Boral Limited
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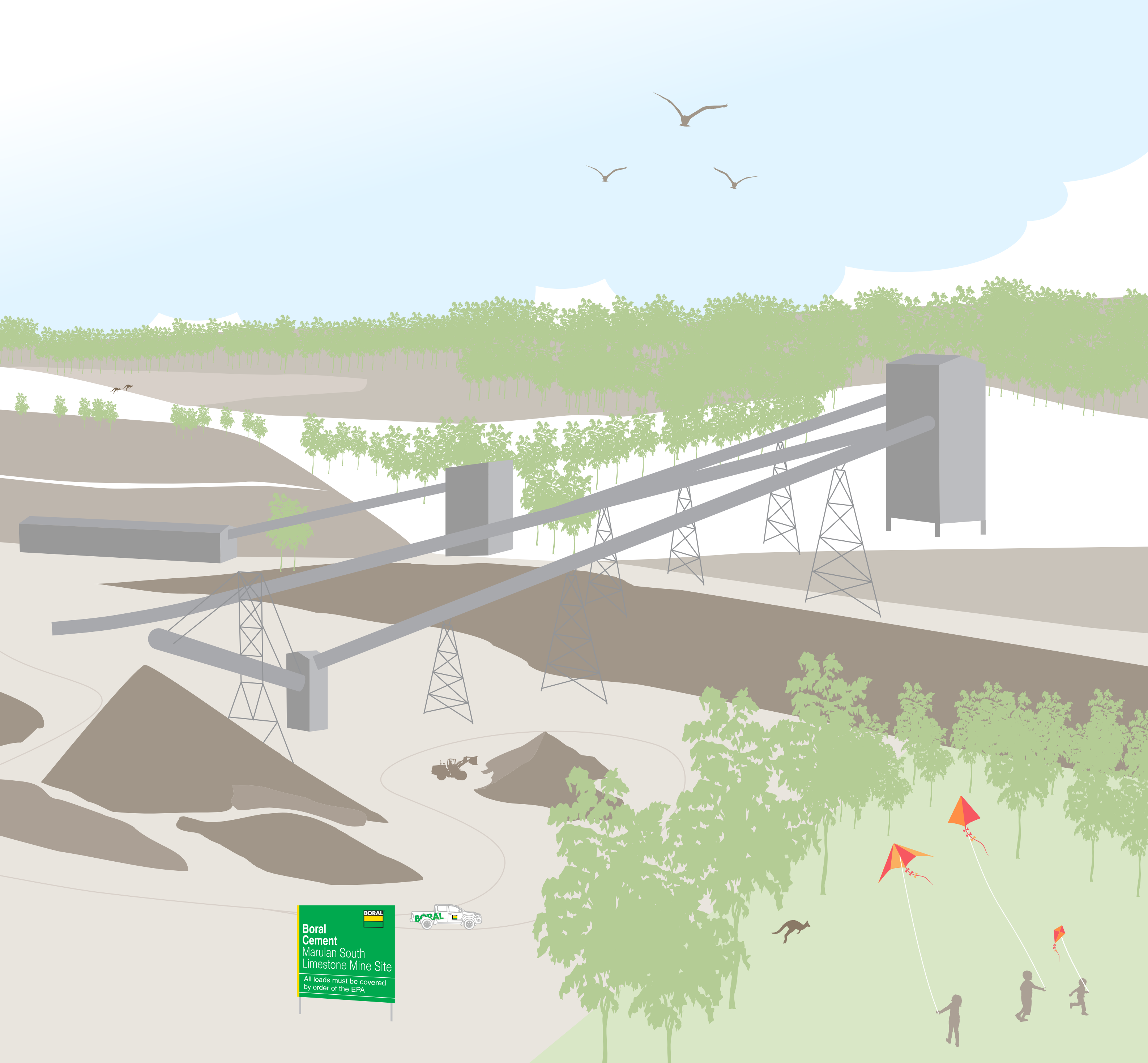
Marulan South Limestone Mine Continued Operations
State Significant Development Application

V2

ENVIRONMENTAL IMPACT STATEMENT

Prepared for Boral Cement Limited | March 2019



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Appendix A

Stakeholder consultation

VOLUME 2

Resource Assessments
Contact: Elle Donnelley
Phone: 9228 6340
Email: elle.donnelley@planning.nsw.gov.au

Mr Rod Wallace
Planning & Development Manager
Boral Cement Pty Ltd
PO Box 42
WENTWORTHVILLE NSW 2148

Dear Mr Wallace

State Significant Development – Secretary's Requirements
Marulan South Limestone Mine Extension Project (SSD-7009)

I have attached a copy of the Secretary's environmental assessment requirements (SEARs) for the preparation of an Environmental Impact Statement (EIS) for the Marulan South Limestone Mine Extension Project.

These requirements are based on the information you have provided to date, and have been prepared in consultation with the relevant government agencies. The agencies' comments are attached for your information (see Attachment 2). You should consult with the relevant agencies and address their comments appropriately in preparing the EIS.

Please note that the Department may alter these requirements at any time, and that you must consult further with the Department if you do not lodge a development application and EIS for the project within two years of the date of issue of these SEARs.

To determine whether the proposed development is a controlled action under Section 68(2) of the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), you should refer it to the Department of the Environment. If an EPBC Act approval is required, please advise the Department as soon as practicable, as impacts on matters of national environmental significance would need to be considered in the NSW approval process, in accordance with the bilateral agreement between NSW and the Commonwealth. This may require the issuing of supplementary SEARs to cover the assessment of controlling provisions under the EPBC Act.

Please contact the Department at least two weeks before you propose to submit the development application and EIS for the project. This will enable the Department to:

- confirm the applicable fee (see Division 1AA, Part 15 of the *Environmental Planning and Assessment Regulation 2000*); and
- determine the number of copies (hard-copy and CD-ROM) of the EIS required for review.

The Department will review the EIS for the project carefully before putting it on public exhibition, and will require you to submit an amended EIS if it does not adequately address the SEARs.

If you have any enquiries about these requirements, please contact Elle Donnelley.

Yours sincerely

DKitto 10/6/2015

David Kitto
Executive Director
Resource Assessments and Business Systems
as delegate of the Secretary

Secretary's Environmental Assessment Requirements

State Significant Development

Section 78A(8A) of the *Environmental Planning and Assessment Act 1979*

Application Number	SSD 7009
Development	The Marulan South Limestone Mine Extension Project, which includes: • expanding the existing open cut mine to extract up to 3.5 million tonnes of limestone a year, and 200,000 tonnes of shale year, for up to 30 years; • upgrading and/or relocating elements of the existing processing facility; • developing a new overburden emplacement area and accepting a small volume of overburden from Boral's adjacent Peppertree Quarry; • constructing a water supply dam on Marulan Creek, and transferring water to the mine via the existing water supply pipeline; • transporting the majority of product to domestic markets via rail, with a small portion transported via road; and • rehabilitating the site.
Location	10 kilometres southeast of Marulan Village, within the Goulburn Mulwaree LGA
Applicant	Boral Cement Pty Ltd
Date of Issue	10 June 2015
General Requirements	The Environmental Impact Statement (EIS) for the development must meet the form and content requirements in Clauses 6 and 7 of Schedule 2 of the *Environmental Planning and Assessment Regulation 2000.* In addition, the EIS must include: • a full description of the development, including: – the resource to be extracted, demonstrating efficient resource recovery within environmental constraints; – the mine layout and scheduling; – minerals processing; – surface infrastructure and facilities; – a waste (overburden, tailings, etc.) management strategy, having regard to the EPA's requirements; – a water management strategy, having regard to the EPA's, NSW Office of Water's and Water NSW's requirements; and – a rehabilitation strategy, having regard to DRE's requirements; • a list of any approvals that must be obtained before the development may commence; • an assessment of the likely impacts of the development on the environment, focussing on the specific issues identified below, including: – a description of the existing environment likely to be affected by the development, using sufficient baseline data; – an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant laws, environmental planning instruments, guidelines, policies, plans and industry codes of practice; – a description of the measures that would be implemented to mitigate and/or offset the potential impacts of the development, and an assessment of: o whether these measures are consistent with industry best practice, and represent the full range of reasonable and feasible mitigation measures that could be implemented; o the likely effectiveness of these measures; and o whether contingency plans would be necessary to manage any residual risks; – a description of the measures that would be implemented to monitor and report on the environmental performance of the development if it is approved; • consolidated summary of all the proposed environmental management and monitoring measures, highlighting commitments included in the EIS; • consideration of the development against all relevant environmental

	planning instruments (including Part 3 of the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007)*; and • the reasons why the development should be approved having regard to biophysical, economic and social considerations, including the principles of ecologically sustainable development. While not exhaustive, Attachment 1 contains a list of some of the environmental planning instruments, guidelines, policies, and plans that may be relevant to the environmental assessment of this development. In addition to the matters set out in Schedule 1 of the *Environmental Planning and Assessment Regulation 2000*, the development application must be accompanied by a signed report from a suitably qualified expert that includes an accurate estimate of the: • capital investment value (as defined in Clause 3 of the *Environmental Planning and Assessment Regulation 2000*) of the development, including details of all the assumptions and components from which the capital investment value calculation is derived; and • jobs that would be created during each stage of the development.
Key issues	The EIS must address the following specific issues: • **Land** - including: - an assessment of the likely impacts of the development on the soils, land capability, and landforms (topography) of the site; - an assessment of the likely agricultural impacts of the development; and - an assessment of the compatibility of the development with other land uses in the vicinity of the development in accordance with the requirements in Clause 12 of *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*; • **Water** – including: - an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, NSW Office of Water's and Water NSW's requirements and the *NSW Aquifer Interference Policy*; - an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users; - a 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; - 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; - 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; and - a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts; • **Air Quality** – including: - an assessment of the likely air quality impacts of the development in accordance with the *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* and the EPA's additional requirements, and having regard to the NSW Government's *Voluntary Land Acquisition and Mitigation Policy: For State Significant Mining, Petroleum and Extractive Industry Developments*; and - an assessment of the likely greenhouse gas impacts of the development, having regard to the EPA's requirements; • **Noise & Blasting** – including: - an assessment of the likely operational noise impacts of the development (including construction noise) under the *NSW Industrial Noise Policy*, including the obligations in chapters 8 and 9 of the policy, and having regard to the NSW Government's *Voluntary Land Acquisition and Mitigation Policy: For State Significant Mining,*

	Petroleum and Extractive Industry Developments; - if a claim is made for specific construction noise criteria for certain activities, then this claim must be justified and accompanied by an assessment of the likely construction noise impacts of these activities under the *Interim Construction Noise Guideline*; - an assessment of the likely road noise impacts of the development under the *NSW Road Noise Policy*; - an assessment of the likely rail noise impacts of the development under the *Rail Infrastructure Noise Guideline*; and - an assessment of the likely blasting impacts of the development on people, livestock, buildings, infrastructure, and significant natural features, having regard to the relevant ANZECC guidelines; • **Biodiversity** – including: - an assessment of the likely biodiversity impacts of the development, having regard to the principles and strategies in the *NSW Biodiversity Offsets Policy for Major Projects* and the requirements of OEH; - measures taken to avoid, reduce or mitigate impacts on biodiversity; - accurate estimates of proposed vegetation clearing; and - a comprehensive offset strategy to ensure the development maintains or improves biodiversity values of the region in the medium to long term; • **Heritage** – including: - an Aboriginal cultural heritage assessment (including both cultural and archaeological significance) which must: o demonstrate effective consultation with Aboriginal communities in determining and assessing impacts, and developing and selecting mitigation options and measures; and o outline any proposed impact mitigation and management measures (including an evaluation of the effectiveness and reliability of the measures), having regard to OEH's requirements; - a Historic heritage assessment (including archaeology) which must: o include a statement of heritage impact (including significance assessment) for any State significant or locally significant historic heritage items; and o outline any proposed mitigation and management measures (including an evaluation of the effectiveness and reliability of the measures), having regard to the Heritage Branch of NSW's requirements; • **Visual** – including an assessment of the likely visual impacts of the development on private landowners in the vicinity of the development and key vantage points in the public domain, paying particular attention to the temporary and permanent modification of the landscape during the various stages of the project (overburden dumps, bunds, etc.), and minimising the lighting impacts of the development; • **Traffic & Transport** – including: - accurate predictions of the road and rail traffic generated by the development; - an assessment of the likely transport impacts of the development on the capacity, condition, safety and efficiency of the local and State road and rail network; - a detailed description of the measures that would be implemented to maintain and/or improve the capacity, efficiency and safety of the road and rail networks in the surrounding area over the life of the development, having regard to Transport NSW's and Goulburn Mulwaree Council's requirements; • **Hazards** – including an assessment of the likely risks to public safety, paying particular attention to the handling, transport and use of dangerous goods and potential bushfire risks, and in accordance with *State Environmental Planning Policy No. 33 – Hazardous and Offensive Development*; • **Social & Economic** – including: - an assessment of the likely social impacts of the development; and - an assessment of the likely economic impacts of the development, paying particular attention to: o the significance of the resource o economic benefits of the project for the State and region; and

	o the demand for the provision of local infrastructure and services.
Consultation	During the preparation of the EIS, you must consult with relevant local, State and Commonwealth Government authorities, service providers, community groups and affected landowners. The EIS must describe the consultation process and the issues raised, and identify where the design of the development has been amended in response to these issues. Where amendments have not been made to address an issue, a short explanation should be provided.

ATTACHMENT 1
Technical and Policy Guidelines

The following guidelines may assist in the preparation of the Environmental Impact Statement. This list is not exhaustive and not all of these guidelines may be relevant to your proposal.

Policies, Guidelines & Plans

Land Resources	
	Agricultural Impact Assessment Guidelines 2012 (DP&I)
	Agfact AC25: Agricultural Land Classification (NSW Agriculture)
	State Environmental Planning Policy No. 55 – Remediation of Land
	Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC)
Water Resources	
Water Sharing Plans	Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011
	Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011
Surface Water	National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Effluent Management (ARMCANZ/ANZECC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC)
	Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC)
	State Water Management Outcomes Plan
	NSW Government Water Quality and River Flow Objectives (DECC)
	Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC)
	Managing Urban Stormwater: Soils & Construction (Landcom) and associated Volume 2E: Mines and Quarries.
	Managing Urban Stormwater: Treatment Techniques (DECC)
	Managing Urban Stormwater: Source Control (DECC)
	Floodplain Development Manual (DIPNR)
	Floodplain Risk Management Guideline (DECC)
	A Rehabilitation Manual for Australian Streams (LWRRDC and CRCCH)
	Technical Guidelines: Bunding & Spill Management (DECC)
	Environmental Guidelines: Use of Effluent by Irrigation (DECC)
Groundwater	NSW Aquifer Interference Policy 2012 (NOW)
	National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)
	NSW State Groundwater Policy Framework Document (DLWC, 1997)
	NSW State Groundwater Quality Protection Policy (DLWC, 1998)
	NSW State Groundwater Quantity Management Policy (DLWC, 1998)
	Murray-Darling Basin Groundwater Quality. Sampling Guidelines. Technical Report No 3 (MDBC)
	Guidelines for the Assessment & Management of Groundwater Contamination (DECC, 2007)
Air Quality	
	Voluntary Land Acquisition and Mitigation Policy: For State Significant Mining, Petroleum and Extractive Industry Developments (DPE 2014)
	Protection of the Environment Operations (Clean Air) Regulation 2002
	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC)
	Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC)
	National Greenhouse Accounts Factors (Commonwealth)
Noise & Blasting	
	Voluntary Land Acquisition and Mitigation Policy: For State Significant Mining, Petroleum and Extractive Industry Developments (DPE 2014)
	NSW Industrial Noise Policy (EPA)
	Environmental Noise Management – Assessing Vibration: a technical guide (DEC)
	NSW Road Noise Policy (DECCW)
	Interim Construction Noise Guideline (EPA)
	Rail Infrastructure Noise Guideline (EPA)
	Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration (ANZECC)

Biodiversity	
	NSW Biodiversity Offset Policy for Major Projects (OEH)
	Threatened Species Survey and Assessment Guidelines: Field Survey Methods for Fauna – Amphibians (DECCW 2009)
	Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities – Working Draft (DECC 2004)
	Threatened Species Assessment Guidelines: the Assessment of Significance (DECC 2007)
	Guidelines for Threatened Species Assessment (DoP 2005)
	BioBanking Assessment Methodology (OEH)
	Environmental Offsets Policy (Commonwealth DoE)
	NSW State Groundwater Dependent Ecosystem Policy (NOW)
	Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW)
	Policy & Guidelines - Fish Friendly Waterway Crossings (NSW Fisheries)
	Policy & Guidelines - Aquatic Habitat Management and Fish Conservation (NSW Fisheries)
	State Environmental Planning Policy No. 44 – Koala Habitat Protection
Heritage	
Aboriginal	Draft Guidelines for Aboriginal Cultural Heritage Assessment and Community Consultation (DEC 2005)
	Aboriginal Cultural Heritage Consultation Requirements for Proponents 2010 (OEH)
	The Burra Charter (The Australia ICOMOS charter for places of cultural significance)
Historic	NSW Heritage Manual (NSW Heritage Office)
	The Burra Charter (The Australia ICOMOS charter for places of cultural significance)
Traffic & Transport	
	Guide to Traffic Generating Development (RTA)
	Road Design Guide (RTA) & relevant Austroads Standards
Socio-Economic	
	Draft Economic Evaluation in Environmental Impact Assessment (DoP)
	Techniques for Effective Social Impact Assessment: A Practical Guide (Office of Social Policy, NSW Government Social Policy Directorate)
Rehabilitation	
	Mine Rehabilitation – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Mine Closure and Completion – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Strategic Framework for Mine Closure (ANZMEC-MCA)
Waste	
	Waste Classification Guidelines (DECC)
Resource	
	Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves 2012 (JORC)
Environmental Planning Instruments - General	
	State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007
	State Environmental Planning Policy (State and Regional Development) 2011
	State Environmental Planning Policy (Infrastructure) 2007
	Goulburn Mulwaree Local Environment Plan 2009

ATTACHMENT 2
Agency Comments

NSW GOVERNMENT | **Department of Primary Industries**

OUT15/11794

Ms Elle Donnelley
Resource Assessments
NSW Department of Planning and Environment
GPO Box 39
SYDNEY NSW 2001

Elle.Donnelley@planning.nsw.gov.au

Dear Ms Donnelley,

Marulan South Limestone Mine Continuation Project (SSD 7009)
Request for input into Secretary's Environmental Assessment Requirements

I refer to your email dated 24 April 2015 to the Department of Primary Industries in respect to the above matter.

<u>Comment by Agriculture NSW</u>
Although most of the quarry is located on vegetated land, it is noted that there are two commercial turkey farm operations to the north-west and south-west of the Marulan South Limestone Mine project and consequently the impact of the project on those farms will need to be addressed as part of the EIS.

The EIS should assess the impacts of the limestone mine on the existing turkey farms and in particular address the following:

- The quantity and quality of surface water as a result of sedimentation and pollution and the impacts on the turkey farm operations will need to be assessed, particularly as soils are sodic and dispersive in nature. It should be noted that water for turkey farm operations is required to be of a high standard to achieve commercial outputs, address animal welfare issues and disease control. Water is for instance required to be treated to drinking water standards.
- Ground water contamination as a result of mining operations and its impact on poultry farm operations also needs to be addressed for similar reasons to surface water requirements outlined above.
- The quality of the air needs to be assessed and monitored with mitigation measures put in place to combat any issues that will impact on the turkey farm operations. Dust in particular is an issue that needs to be addressed.

- Noise and blasting needs to be assessed as to the impacts on the turkey farm operations. Monitoring and mitigation measures will need to be addressed if applicable.
- Other risks to agriculture generally such as weed management, biosecurity, subsidence, dust, noise, vibration, fire and traffic conditions that may affect any surrounding farmers will also needs to be addressed..

The guideline "Agriculture Issues for Extractive Industry Development" provides further information on the issues and information to be included in an EIS for extractive industries and can be accessed at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/367763/Agriculture-issues-for-extractive-industry-development.pdf

For further information please contact Wendy Goodburn, Resource Management Officer (Goulburn Office) on 4828 6635 or at wendy.goodburn@dpi.nsw.gov.au.

Comment by NSW Office of Water

The NSW Office of Water (Office of Water) has reviewed the supporting documentation accompanying the request for Secretary's Environmental Assessment Requirements (SEARs) and provides the comments below, and further detail in **Attachment A**.

The key issues for the Office of Water for this project are:

- water demand and supply requirements and
- the proposed Marulan Creek Dam.

It is recommended that the EIS be required to include:

- Details of water proposed to be taken (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.
- Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project).
- The identification of an adequate and secure water supply for the life of the project. Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased.
- A detailed and consolidated site water balance.
- A detailed assessment against the NSW Aquifer Interference Policy (2012) using the NSW Office of Water's assessment framework.
- Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.
- Full technical details and data of all surface and groundwater modelling, and an independent peer review.
- Proposed surface and groundwater monitoring activities and methodologies.

- Proposed management and disposal of produced or incidental water.
- Details surrounding the final landform of the site, including final void management (where relevant) and rehabilitation measures.
- Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.
- Consideration of relevant policies and guidelines.
- A statement of where each element of the SEARs is addressed in the EIS (i.e. in the form of a table).

Should you require further information please contact David Zerafa, Senior Water Regulation Officer on (02) 4428 9142.

Comment by Crown Lands
Crown Lands advise that it is evident that mining operations for the mine have and will continue within the Consolidated Mining Lease No. 16 (CML 16) which remains valid until 26th February 2023. This Office acknowledges that mining operations remain within this consent area, including described Crown Reserves 13386, 31526, 750029 and 70367, and that consent and associated conditions for mining operations conducted on this land are adequately authorised under legislation such as the Mining Act 1992 and Protection of the Environment Operations Act 1997.

Generally, NSW Trade & Investment Crown Lands would like reiterate the importance of the long term maintenance of the natural resources (water, soil, flora, fauna and scenic quality) of the Crown land adjoining the proposed boundary of disturbance identified in the PEA. Further, it is also considered paramount that the disturbed areas of Crown land, namely the Reserves listed above are progressively rehabilitated using leading practise mine reclamation techniques throughout the life of the mine that results in a stable post-mining landscape.

