	7		0.001	<0.001	0.002	0.025	<0.001	0.013	<0.05	None visible
10/03/2020	7.67	659	8	428	46	78.6	13	0.02	61	11	14	97	5		0.002	0.002	0.005	0.07	0.002	0.012	2.44	None visible
9/06/2020	8.09	752	10.4	381	19	27.5	9.1	0.02	73	11	17	83	8		0.001	0.002	0.003	0.051	<0.001	0.006	1.06	None visible
15/12/2020	8.00	634	8.4	412	28	28.5	7.2	<0.01	76	14	16	83	7		0.001	0.001	0.002	0.028	<0.001	<0.005	1.07	None visible
16/03/2021	8.47	707	8.6	460	10	19.0	6.6	0.02	101	16	21	95	8		<0.001	<0.001	<0.001	0.024	<0.001	<0.005	0.63	None visible
15/06/2021	8.29	722	11.2	469	8	14.4	9.3	<0.01	96	16	23	96	8		<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.05	None visible

Table B.6 Water quality results – Quarry water management system monitoring site drop cut (in-pit sump)

	pH	EC	Dissolved oxygen	TDS	TSS	Turbidity	Total nitrogen	Total phosphorus	Chloride	Calcium	Magnesium	Sodium	Potassium	Total aluminium	Total arsenic	Total cobalt	Total copper	Total manganese	Total nickel	Total zinc	Total iron	Oil and grease
Units	pH units	µS/cm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
DGV	6.5–8.0	30–350				2–25	0.25	0.02						0.055	0.013	0.0014	0.0014	1.9	0.011	0.008	0.3	
21/06/2018	8.09	1,260	9.4	819	14	24.3	11.1	0.01	349	42	47	128	6	1.12	<0.001	<0.001	0.003	0.032	0.001	<0.005	0.88	None visible
27/09/2018	7.94	882	8.8	573	16	7.3	5.4	0.04	162	29	27	75	5		<0.001	<0.001	<0.001	0.01	<0.001	<0.005	0.18	None visible
29/11/2018	8.56	933	11.6	606	5	0.9		<0.01	216	34	34	90	5		<0.001	<0.001	<0.001	0.006	<0.001	<0.005	0.12	None visible
2/04/2019	7.54	1,440	9.8	936	17	20.5	0.8	0.02	434	32	55	130	4		<0.001	<0.001	0.002	0.035	0.002	<0.005	0.77	None visible
2/07/2019	8.26	1,250	9.8	812	6	4.8	3.5	<0.01	318	45	51	120	7		<0.001	<0.001	0.001	0.026	<0.001	<0.005	<0.05	None visible
26/09/2019	7.24	415	7	270	30	171	6.7	0.05	54	11	10	46	4		0.001	0.004	0.009	0.078	0.001	0.014	6.8	None visible
10/12/2019	8.09	1,260	9.4	819	14	24.3	11.1	0.01	349	42	47	128	6	1.12	<0.001	<0.001	0.003	0.032	0.001	<0.005	0.88	None visible
10/03/2020	7.94	882	8.8	573	16	7.3	5.4	0.04	162	29	27	75	5		<0.001	<0.001	<0.001	0.01	<0.001	<0.005	0.18	None visible
9/06/2020	7.62	552	9.4	313	34	92.7	8.2	0.02	68	16	15	62	4		<0.001	0.002	0.004	0.04	0.001	0.011	2.49	None visible
15/12/2020	7.61	668	8.6	434	24	18.5	9.1	<0.01	117	23	19	76	12		<0.001	0.001	0.002	0.016	<0.001	<0.005	0.94	None visible
16/03/2021	7.99	768	7.6	499	<5	6.1	8.0	<0.01	131	26	24	87	5		<0.001	0.001	0.002	0.008	<0.001	<0.005	0.21	None visible
15/06/2021	7.70	646	9.6	420	5	10.7	8.3	<0.01	99	24	21	74	5		<0.001	<0.001	0.001	0.011	<0.001	<0.005	<0.05	None visible

Annexure C

Maximum Harvestable Right Dam Capacity

Maximum Harvestable Right Dam Capacity

Information provided by the user

1. The location of the proposed dam is:

- Latitude: **-34.671498**
- Longitude: **149.966827**

2. Total property area to use for calculating the size of the dam is **227 Hectares**

Result

The maximum Harvestable right dam capacity for your property is **17.025** ML (Megalitres)

Date

14/12/2020

Name

Gunlake Quarry

Limitations of the calculator

a) Where to site a dam

You can only construct a harvestable rights dam where the Harvestable Rights Orders apply, refer to NSW Government Gazette 40 dated 31 March 2006 (pages 1628 to 1631).

b) First and Second order streams

The maximum harvestable right calculator does not verify that the location of the proposed dam sits on a first or second order stream. A factsheet : "Where can they be built without a licence?" is available on WaterNSW website to help you work out the stream orders.

You will need to use the legislated topographic map for your area to identify the stream order. This map is the gazetted map as per NSW Government Gazette 37 dated 24 March 2006 (pages 1500-1509).

c) Size of property and dam

The calculator does not take into account other dams already on your property. If you have existing harvestable rights dams on your property, you must take the capacity of these dams into account when constructing a new dam. In the Eastern and Central Divisions other dams must also be taken into account, as described in the NSW Government Gazette 40 dated 31 March 2006 (pages 1628 to 1631).

d) Protected wetlands

The Harvestable Rights Orders specify that you are not allowed to build a dam on or within 3 km of a RAMSAR wetland site. There are 12 RAMSAR wetlands in NSW. Further information on the location of those 12 RAMSAR sites in NSW can be found on the NSW Environment and Heritage government website.

www.emmconsulting.com.au