The Department requests that a Crown Lands status search be undertaken by the proponent to identify any Crown roads impacted by the proposal. The preliminary environmental assessment makes no reference to Crown roads affected by the mine continuation proposal within the proposed boundary of disturbance. During this Office's investigation it became apparent that there are several Crown roads that are affected by the mine continuation proposal, namely the Crown roads to the:

- north & east of Lot 197 DP 750029,
- south & west of Lot 154 DP 750029,
- west of Lot 115 DP 750029,
- south & north of Lot 165 DP750029,
- east of Lot 2 DP1186554,
- north of Lot 4 DP 106569,
- north of Lot 21 DP 657523,
- north of Lot 100 DP 1064794,
- north of Lot 83 DP750029, and
- west of Lot 1701 DP 610507.

The affected Crown roads should be closed and purchased by the proponent.
It is noted that Native Title issues will be further addressed as part of the development process. This Office will need to be provided with advice from the proponent on how these issues shall be resolved into the future.

If you have any queries regarding the aforementioned or this Office can be of any further assistance, please do not hesitate to call John Flarrety, Group Leader, Goulburn Office on (02) 4824-3714.

Yours sincerely

Kristian Holz
Director Policy, Legislation and Innovation

Attachment A

Marulan South Limestone Mine Continuation Project (SSD 7009)
Request for input into Secretary's Environmental Assessment Requirements
Additional Comments by NSW Office of Water

The following detailed assessment requirements are provided to assist in adequately addressing the assessment requirements for this proposal.

For further information visit the NSW Office of Water website, www.water.nsw.gov.au

Key Relevant Legislative Instruments

This section provides a basic summary to aid proponents in the development of an Environmental Impact Statement (EIS), and should not be considered a complete list or comprehensive summary of relevant legislative instruments that may apply to the regulation of water resources for a project.

The EIS should take into account the objects and regulatory requirements of the *Water Act 1912* (WA 1912) and *Water Management Act 2000* (WMA 2000), and associated regulations and instruments, as applicable.

Water Management Act 2000 (WMA 2000)
Key points:

- Volumetric licensing in areas covered by water sharing plans.
- Works within 40m of waterfront land.
- SSD & SSI projects are exempt from requiring water supply work approvals and controlled activity approvals as a result of the *Environmental Planning & Assessment Act 1979 (EP&A Act).*
- No exemptions for volumetric licensing apply as a result of the *EP&A Act*.
- Basic landholder rights, including harvestable rights dams.
- Aquifer interference activity approval and flood management work approval provisions have not yet commenced and are regulated by the *Water Act 1912.*
- Maximum penalties of $2.2 million plus $264,000 for each day an offence continues apply under the *WMA 2000.*

Water Act 1912 (WA 1912)
Key points:

- Volumetric licensing in areas where no water sharing plan applies.
- Monitoring bores.
- Aquifer interference activities that are not regulated as a water supply work under the *WMA 2000.*
- Flood management works.
- No exemptions apply to licences or permits under the *WA 1912* as a result of the *EP&A Act.*
- Regulation of water bore driller licensing.

Water Management (General) Regulation 2011
Key points:

- Provides various exemptions for volumetric licensing and activity approvals.
- Provides further detail on requirements for dealings and applications.

Water Sharing Plans – these are considered regulations under the *WMA 2000*

Access Licence Dealing Principles Order 2004

Harvestable Rights Orders

Water Sharing Plans (WSPs)

The following WSPs are relevant to the project site.

- **Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011.** The Project area is within the Barbers Creek Management Zone (within the Shoalhaven River Gorge Management Zones) within the Shoalhaven River Water Source.
- **Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.** The Project area is within the Goulburn Fractured Rock Groundwater Source.

The EIS is required to:

- Demonstrate how the proposal is consistent with the relevant rules of the Water Sharing Plan including rules for access licences, distance restrictions for water supply works and rules for the management of local impacts in respect of surface water and groundwater sources, ecosystem protection (including groundwater dependent ecosystems), water quality and surface-groundwater connectivity.
- Provide a description of any site water use (amount of water to be taken from each water source) and management including all sediment dams, clear water diversion structures with detail on the location, design specifications and storage capacities for all the existing and proposed water management structures.
- Provide an analysis of the proposed water supply arrangements against the rules for access licences and other applicable requirements of any relevant WSP, including:
  - Sufficient market depth to acquire the necessary entitlements for each water source.
  - Ability to carry out a "dealing" to transfer the water to relevant location under the rules of the WSP.
  - Daily and long-term access rules.
  - Account management and carryover provisions.
- Provide a detailed and consolidated site water balance.
- Further detail on licensing requirements is provided below.

Relevant Policies and Guidelines

The EIS should take into account the following policies (as applicable):

- NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012)
- NSW Aquifer Interference Policy (NOW, 2012)
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW, 2012)
- Australian Groundwater Modelling Guidelines (NWC, 2012)
- NSW State Rivers and Estuary Policy (1993)
- NSW State Groundwater Policy Framework Document (1997)
- NSW State Groundwater Quality Protection Policy (1998)
- NSW State Groundwater Dependent Ecosystems Policy (2002)
- NSW Water Extraction Monitoring Policy (2007)

Office of Water policies can be accessed at the following links:
http://www.water.nsw.gov.au/Water-management/Law-and-policy/Key-policies/default.aspx

http://www.water.nsw.gov.au/Water-licensing/Approvals/Controlled-activities/default.aspx

An assessment framework for the NSW Aquifer Interference Policy can be found online at: http://www.water.nsw.gov.au/Water-management/Law-and-policy/Key-policies/Aquifer-interference.

Proposed Marulan Creek Dam

The PEA indicates that a detailed options analysis is proposed as a part of the EIS to support the case for an in river dam and this is supported by the NSW Office of Water.

More specifically, the proposed dam site is on Marulan Creek which is a 4th order "river" as defined under the Water Management Act 2000. The site is located within the Barbers Creek Management Zone under the Greater Metropolitan Region Water Sharing Plan. The Barbers Creek management zone includes the hydrological catchment of Barbers Creek. Under the Greater Metropolitan Water Sharing Plan, the construction of new in river dams is prohibited in Barbers Creek Management Zone where the subject site is located.

The PEA correctly identifies however, that certain exemptions apply to State Significant Developments under section 89J of the Environmental Planning and Assessment Act 1979. This includes an exemption from the need for works and use approvals (for dams) under the Water Management Act 2000. As such, a dam on Marulan Creek could be considered however substantial and appropriate justification as suggested by undertaking an options analysis is considered absolutely appropriate and essential.

The exemptions under Section 89J however do not apply to volumetric licensing and so all predicted water use (take) must be accounted for by having adequate entitlement and appropriate licensing.

Volumetric licensing and trading entitlement

The NSW Office of Water wishes to highlight that the process for seeking and trading of licensed water entitlement for a new dam will be subject to trading rules as outlined in the Water Sharing Rules for the Barbers Creek Management Zone (attached).

These rules are potentially more constrained than the rules which applied to the trading of entitlement for the dam site on Tangarang Creek for the adjoining Peppertree Quarry. The Peppertree dam site and trading of entitlement was assessed and authorised under the Water Act 1912 prior to the gazettal of the Greater Metropolitan Region Water Sharing Plan in 2011.

Under the Water Act 1912, the transfer of licensed water entitlement for the Peppertree Quarry site allowed for a larger catchment area to source and trade entitlement from. Since the Peppertree Quarry licence was issued, the Water Act 1912 has been repealed and replaced by the Greater Metropolitan Region Water Sharing Plan under the Water Management Act 2000 which commenced on 1 July 2011.

The trading rules for the Barbers Creek Management Zone are specific in that they only allow for the trading of licensed water entitlement **WITHIN** the management zone only. Trading from outside the zone into Barbers Creek Management Zone is not permitted if the trade will increase the total licensed entitlement for the management zone.

Licensing Considerations

The EIS is required to provide:

- Identification of water requirements for the life of the project in terms of both volume and timing (including predictions of potential ongoing groundwater take following the cessation of operations at the site – such as evaporative loss from open voids or inflows).
- Details of the water supply source(s) for the proposal including any proposed surface water and groundwater extraction from each water source as defined in the relevant Water Sharing Plan/s and all water supply works to take water.
- Explanation of how the required water entitlements will be obtained (i.e. through a new or existing licence/s, trading on the water market, controlled allocations etc).
- Information on the purpose, location, construction and expected annual extraction volumes including details on all existing and proposed water supply works which take surface water, (pumps, dams, diversions, etc).
- Details on all bores and excavations for the purpose of investigation, extraction, dewatering, testing and monitoring. All predicted groundwater take must be accounted for through adequate licensing.
- Details on existing dams/storages (including the date of construction, location, purpose, size and capacity) and any proposal to change the purpose of existing dams/storages.
- Details on the location, purpose, size and capacity of any new proposed dams/storages.
- Applicability of any exemptions under the *Water Management (General) Regulation 2011* to the project.

Water allocation account management rules, total daily extraction limits and rules governing environmental protection and access licence dealings also need to be considered.

The Harvestable Right gives landholders the right to capture and use for any purpose 10 % of the average annual runoff from their property. The Harvestable Right has been defined in terms of an equivalent dam capacity called the Maximum Harvestable Right Dam Capacity (MHRDC). The MHRDC is determined by the area of the property (in hectares) and a site-specific run-off factor. The MHRDC includes the capacity of all existing dams on the property that do not have a current water licence. Storages capturing up to the harvestable right capacity are not required to be licensed but any capacity of the total of all storages/dams on the property greater than the MHRDC may require a licence.

For more information on Harvestable Right dams, including a calculator, visit: http://www.water.nsw.gov.au/Water-licensing/Basic-water-rights/Harvesting-runoff/Harvesting-runoff

Dam Safety

Where new or modified dams are proposed, or where new development will occur below an existing dam, the NSW Dams Safety Committee should be consulted in relation to any safety issues that may arise. Conditions of approval may be recommended to ensure safety in relation to any new or existing dams.

See www.damsafety.nsw.gov.au for further information.

Surface Water Assessment

The predictive assessment of the impact of the proposed project on surface water sources should include the following:

- Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project.
- Identification of all surface water sources as described by the relevant water sharing plan.

- Detailed description of dependent ecosystems and existing surface water users within the area, including basic landholder rights to water and adjacent/downstream licensed water users.
- Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources.
- Assessment of predicted impacts on the following:
    - flow of surface water, sediment movement, channel stability, and hydraulic regime,
    - water quality,
    - flood regime,
    - dependent ecosystems,
    - existing surface water users, and
    - planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans.

Groundwater Assessment

To ensure the sustainable and integrated management of groundwater sources, the EIS needs to include adequate details to assess the impact of the project on all groundwater sources including:

- Works likely to intercept, connect with or infiltrate the groundwater sources.
- Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes.
- Bore construction information is to be supplied to the Office of Water by submitting a "Form A" template. The Office of Water will supply "GW" registration numbers (and licence/approval numbers if required) which must be used as consistent and unique bore identifiers for all future reporting.
- A description of the watertable and groundwater pressure configuration, flow directions and rates and physical and chemical characteristics of the groundwater source (including connectivity with other groundwater and surface water sources).
- Sufficient baseline monitoring for groundwater quantity and quality for all aquifers and GDEs to establish a baseline incorporating typical temporal and spatial variations.
- The predicted impacts of any final landform on the groundwater regime.
- The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts.
- An assessment of groundwater quality, its beneficial use classification and prediction of any impacts on groundwater quality.
- An assessment of the potential for groundwater contamination (considering both the impacts of the proposal on groundwater contamination and the impacts of contamination on the proposal).
- Measures proposed to protect groundwater quality, both in the short and long term.
- Measures for preventing groundwater pollution so that remediation is not required.
- Protective measures for any groundwater dependent ecosystems (GDEs).
- Proposed methods of the disposal of waste water and approval from the relevant authority.
- The results of any models or predictive tools used.

Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:

- Any proposed monitoring programs, including water levels and quality data.
- Reporting procedures for any monitoring program including mechanism for transfer of information.
- An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal.
- Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category).
- Description of the remedial measures or contingency plans proposed.
- Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.

Groundwater Dependent Ecosystems

The EIS must consider the potential impacts on any Groundwater Dependent Ecosystems (GDEs) at the site and in the vicinity of the site and:

- Identify any potential impacts on GDEs as a result of the proposal including:
  - the effect of the proposal on the recharge to groundwater systems;
  - the potential to adversely affect the water quality of the underlying groundwater system and adjoining groundwater systems in hydraulic connections; and
  - the effect on the function of GDEs (habitat, groundwater levels, connectivity).
- Provide safeguard measures for any GDEs.

Watercourses, Wetlands and Riparian Land

The EIS should address the potential impacts of the project on all watercourses likely to be affected by the project, existing riparian vegetation and the rehabilitation of riparian land. It is recommended the EIS provides details on all watercourses potentially affected by the proposal, including:

- Scaled plans showing the location of:
  - wetlands/swamps, watercourses and top of bank;
  - riparian corridor widths to be established along the creeks;
  - existing riparian vegetation surrounding the watercourses (identify any areas to be protected and any riparian vegetation proposed to be removed);
  - the site boundary, the footprint of the proposal in relation to the watercourses and riparian areas; and
  - proposed location of any asset protection zones.
- Photographs of the watercourses/wetlands and a map showing the point from which the photos were taken.
- A detailed description of all potential impacts on the watercourses/riparian land.
- A detailed description of all potential impacts on the wetlands, including potential impacts to the wetlands hydrologic regime; groundwater recharge; habitat and any species that depend on the wetlands.
- A description of the design features and measures to be incorporated to mitigate potential impacts.

- Geomorphic and hydrological assessment of water courses including details of stream order (Strahler System), river style and energy regimes both in channel and on adjacent floodplains.

Drill Pad, Well and Access Road Construction

- Any construction activity within 40m of a watercourse, should be designed by a suitably qualified person, consistent with the NSW *Guidelines for Controlled Activities on Waterfront Land* (July 2012).
- Construction of all wells must be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (3rd edition 2012) by a driller holding a bore drillers' licence valid in New South Wales.
- The length of time that a core hole is maintained as an open hole should be minimised.

Landform rehabilitation (including final void management)

The Environmental Impact Statement report should include:

- Justification of the proposed final landform with regard to its impact on local and regional surface and groundwater systems;
- A detailed description of how the site would be progressively rehabilitated and integrated into the surrounding landscape;
- Outline of proposed construction and restoration of topography and surface drainage features if affected by the project;
- Detailed modelling of potential groundwater volume, flow and quality impacts of the presence of an inundated final void (where relevant) on identified receptors specifically considering those environmental systems that are likely to be groundwater dependent;
- An outline of the measures to be put in place to ensure that sufficient resources are available to implement the proposed rehabilitation; and
- The measures that would be established for the long-term protection of local and regional aquifer systems and for the ongoing management of the site following the cessation of the project.

Sustainable Water Supply

Competition for water in NSW is extremely high. In areas where a WSP has commenced, a long term average extraction limit has been established which constrains overall growth in extractions in an area. In these areas there are limited types of new licenses that can be issued, for example for aboriginal cultural purposes or growth in town water supplies. Therefore in most instances new enterprises are required to enter the water market to purchase adequate water licences to meet their water demand requirements.

In areas where a WSP has not yet commenced, the NSW Government has established embargoes on applying for new licences. There are limited exemptions in some areas which need to be considered and applied for by a proponent. If an exemption does not apply, then again new enterprises need to enter the water market to purchase the required water licences. In some areas where a WSP has not yet commenced, there is still available water and the proponent may be able to apply for a new licence to account for the water taken from that water source.

The onus is on the proponent to assess which of the above is relevant and identify the potential sources of water of an appropriate reliability and quantity to meet their water supply requirements. The water supply requirements and potential water available should be identified in the EIS to enable the Office of Water to assess the viability of the water supply required. Assurances should also be made that the proponent will enter the water market as required.

Therefore the assessment is required to address the issue of provision of a sustainable water supply for any project proposal. The assessment should include Water Management Plans detailing how a sustainable water supply can be sourced and implemented. Through the implementation of BASIX, Integrated Water Cycle Management and Water Sensitive Urban Design, any proposed development should also exhibit high water use efficiency.

End Attachment A

PCU059526

Heritage Council of New South Wales
NSW GOVERNMENT

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heritage@heritage.nsw.gov.au
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Contact: Stela Rahman
Telephone: (02) 9873 8524
Email: stela.rahman@environment.nsw.gov.au
File: SF15/19861
Job ID No: DOC15/135886
Your Ref: SSD 7009

Department of Planning
Received
13 MAY 2015
Scanning Room

Elle Donnelley
Department of Planning and Environment
GPO Box 39
SYDNEY NSW 2001

Dear Ms Donnelley

RE: Request for Secretary's Environmental Assessment Requirements for SSD 7009 – Expansion of existing open-cut mine of Marulan South Limestone Mine and upgrade/relocation of elements of the existing facility, overburden emplacement area, construction of a water supply dam on Marulan Creek and site rehabilitation.

I refer to your letter received on 24 April 2015, requesting input from the Heritage Council of NSW (the Heritage Council) regarding the Secretary's Environmental Assessment Requirements (SEARs) for the preparation of the Environmental Impact Statements (EIS) for the above major project.

As delegate of the Heritage Council of NSW, I recommend that the following conditions should be included in the SEARs:

1. The Applicant must undertake a detailed archaeological assessment which includes a consideration of Aboriginal and non-Aboriginal. The proposed mine pit expansion, overburden emplacement and haul road construction has a high potential to impact on Aboriginal sites. The detailed archaeological assessment should consider the proposed below ground impacts on any potential archaeology and in addition, consider what archaeological works have already been undertaken on this site which may provide information to aid in this assessment. The assessment should include overlay maps and assessments of significance for the potential archaeological resource utilising appropriate Heritage Council Guidelines such as 'Assessing the Significance of Archaeological Sites and Relics'. It is should also contain mitigation strategies to manage this potential archaeological resource which may include redesign to avoid significant archaeology or archaeological testing or salvage during project works.

2. The Applicant should submit a Heritage Impact Assessment (HIA) as part of the EIS. The HIA should address the potential heritage impacts of the proposal to the Marulan Village and other state significant heritage items in the vicinity of the site, including views and settings to and from these heritage items. Identification of potential impacts should include potential cumulative impacts from surrounding projects as the mine expansion proposal consists of a

large scope of works in dislocated areas of Marulan. The HIA should include measures to manage, mitigate, monitor and offset potential adverse impacts. The applicant should also assess if the proposed works will have an impact on any archaeology protected under the *Heritage Act 1977*.

3. The relics provisions in the *Heritage Act 1977* require an excavation permit to be obtained from the Heritage Council of NSW, or an exception to be endorsed by the Heritage Council of NSW, prior to commencement of works if disturbance to a site with known or potential archaeological relics is proposed. Where possible, refer to archaeological zoning plans or archaeological management plans held by Local Councils. If any unexpected archaeological relics are discovered during the course of work, excavation should cease. An excavation permit, or an exception notification endorsement, should be obtained.

If you have any further enquiries regarding this matter, please contact Stela Rahman, Heritage Officer, Heritage Division, Office or Environment and Heritage on (02) 9873 8524.

Yours sincerely

ED BEEBE
A/Manager Conservation
Heritage Division
Office of Environment & Heritage

<u>As Delegate of the NSW Heritage Council</u>

Date 12 May 2015

Office of Environment & Heritage
NSW GOVERNMENT

Your reference: SSD 7009
Our reference: DOC15/157666
Contact: Miles Boak
Ph. 02 62297095

Ms Elle Donnelley
Resource Assessments
Department of Planning and Environment
GPO Box 39
SYDNEY NSW 2001

Dear Ms Donnelley

RE: SEARs for Marulan South Limestone Mine Continuation Project (SSD 7009)

I refer to your email dated 24 April 2015 seeking input into the Department of Planning and Environment Secretary's Environmental Assessment Requirements (SEARs) for the preparation of an Environmental Impact Statement (EIS) for the Marulan South Limestone Mine Continuation Project (SSD 7009).

OEH understands that the proposal would comprise expanding the existing open cut mine to extract up to 3.5 million tonnes of limestone a year, and 200,000 tonnes of shale year, for up to 30 years; upgrading and/or relocating elements of the existing processing facility; developing a new overburden emplacement area and accepting a small volume of overburden from Boral's adjacent Peppertree Quarry; constructing a water supply dam on Marulan Creek, realigning sections of the access roads; and rehabilitating the site. The EIS should ensure that the effects of all aspects of the project are considered, including all upgraded infrastructure associated with the project.

OEH has reviewed the available supporting documentation and provides SEARs for the proposed development in Attachments A and B and guidance material in Attachment C (please note that both Attachments A and B include biodiversity matters that will need to be addressed). The assessment must address all ancillary infrastructure and rehabilitation measures proposed for the site.

OEH recommends the EIS needs to appropriately address the following:

1. Biodiversity and offsetting
2. Aboriginal cultural heritage
3. Water and soils
4. Flooding

Please note that the NSW Biodiversity Offsets Policy for Major Projects www.environment.nsw.gov.au/resources/biodiversity/140672biopolicy.pdf is now being implemented. The policy provides a standard method for assessing impacts of major projects on biodiversity and determining offsetting arrangements. The policy is underpinned by the Framework for Biodiversity Assessment (FBA) www.environment.nsw.gov.au/resources/biodiversity/140675fba.pdf which contains the assessment methodology that is adopted by the policy to quantify and describe the impact assessment requirements and offset guidance that applies to Major Projects. The FBA must be used by a proponent to assess all impacts associated with the development.

The Bungonia koala local population is quite significant making up 80% of the known records within Goulburn Mulwaree Shire council area. Indications are that numbers are flucuating in recent times so it is important to get an accurate assessment of koala numbers on the Boral lease area to determine the significance of the development in regards to the Koala population.

The site is adjacent to Bungonia State Recreation Area (SCA) which is a reserve of considerable significance being geologically complex and having a unique range of karst features including 182 known caves and one of the world's finest limestone gorges; - the caves are deep compared to most other Australian cave systems and contains the second deepest cave on mainland Australia and the deepest limestone gorge. It is considered as one of the three most important recreational caving areas in Australia; Bungonia has been a reserve since 1872 and was established the same year as the world's first national park, Yellowstone in the USA. *(Source: Bungonia SCA Plan of Management NPWS 1998).*

The existing quarrying already significantly affects views from the Bungonia Lookdown and Adams Lookout and some walking tracks in the SRA, reducing the feeling of naturalness and isolation. It is important that the southern lip of the existing south pit excavation area be maintained. This is critical to avoid risk of materials entering the gorge. The visual impact from look out and safety of users of SCA are important considerations in this regard. NPWS Bungonia SCA staff should be contacted directly on the detailed plans and impacts on the adjacent state recreation area.

If you have any questions regarding this matter please contact Miles Boak on (02) 6229 7905 or at Miles.Boak@environment.nsw.gov.au.

Yours sincerely

Allison Treweek 12 May 2015.

ALLISON TREWEEK
Senior Team Leader Planning
Regional Operations
Office of Environment and Heritage

ATTACHMENT A - Environmental Assessment Requirements
ATTACHMENT B - Project specific Environmental Assessment Requirements
ATTACHMENT C - Guidance Material

Attachment A – Standard Environmental Assessment Requirements

Biodiversity
1. Biodiversity impacts related to the proposed project are to be assessed and documented in accordance with the Framework for Biodiversity Assessment, unless otherwise agreed by OEH, by a person accredited in accordance with s142B(1)(c) of the *Threatened Species Conservation Act 1995.*
Aboriginal cultural heritage
2. The EIS must identify and describe the tangible and intangible Aboriginal cultural heritage values that exist across the whole area that will be affected by the project and document these in the EIS. This may include the need for surface survey and test excavation. The identification of cultural heritage values should be guided by the Guide to investigating, assessing and reporting on Aboriginal Cultural Heritage in NSW (DECCW, 2011) and consultation with OEH regional officers.
3. Where Aboriginal cultural heritage values are identified, consultation with Aboriginal people must be undertaken and documented in accordance with the *Aboriginal cultural heritage consultation requirements for proponents 2010* (DECCW). The significance of cultural heritage values for Aboriginal people who have a cultural association with the land must be documented in the EIS.
4. Impacts on Aboriginal cultural heritage values are to be assessed and documented in the EIS. The EIS must demonstrate attempts to avoid impact upon cultural heritage values and identify any conservation outcomes. Where impacts are unavoidable, the EIS must outline measures proposed to mitigate impacts. Any objects recorded as part of the assessment must be documented and notified to OEH.
Water and soils
5. The EIS must map the following features relevant to water and soils including: a. Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment). b. Groundwater. c. Groundwater dependent ecosystems. d. Proposed intake and discharge locations.
6. The EIS must describe background conditions for any water resource likely to be affected by the project including: a. Existing surface and groundwater. b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations. c. Water Quality Objectives (as endorsed by the NSW Government www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters. d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.
7. The EIS must assess the impacts of the project on water quality, including:

a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how Water Quality Objectives are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction. b. Identification of proposed monitoring of water quality.
8. The EIS must assess the impact of the proposed project on hydrology, including: a. Water balance including quantity, quality and source. b. Effects to downstream rivers, waters and floodplain areas. c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems and stygofauna . d. Impacts to natural processes and functions within rivers, wetlands, and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (eg river benches). e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water. f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options. g. Identification of proposed monitoring of hydrological attributes.
Flooding
9. The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a. Flood prone land b. Flood planning area, the area below the flood planning level. c. Hydraulic categorisation (floodways and flood storage areas).
10. The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.
11. Modelling in the EIS must consider and document: a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. b. Impacts of the proposed project on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. c. Relevant provisions of the NSW Floodplain Development Manual 2005.
12. The EIS must assess the impacts on the projecton flood behaviour, including: a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure. b. Consistency with Council floodplain risk management plans. c. Compatibility with the flood hazard of the land.

d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.

e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.

f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

g. Any impacts the proposed project may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.

h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council.

i. Emergency management, evacuation and access, and contingency measures for the proposed project considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES.

j. Any impacts the proposed project may have on the social and economic costs to the community as consequence of flooding.

Attachment B – Project specific Environmental Assessment Requirements

Biodiversity
1. Impacts on the following species, populations and ecological communities will require further consideration and provision of the information specified in s9.2 of the Framework for Biodiversity Assessment: • White box yellow box Blakely's red gum woodland "Box gum woodland" - endangered ecological community • Eastern bent-wing bat, *Miniopterus schreibersii oceanensis* • Koala, *Phascolarctos cinereus* The assessment for the Eastern bent-wing bat must assess the impacts of the proposed development on foraging habitat for this species, as the project is within an important ecological area for this species. Impacts to the karst system that the Eastern bent-wing bats utilise in the area will be assessed outside of the FBA, as described below. Audrey Kutzner (Ranger) Bungonia SRA has been monitoring koala records within the adjoining SCA lands and should be consulted on assessing the Bungonia local koala population numbers.
2. The EA must identify: a. The natural features (both surface and sub-surface) that could be affected by mining activities or subsidence that the Eastern bent-wing bat (*Miniopterus schreibersii oceanensis)* utilises for roosting, and breeding habitat. b. An assessment of the potential direct and indirect ecological impacts of the predicted mining activities in the short, medium and long term on the breeding habitat. c. Measures proposed to avoid, minimise, manage and offset the direct and indirect impacts, including an evaluation of the effectiveness and reliability of the proposed measures.
3. The EIS must identify: a. Matters to be considered outlined in the *Guidelines for developments adjoining land and water managed by DECCW* (DECCW 2010) and include: i. The nature of the impacts, including direct and indirect impacts. ii. The extent of the direct and indirect impacts. iii. The duration of the direct and indirect impacts. iv. The objectives of the reservation of the land. b. Measures proposed to prevent, control, abate, minimise and manage the direct and indirect impacts including an evaluation of the effectiveness and reliability of the proposed measures. c. Residual impacts.

Aboriginal cultural heritage	
1.	The assessment of Aboriginal cultural heritage values must include a surface survey undertaken by a qualified archaeologist in conjunction with Registered Aboriginal Parties. The result of the surface survey is to inform the need for targeted test excavation to better assess the integrity, extent, distribution, nature and overall significance of the archaeological record. The results of surface surveys and test excavations are to be documented in the EIS.
2.	Consultation with Aboriginal people must be undertaken and documented in accordance with the *Aboriginal cultural heritage consultation requirements for proponents 2010* (DECCW). OEH notes that section 13.3 of the Preliminary Environmental Assessment (dated April 2015) refers to consultation will be undertaken in accordance with the *Interim Community Consultation Requirements for Applicants* (DEC 2005). OEH advises that the 2010 *Aboriginal Cultural Heritage Consultation Requirements for Proponents,* as stated in section 1.2 of these requirements, have now replaced the *Interim Community Consultation Requirements for Applicants.*
3.	Impacts on Aboriginal cultural heritage values are to be assessed and documented in the EIS. The EIS must: a. demonstrate attempts to avoid impact upon Aboriginal cultural heritage values and identify any conservation outcomes; b. where impacts are unavoidable, outline measures proposed to mitigate impacts; c. outline procedures to be followed if Aboriginal objects are found at any stage of the life of the project to formulate appropriate measures to manage unforseen impacts; and d. outline procedures to be followed in the event Aboriginal burials or skeletal material is uncovered during construction to formulate appropriate measures to manage the impacts to this material.
4.	Any Aboriginal objects recorded as part of the assessment must be documented and notified to OEH. Copies of the relevant Archaeological Report and Aboriginal Cultural Heritage Assessment Report must also be forwarded to OEH.

Attachment C – Guidance material

Title	Web address
Relevant Legislation	
Commonwealth Environment Protection and Biodiversity Conservation Act 1999	www.austlii.edu.au/au/legis/cth/consol_act/epabca1999588/
Environmental Planning and Assessment Act 1979	www.legislation.nsw.gov.au/maintop/view/inforce/act+203+1979+cd+0+N
Fisheries Management Act 1994	www.legislation.nsw.gov.au/maintop/view/inforce/act+38+1994+cd+0+N
Marine Parks Act 1997	www.legislation.nsw.gov.au/maintop/view/inforce/act+64+1997+cd+0+N
National Parks and Wildlife Act 1974	www.legislation.nsw.gov.au/maintop/view/inforce/act+80+1974+cd+0+N
Protection of the Environment Operations Act 1997	www.legislation.nsw.gov.au/maintop/view/inforce/act+156+1997+cd+0+N
Threatened Species Conservation Act 1995	www.legislation.nsw.gov.au/maintop/view/inforce/act+101+1995+cd+0+N
Water Management Act 2000	www.legislation.nsw.gov.au/maintop/view/inforce/act+92+2000+cd+0+N
Wilderness Act 1987	www.legislation.nsw.gov.au/viewtop/inforce/act+196+1987+FIRST+0+N
Biodiversity	
NSW Biodiversity Offsets Policy for Major Projects (OEH, 2013)	www.environment.nsw.gov.au/resources/biodiversity/140672biopolicy.pdf
Framework for Biodiversity Assessment (OEH, 2013)	www.environment.nsw.gov.au/resources/biodiversity/140675fba.pdf
OEH Threatened Species Website	www.environment.nsw.gov.au/threatenedspecies/
NSW BioNet (Atlas of NSW Wildlife)	www.bionet.nsw.gov.au/
Fisheries NSW policies and guidelines	www.dpi.nsw.gov.au/fisheries/habitat/publications/policies,-guidelines-and-manuals/fish-habitat-conservation
List of national parks	www.environment.nsw.gov.au/NationalParks/parksearchatoz.aspx
Guidelines for developments adjoining land and water managed by the Department of Environment, Climate Change and Water (DECCW, 2010)	www.environment.nsw.gov.au/resources/protectedareas/080290devadjoindecc.pdf
OEH Spatial Data Online Access	http://mapdata.environment.nsw.gov.au/geonetwork/srv/en/main.home
Heritage	
The Burra Charter (The Australia ICOMOS charter for places of cultural significance)	http://australia.icomos.org/wp-content/uploads/The-Burra-Charter-2013-Adopted-31.10.2013.pdf
Statements of Heritage Impact 2002 (HO & DUAP)	www.environment.nsw.gov.au/resources/heritagebranch/heritage/hmstatementsofhi.pdf

Title	Web address
NSW Heritage Manual (DUAP) (scroll through alphabetical list to 'N')	www.environment.nsw.gov.au/Heritage/publications/index.htm#M-O
Aboriginal Cultural Heritage	
Aboriginal Cultural Heritage Consultation Requirements for Proponents (DECCW, 2010)	www.environment.nsw.gov.au/resources/cultureheritage/commconsultation/09781ACHconsultreq.pdf
Code of Practice for the Archaeological Investigation of Aboriginal Objects in New South Wales (DECCW, 2010)	www.environment.nsw.gov.au/resources/cultureheritage/10783FinalArchCoP.pdf
Guide to investigating, assessing and reporting on Aboriginal cultural heritage in NSW (OEH 2011)	www.environment.nsw.gov.au/resources/cultureheritage/20110263ACHguide.pdf
Aboriginal Site Recording Form	www.environment.nsw.gov.au/resources/parks/SiteCardMainV1_1.pdf
Aboriginal Site Impact Recording Form	www.environment.nsw.gov.au/resources/cultureheritage/120558asirf.pdf
Aboriginal Heritage Information Management System (AHIMS) Registrar	www.environment.nsw.gov.au/contact/AHIMSRegistrar.htm
Care Agreement Application form	www.environment.nsw.gov.au/resources/cultureheritage/20110914TransferObject.pdf
Water and Soils	
Acid sulphate soils	
Acid Sulfate Soils Planning Maps via 'The NSW Natural Resource Atlas'	www.nratlas.nsw.gov.au/
Acid Sulfate Soils Manual (Stone et al. 1998)	Manual available for purchase from: www.landcom.com.au/whats-new/the-blue-book.aspx Chapters 1 and 2 are on DPI's Guidelines Register at: Chapter 1 Acid Sulfate Soils Planning Guidelines: www.planning.nsw.gov.au/rdaguidelines/documents/NSW%20Acid%20Sulfate%20Soils%20Planning%20Guidelines.pdf Chapter 2 Acid Sulfate Soils Assessment Guidelines: www.planning.nsw.gov.au/rdaguidelines/documents/NSW%20Acid%20Sulfate%20Soils%20Assessment%20Guidelines.pdf
Acid Sulfate Soils Laboratory Methods Guidelines (Ahern et al. 2004)	www.advancedenvironmentalmanagement.com/Reports/Savannah/Appendix%2015.pdf This replaces Chapter 4 of the Acid Sulfate Soils Manual above.
Flooding	
Floodplain development manual	http://www.environment.nsw.gov.au/floodplains/manual.htm
NSW Climate Impact Profile	NSW Climate Impact Profile
Climate Change Impacts and Risk Management	Climate Change Impacts and Risk Management: A Guide for Business and Government, AGIC Guidelines for Climate Change Adaptation
Water	
Water Quality Objectives	www.environment.nsw.gov.au/ieo/index.htm

Title	Web address
ANZECC (2000) Guidelines for Fresh and Marine Water Quality	www.environment.gov.au/water/publications/quality/australian-and-new-zealand-guidelines-fresh-marine-water-quality-volume-1
Applying Goals for Ambient Water Quality Guidance for Operations Officers – Mixing Zones	http://deccnet/water/resources/AWQGuidance7.pdf
Approved Methods for the Sampling and Analysis of Water Pollutant in NSW (2004)	www.environment.nsw.gov.au/resources/legislation/approvedmethods-water.pdf

NSW GOVERNMENT | Resources & Energy

Our Reference: V15/412
OUT15/11507

Ms Elle Donelly
A/Senior Planner
Resource Assessments, Planning Services
Department of Planning & Environment
GPO Box 39
SYDNEY NSW 2001

elle.donnelly@planning.nsw.gov.au

Dear Ms Donelly

Proposed Marulan South Limestone Mine Continued Operations (SSD 7009)
Request for input to Secretary's Environmental Assessment Requirements

In regard to your email dated 24 April 2015 inviting input for Secretary's Environmental Assessment Requirements (SEARs) for the proposed Marulan South Limestone Mine Continued Operations proposed by Boral Cement Limited.

Technical experts from the Department of Trade and Investment, Regional Infrastructure and Services, Division of Resources & Energy (DRE) have reviewed the Preliminary Environmental Assessment dated April 2015 and provide the following requirements located at Tab A.

Should you have any enquires regarding this matter please contact me on (02) 4931 6437 or adrian.delany@trade.nsw.gov.au.

Yours sincerely

Adrian Delany
A/Director Industry Coordination
18.5.15

TAB A

Division of Resources & Energy
Secretary's Environmental Assessment Requirements - Mining Proposals

PROJECT DESCRIPTION
To ensure that a project and its environmental interactions can be understood and assessed by the Department of Trade & Investment, Division of Resources & Energy (DRE), an Environmental Impact Statement (EIS) should provide a comprehensive description of all aspects (including the mineral extraction and mining purposes) of the project. In terms of text, plans or charts, it must also clearly show the proposed extent and sequence of the development.

GEOLOGY
The EIS is to include a brief description of the geological setting of the deposit. Of importance is a description of the geology and mineralisation of the deposit itself. This should include specific details about the shape, physical dimensions, mineralogy and ore mineral distribution for individual ore bodies/lenses.

Supporting information including plans and cross-sections need to show the extent of the mineralised zones to be mined and those located adjacent/beneath planned mining voids which may be sterilised by planned activities. Where this may impact on resource utilisation and planned final voids, information such as grade and width/tonnes needs to be included.

The EIS is to include whole rock, minor and trace element geochemistry of the ore, tailings and waste rock. This information is often a key component in understanding the environmental effects of the proposal.

RESOURCE AND RESERVE STATEMENT
The EIS is to include a resource/reserve statement appropriate to the type of deposit and based on a simple volume and/or quality estimation.

The EIS needs to include an estimate of the grade ($CaCO_3$ %) of the limestone and should include an estimate of any lower-grade limestone to be mined. A statement to at least an Indicated & inferred level of confidence (equivalent to the JORC code) that covers the next major phase of mining of (~ probably about 7 years) needs to be included. Also, a volume estimate of clay/shale present within the stated 100 Mt of overburden to limestone should also be included along with a statement regarding the lithology and nature of that material.

LIFE OF MINE PRODUCTION SCHEDULE
The proponent must supply a life of mine production schedule for each year of operation of the mine and for the life of the project. The production schedule is to include:

- details of run-of-mine ore, low grade mineralised waste and waste rock tonnage planned to be extracted for each year and for the life of the project, and an estimate of the saleable product produced for each year and the life of the project;

- in terms of text, plans or charts, an EIS must clearly show the proposed extent and sequence of the development and;
- an estimate of which market segment that product tonnes would be sold into.

DRE understands that an estimate of product tonnes split into a particular market segment is difficult to estimate at a particular point in time and is dependent on market conditions as the life of the mine progresses, however DRE requires the proponent to provide its best estimate of their market mix at the initial stages of the project.

MINING TITLE
As limestone is a prescribed under the *Mining Act 1992*, BCL is required to hold an appropriate mining title(s) from DRE in order to mine the mineral.

The removal of the current depth restriction and proposed mining down to the 365 level will make available at least a 100 Mt of limestone over 30 years of mining. The proposal exceeds the work proposed in Mining Lease Application 481 and as such must be covered by future MOPs for each major stage of mining.

For mining purposes as prescribed by section 6 of the *Mining Act 1992*, in so far as the mining purposes are to be carried out in connection with and in the immediate vicinity of a mining lease in respect of a mineral, the proponent is required to hold an appropriate mining title(s).

The proponent must demonstrate that the proposal has sufficient title over the project area to satisfy the requirements of section 380AA of the *Mining Act 1992*.

Any EIS for a project should clearly identify existing mineral titles, mineral title applications and the final proposed mining lease area(s) for the project site and areas surrounding the proposed project area and address the environmental impacts and management measures for the mining and mining purpose activities as licensed under the *Mining Act 1992*.

Where a proposal includes Crown Land the proponent is required to comply with the *Commonwealth Native Title Act 1993* and undertake the right to negotiate process for the Crown Lands within the current exploration licence area(s) if proof of extinguishment cannot be determined.

DESCRIPTION OF EXISTING ENVIRONMENT, IDENTIFICATION OF IMPACTS AND CONSTRAINTS
All areas affected by the proposal should be shown in the context of the natural and built environments. This should be in sufficient detail to enable an understanding of the scale of impacts and gauge the effectiveness of proposed control measures.

The EIS should state the interaction between the proposed mining activities and the existing environment and so include a comprehensive description of the following activities and their impacts:

- Mine layout and scheduling, including maximising opportunities for progressive final rehabilitation. The final rehabilitation schedule should be mapped against key production milestones (i.e. ROM tonnes or recovered ore) of the mine layout sequence before being translated to indicative timeframes throughout the mine life. The mine plan should maximise opportunities for progressive rehabilitation;

- mineral processing and handling, rejects handling and disposal management activities;
- infrastructure facilities and storage requirements;
- surface and groundwater usage and management; and
- mine closure including rehabilitation and decommissioning activities.

The proponent must clearly demonstrate by way of plans, cross sections and/or long sections the extent of mineralised zones adjacent to the planned mine extraction area/void that may be effectively sterilised by the proposed mine infrastructure or be sterilised should back filling of any planned pits be required.

Impacts associated with the operational and post closure stages of the project must also be identified in detail and control management strategies outlined. The identification and description of impacts must draw out those aspects of the site that may present barriers or limitations to effective rehabilitation and which may limit the mine closure potential of the land. The following are the key issues to be addressed in the EIS that are likely to have a bearing on rehabilitation and mine closure:

- An evaluation of current rehabilitation techniques and performance against existing rehabilitation objectives and completion criteria;
- an assessment and life of mine management strategy of the potential for geochemical constraints to rehabilitation (e.g. acid rock drainage, spontaneous combustion etc.), particularly associated with the management of overburden/interburden and reject material. Based on this assessment, the EIS is to document the processes that will be implemented throughout the mine life to identify and appropriately manage geochemical risks that may affect the ability to achieve sustainable rehabilitation outcomes;
- a life of mine tailings management strategy, which details measures to be implemented to avoid the exposure of tailings material that may cause environmental risk, as well as promote geotechnical stability of the rehabilitated landform;
- existing and surrounding landforms (showing contours and slopes) and how similar characteristics can be incorporated into the post-mining final landform design. This should include an evaluation of how the key geomorphological characteristics evident in stable landforms within the natural landscape can be adapted to the materials and other constraints associated with the site;
- where a void is proposed to remain as part of the final landform, the assessment is to provide details in regards to the following:

    1) a constraints and opportunities analysis of final void options, including backfilling, to justify that the proposed design is the most feasible and environmentally sustainable option to minimise the sterilisation of land post-mining;

2) a preliminary geotechnical assessment to identify the likely long term stability risks associated with the proposed remaining high wall(s) and low wall(s) along with associated measures that will be required to minimise potential risks to public safety and

3) outcomes of the surface and groundwater assessments in relation to the likely final water level in the void. This should include an assessment of the potential for fill and spill along with measures required be implemented to minimise associated impacts to the environment and downstream water users.

Open cut mining
The EIS must assess surface water flow and flooding regimes and how these will be impacted and mitigated by the project both during and after mining has ceased. This is to include an evaluation of potential impacts from the final void on both surface and groundwater quality and flow regimes.

To carry out the assessment of the impact of mining the proponent must:

- conduct a groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging (e.g. acid or neutral mine drainage) from the workings post cessation of mining
- include a consideration of the likely controls required to either prevent or mitigate against these risks as part of the closure plan for the site
- assess the biological resources associated with the proposed disturbance area and how they can be practically salvaged for utilisation in rehabilitation (i.e. topsoil, seed banks, tree hollows and logs, native seed etc.). This should include an evaluation of how topsoil/subsoil of suitable quality can be direct-returned for use in rehabilitation
- assess the flora, fauna and ecological attributes of the disturbed area should be recorded and placed in a regional context
- carry out an evaluation of current land capability class and associated condition
- characterise soils across the proposed area of surface disturbance and assess their value and identify opportunities and constraints for use in rehabilitation

Where an agricultural land use is proposed, the EIS should demonstrate:

- that the landscape will be returned to the Agricultural Suitability Class that existed before mining commenced or better
- where the intended land use is likely to be grazing, the existing capacity in terms of Dry Sheep Equivalent or similar must be calculated and a timeframe from vegetation establishment be given for the return to agricultural production to at least the existing stock capacity
- provide information on how soil would be developed in order to achieve the proposed stock capacity.

Where an ecological land use is proposed, the EIS should demonstrate that the revegetation strategy (e.g. seed mix, habitat features, corridor width etc.) has been developed in consideration of the target vegetation community(s).

REHABILITATION & MINE CLOSURE STRATEGY

DRE's role focuses on ensuring that mined land in NSW is effectively rehabilitated and returned to beneficial post mining land uses. This is undertaken by requiring mine operators to have strategies in place to ensure the rehabilitation of all mined land, and strategies for an orderly transition from a mining land use to an agreed stable and beneficial post mining use. At the EIS stage, the strategies may be conceptual in nature.

The EIS is to include a detailed description of the scope of decommissioning and rehabilitation activities required to meet the nominated closure objectives and completion criteria for each domain. The scope of these activities must be developed in consideration of the existing environment, identification of impacts and constraints as listed above.

Each of the following aspects of rehabilitation planning should be addressed in the strategy:

- **Post Mining Land Use** – the proponent must identify and assess post mining land use options and provide a statement of the preferred post mining land use outcome in the EIS. This should include a discussion of how the final land use(s) are aligned with relevant local and regional strategic land use objectives. In addition, the benefits of the post mining land to the surrounding environment, a subsequent landowner, the local community and the state of NSW.

  In addition, the proponent must identify how the rehabilitation of the project will integrate with the rehabilitation strategies of neighbouring mines within the region. On a local scale this should include the project and adjacent mines, with a particular emphasis on the coordination of rehabilitation activities along common boundary areas.

- **Rehabilitation Objectives and Domains** – a set of project rehabilitation objectives and completion criteria must be included that clearly define the environmental outcomes required to achieve the final land use for each domain. The completion criteria must be specific, measurable, achievable, realistic and time-bound.

  If necessary, objective criteria may be presented as ranges rather than finite indicator levels. Subjective criteria may also apply where a gap in technical knowledge is experienced. Further refinement of these criteria will be undertaken and included in the Rehabilitation Management Plan (RMP).

- **Rehabilitation Methodology** - provide details regarding the rehabilitation methods for disturbed areas and expected time frames for each stage of the rehabilitation process. Provide details on proposed rehabilitation monitoring and an outline of proposed rehabilitation research programs and trials.

- **Conceptual Final Landform Design** – a drawing at an appropriate scale with final landform contours should be provided. This drawing should identify the following attributes of the final landform: vegetation types; habitat features; contaminated areas; final voids; drainage infrastructure; access and internal roads; fencing design; and other remaining infrastructure such as sheds, dams, bores and pipelines.

- **Monitoring and Research** - outline the proposed monitoring programs that will be implemented to assess how rehabilitation is trending towards the nominated land use objectives and completion criteria. This should include details of the process for triggering intervention and adaptive management measures to address potential adverse results as well as continuously improve rehabilitation practices.

In addition, an outline of proposed rehabilitation research programs and trials, including objectives, are to be included in the EIS. This should include details of how the outcomes of research are considered as part of the ongoing review and improvement of rehabilitation practices.

- **Post-closure maintenance:** - Describe how post-rehabilitation areas will be actively managed and maintained in accordance with the intended land use(s) in order to demonstrate progress towards meeting the closure objectives and completion criteria in a timely manner.

Justification must be supported by the information provided by the proponent, including, but not limited to:

- description of the proposed mining operation (e.g. mining methods, layout and sequences);
- general and relevant site conditions including depths of cover, geological, hydrogeological, hydrological, geotechnical, topographic and climatic conditions;
- identification and general characteristics of any previously excavated or abandoned workings that may interact with the proposed or existing mine workings;

The information required above must be clear and adequate for the purpose of assessment of the EIS.

NSW EPA

Department of Planning & Environment
Resource Assessments - Planning Services
GPO Box 39
SYDNEY NSW 2001
Attention: Elle Donnelley - A/Senior Planner

Notice Number	1530395
File Number	EF13/2680: DOC15/148091
Date	08-May-2015

RE: Marulan South Limestone Mine Continuation Project (SSD 7009)

I refer to a request by the Department of Planning and Environment (DP&E) for the Environment Protection Authority's (EPA) Secretary's Requirements for the preparation of an Environmental Impact Statement (EIS) for the above development application, received by the EPA on 24 April 2015.

The EPA has considered the details of the proposal as provided by DP&E and has identified the information it requires in order to properly assess the environmental impacts of the proposal in **Attachment A** to this letter. In summary, the EPA's key information requirements for the proposal include an adequate assessment of:

1. Air quality, particularly dust managment;
2. Noise impacts; and
3. Water quality

In carrying out the assessment, the proponent should refer to the relevant guidelines as listed in **Attachment B** and any relevant industry codes of practice and best practice management guidelines.

The Proponent should be made aware that any commitments made in the EIS may be formalised as approval conditions and may also be placed as EPA licence conditions.

The EPA requests that one hard copy and one electronic copy of the EIS are provided to the EPA for assessment. These documents should be lodged at EPA's South East Regional Office, 11 Farrer Place, Queanbeyan, NSW 2620, queanbeyan@epa.nsw.gov.au.

Should you wish to discuss the matter further please contact Michael Heinze of this office on 6229 7002.

Yours sincerely

....

Julian Thompson

Unit Head

South East - Queanbeyan

(by Delegation)

ATTACHMENT A: EIS REQUIREMENTS FOR

Marulan South Limestone Mine Continuation Project (SSD 7009)

The EIS must include a comprehensive description of the production processes, all discharges and emissions to the environment, an assessment of likely environmental impacts, and a comprehensive description of any proposed control measures.

The environmental sensitivity of the site and surrounds should be discussed. Details are required on the location of the proposed development, including the affected environment, to place the proposal in its local and regional environmental context including surrounding land uses, land use zonings and potential sensitive receptors.

The EIS should describe mitigation and management options that will be used to prevent, control, abate or mitigate identified environmental impacts associated with the project and to reduce risks to human health and prevent the degradation of the environment. This should include an assessment of the effectiveness and reliability of the measures and any residual impacts after these measures are implemented.

The EIS should address the specific requirements outlined below and assess impacts in accordance with the relevant guidelines mentioned. A full list of guidelines is at **Attachment B**.

How to use these requirements

The EPA requirements have been structured in accordance with the DIPNR EIS Guidelines, as follows. It is suggested that the EIS follow the same structure:

A. Executive summary

B. The proposal

C. The location

D. Identification and prioritisation of issues

E. The environmental issues

F. List of approvals and licences

G. Compilation of mitigation measures

H. Justification for the proposal

A Executive summary

The executive summary should include a brief discussion of the extent to which the proposal achieves identified environmental outcomes.

B The proposal

1. Objectives of the proposal

- The objectives of the proposal should be clearly stated and refer to:
  a) the size and type of the operation, the nature of the processes and the products, by-products and wastes produced
  b) a life cycle approach to the production, use or disposal of products
  c) the anticipated level of performance in meeting required environmental standards and cleaner production principles
  d) the staging and timing of the proposal and any plans for future expansion
  e) the proposal's relationship to any other industry or facility.

2. Description of the proposal

General

- Outline the production process including:
  a) the environmental "mass balance" for the process – quantify in-flow and out-flow of materials, any points of discharge to the environment and their respective destinations (sewer, stormwater, atmosphere, recycling, landfill etc)
  b) any life-cycle strategies for the products.
- Outline cleaner production actions, including:
  a) measures to minimise waste (typically through addressing source reduction)
  b) proposals for use or recycling of by-products
  c) proposed disposal methods for solid and liquid waste
  d) air management systems including all potential sources of air emissions, proposals to re-use or treat emissions, emission levels relative to relevant standards in regulations, discharge points
  e) water management system including all potential sources of water pollution, proposals for re-use, treatment etc, emission levels of any wastewater discharged, discharge points, summary of options explored to avoid a discharge, reduce its frequency or reduce its impacts, and rationale for selection of option to discharge.
  f) soil contamination treatment and prevention systems.
- Outline construction works including:
  a) actions to address any existing soil contamination
  b) any earthworks or site clearing; re-use and disposal of cleared material (including use of spoil on-site)
  c) construction timetable and staging; hours of construction; proposed construction methods
  d) environment protection measures, including noise mitigation measures, dust control measures and erosion and sediment control measures.

Air

- Identify all sources of air emissions from the development.
  Note: emissions can be classed as either:
  - *point (e.g emissions from stack or vent) or*
  - *fugitive (from wind erosion, leakages or spillages, associated with loading or unloading, conveyors, storage facilities, plant and yard operation, vehicle movements (dust from road, exhausts, loss from load), land clearing and construction works).*
- Provide details of the project that are essential for predicting and assessing air impacts including:
  a) the quantities and physio-chemical parameters (e.g concentration, moisture content, bulk density, particle sizes etc) of materials to be used, transported, produced or stored
  b) an outline of procedures for handling, transport, production and storage
  c) the management of solid, liquid and gaseous waste streams with potential for significant air impacts.

Noise and vibration

- Identify all noise sources from the development (including both construction and operation phases). Detail all potentially noisy activities including ancillary activities such as transport of goods and raw materials.
- Specify the times of operation for all phases of the development and for all noise producing activities.
- For projects with a significant potential traffic noise impact provide details of road alignment (include gradients, road surface, topography, bridges, culverts etc), and land use along the proposed road and measurement locations – diagrams should be to a scale sufficient to delineate individual residential blocks.

Water

- Provide details of the project that are essential for predicting and assessing impacts to waters:
  a) including the quantity and physio-chemical properties of all potential water pollutants and the risks they pose to the environment and human health, including the risks they pose to Water Quality Objectives in the ambient waters (as defined on www.environment.nsw.gov.au/ieo, using technical criteria derived from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC 2000)
  b) the management of discharges with potential for water impacts
  c) drainage works and associated infrastructure; land-forming and excavations; working capacity of structures; and water resource requirements of the proposal.
- Outline site layout, demonstrating efforts to avoid proximity to water resources (especially for activities with significant potential impacts e.g effluent ponds) and showing potential areas of modification of contours, drainage, etc.
- Outline how total water cycle considerations are to be addressed showing total water balances for the development (with the objective of minimising demands and impacts on water resources). Include water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.

Waste and chemicals

- Provide details of the quantity and type of both liquid waste and non-liquid waste generated, handled, processed or disposed of at the premises. Waste must be classified according to the *Waste Classification Guidelines* (DECCW, 2008).
- Provide details of liquid waste and non-liquid waste management at the facility, including:
  a) the transportation, assessment and handling of waste arriving at or generated at the site
  b) any stockpiling of wastes or recovered materials at the site
  c) any waste processing related to the facility, including reuse, recycling, reprocessing (including composting) or treatment both on- and off-site
  d) the method for disposing of all wastes or recovered materials at the facility
  e) the emissions arising from the handling, storage, processing and reprocessing of waste at the facility
  f) the proposed controls for managing the environmental impacts of these activities.
- Provide details of spoil disposal with particular attention to:

a) the quantity of spoil material likely to be generated
b) proposed strategies for the handling, stockpiling, reuse/recycling and disposal of spoil
c) the need to maximise reuse of spoil material in the construction industry
d) identification of the history of spoil material and whether there is any likelihood of contaminated material, and if so, measures for the management of any contaminated material
e) designation of transportation routes for transport of spoil.

- Provide details of procedures for the assessment, handling, storage, transport and disposal of all hazardous and dangerous materials used, stored, processed or disposed of at the site, in addition to the requirements for liquid and non-liquid wastes.
- Provide details of the type and quantity of any chemical substances to be used or stored and describe arrangements for their safe use and storage.
- Reference should be made to the guidelines: *Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes* (NSW EPA, 1999).

ESD

- Demonstrate that the planning process and any subsequent development incorporates objectives and mechanisms for achieving ESD, including:
  a) an assessment of a range of options available for use of the resource, including the benefits of each option to future generations
  b) proper valuation and pricing of environmental resources
  c) identification of who will bear the environmental costs of the proposal.

3. Rehabilitation

- Outline considerations of site maintenance, and proposed plans for the final condition of the site (ensuring its suitability for future uses).

4. Consideration of alternatives and justification for the proposal

- Consider the environmental consequences of adopting alternatives, including alternative:

a) sites and site layouts
b) access modes and routes
c) materials handling and production processes
d) waste and water management
e) impact mitigation measures
f) energy sources

- Selection of the preferred option should be justified in terms of:
  a) ability to satisfy the objectives of the proposal
  b) relative environmental and other costs of each alternative
  c) acceptability of environmental impacts and contribution to identified environmental objectives
  d) acceptability of any environmental risks or uncertainties
  e) reliability of proposed environmental impact mitigation measures
  f) efficient use (including maximising re-use) of land, raw materials, energy and other resources.

C The location

1. General

- Provide an overview of the affected environment to place the proposal in its local and regional environmental context including:
  a) meteorological data (e.g rainfall, temperature and evaporation, wind speed and direction)
  b) topography (landform element, slope type, gradient and length)
  c) surrounding land uses (potential synergies and conflicts)
  d) geomorphology (rates of landform change and current erosion and deposition processes)
  e) soil types and properties (including erodibility; engineering and structural properties; dispersibility; permeability; presence of acid sulfate soils and potential acid sulfate soils)
  f) ecological information (water system habitat, vegetation, fauna)
  g) availability of services and the accessibility of the site for passenger and freight transport.

2. Air

- Describe the topography and surrounding land uses. Provide details of the exact locations of dwellings, schools and hospitals. Where appropriate provide a perspective view of the study area such as the terrain file used in dispersion models.
- Describe surrounding buildings that may effect plume dispersion.
- Provide and analyse site representative data on following meteorological parameters:
  a) temperature and humidity
  b) rainfall, evaporation and cloud cover
  c) wind speed and direction
  d) atmospheric stability class
  e) mixing height (the height that emissions will be ultimately mixed in the atmosphere)

3. Noise and vibration

- Identify any noise sensitive locations likely to be affected by activities at the site, such as residential properties, schools, churches, and hospitals. Typically the location of any noise sensitive locations in relation to the site should be included on a map of the locality.
- Identify the land use zoning of the site and the immediate vicinity and the potentially affected areas.

4. Water

- Describe the catchment including proximity of the development to any waterways and provide an assessment of their sensitivity/significance from a public health, ecological and/or economic perspective. The Water Quality and River Flow Objectives on the website: www.environment.nsw.gov.au/ieo should be used to identify the agreed environmental values and human uses for any affected waterways. This will help with the description of the local and regional area.

5. Soil Contamination Issues

- Provide details of site history – if earthworks are proposed, this needs to be considered with regard to possible soil contamination, for example if the site was previously a landfill site or if irrigation of effluent has occurred.

D Identification and prioritisation of issues / scoping of impact assessment

- Provide an overview of the methodology used to identify and prioritise issues. The methodology should take into account:
  a) relevant NSW government guidelines
  b) industry guidelines
  c) EISs for similar projects
  d) relevant research and reference material
  e) relevant preliminary studies or reports for the proposal
  f) consultation with stakeholders.
- Provide a summary of the outcomes of the process including:
  a) all issues identified including local, regional and global impacts (e.g increased/ decreased greenhouse emissions)
  b) key issues which will require a full analysis (including comprehensive baseline assessment)
  c) issues not needing full analysis though they may be addressed in the mitigation strategy
  d) justification for the level of analysis proposed (the capacity of the proposal to give rise to high concentrations of pollution compared with the ambient environment or environmental outcomes is an important factor in setting the level of assessment).

E The environmental issues

1. General

- The potential impacts identified in the scoping study need to be assessed to determine their significance, particularly in terms of achieving environmental outcomes, and minimising environmental pollution.
- Identify gaps in information and data relevant to significant impacts of the proposal and any actions proposed to fill those information gaps so as to enable development of appropriate management and mitigation measures. This is in accordance with ESD requirements.

Note: The level of detail should match the level of importance of the issue in decision making which is dependent on the environmental risk.

Describe baseline conditions

- Provide a description of existing environmental conditions for any potential impacts.

Assess impacts

- For any potential impacts relevant for the assessment of the proposal provide a detailed analysis of the impacts of the proposal on the environment including the cumulative impact of the proposal on the receiving environment especially where there are sensitive receivers.
- Describe the methodology used and assumptions made in undertaking this analysis (including any modelling or monitoring undertaken) and indicate the level of confidence in the predicted outcomes and the resilience of the environment to cope with the predicted impacts.
- The analysis should also make linkages between different areas of assessment where necessary to enable a full assessment of environmental impacts eg assessment of impacts on air quality will often need to draw on the analysis of traffic, health, social, soil and/or ecological systems impacts; etc.
- The assessment needs to consider impacts at all phases of the project cycle including: exploration (if relevant or significant), construction, routine operation, start-up operations, upset operations and decommissioning if relevant.
- The level of assessment should be commensurate with the risk to the environment.

Describe management and mitigation measures

- Describe any mitigation measures and management options proposed to prevent, control, abate or mitigate identified environmental impacts associated with the proposal and to reduce risks to human health and prevent the degradation of the environment. This should include an assessment of the effectiveness and reliability of the measures and any residual impacts after these measures are implemented.
- Proponents are expected to implement a 'reasonable level of performance' to minimise environmental impacts. The proponent must indicate how the proposal meets reasonable levels of performance. For example, reference technology based criteria if available, or identify good practice for this type of activity or development. A 'reasonable level of performance' involves adopting and implementing technology and management practices to achieve certain pollutant emissions levels in economically viable operations. Technology-based criteria evolve gradually over time as technologies and practices change.
- Use environmental impacts as key criteria in selecting between alternative sites, designs and technologies, and to avoid options having the highest environmental impacts.

- Outline any proposed approach (such as an Environmental Management Plan) that will demonstrate how commitments made in the EIS will be implemented. Areas that should be described include:

  a) operational procedures to manage environmental impacts

  b) monitoring procedures

  c) training programs

  d) community consultation

  e) complaint mechanisms including site contacts

  f) strategies to use monitoring information to improve performance

  g) strategies to achieve acceptable environmental impacts and to respond in event of exceedences.

4. Air

Describe baseline conditions

- Provide a description of existing air quality and meteorology, using existing information and site representative ambient monitoring data. This description should include the following parameters:

  a) PM10 (24-hour and annual average)

  b) total suspended particulates

  c) deposited dust impacts.

Assess impacts

- Identify all pollutants of concern and estimate emissions by quantity (and size for particles), source and discharge point.
- Estimate the resulting ground level concentrations of all pollutants. Where necessary (e.g. potentially significant impacts and complex terrain effects), use an appropriate dispersion model to estimate ambient pollutant concentrations. Discuss choice of model and parameters with the EPA.
- Describe the effects and significance of pollutant concentration on the environment, human health, amenity and regional ambient air quality standards or goals.
- Describe the contribution that the development will make to regional and global pollution, particularly in sensitive locations.

  Note: With dust and odour, it may be possible to use data from existing similar activities to generate emission rates.

- Reference should be made to relevant guidelines e.g. *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2001); *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW* (DEC, 2007); *Load Calculation Protocol for use by holders of NSW Environment Protection Licences when calculating Assessable Pollutant Loads* (DECC, 2009).

Describe management and mitigation measures

- Outline specifications of pollution control equipment (including manufacturer's performance guarantees where available) and management protocols for both point and fugitive emissions. Where possible, this should include cleaner production processes.

5. Noise and vibration

Describe baseline conditions

- Determine the existing background (LA90) and ambient (LAeq) noise levels in accordance with the *NSW Industrial Noise Policy*.
- Determine the existing road traffic noise levels in accordance with the *NSW Road Noise Policy*, where road traffic noise impacts may occur.
- The noise impact assessment report should provide details of all monitoring of existing ambient noise levels including:
  a) details of equipment used for the measurements
  b) a brief description of where the equipment was positioned
  c) a statement justifying the choice of monitoring site, including the procedure used to choose the site, having regards to the definition of 'noise sensitive locations(s)' and 'most affected locations(s)' described in Section 3.1.2 of the *NSW Industrial Noise Policy*
  d) details of the exact location of the monitoring site and a description of land uses in surrounding areas
  e) a description of the dominant and background noise sources at the site
  f) day, evening and night assessment background levels for each day of the monitoring period
  g) the final Rating Background Level (RBL) value
  h) graphs of the measured noise levels for each day should be provided
  i) a record of periods of affected data (due to adverse weather and extraneous noise), methods used to exclude invalid data and a statement indicating the need for any re-monitoring under Step 1 in Section B1.3 of the *NSW Industrial Noise Policy*
  j) determination of LAeq noise levels from existing industry.

Assess impacts

- Determine the project specific noise levels for the site. For each identified potentially affected receiver, this should include:
  a) determination of the intrusive criterion for each identified potentially affected receiver
  b) selection and justification of the appropriate amenity category for each identified potentially affected receiver
  c) determination of the amenity criterion for each receiver
  d) determination of the appropriate sleep disturbance limit.
- Maximum noise levels during night-time period (10pm-7am) should be assessed to analyse possible affects on sleep. Where LA1(1min) noise levels from the site are less than 15 dB above the background LA90 noise level, sleep disturbance impacts are unlikely. Where this is not the case, further analysis is required. Additional guidance is provided in Appendix B of the *NSW Road Noise Policy*.
- Determine expected noise level and noise character (e.g tonality, impulsiveness, vibration, etc) likely to be generated from noise sources during:
  a) site establishment
  b) construction
  c) operational phases

d) transport including traffic noise generated by the proposal

e) other services.

Note: *The noise impact assessment report should include noise source data for each source in 1/1 or 1/3 octave band frequencies including methods for references used to determine noise source levels. Noise source levels and characteristics can be sourced from direct measurement of similar activities or from literature (if full references are provided).*

- Determine the noise levels likely to be received at the most sensitive locations (these may vary for different activities at each phase of the development). Potential impacts should be determined for any identified significant adverse meteorological conditions. Predicted noise levels under calm conditions may also aid in quantifying the extent of impact where this is not the most adverse condition.
- The noise impact assessment report should include:
  a) a plan showing the assumed location of each noise source for each prediction scenario
  b) a list of the number and type of noise sources used in each prediction scenario to simulate all potential significant operating conditions on the site
  c) any assumptions made in the predictions in terms of source heights, directivity effects, shielding from topography, buildings or barriers, etc
  d) methods used to predict noise impacts including identification of any noise models used. Where modelling approaches other than the use of the ENM or SoundPlan computer models are adopted, the approach should be appropriately justified and validated
  e) an assessment of appropriate weather conditions for the noise predictions including reference to any weather data used to justify the assumed conditions
  f) the predicted noise impacts from each noise source as well as the combined noise level for each prediction scenario under any identified significant adverse weather conditions as well as calm conditions where appropriate
  g) for developments where a significant level of noise impact is likely to occur, noise contours for the key prediction scenarios should be derived
  h) an assessment of the need to include modification factors as detailed in Section 4 of the *NSW Industrial Noise Policy*.
- Discuss the findings from the predictive modelling and, where relevant noise criteria have not been met, recommend additional mitigation measures.
- The noise impact assessment report should include details of any mitigation proposed including the attenuation that will be achieved and the revised noise impact predictions following mitigation.
- Where relevant noise/vibration criteria cannot be met after application of all feasible and cost effective mitigation measures the residual level of noise impact needs to be quantified by identifying:
  a) locations where the noise level exceeds the criteria and extent of exceedence
  b) numbers of people (or areas) affected
  c) times when criteria will be exceeded
  d) likely impact on activities (speech, sleep, relaxation, listening, etc.)
  e) change on ambient conditions
  f) the result of any community consultation or negotiated agreement.
- For the assessment of existing and future traffic noise, details of data for the road should be included such as assumed traffic volume; percentage heavy vehicles by time of day; and details of the calculation process. These details should be consistent with any traffic study carried out in the EIS.

- Where blasting is intended an assessment in accordance with the *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration* (ANZECC, 1990) should be undertaken. The following details of the blast design should be included in the noise assessment:
    a) bench height, burden spacing, spacing burden ratio
    b) blast hole diameter, inclination and spacing
    c) type of explosive, maximum instantaneous charge, initiation, blast block size, blast frequency.

Describe management and mitigation measures

- Determine the most appropriate noise mitigation measures and expected noise reduction including both noise controls and management of impacts for both construction and operational noise. This will include selecting quiet equipment and construction methods, noise barriers or acoustic screens, location of stockpiles, temporary offices, compounds and vehicle routes, scheduling of activities, etc.
- For traffic noise impacts, provide a description of the ameliorative measures considered (if required), reasons for inclusion or exclusion, and procedures for calculation of noise levels including ameliorative measures. Also include, where necessary, a discussion of any potential problems associated with the proposed ameliorative measures, such as overshadowing effects from barriers. Appropriate ameliorative measures may include:
    a) use of alternative transportation modes, alternative routes, or other methods of avoiding the new road usage
    b) control of traffic (e.g: limiting times of access or speed limitations)
    c) resurfacing of the road using a quiet surface
    d) use of (additional) noise barriers or bunds
    e) treatment of the façade to reduce internal noise levels buildings where the night-time criteria is a major concern
    f) more stringent limits for noise emission from vehicles (i.e. using specially designed 'quite' trucks and/or trucks to use air bag suspension
    g) driver education
    h) appropriate truck routes
    i) limit usage of exhaust breaks
    j) use of premium muffles on trucks
    k) reducing speed limits for trucks
    l) ongoing community liaison and monitoring of complaints
    m) phasing in the increased road use.

4. Water

Describe baseline conditions

- Describe existing surface and groundwater quality – an assessment needs to be undertaken for any water resource likely to be affected by the proposal and for all conditions (e.g. a wet weather sampling program is needed if runoff events may cause impacts).

  Note: *Methods of sampling and analysis need to conform with an accepted standard (e.g. Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC 2004) *or be approved and analyses undertaken by accredited laboratories).*

- Provide site drainage details and surface runoff yield.
- State the ambient Water Quality and River Flow Objectives for the receiving waters. These refer to the community's agreed environmental values and human uses endorsed by the Government as goals for the ambient waters. These environmental values are published on the website: www.environment.nsw.gov.au/ieo. The EIS should state the environmental values listed for the catchment and waterway type relevant to your proposal. NB: A consolidated and approved list of environmental values are not available for groundwater resources. Where groundwater may be affected the EIS should identify appropriate groundwater environmental values and justify the choice.
- State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC 2000 *Guidelines for Fresh and Marine Water Quality* (Note that, as at 2004, the NSW Water Quality Objectives booklets and website contain technical criteria derived from the 1992 version of the ANZECC Guidelines. The Water Quality Objectives remain as Government Policy, reflecting the community's environmental values and long-term goals, but the technical criteria are replaced by the more recent ANZECC 2000 Guidelines). (http://www.environment.gov.au/resource/australian-and-new-zealand-guidelines-fresh-and-marine-water-quality-volume-1-guidelines).

  NB: While specific guidelines for groundwater are not available, the ANCECC 2000 Guidelines endorse the application of the trigger values and decision trees as a tool to assess risk to environmental values in groundwater

- State any locally specific objectives, criteria or targets, which have been endorsed by the government e.g. the Healthy Rivers Commission Inquiries (http://www.nrc.nsw.gov.au/Default.aspx) or the NSW Salinity Strategy (DLWC, 2000):

  (http://www.environment.nsw.gov.au/salinity/government/nswstrategy.htm).

- Where site specific studies are proposed to revise the trigger values supporting the ambient Water Quality and River Flow Objectives, and the results are to be used for regulatory purposes (e.g. to assess whether a licensed discharge impacts on water quality objectives), then prior agreement from the EPA on the approach and study design must be obtained.
- Describe the state of the receiving waters and relate this to the relevant Water Quality and River Flow Objectives (i.e. are Water Quality and River Flow Objectives being achieved?). Proponents are generally only expected to source available data and information. However, proponents of large or high risk developments may be required to collect some ambient water quality / river flow / groundwater data to enable a suitable level of impact assessment. Issues to include in the description of the receiving waters could include:

  a) lake or estuary flushing characteristics

  b) specific human uses (e.g. exact location of drinking water offtake)

  c) sensitive ecosystems or species conservation values

  d) a description of the condition of the local catchment e.g. erosion levels, soils, vegetation cover, etc

e) an outline of baseline groundwater information, including, but not restricted to, depth to watertable, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment

f) historic river flow data where available for the catchment.

Assess impacts

- No proposal should breach clause 120 of the *Protection of the Environment Operations Act* 1997 (i.e. pollution of waters is prohibited unless undertaken in accordance with relevant regulations).
- Identify and estimate the quantity of all pollutants that may be introduced into the water cycle by source and discharge point including residual discharges after mitigation measures are implemented.
- Include a rationale, along with relevant calculations, supporting the prediction of the discharges.
- Describe the effects and significance of any pollutant loads on the receiving environment. This should include impacts of residual discharges through modelling, monitoring or both, depending on the scale of the proposal. Determine changes to hydrology (including drainage patterns, surface runoff yield, flow regimes, wetland hydrologic regimes and groundwater).
- Describe water quality impacts resulting from changes to hydrologic flow regimes (such as nutrient enrichment or turbidity resulting from changes in frequency and magnitude of stream flow).
- Identify any potential impacts on quality or quantity of groundwater describing their source.
- Identify potential impacts associated with geomorphological activities with potential to increase surface water and sediment runoff or to reduce surface runoff and sediment transport. Also consider possible impacts such as bed lowering, bank lowering, instream siltation, floodplain erosion and floodplain siltation.
- Identify impacts associated with the disturbance of acid sulfate soils and potential acid sulfate soils.
- Containment of spills and leaks shall be in accordance with the technical guidelines section 'Bunding and Spill Management' of the *Authorised Officers Manual* (EPA, 1995) (http://www.epa.nsw.gov.au/mao/bundingspill.htm) and the most recent versions of the Australian Standards referred to in the Guidelines. Containment should be designed for no-discharge.
- The significance of the impacts listed above should be predicted. When doing this it is important to predict the ambient water quality and river flow outcomes associated with the proposal and to demonstrate whether these are acceptable in terms of achieving protection of the Water Quality and River Flow Objectives. In particular the following questions should be answered:

  a) will the proposal protect Water Quality and River Flow Objectives where they are currently achieved in the ambient waters; and

  b) will the proposal contribute towards the achievement of Water Quality and River Flow Objectives over time, where they are not currently achieved in the ambient waters.
- Where a licensed discharge is proposed, provide the rationale as to why it cannot be avoided through application of a reasonable level of performance, using available technology, management practice and industry guidelines.
- Where a licensed discharge is proposed, provide the rationale as to why it represents the best environmental outcome and what measures can be taken to reduce its environmental impact.
- Reference should be made to relevant guidelines e.g. *Managing Urban Stormwater: Soils and Construction* (DECC, 2008), *Guidelines for Fresh and Marine Water Quality* ANZECC 2000).

Describe management and mitigation measures

- Outline stormwater management to control pollutants at the source and contain them within the site. Also describe measures for maintaining and monitoring any stormwater controls.

- Outline erosion and sediment control measures directed at minimising disturbance of land, minimising water flow through the site and filtering, trapping or detaining sediment. Also include measures to maintain and monitor controls as well as rehabilitation strategies.
- Describe waste water treatment measures that are appropriate to the type and volume of waste water and are based on a hierarchy of avoiding generation of waste water; capturing all contaminated water (including stormwater) on the site; reusing/recycling waste water; and treating any unavoidable discharge from the site to meet specified water quality requirements.
- Outline pollution control measures relating to storage of materials, possibility of accidental spills (e.g preparation of contingency plans), appropriate disposal methods, and generation of leachate.
- Describe hydrological impact mitigation measures including:
  a) site selection (avoiding sites prone to flooding and waterlogging, actively eroding or affected by deposition)
  b) minimising runoff
  c) minimising reductions or modifications to flow regimes
  d) avoiding modifications to groundwater.
- Describe groundwater impact mitigation measures including:
  a) site selection
  b) retention of native vegetation and revegetation
  c) artificial recharge
  d) providing surface storages with impervious linings
  e) monitoring program.
- Describe geomorphological impact mitigation measures including:
  a) site selection
  b) erosion and sediment controls
  c) minimising instream works
  d) treating existing accelerated erosion and deposition
  e) monitoring program.
- Any proposed monitoring should be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC 2004).

5. Soils and contamination

Describe baseline conditions

- Provide any details (in addition to those provided in the location description - Section C) that are needed to describe the existing situation in terms of soil types and properties and soil contamination.

Assess impacts

- Identify any likely impacts resulting from the construction or operation of the proposal, including the likelihood of:
  a) disturbing any existing contaminated soil
  b) contamination of soil by operation of the activity
  c) subsidence or instability

d) soil erosion

e) disturbing acid sulfate or potential acid sulfate soils.

- Reference should be made to relevant guidelines e.g. *Contaminated Sites – Guidelines for Consultants Reporting on Contaminated Sites* (OEH, 2011); *Contaminated Sites – Guidelines on Significant Risk of Harm from Contaminated Land and the Duty to Report* (EPA, 2003).

Describe management and mitigation measures

- Describe and assess the effectiveness or adequacy of any soil management and mitigation measures during construction and operation of the proposal including:

  a) erosion and sediment control measures

  b) proposals for site remediation – see *Managing Land Contamination, Planning Guidelines SEPP 55 – Remediation of Land* (Department of Urban Affairs and Planning and Environment Protection Authority, 1998)

  c) proposals for the management of these soils – see *Assessing and Managing Acid Sulfate Soils*, Environment Protection Authority, 1995 (note that this is the only methodology accepted by the EPA).

6. Waste and chemicals

Describe baseline conditions

- Describe any existing waste or chemicals operations related to the proposal.

Assess impacts

- Assess the adequacy of proposed measures to minimise natural resource consumption and minimise impacts from the handling, transporting, storage, processing and reprocessing of waste and/or chemicals.
- Reference should be made to relevant guidelines e.g. *Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes* (EPA, 1999).

Describe management and mitigation measures

- Outline measures to minimise the consumption of natural resources.
- Outline measures to avoid the generation of waste and promote the re-use and recycling and reprocessing of any waste.
- Outline measures to support any approved regional or industry waste plans.

7. Cumulative impacts

- Identify the extent that the receiving environment is already stressed by existing development and background levels of emissions to which this proposal will contribute.
- Assess the impact of the proposal against the long term air, noise and water quality objectives for the area or region.
- Identify infrastructure requirements flowing from the proposal (e.g water and sewerage services, transport infrastructure upgrades).

- Assess likely impacts from such additional infrastructure and measures reasonably available to the proponent to contain such requirements or mitigate their impacts (e.g travel demand management strategies).

F. List of approvals and licences

- Identify all approvals and licences required under environment protection legislation including details of all scheduled activities, types of ancillary activities and types of discharges (to air, land, water).

G. Compilation of mitigation measures

- Outline how the proposal and its environmental protection measures would be implemented and managed in an integrated manner so as to demonstrate that the proposal is capable of complying with statutory obligations under EPA licences or approvals (e.g outline of an environmental management plan).
- The mitigation strategy should include the environmental management and cleaner production principles which would be followed when planning, designing, establishing and operating the proposal. It should include two sections, one setting out the program for managing the proposal and the other outlining the monitoring program with a feedback loop to the management program.

H. Justification for the Proposal

- Reasons should be included which justify undertaking the proposal in the manner proposed, having regard to the potential environmental impacts.

ATTACHMENT B: GUIDANCE MATERIAL

Title	Web address
Relevant Legislation	
Contaminated Land Management Act 1997	http://www.legislation.nsw.gov.au/maintop/view/inforce/act+140+1997+cd+0+N
Environmentally Hazardous Chemicals Act 1985	http://www.legislation.nsw.gov.au/maintop/view/inforce/act+14+1985+cd+0+N
Environmental Planning and Assessment Act 1979	http://www.legislation.nsw.gov.au/maintop/view/inforce/act+203+1979+cd+0+N
Protection of the Environment Operations Act 1997	http://www.legislation.nsw.gov.au/maintop/view/inforce/act+156+1997+cd+0+N
Water Management Act 2000	http://www.legislation.nsw.gov.au/maintop/view/inforce/act+92+2000+cd+0+N
Licensing	
Guide to Licensing	www.epa.nsw.gov.au/licensing/licenceguide.htm
Air Issues	
Air Quality	
Approved methods for modelling and assessment of air pollutants in NSW (2005)	http://www.epa.nsw.gov.au/resources/air/ammodelling05361.pdf
POEO (Clean Air) Regulation 2010	http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+428+2010+cd+0+N
Noise and Vibration	
Interim Construction Noise Guideline (DECC, 2009)	http://www.epa.nsw.gov.au/noise/constructnoise.htm
Assessing Vibration: a technical guideline (DEC, 2006)	http://www.epa.nsw.gov.au/noise/vibrationguide.htm
Industrial Noise Policy Application Notes	http://www.epa.nsw.gov.au/noise/applicnotesindustnoise.htm
Environmental Criteria for Road Traffic Noise (EPA, 1999)	http://www.epa.nsw.gov.au/resources/noise/roadnoise.pdf
Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (DECC, 2007)	http://www.epa.nsw.gov.au/noise/railinfranoise.htm
Environmental assessment requirements for rail traffic-generating developments	http://www.epa.nsw.gov.au/noise/railnoise.htm

Waste, Chemicals and Hazardous Materials and Radiation	
Waste	
Environmental Guidelines: Solid Waste Landfills (EPA, 1996)	http://www.epa.nsw.gov.au/resources/waste/envguidlns/solidlandfill.pdf
Draft Environmental Guidelines - Industrial Waste Landfilling (April 1998)	http://www.epa.nsw.gov.au/resources/waste/envguidlns/industrialfill.pdf
Waste Classification Guidelines (DECC, 2009)	http://www.epa.nsw.gov.au/waste/envguidlns/index.htm
Resource recovery exemption	http://www.epa.nsw.gov.au/waste/RRecoveryExemptions.htm
Chemicals subject to Chemical Control Orders	
Chemical Control Orders (regulated through the EHC Act)	http://www.epa.nsw.gov.au/pesticides/CCOs.htm
National Protocol - Approval/Licensing of Trials of Technologies for the Treatment/Disposal of Schedule X Wastes - July 1994	Available in libraries
National Protocol for Approval/Licensing of Commercial Scale Facilities for the Treatment/Disposal of Schedule X Wastes - July 1994	Available in libraries
Water and Soils	
Acid sulphate soils	
Coastal acid sulfate soils guidance material	http://www.environment.nsw.gov.au/acidsulfatesoil/
Acid Sulfate Soils Planning Maps	http://www.environment.nsw.gov.au/acidsulfatesoil/riskmaps.htm
Contaminated Sites Assessment and Remediation	
Managing land contamination: Planning Guidelines – SEPP 55 Remediation of Land	http://www.planning.nsw.gov.au/assessingdev/pdf/gu_contam.pdf
Guidelines for Consultants Reporting on Contaminated Sites (EPA, 2000)	http://www.epa.nsw.gov.au/resources/clm/20110650consultantsglines.pdf
Guidelines for the NSW Site Auditor Scheme - 2nd edition (DEC, 2006)	http://www.epa.nsw.gov.au/resources/clm/auditorglines06121.pdf
Sampling Design Guidelines (EPA, 1995)	Available by request from EPA's Environment Line
National Environment Protection (Assessment of Site Contamination) Measure 1999 (or update)	http://www.scew.gov.au/nepms/assessment-site-contamination

Soils – general	
Managing land and soil	http://www.environment.nsw.gov.au/soils/landandsoil.htm
Managing urban stormwater for the protection of soils	http://www.environment.nsw.gov.au/stormwater/publications.htm
Landslide risk management guidelines	http://www.australiangeomechanics.org/resources/downloads/
Site Investigations for Urban Salinity (DLWC, 2002)	http://www.environment.nsw.gov.au/resources/salinity/booklet3siteinvestigationsforurbansalinity.pdf
Local Government Salinity Initiative Booklets	http://www.environment.nsw.gov.au/salinity/solutions/urban.htm
Water	
Water Quality Objectives	http://www.environment.nsw.gov.au/ieo/index.htm
ANZECC (2000) Guidelines for Fresh and Marine Water Quality	http://www.environment.gov.au/water/publications/quality/nwqms-guidelines-4-vol1.html
Applying Goals for Ambient Water Quality Guidance for Operations Officers – Mixing Zones	Contact the EPA on 131555
Approved Methods for the Sampling and Analysis of Water Pollutant in NSW (2004)	http://www.environment.nsw.gov.au/resources/legislation/approvedmethods-water.pdf

GOULBURN MULWAREE COUNCIL

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Contact: Louise Wakefield

12 May 2015

Elle Donnelley
A/Senior Planner
Resource Assessment, Planning Services
Department of Planning and Environment
GPO Box 39
SYDNEY NSW 2001

Dear Elle

Subject: Marulan South Limestone Mine Continuation Project (SSD 7009) Request for Input into Secretary's Requirements

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Further to a request from Department of Planning & Environment in relation to the above project, we provide the following comments for consideration:

Air Quality

Council requests that air quality impacts, particularly dust, are addressed in the environmental assessment and appropriate practices proposed to minimise the generation of dust from the operations and the potential impacts on surrounding properties.

Haulage Route

- The report indicates the project will not generate significant increase volume of finished products transported by road. Council requests that an environmental assessment includes specific estimated volumes, and the proposed management of potential road impacts should the rail link cannot be accessed or used for any period of time.

- An updated assessment of South Marulan Road as a B-double route is required. It should be noted that the current Goulburn Mulwaree Section 94 Development Contributions Plan 2009 states that "a pavement shall have a minimum remaining life of 10 years". The haulage route along Marulan South Road shall be investigated for this standard and rectified where deficient, noting that the minimum standard specified in the DCP involves a 7 metre sealed carriageway plus 1m shoulders (0.5m of which are sealed) each side.

- South Marulan Road is to be realigned and constructed in accordance with Council's Standards for Engineering Works 2013.

- Council requires details of the proposed annual verification method in relation to the actual loads using South Marulan Road.

- In accordance with Council's Section 94 Development Contributions Plan 2009, a contribution shall be made for the heavy vehicle movements. It is noted that the current (2014/15) rate is $0.0456 per tonne per kilometre, which shall be applied to the length along Marulan South Road.

Please contact me on (02) 48 234 480 if you require any further information.

Yours sincerely

Louise Wakefield
Director Planning & Development

NSW GOVERNMENT | Transport for NSW

Ms Elle Donnelley
A/Senior Planner
Resource Assessments
Planning Services
Department of Planning and Environment
GPO Box 39
Sydney NSW 2001

Request for SEARs for Marulan South Limestone Mine Continuation Project (SSD 7009)

Dear Ms Donnelley

Thank you for your email message dated 27 April 2015 requesting Transport for NSW (TfNSW) provide input into the Secretary's Environmental Assessment Requirements (SEARs) for Marulan South Limestone Mine Continuation Project.

TfNSW requests that the following information be included in the SEARs:

Transport - Rail

The EIS shall include a Traffic and Transport Impact Assessment that provides, but is not limited to, the following:

- Detail existing peak and daily train movements on the rail network located adjacent to the proposed development;
- Estimate additional daily and peak train movements (including size, configuration and frequency of trains) generated by the proposed expansion; and
- Include an assessment of the potential rail impacts of the proposed expansion on the capacity, efficiency and safety of the local and regional rail network, including railway crossings that would be impacted.

Traffic and Transport - Road

The EIS shall include a Traffic and Transport Impact Assessment that provides, but is not limited to, the following:

- Detail existing daily and peak hour vehicle movements on the road network located adjacent to the proposed development;
- Estimate daily and peak hour traffic generated from the proposed mine expansion (including vehicle type and the likely arrival and departure times) during construction and operation;
- Detail origin and destination of vehicle movements and haulage routes;

- Assessment and details of traffic, transport and safety impacts on intersection along the Hume Highway during construction and operation and how these impacts will be mitigated;
- Detail delivery, servicing and loading arrangements for the proposed mine expansion;
- Detail emergency vehicle access arrangement;
- Include an assessment for the access of Higher Productivity Vehicle movements to the mine (at a minimum PBS 2B combinations at Higher Mass Limits) in terms of ability to access the mine and surrounding roads, impact on road infrastructure (bridges and pavement) and potential increased road safety risks;
- Include a description and plans of any road upgrades required for the expansion; and
- Include detailed plans of the proposed layout of the internal road network and parking on site in accordance with the relevant Australian standards.

Planning Documents

The proposal needs to assess the proposal against the relevant provisions of the applicable environmental planning instruments and policies including:

- NSW Long Term Transport Master Plan
- Southern Regional Transport Plan

Guidelines

The proponent needs to review the following documentation for information and requirements and address any relevant issues:

- Guide to Traffic Generating Developments (RMS)
- Austroads Guide to Traffic Management Part 12: Traffic Impacts of Development
- Austroads Guide to Road Design

Consultation

During the preparation of the EIS, the proponent needs to consult with the following transport agencies:

- Roads and Maritime Services
- Transport for NSW

Should you have any questions regarding this matter, please contact Para Sangar, Senior Transport Planner on 8202 2672.

Yours sincerely

6/5/15

Mark Ozinga
Manager, Land Use Planning and Development
Planning and Programs

CD15/07300

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Ref: D201557963

Ms Elle Donnelly
A/Senior Planner Resources Assessments
Department of Planning & Environment
GPO Box 39
SYDNEY NSW 2001

Dear Ms Donnelly

Marulan South Limestone Mine Continuation Project (SSD 7009)
Request for Input into Secretary's Requirements

I refer to your email received 27 April 2015 seeking Water NSW's inputs into the Secretary's requirements for the continued operations of the Marulan South Limestone Mine. Water NSW appreciates the opportunity and offers the following comments for consideration.

The subject land is located in the Shoalhaven catchment which forms part of the water supply system for Sydney, the Illawarra and the Shoalhaven areas. Bungonia Creek is located less than 1km to the south and flows into the Shoalhaven River located approximately 1.5km to the south-east. Lake Yarrunga, one of Water NSW's water supply reservoirs, is located approximately 20km downstream.

The proximity of the site to Bungonia Creek and Shoalhaven River and any impacts on water quality and quantity from the proposed project are of concern to Water NSW. The EIS will need to demonstrate that the proposed measures to capture and treat water impacted by the proposal will have no impact on water quality within the Shoalhaven River. To address the above issues Water NSW recommends the following be included in the Secretary's requirements.

- As agreed with via correspondence from Department of Planning & Infrastructure (Ref qb 174202 dated 5 August 2011) the following be included as a standard Secretary's Requirement in the Drinking Water Catchment:

  "The EIS must assess potential risks to surface and groundwater quality during construction and operation, demonstrating clear consideration of the principle of achieving a neutral or beneficial effect on water quality in the drinking water catchment, consistent with the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011. The EIS must include a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation"
- A detailed description of those aspects of the project which have the potential to impact on the quality and quantity of surface and ground waters at and adjacent to the project. This should include:
  - the location, management and storage of all hazardous materials
  - the location of road crossings, unsealed roads and their proximity to watercourses
  - the location of and description of all water quality management measures
  - the location of and description of all water monitoring points (surface and ground waters).

- The surface water and groundwater assessment should also address the following matters:
    - pre-development and post development run off volumes and pollutant loads from the site
    - details of the measures to manage wastewaters associated with processing quarry materials, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied
    - details of how impacts associated with the diversion, storage or relocation of any watercourses will be managed and mitigated
    - details of how potential connections between waters within the quarry area will be separated from groundwater and external surface water
    - assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including implications from keeping the quarry void
    - details of the structural stability and integrity of all stormwater management measures including the structural stability and integrity of dams over the life of the project
    - details of the ongoing maintenance and monitoring of stormwater management measures including dams on the site
    - details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor and, if necessary, mitigate impacts on surface water and groundwater resources.
- Consider the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather.
- Consider the principles outlined in the 'Managing Urban Stormwater – Soils and Construction – Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008).
- Provide details of measured and predicted quarry performance with respect to water quality management since its commencement including details of any incidents.
- Provide concept plans/protocols/procedures for the following:
    - Environmental Management Plan
    - Soil and Water Management Plan – including triggers, actions, responses
    - Procedures for managing spills
    - Details of the practices proposed to ensure materials transported to and from the site do not spill or otherwise cause soil or water pollution
    - Post-quarrying rehabilitation Plan.

Water NSW notes that there are a number of large quarries operating in the Marulan area. These quarries have the potential to have a cumulative impact. Water NSW recommends the Secretary's requirements specifically address cumulative impacts with respect to water quality and water quantity.

It is requested that Water NSW be included as a stakeholder for the proposal. If a Planning Focus meeting is held Water NSW would like to be invited. Further, Water NSW would appreciate being notified when the Department has issued the Secretary's requirements.

If you wish to discuss this matter further please contact Jim Caddey on 4824 3401.

Malcolm Hughes

MALCOLM HUGHES
Senior Manager Planning & Environment

11/05/15

Planning Services
Resource Assessments
Contact: Genevieve Seed
Phone: 9228 6489
Email: genevieve.seed@planning.nsw.gov.au

Mr Rod Wallace
Planning & Development Manager
Boral Cement Pty Ltd
PO Box 42
WENTWORTHVILLE NSW 2148

Dear ~~Mr Wallace~~ Rod

Marulan South Limestone Mine Extension Project (SSD-7009)
Revised Secretary's Requirements

On 10 September 2015, the Commonwealth's Minister for the Environment determined the project to be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999.*

Under a bilateral agreement, the Commonwealth's Department of Environment has accredited the Department's State Significant Development assessment process for the project. Accordingly, the Department of Environment has provided its assessment requirements and these have been attached to, and form part of, the revised Secretary's requirements (Attachment 3).

I have enclosed a copy of the revised Secretary's environmental assessment requirements (SEARs) for the preparation of an Environmental Impact Statement (EIS) for the Marulan South Limestone Mine Extension Project.

If you have any enquiries about these requirements, please contact Genevieve Seed.

Yours sincerely

Howard Reed

Howard Reed 27.10.15
Director
Resource Assessments
As nominee of the Secretary

Guidelines for preparing Assessment Documentation relevant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Marulan South Limestone Mine Extension Project (EPBC 2015/7521)

1. On [date] it was determined that the Marulan South Limestone Mine Extension Project will impact upon the following matters of national environmental significance (MNES) protected under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*:

    – **threatened species and communities**.

2. The project will be assessed in accordance with the NSW Assessment Bilateral Agreement (2015). These guidelines do not stand alone but are a supplement to the Secretary's Environmental Assessment Requirements issued on 10 June 2015 and must be addressed in conjunction with these requirements. The Guidelines are intended there is sufficient information in the assessment report relevant to MNES such that the Commonealth decision-maker may make a determination on whether or not to approve the action.

3. The proponent must undertake an assessment of all the protected matters that may be impacted by the development under the controlling provision identified in Item 1. A list of protected matters that the Department of the Environment considered likely to be significantly impacted is provided at Attachment A to these Guidelines. Note that this may not be a complete list and it is the responsibility of the proponent to ensure any protected matters under this controlling provision, likely to be significantly impacted, are assessed for the Commonwealth decision-maker's consideration.

General Requirements

The EIS must address the following issues:

4. the precise location and description of all works to be undertaken (including associated offsite works and infrastructure), structures to be built or elements of the action that may have impacts on matters of national environmental significance (MNES).
5. an assessment of the likely impacts of the development on each EPBC Act-listed species and/or ecological community where there is likely to be a significant impact from the proposed development.

Key Issues – Biodiversity

6. The EIS must address the following issues in relation to Biodiversity including:

    – identification of all EPBC Act listed threatened species and community likely to be located in the project area or in the vicinity; and

    – identification of all EPBC Act listed threatened species and community likely to be significantly impacted by the development in accordance with the Matters of National Environmental Significance - Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999 (Significant Impact Guidelines).

7. For <u>each</u> of the relevant EPBC Act listed threatened species and community likely to be significantly impacted by the development the EIS must provide:

    – a description of the environment (including identification and mapping of suitable breeding habitat, suitable foraging habitat, important populations and habitat critical for survival), with consideration of, and reference to, any relevant Commonwealth guidelines and policy statements including listing advice, conservation advice and recovery plans;

- details of the scope, timing and methodology for studies or surveys used and how they are consistent with (or justification for divergence from) published Australian Government guidelines and policy statements; and
- specifically:
    i. identification and details of habitat critical for survival of the koala in accordance with the *EPBC Act referral guidelines for the vulnerable Koala* (Department of the Environment 2014) for both the impact site and any proposed offset site;
    ii. detailed mapping identifying the extent and quality of the EPBC Act listed critically endangered White Box-Yellow Box-Blakey's Red Gum Grassy Woodland and Derived Native Grasslands in accordance with the EPBC Act listing criteria and policy statement for that community for both the impact site and proposed offset site. [Note further guidance for mapping this EPBC Act listed community is provided at Attachment B]

Impacts

8. For <u>each</u> of the relevant EPBC Act listed threatened species and community likely to be significantly impacted by the development the EIS must provide a description of the impacts of the action having regard to the full national extent of the species or community's range including;

    - a detailed assessment of the extent, nature and consequence of the likely direct, indirect and consequential impacts – refer to the Significant Impact Guidelines for guidance on the various types of impact that need to be considered;
    - a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible; and
    - a description of any likely cumulative impacts, where potential project impacts are in addition to existing impacts of other activities (including known potential future expansions or developments by the proponent and other proponents in the region and vicinity).

Avoidance and mitigation

9. For <u>each</u> of the relevant EPBC Act listed threatened species and community likely to be significantly impacted by the development the EIS must provide information on proposed avoidance and mitigation measures to manage the relevant impacts of the action including:

    - a description of proposed avoidance and mitigation measures to deal with relevant impacts of the action;
    - assessment of the expected or predicted effectiveness of the mitigation measures, and
    - a description of the outcomes that the avoidance and mitigation measures will achieve.

10. For each of the relevant EPBC Act listed threatened species and community likely to be significantly impacted by the development the EIS must provide reference to, and consideration of relevant Commonwealth guidelines and policy statements including conservation advice, recovery plans, threat abatement plans and wildlife conservation plans.

[Note: the relevant guidelines and policy statements for each species and community are available from the Department of the Environment Species Profiles and Threats Database.
http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl]

Residual impacts and offsets

11. For each of the relevant EPBC Act listed threatened species and community likely to be significantly impacted by the development the EIS must provide:

    - identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account.
    - details of how the current published NSW Framework for Biodiversity Assessment (FBA) has been applied in accordance with the objects of the EPBC Act to offset significant residual adverse impacts;
    - details of the offset package to compensate for significant residual impacts including details of the credit profiles required to offset the development in accordance with the FBA and/or mapping and descriptions of the extent and condition of the relevant habitat and/or threatened communities occurring on proposed offset sites.

    [Note: For the purposes of approval under the EPBC Act, it is a requirement that offsets directly contribute to the ongoing viability of the specific protected matter impacted by a proposed action i.e. 'like for like'. In applying the FBA, residual impacts on EPBC Act listed threatened ecological communities must be offset with Plant Community Type(s) (PCT) that are ascribed to the specific EPBC listed ecological community. PCTs from a different vegetation class will not generally be acceptable as offsets for EPBC listed communities.]

12. Any significant residual impacts not addressed by the FBA may need to be addressed in accordance with the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offset Policy. http://www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy. [Note if the EPBC Act Environmental Offset Policy is used to calculate proposed offsets for a threatened species or community you may wish to seek further advice from the Department of Planning and Environment.]

Environmental Record of person proposing to take the action

13. The information provided must include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against the person proposing to take the action; and for an action for which a person has applied for a permit, the person making the application.

14. If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must also be included.

REFERENCES

1. *Environment Protect and Biodiversity Conservation Act 1999* - section 51-55, section 96A(3)(a)(b), 101A(3)(a)(b), section 136, section 527E
2. NSW Assessment Bilateral Agreement (2015) - Item 18.1, Item 18.5, Schedule 1
3. *Matters of National Environmental Significance - Significant impact guidelines 1.1* (2013) EPBC Act
4. *EPBC Act referral guidelines for the vulnerable Koala* (Department of the Environment, 2014)
5. *Environment Protect and Biodiversity Conservation Act 1999* Environmental Offsets Policy October 2012

Attachment A

The Department of the Environment's Environment Reporting Tool (ERT) identifies that 37 threatened species and communities may occur within 10 km of the proposed action. Based on the information in the referral documentation, the location of the action, species records and likely habitat present in the area, the Department of the Environment considers that there are likely to be significant impacts to:

- *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (critically endangered)
- Koala (*Phascolarctos cinereus)* (vulnerable)
- Greyheaded Flying Fox (*Pteropus poliocephalus)* (vulnerable)
- Large-eared Pied Bat (*Chalinolobus dwyeri)* (vulnerable)
- Regent Honeyeater (*Anthochaera phrygia*) (vulnerable)

The Department of the Environment considers their is some risk that there may be significant impacts on the following matters:

- Plumed-Midge-orchid (*Genoplesium plumosum) (*endangered)
- Wingless Raspwort (*Haloragis exelata subs. exalata) (*vulnerable*)*
- Contoneaster Pomaderris (*Pomaderris contoeaster)* (endangered)
- Macquarie Perch (*Macquaria australasica*) (endangered)

Attachment B

General Guidance on defining EPBC Act listed Box Gum Woodland

The EPBC Act listed *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* must be defined and mapped in accordance with the:

- *Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee (*Listing Advice*)* (May 2006); and
- *EPBC Act Policy Statement on White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

These documents are available at:

http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=43

Box Gum Woodland occurs as a **native understorey** with an **overstorey of eucalypts** and/or just as a **native understorey** where trees have been cleared.

1. In order to determine the extent of the Box Gum Woodland on a site, the **overstorey** and **understorey** across the whole of the project area must be assessed for the potential occurrence of the listed community.
2. A patch of Box Gum Woodland is a continuous area of predominantly **native understorey** (at least 50% of the perennial ground cover is made up of native species) that:
   - contains, or previously contained, White Box, Yellow Box or Blakely's Red Gum overstorey species;
   - contains somewhere in the patch, more than 12 native, non-grass species, and at least one important species;
   - does not include areas of other ecological communities such as woodlands dominated by other species.

Patches are not limited to those areas of higher floral diversity (i.e. where 12 or more native, non-grass species occur). Any native understorey that is continuous with those diverse areas, and not attributed to another ecological community, is considered to be part of the one patch and therefore listed Box Gum Woodland.

3. The patch is the larger of:
   - an area that contains five or more trees in which no tree is greater than 75 m from another tree, or
   - the area over which the understorey is predominantly native.

As understorey patches only need to be at a scale of 0.1 ha or greater, the landscape must be assessed at this scale.

If applying the NSW Framework for Biodiversity Assessment (FBA), you must include in the native vegetation extent map (FBA 4.1.14 and 5.1), any derived native grasslands with predominantly native vegetation cover (greater than 50%), to ensure potential listed Box Gum Woodland is not inadvertantly excluded at this stage of the process.

The whole area mapped as native vegetation extent must be assessed for patches of EPBC-listed Box Gum Woodland. It is advisable to identify potential areas of EPBC-listed Box Gum Woodland prior to identifying and mapping plant community types (PCTs) and vegetation zones.

To assist the regulators in verifying mapping, proponents must provide the data used to determine the presence/absence of Box Gum Woodland.

Planning Services
Resource Assessments

Contact: Lauren Evans
Phone: (02) 9274 6311
Email: lauren.evans@planning.nsw.gov.au

Rod Wallace
Planning & Development Manager
PO Box 6041
North Ryde NSW 2113

Dear Mr Wallace Rod

Marulan South Limestone Mine Extension Project (SSD 7009)
Environmental Assessment Requirements

I refer to your letter dated 6 September 2017, seeking the Department's agreement that the Secretary's Environment Assessment Requirements (SEARs) for the Marulan South Limestone Extension Project, issued on 10 June 2015, can be relied upon until 30 June 2018.

The Department understands that while this project has been delayed following a review of the proposed mine plan, the preparation of the EIS has now substantially progressed. The Department has reviewed the SEARs issued on 10 June 2015 and is satisfied that they can be relied upon for the completion of the EIS, provided the EIS is finalised and submitted by 30 June 2018. However, the current SEARs will be subject to the following adjustments:

- the Air Quality Assessment must be prepared in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016);
- under the transitional arrangements for the Department's *Social impact assessment guideline for State significant mining, petroleum production and extractive industry development* (2017), any EIS submitted on or after 8 March 2018 must follow the new guideline; and
- under the transitional provisions of the *Biodiversity Conservation (Savings and Transitional Regulation 2017*, any EIS submitted on or after 25 February 2019 must be prepared in accordance with Part 7 of the *Biodiversity Conservation Act 2016*.

If the EIS is not submitted by 30 June 2018, you will need to consult further with the Secretary.

If you have any further enquiries, please contact Lauren Evans.

Yours sincerely

Howard Reed

Howard Reed 8.9.17
Director
Resource Assessments
As nominee of the Secretary

Planning Services
Resource Assessments
Contact: Lauren Evans
Phone: (02) 9274 6311
Email: lauren.evans@planning.nsw.gov.au

Rod Wallace
Planning & Development Manager
Boral Property Group (NSW/ACT)
PO Box 6041
North Ryde NSW 2113

Dear Mr Wallace Rod

Marulan South Limestone Mine Extension Project (SSD 7009)
Environmental Assessment Requirements

I refer to your letter dated 21 June 2018, seeking the Department's agreement that the Secretary's Environment Assessment Requirements (SEARs) for the Marulan South Limestone Extension Project, issued on 10 June 2015, can be relied upon until 30 December 2018.

The Department previously granted an extension until 30 June 2018, following changes to the mine plan. The Department understands that the technical studies supporting the Environmental Impact Statement (EIS) have now been completed, with the exception of the Social Impact Assessment (SIA). The Department also understands that a further extension of time is required to allow community participation in the preparation of the SIA.

The Department has reviewed the SEARs issued on 10 June 2015 and is satisfied that they can be relied upon for the completion of the EIS, provided the EIS is finalised and submitted by 30 December 2018. However, the SEARs will be subject to the following adjustments:

- the Air Quality Assessment must be prepared in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016);
- the Noise Impact Assessment must be prepared in accordance with the *Noise Policy for Industry* (2017);
- the SIA must be prepared in accordance with the Department's *Social impact assessment guideline for State significant mining, petroleum production and extractive industry development* (2017); and
- under the transitional provisions of the *Biodiversity Conservation (Savings and Transitional Regulation 2017*, any EIS submitted on or after 25 February 2019 must be prepared in accordance with Part 7 of the *Biodiversity Conservation Act 2016*.

If the EIS is not submitted by 30 December 2018, you will need to consult further with the Secretary.

If you have any further enquiries, please contact Lauren Evans.

Yours sincerely

Howard Reed

Howard Reed 25·6·18
Director
Resource Assessments
As nominee of the Secretary

Appendix B

Quantity surveyor's report - Capital investment value

VOLUME 2

Quantity Surveyor's Report - Capital Investment Value

Marulan South Limestone Mine Continued Operations

For

Boral Cement Limited

DOCUMENT TITLE: QS Report – Capital Investment Value

ISSUE DATE: 14 December 2018

AltusExpertServices

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Quality Information

Document: QS Report - Capital Investment Value

Project No.: 71130.100788

Prepared By: Daniel Luk

DOCUMENT CONTROL:

Signature:	Date:	17 December 2018
	Reviewed by:	Stephen Ngai pp. Anthea Chang
	Prepare by:	Daniel Luk

CONTENTS

1. Introduction

Altus Group has been requested by Element Environment Pty Ltd on behalf of Boral Cement Limited to prepare a Quantity Surveyor's Report on the Capital Investment Value for proposed capital and recurring works at the Marulan South Limestone Mine Continued Operations as a State Significant Development.

2. Executive Summary

The estimated Capital Investment Value as at 14 December 2018 for the proposed capital and recurring works is $111,535,500.00 excluding GST.

The capital investment value has been assessed in accordance with the NSW Department of Planning – Planning Circular No. PS 10-008 dated 10 May 2010 under the Environmental Planning and Assessment Regulation 2000.

3. Project Scope

This Cost Estimate of Capital Investment Value is prepared for the proposed capital and recurring works at the Marulan South Limestone Mine Continued Operations for a period of 30 years and the scope of the capital and recurring works comprise the following:-

- Associated infrastructure works including construction of proposed Marulan Creek dam, water supply pipelines, site access roads, and relocation of power line and gas pipelines (to be progressively carried out during 30years).
- Major fixed plant replacement or upgrades (one-off).
- Mobile equipment replacement (over 30 years).

4. Basis of Cost Estimate

This Cost Estimate of the Capital Investment Value of the proposed capital works has been prepared based on the following information:-

- Summary of capital expenditure items for the project over 30 years life.

This preliminary cost estimate is priced at market rates for major civil engineering works on the basis of competitive lump sum tenders with escalation during the construction period included in the cost.

5. List of Exclusions

- Land costs and land acquisition costs.
- Interest/ Finance/ Legal Fees.
- License costs such as mining licenses, continuing use rights, purchase of water entitlement, etc.
- Operating costs for mining operation for limestone and shale other than overburden stripping above limestone.
- Works outside project boundaries.
- General inventory and consumables.
- Contingencies
- Future increase in costs from date of this estimate to date of actual commencement of construction works (Note: Cost estimate as at today's price. Majority of the project works will be progressively carried out over a period of 30 years).
- Goods and Service Tax (GST).

6. Summary of Cost Estimate

Capital Work Cost	
1. Annual Projects – Plant Improvement and Growth Projects	$26,603,500
2. Major Fixed Plant Replacement / Upgrades	$47,800,000
3. Mobile Equipment Replacement	$36,600,000
Estimated Total Construction Cost	**$111,003,500**
Other Costs	
4. Consultants and Authorities Fees (2% of Items 1)	$532,000
Estimated Capital Investment Value (excl. GST)	**$111,535,500**

Note: Please refer to Section 5 - List of Exclusions and cost estimate details in Appendix A – Cost Estimate Summary.

Appendix A – Cost Estimate Summary

Ref.	Description	Quantity	Unit	Rate	Total
	Cost Summary				
	Annual Projects - Plant Improvement and Growth Projects				26,603,500
	Major Fixed Plant Replacement/Upgrades				47,800,000
	Mobile Equipment Replacement				36,600,000
	Estimated Total Construction Cost (excl. GST)				**111,003,500**

Ref.	Description	Quantity	Unit	Rate	Total
	Annual Projects - Plant Improvement and Growth Projects				
	ASSOCIATED INFRASTRUCTURE				
	Water Supply				
	Construction of proposed Marulan Creek Dam (Budget Allowance)				
	Allow for stripping off existing vegetation and trees. (approx. area 210,000m2)	1	Item	55,000	55,000
	Allow for stripping off topsoil layer, including temporary stockpiling for future re-sue and spreading. (approx area 210,000)	1	Item	85,000	85,000
	Allow for excavation and earhtwwork for dam site and dam wall site	1	Item	1,850,000	1,850,000
	Allow for constructing embankment with cut-off trench at base	1	Item	3,631,000	3,631,000
	Allow for forming spillway and channels at end of embankment	1	Item	1,050,000	1,050,000
	Allow for drainage pipework for trickle flows from dam	1	Item	205,000	205,000
	Allow for siter restoration to surfaces of embankment with topsoil and grass cover	1	Item	258,000	258,000
	Allow for construction of new roads and road paving at top of embankment, including removal and upgrade of existing road	1	Item	1,290,000	1,290,000
	Allow for environmental monitoring	1	Item	70,000	70,000
	Allow for miscellaneous items such as fencing, safety barriers, concrete work, geotextile lining, etc	1	Item	256,000	256,000
	Alllow for preliminaries and margin (20%)	1	Item	1,750,000	1,750,000
	Allow for engineering and contingencies (20%)	1	Item	2,100,000	2,100,000
	Subtotal				12,600,000
	Additional cost for construction of Marual Creek Dam Wall, including pumping stations, raisgin of railway line and vehcial access track	1	item	2,100,000	2,100,000
	Other Water Supply Works				
	Allow for supply and lay of supply pipes from the proposed dam connectiong to the adjoining Tallong water pipeline	1	Item	300,000	300,000
	Allow for remediation of water supply pipeline from Tallong (allow 7,400m length)	1	Item	450,000	450,000
	Allow for construction of groundwater extraction bores for water supply sources	1	Item	375,000	375,000

Ref.	Description	Quantity	Unit	Rate	Total
	Annual Projects - Plant Improvement and Growth Projects				
	Note: Cost of purchase of water entitlements excluded		Note		
	Site Access Roads				
	Construction of proposed re-alignment of Marulan South Road, allow 6.0m wide	1,164	m	900	1,047,600
	Construction of new access road to proposed Muralan Creek Dam, allow 6.0m wide	1,231	m	900	1,107,900
	Construction of internal link road within mine, allow 6.0m wide	5,650	m	420	2,373,000
	Additional cost for Marulan South Road Realignment	1	item	3,800,000	3,800,000
	Additional cost for widening of pavement in narrower sections of Marulan South Road	1	item	800,000	800,000
	Electricity				
	Allow for relocating sections of the power lines located on Boral's property	1	Item	500,000	500,000
	Additional cost for relocation of HV power lines	1	item	800,000	800,000
	Gas				
	Allow for relocating or burying sections of the gas pipelines located on Boral's property	1	Item	350,000	350,000
	Annual Projects - Plant Improvement and Growth Projects TOTAL (Excl GST)				**26,603,500**
	Major Fixed Plant Replacement/Upgrades				
	Major Fixed Plant Replacement /Upgrade				
	Note: The following major fixed plant is to be replaced or upgrades within a period of 30 years				
	Replace existing crusher feed system with new , comprising primary and secondary crushing. screening, filtering and separation plant, etc - capital budget allowance	1	Item	24,000,000	24,000,000
	Allow for removal of existing plant	1	Item		Included
	Allow for associated builders works	1	Item		Included
	Relocate stockpile conveyors, including replacement with new as required - capital budget allowance	1	Item	17,800,000	17,800,000
	Allow for removal of existing stockpile conveyors	1	Item		Included
	Allow for associated builders works	1	Item		Included
	Electrical switchgear upgrade projects - capital budget allowance	1	Item	6,000,000	6,000,000

Ref.	Description	Quantity	Unit	Rate	Total
	Major Fixed Plant Replacement/Upgrades				
	Allow for removal and decomission of existing electrical switchgear	1	Item		Included
	Allow for associated builders works	1	Item		Included
	Major Fixed Plant Replacement/Upgrades TOTAL (Excl GST)				**47,800,000**
	Mobile Equipment Replacement				
	Mobile Equipment Replacement				
	Note: The following mobile equipment is to be replaced within a period of 30 years				
	Front End Loaders				
	Capital budget allowance for front end loaders comprising the following:				
	Cat 993K Front end loader	1	Item	12,000,000	12,000,000
	Cat 992G Front end loader	1	Item		Included
	Cat 988 Front end loader	1	Item		Included
	Komatsu WA 800-3 Front end loader	1	Item		Included
	Komatsu WA 100-3 Front end loader	1	Item		Included
	Subtotal				12,000,000
	Haul Trucks				
	Capital budget allowance for haul trucks comprising the following:				
	Cat 777D haul trucks	1	Item	14,400,000	14,400,000
	Cat 777C haul trucks	1	Item		Included
	Cat 111B haul truck	1	Item		Included
	Cat 250D Articulated dump truck	1	Item		Included
	Subtotal				14,400,000
	Excavators				
	Capital budget allowance for excavators comprising the following:				
	Cat 245 Excavator/ Rock breaker	1	Item	3,000,000	3,000,000
	Cat 432D Backhoe	1	Item		Included
	Liebherr R984 Excavator	1	Item		Included
	Atlas Copco LM800 Drill Rig	1	Item		Included
	Terex GUBEX QXR Drill Rig	1	Item		Included

Ref.	Description	Quantity	Unit	Rate	Total
	Mobile Equipment Replacement				
	Subtotal				3,000,000
	Graders				
	Capital budget allowance for graders comprising the following:				
	Komatsu 12 Grader	1	Item	1,400,000	1,400,000
	Subtotal				1,400,000
	Trucks				
	Capital budget allowance for trucks comprising the following:				
	Cat 773 Water Cart	1	Item	2,000,000	2,000,000
	Service Truck	1	Item		Included
	Explosives mixing and handling truck	1	Item		Included
	Subtotal				2,000,000
	Others				
	Capital budget allowance for others comprising the following:				
	Tandano 25t Crane	1	Item	3,800,000	3,800,000
	Mustang Bobcat	1	Item		Included
	Fork lifts	1	Item		Included
	4WD light vehicles	1	Item		Included
	Subtotal				3,800,000
	Mobile Equipment Replacement TOTAL (Excl GST)				**36,600,000**

Cement Division BORAL

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23rd March 2016

Employment Forecast for Marulan South Limestone Mine Continued Operations

This operation currently engages permanent employees, contractors and casual employees directly on the mine as well as other employees working as a result of activities within the operation, these relate to such things as logistics, technical, sales, etc.

Currently there are approximately 118 permanent employees engaged directly in the Marulan Lime and Limestone operations.

There are up to a further 75 employees indirectly engaged through the activities of the Lime and Limestone operations.

It is anticipated that this number of employees engaged is likely to remain fairly static unless there are significant changes in market demands in which case the manning levels will be adjusted accordingly.

These levels are otherwise likely to fluctuate through Continuous Improvement activities which may result in different manpower requirements.

Girish Yadwad
National General Manager Operations
Boral Cement

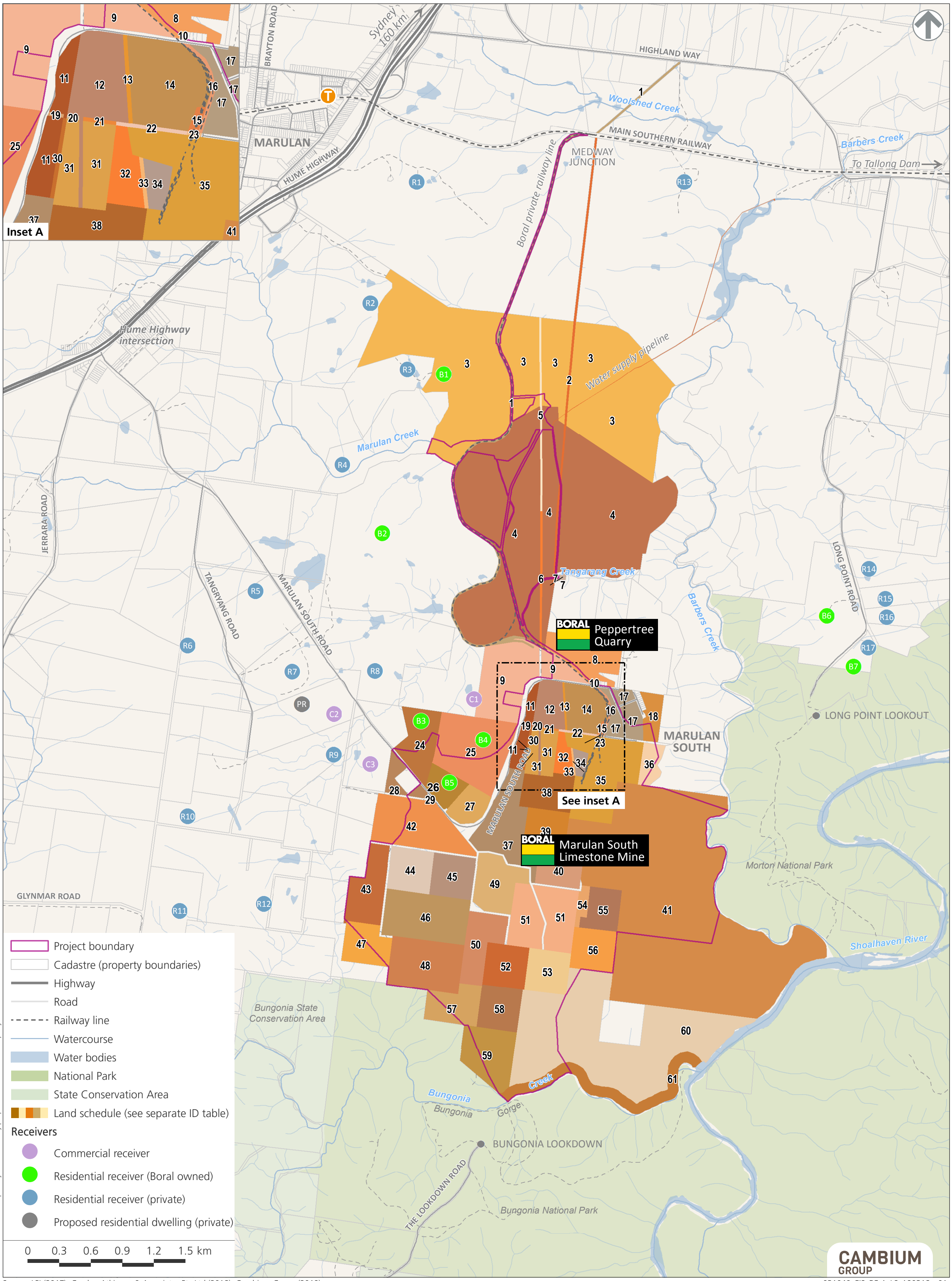
Appendix C

Schedule of lands

VOLUME 2

Figure C.1
Land schedule

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2019).

031040_EIS_FC-1_LS_190318_v01

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
LAND SCHEDULE_181217_v03

Boundary	version	Label	Lot Number	Plan Number	Category	Land Onwership
Project_boundary	180806_v13	1	1	1124189	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	2	2	1124189	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	3	12	881240	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	4	23	867667	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	5	3	203290	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	6	4	203290	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	7	282	750029	CROWN	Crown Land
Project_boundary	180806_v13	8	24	867667	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	9	22	867667	FREEHOLD	Boral Limited/Boral Cement Limited*
Project_boundary	180806_v13	10	1	261615	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	11	1	860561	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	12	2	860561	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	13	1	106569	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	14	2	527500	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	15	1	527500	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	16	2	106569	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	17	100	1064794	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	18	12	570616	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	19	16	111641	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	20	14	111641	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	21	15	111641	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	22	7	111641	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	23	6	111641	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	24	111	830458	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	25	114	830458	FREEHOLD	Boral Limited
Project_boundary	180806_v13	26	112	830458	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	27	113	830458	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	28	2	1186554	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	29	1	617992	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	30	9	111645	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	31	1	132244	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	32	2	132244	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	33	3	106569	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	34	3	527501	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	35	4	106569	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	36	21	657523	FREEHOLD	Boral Resources (NSW) Pty Ltd
Project_boundary	180806_v13	37	3	617992	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	38	114	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	39	82	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	40	132	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	41	7300	1149129	CROWN	Crown Land
Project_boundary	180806_v13	42	165	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	43	193	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	44	115	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	45	131	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	46	154	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	47	186	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	48	179	750029	FREEHOLD	Freehold
Project_boundary	180806_v13	49	156	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	50	197	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	51	83	750029	FREEHOLD	Freehold
Project_boundary	180806_v13	52	155	750029	FREEHOLD	Freehold
Project_boundary	180806_v13	53	87	750029	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	54	1701	610507	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	55	1702	610507	FREEHOLD	Boral Cement Limited
Project_boundary	180806_v13	56	98	750029	CROWN	Crown Land
Project_boundary	180806_v13	57	187	750029	FREEHOLD	Freehold
Project_boundary	180806_v13	58	191	750029	FREEHOLD	Freehold
Project_boundary	180806_v13	59	7302	1149129	CROWN	Crown Land
Project_boundary	180806_v13	60	7301	1149129	CROWN	Crown Land
Project_boundary	180806_v13	61	7303	1149129	CROWN	Crown Land

Land Ownership	Area within Project_boundary_180806_v13
Boral Cement Limited	411.25
Boral Limited	23.14
Boral Resources (NSW) Pty Ltd	47.06
Crown Land	236.61
Freehold	110.48
Undefined	17.8
Total	**846.34**

*Part owned by 2 entities - Boral Cement Limited owns railway portion?

Appendix D

Geological report

VOLUME 2

Marulan South Limestone Mine

Geological Report for DRE's input to SEARs

18th July 2018

Final version V4.3 (18th July 2018).

Report for
Boral Cement Limited

By
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MAusIMM CPGeo

GeoRes
Project
GR1807

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TABLES

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ABBREVIATIONS

AGE	Australasian Groundwater and Environmental Consultants Pty Ltd.
Al	Aluminium (element).
APC	Australian Portland Cement Ltd (merged with SPC in 1971/4)
APCM	Associated Portland Cement Manufacturers (Australia) Ltd.
AusIMM	The Australasian Institute of Mining and Metallurgy.
BCL	Boral Cement Limited.
BCSC	Blue Circle Southern Cement Ltd.
Ca	Calcium (element).
Drillit	Drillit Consulting Pty Ltd
DSD	Dave Shepherd Drive.
EL	Eastern Limestone.
EOH	‘End of hole’.
E/W/N/S	East/West/North/South.
Fe	Iron (element).
Gr	Granodiorite (Consultant’s abbreviation only used here).
JORC	Joint Ore Reserves Committee (of The Australasian Institute of Mining and Metallurgy).
LL	Mt Frome Lower Limestone.
L&M	Longworth & McKenzie Pty Ltd.
m	Metre (metric distance).
m^3	Cubic metre (metric volume).
Mg	Magnesium (element).
ML	Mt Frome Middle Limestone.
Mt	Million tonnes.
Mtpa	Million tonnes per annum (extraction rate).
NCD	New Competitive Drilling Pty Ltd.
%	Percent
pa	Per annum
PSM	Pells Sullivan Meynink (Engineering Consultants).
RC	Reverse circulation drilling method.
RGS	RGS Environmental.
RPS	RPS Group Plc.
ROM	‘Run of Mine’ ore.
Si	Silica (element).
SPC	Southern Portland Cement Ltd (merged with APC in 1971/4)
t	Tonne (metric weight).
tpa	Tonnes per annum (metric extraction rate).
t/m^3	Tonnes per cubic metre (a unit for metric density).
UL	Mt Frome Upper Limestone.
WT	Water table.

Exploration drilling phases:

P1	Phase 1 (mid 2016)
P2	Phase 2 (late 2016)
P3	Phase 3 (early 2017)

Limestone names:

EL	Eastern Limestone (Lookdown Limestone)
LL	Mt Frome Lower Limestone (Folly Point Limestone)
ML	Mt Frome Middle Limestone (“)
UL	Mt Frome Upper Limestone (“)

1 BACKGROUND

This document is prepared by Mr Robin Rankin, the Consulting Geologist (through his independent geological consultancy GeoRes) to Boral Cement Limited (BCL), in support of an Environmental Impact Statement (EIS) for the Marulan South Limestone Mine (the 'Mine'). This reporting was assigned GeoRes project number GR1807.

The document provides the **geological** and **Resource** information relating to the Division of Resources & Energy's (DRE) input to the *Secretary's Environmental Assessment R*equirements (**SEARs**) of the NSW Government's Department of Planning & Environment for proposed continuance of mine operations at the Marulan South Limestone Mine. The SEARs were to be addressed in BCL's EIS.

The SEARs were contained in a DRE document dated 14/5/2015 entitled ***Proposed Marulan South Limestone Mine Continued Operations (SSD 7009) – Request for input to Secretary's Environmental Assessment Requirements*** (reference V15/412, OUT15/11507) where the requirements were located at Tab A.

2 INTRODUCTION

This document answers the SEARs document requirements for **geological** and **Resource** information. To simplify navigation of this document the SEARs are referenced against this document's Sections in Table 1 in Section 1 below.

As the SEARs directly relate to the Consultant's recent geological work on the Mine since ~2015 his relevant background reports are listed in Section 2.2.

2.1 SEARS SECTION REFERENCES

The specific SEARs were detailed in a TAB A. They are tabulated in the left column of Table 1 below, with this document's Sections or comments referenced in the right column.

Table 1 SEAR's requirements with Section references

TAB A: Secretary's Environmental Assessment Requirements – Mining Proposals	This document reference
GEOLOGY The EIS:	Robin Rankin, June 2018 (Final V4.2) Geological Report for DRE's input to SEARs GeoRes project GR1807
• Is to include a brief description of the geological setting of the deposit.	Section 3 (particularly 3.2 and 3.3)
• Of importance is a description of the geology and mineralisation of the deposit itself. This should include specific details about; ○ The shape ○ Physical dimensions ○ Mineralogy ○ Ore mineral distribution for individual ore bodies/lenses	Sections 4, 5, 6 & 1. Figs 5 & 6 Sections 5.1, 5.2, 5.3 & 5.4. Figs 9 to 26 Sections 3.3.4, 3.3.5 and 5.1 Section 5.4 Section 1
• Supporting information including plans and cross-sections need to; ○ show the extent of the mineralised zones to be mined, and ○ those located adjacent/beneath planned mining voids which may be sterilised by planned activities, and ○ where this may impact on resource utilisation and planned final voids, information such as grade and width/tonnes needs to be included.	Section 1 provides plans and a representative selection of cross-sections fully illustrating the ore body in the mining area. Sterilization in the future will be set simply by the final pit depth determined from the mining economics.
• is to include whole rock, minor and trace element geochemistry of the ore, tailings and waste rock. (this information is often a key component in understanding the environmental effects of the proposal)	Sections 1 & 1
RESOURCE AND RESERVE STATEMENT The EIS:	
• is to include a resource/reserve statement appropriate to the type of deposit and based on a simple volume and/or quality estimation.	Sections 11.4 & 11.511.2
• needs to include an estimate of the grade ($CaCO_3$ %) of the limestone and should include an estimate of any lower-grade limestone to be mined.	Sections 6, 7.2 & 11.6
• needs to include a statement to at least an Indicated & Inferred level of confidence (equivalent to the JORC code) that covers the next major phase of mining of (probably about 7 years).	Sections 11.10 & 11.7
• also needs to include a volume estimate of clay/shale present within the previously stated 100Mt of overburden to be extracted to obtain an equivalent quantity of limestone, along with a statement regarding the lithology and nature of that material.	Section 11.11

2.2 BACKGROUND REPORTS

The document summarises geological information originally reported in detail to BCL in a number of documents on mine geology and exploration. The most recent and relevant documents include:

Rankin, R., 28 September 2015. *Marulan South limestone Mine – CML16 – Geology – for DRE*. Final version V4.2. Report referred to here as '2015 geology'.

Rankin, R., 1 August 2016. *Marulan South limestone Mine – Exploration drilling 2016 – Phase 1*. Final version V6. Report referred to here as '2016 exploration'.

Rankin, R., 19 February 2018. *Marulan South limestone Mine – Exploration drilling 2016/17 – Phases 1 to 3*. Final draft V2. Report referred to here as '2016/8 exploration'.

The 2015 geology document contains a full reference to all past reports directly or indirectly geologically related to the mine. A number of those references are included in Section 0 below.

The 2016 and 2018 exploration documents are internal Boral reports.

3 GEOLOGY

3.1 SEARS REQUIREMENTS

The EIS was to include a brief description of the geological setting of the deposit, including a description of the geology and mineralisation of the deposit. It would include details of the shape, dimensions, mineralogy and ore mineral distribution of the ore body(s).

3.2 REGIONAL GEOLOGICAL SETTING

Location: Marulan South Limestone Mine is located at Marulan South in the NSW Southern Tablelands. It is on the very edge of gently undulating topography and sharply incised valleys leading locally southwards down to the Bungonia Gorge and regionally within the catchment of the Shoalhaven River.

Regional geology: The following geological summary is mostly after L&M 1976 and Carr et al, 1983 (see References). It is partially updated from the Geo Survey 2012 explanatory notes for the 1:250,000 Goulburn sheet mapping (see References).

Marulan South is located within a geological province formed as part of the Capertree High structural zone within the state-wide Lachlan Fold Belt or geosyncline. It falls virtually on the border of the 1:250,000 Goulburn (W, 2012) and Wollongong (E, 1966) geological map sheets, being just slightly on the Wollongong sheet (or older Marulan and Bungonia sheets).

This SE region of NSW was characterised in the Palaeozoic era by widespread marine environments which lead to variable and complex thick sedimentary sequences (including formation of the limestones), volcanic associations, and tectonic activity. The resulting rocks were then subject to substantial erosion and weathering before further sedimentation encroached from the Sydney Basin to the north and east. Further subaerial erosion in the Mesozoic era then reduced the local land surface to one of low relief close to sea level. The Cainozoic era brought landscape altering basaltic eruptions followed in the Pliocene by a widespread episode of epeirogenic uplift which raised the tablelands to their current height. The elevation increase rejuvenated river systems and erosion, culminating in the deeply incised valleys surrounding the Mine and the Bungonia Gorge. This recent erosion uncovered and highlights the outcrops of ~N/S striking, west dipping, Palaeozoic limestone and sediments of the Bungonia Group (Sb).

3.3 LOCAL GEOLOGY

The local geological sequence is given in Figure 1 that replicates the legend for the Figure 2 1986 geological map by the NSW Geo Survey (Lishmund et al, 1986, Geological Survey of NSW report on limestone deposits of NSW). The particular map presented here is an earlier version of the Geo Survey map and was extracted from Blue Circle Southern Cement Ltd's (BCSC's) last geological map for the Mine compiled in 1979. BCSC was the Mine owner prior to Boral Cement Limited (BCL).

The 1986 Geo Survey rock name terminology is generally consistent with most Mine documents stretching back to the 1950s and consequently is used here for continuity.

However be aware that parts of the sequence have been re-named in the most recent 2012 Geo Survey mapping. The new names (with mapping abbreviations) are appended in italics after the 'older' names commonly used at the Mine in the sequence below.

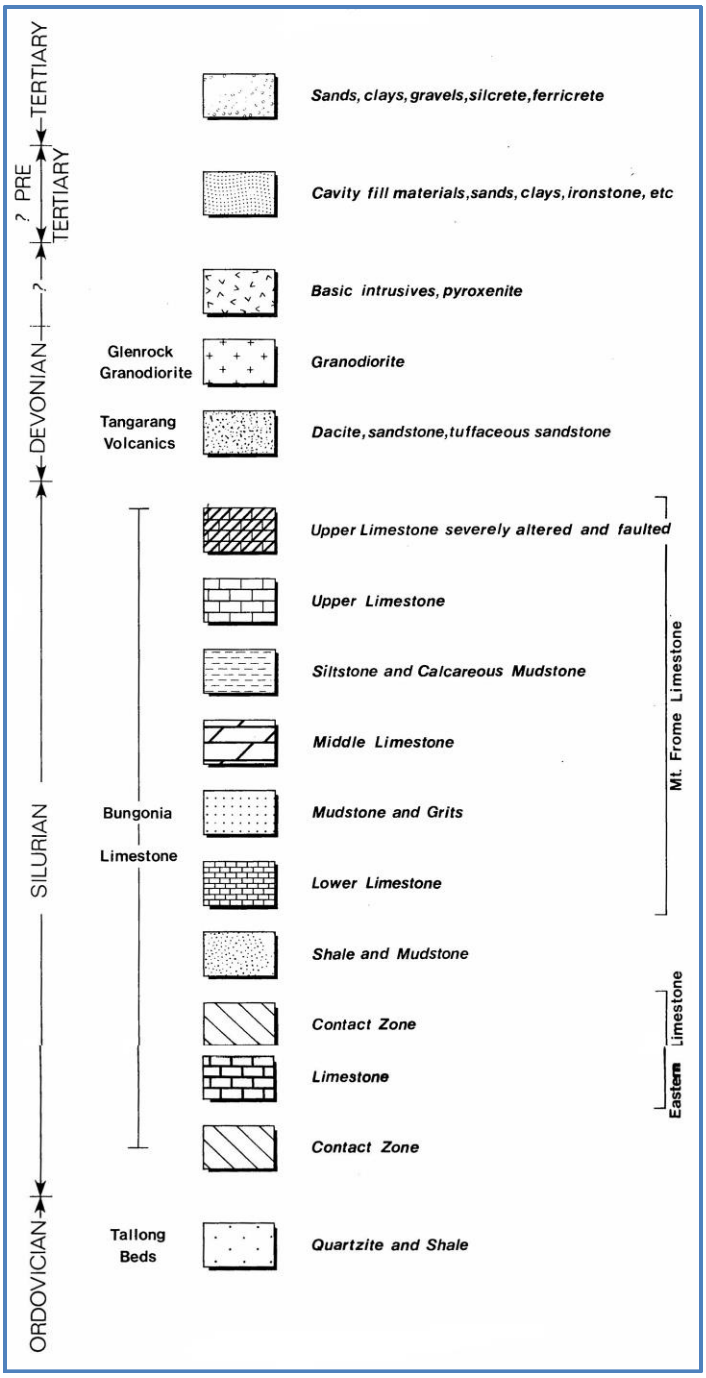
3.3.1 GEOLOGICAL SEQUENCE

The geological sequence at Marulan South contains four major components. They are listed below by increasing age (youngest at top) and (excluding the granodiorite intrusive which is located in the NE) by increasing easting (Tangerang Volcanics in the west to Tallong Beds in the east). The sequence is illustrated by the mapping legend in Figure 1.

- Glenrock Granodiorite: *(now 1 of 12 plutons of the Arthurslie Suite (Da))*
    - Granodiorite intrusive.

  - Located at the NE end of the mine limestone.
  - Intruding pluton from the Marulan batholith.
- Tangarang Volcanics: *(now Tangarang Formation (Dkt) of the Bindook Group (Dk))*
  - Volcanic and associated sedimentary rocks.
  - Located west of the mine limestone.
  - Dacite, sandstones, tuffs, tuffaceous sediments, ignimbrites, sandstones.
  - Intrusive unconformity at base (?).
- Bungonia Limestone Group: *(now "Bungonia Group" (Sb))*
  - Limestones interbedded with fine sediments.
  - Increasing age sequence going east:
    - Mt Frome Limestone: *(now Folly Point Limestone Member (Sbff) of the Frome Hill Formation (Sbf))*
      - Upper Limestone (furthest west).
      - Middle Limestone.
      - Lower Limestone (furthest east).
    - Eastern Limestone. *(now Lookdown Limestone Member (Sbcl), lower part of the Cardinal View Formation (Sbc))*
  - Mt Frome units relatively thin (generally <50 m horizontal width) with modern mining only recently commencing on the Middle Limestone.
  - Eastern Limestone relatively thick (generally 150 t0 250 m horizontal width) and overwhelmingly constituting the principal Mine Resource.
  - Roughly conformable progression.
  - Sequence average strike is **~020°** and typical (but not everywhere in limestone) dip is **~50-70° W**.
  - Very latest (1/2018) interpretation has the Eastern Limestone repeatedly cross-cut along strike (at least in the Mine pit area) by numerous ~E/W trending sub-vertical faults exhibiting off-sets and rotations. At least some of these faults extend west into the Mt Frome Limestone units.
  - Vertical fault/angular unconformity (contentious issue) at base of the Eastern Limestone along northern 2/3rds of pit.
- Tallong Beds: *(now "Abercrombie Formation (Oaa) of the Adaminaby Group" (Oa))*
  - Basement sediments.
  - Tightly and repeatedly folded.

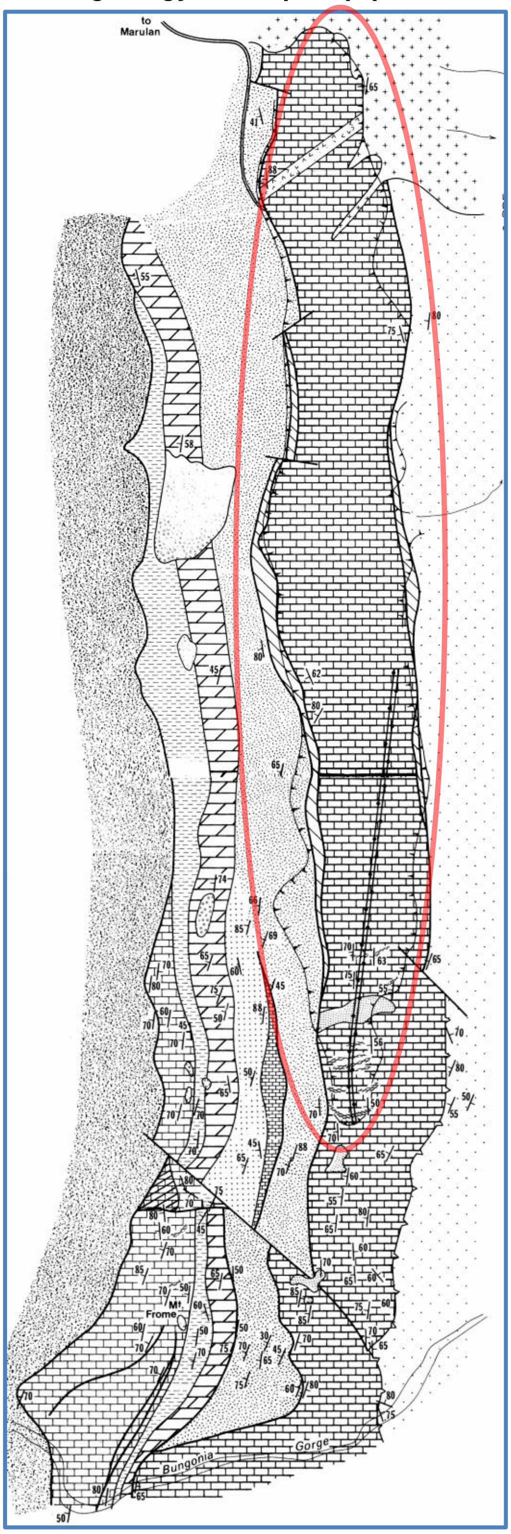
Figure 1 Local geology mapping legend (1986)



3.3.2 GEOLOGICAL MAPPING

Figure 2 maps the Mine area geology relating to the Figure 1 legend. The limestone bodies strike ~020° and the Figure has been rotated to have this 020° heading oriented to a local grid N/S (up and down page). The map covers ~3.5 km N/S and ~1 km E/W. Coordinates are missing from the map but it may be orientated from those given with Figure 8.

Figure 2 Local geology outcrop map (Geo Survey, 1986)



The Mine area is roughly within the red oval and is ~2.5 km long N/S. It principally targets the thick Eastern Limestone unit (on the right) from the where it is cut-off by the granodiorite in the north (very top of the Figure) down to east of the thickest part of the short Mt Frome Lower Limestone lens in the south.

The limestone sequence is considerably disrupted by a major NW/SE trending cross-cutting fault south of the Mine. The deep (400 m) Bungonia Gorge cuts ~E/W across the full sequence to the south (at the very bottom of the map). Limestones are also very prominent south of the gorge (below the Figure) and a prominent viewing platform on a high crest of the Eastern Limestone continuation is assumed to constitute the reason for the 2012 re-naming of the Eastern Limestone to the *Lookdown Limestone*. The platform affords a particularly clear view (looking N) of the limestone units and of the Mine itself.

3.3.3 Geological Description

At the base of the sequence (to the east) are fine grained sediments of the Tallong Beds. Most recent Geo Survey mapping has these in the *Abercrombie Formation (Oaa) of the Adaminaby Group*, and the name Tallong may simply reflect the locality (Tallong being just to the north of the Mine). Rock types include shales, siltstones, slates, cherts and quartzites. These are thinly bedded and tightly isoclinally folded.

The upper boundary of the Tallong Beds with the lowest limestone member of the Bungonia Limestone Group is apparently unconformable, but this is still possibly a contentious issue. For most of the northern and middle length of the Mine the eastern boundary is a fairly linear vertically faulted one. But for the southern end, and continuing south to the Bungonia Gorge and beyond, the boundary is an angular unconformity dipping west.

The Bungonia Limestone Group is the primary focus of this report. It's renaming to the *Bungonia Group*, and subdivision into an upper *Frome Hill Formation* (containing the previous Mt Frome Middle and Upper Limestones and bounding sediments) and a lower *Cardinal View Formation* (containing the Eastern Limestone and overlying sediments), began with Bauer in 1994. The current 2012 Geo Survey subdivision of its components is illustrated in Figure 3 (but not used further in this document).

Figure 3 Bungonia Group 2012 classification

Bungonia Group	Frome Hill Formation	
	Folly Point Limestone Member	
	Cardinal View Formation	
	Lookdown Limestone Member	

The **Eastern Limestone** (EL) *(now lower Lookdown Limestone Member of the Cardinal View Formation)* is the lowest (oldest) and thickest unit of the Bungonia Limestone Group. It is the unit predominantly being mined, and has also been known as the Lower or Main Limestone.

Above the Eastern Limestone (outcropping to the west) is the younger sub-parallel **Mt Frome Limestone** *(now part of the Frome Hill Formation)* which has also been known as the Upper or Western Limestone. Mt Frome exists as a pinnacle to the west of the southern end of the South Pit and was briefly mined in the past. The Mt Frome Limestone contains three sub-parallel sub-units – the Lower (LL), Middle (ML) and Upper (UL) Limestones from east to west and decreasing in age respectively. These only occur with any combined significant width south of the Mine, with the Lower petering out roughly adjacent to the southern end of the Mine. The Middle Limestone however does extend the full length of the Eastern Limestone and probably even a little further north. Although the mapping in Figure 2 shows the Upper Limestone also petering out not far north of the Lower Limestone it is now interpreted to extend further north, probably to at least adjacent to the middle of the Mine. Mining of Mt Frome Middle Limestone commenced in ~2016 from a section west of the central part of the existing Mine.

Conformably separating the limestones (within the Bungonia Group) are fine grained sediments – shales, mudstones, siltstones, and minor fine sandstones. Inter-bedded tuffs appear towards the upper parts of the Mt Frome sedimentary interbeds. Narrow sub-vertical mafic dykes sporadically cross-cut the EL and one in the south runs along strike roughly parallel to bedding.

Average horizontal dimensions of the limestone sequence are given within Section 3.3.4 and depth within Section 3.3.5.

Overlying (and outcropping to the west) the Bungonia Limestone Group apparently unconformably are the Tangarang Volcanics *(now Tangarang Formation of the Bindook Group)* containing dacite, quartzite, tuffaceous sandstones and ignimbrites. These rocks would be genetically related to tuffs found inter-fingered in upper sediments of the Bungonia Group.

The youngest rock (excluding minor thin mafic dykes and very patchy tertiary cover) is the Glenrock Granodiorite intruding and terminating the Eastern Limestone in the north and north east. This is a pluton of the Marulan Batholith.

3.3.4 LIMESTONE PACKAGE WIDTH

Total outcrop horizontal width of the Bungonia Limestone Group is ~670 m E/W and it has an ~580 m stratigraphic thickness (normal to the layering). Rough horizontal widths of the sequence members from east to west are:

- Eastern Limestone – average ~280 m (range 200-350 m).
  - Sediments – average ~150 m (range 100-250 m).
- Mt Frome Lower Limestone – average <50 m.
  - Sediments – average <100 m.
- Mt Frome Middle Limestone – average ~80 m (range 50-120 m).
  - Sediments – average ~120 m (range 100-150 m).
- Mt Frome Upper Limestone – average ~50 m (range 50-100 m (but much thicker south of Mt Frome)).

3.3.5 LIMESTONE PACKAGE DEPTH

The actual true depth of the Bungonia Limestone is not known as it is not visible (either in the Mine or at the bottom of the Bungonia Gorge). To date even the deepest drill holes (~300 m) along both pits in the Mine have ended in limestone. It is vertically present over at least 450 m going on the exposure in the depths of Bungonia Gorge at ~175 m RL and at the top of the north wall of the North Pit at ~600 m RL. Similarly the depth of the intruding granodiorite at the limestone NE contact is not known.

4 MINE

Mining at the Marulan South Limestone Mine is by conventional truck and loader or excavator in a benched open cut. Benches are typically 15 m high. The limestone requires blasting, the overburden and interburden typically does not. Ore is crushed and stockpiled within the pit rim at the very north and then transferred by conveyors to the plant immediately north of the pit. Overburden is currently trucked to the 'Western Overburden Emplacements' via a haul road leading west from adjacent to the middle of the pit. Figure 4 shows the Mine (~ 2 km long N/S) in perspective view (looking downwards towards the NNW as at October 2016).

Historically limestone mining was principally on the **Eastern Limestone** and was split between a **North Pit** and a **South Pit** – divided roughly in the middle of its ~2 km mined length (at 6,147,200 N). The average horizontal width of the mined limestone is ~2-300 m. At one time these two pits were run by different companies. Blue Circle Southern Cement (BCSC), subsequently Boral Cement Limited (BCL), became the combined operator in the early 1970s. An in-situ limestone wall, rising to 550 RL (almost the original land surface), divided the two pits and a sight screen bund was placed on top to hide the North Pit from observation from the south.

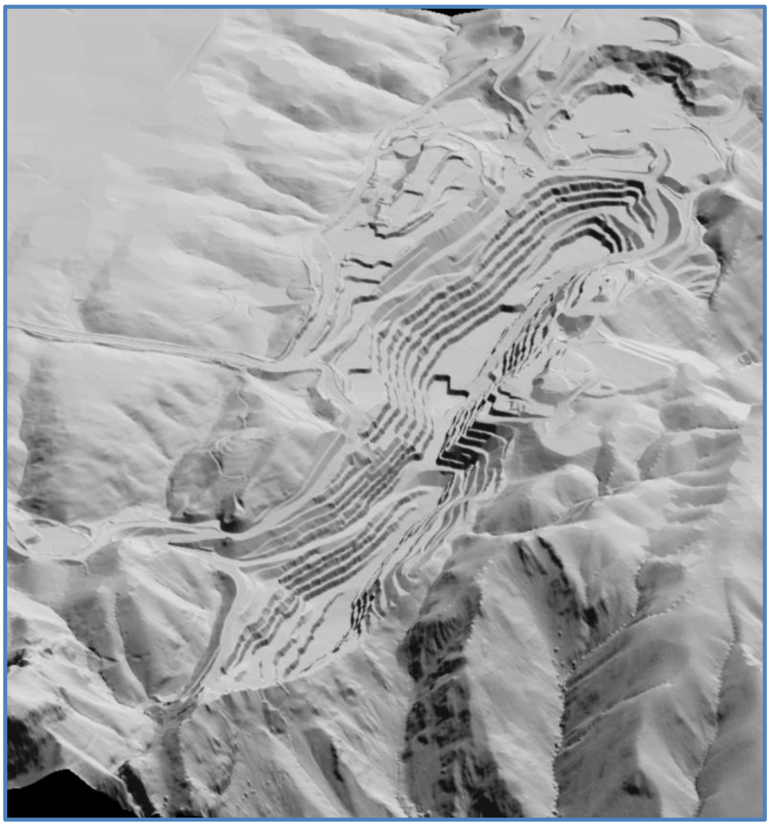
The South Pit was eventually mined to an interim completion stage nearly 10 years ago, essentially limiting extraction of the very southern walls to maintain a buffer with the gorge to the south. The current base of the South Pit at 365 m RL is some 50 m below the southern rim. The 40 m wide base of the northern half of the South Pit is currently too narrow to permit much further mining without pushing back the west wall. The North Pit is currently being mined in spots along most of its length.

The North and South Pits were recently (~2016/7) amalgamated to form a single contiguous pit. This involved removing the dividing wall down to ~470 m RL or below, essentially the previous base of the North Pit there. Figure 4 shows the Mine just after the dividing wall was removed and the pits joined. Figure 5 and Figure 6 show the pit in plan view, also after the wall was removed. A new ramp has now been established into the South Pit through the join and further mining is now occurring there to remove remnant benches at the south end.

Decisions on the final pit shape (such as how much more of the South pit will be extracted, whether to widen the pit in the old bund wall area, and the shape of the pit in the north) are now possible due to the recent exploration drilling and revised limestone interpretation (see Section 0).

Although the Mine is now a single contiguous pit shape the North/South Pit nomenclature remains important as current mining operation locations continue to be reported with respect to one or other of the old pits.

Figure 4 Marulan South Limestone Mine October 2016



Mining also recently (~2016) re-commenced on the **Mt Frome Middle Limestone** body sub-parallel to and west of the North Pit. This body had been mined early in the Mine life in a limited way, mostly in the south. The horizontal width of this body is ~70-100 m in the area being mined west of the North Pit. It is horizontally separated there from the main Eastern Limestone body by ~80 m of sediments.

Details on Mine limestone production are given in Section 1 on ore distribution.

North of the Mine is an extractive 'hard rock' operation, 'Peppertree Quarry', also owned and operated by Boral. The Quarry extracts granodiorite presumed to be contiguous with the granodiorite truncating the Eastern Limestone at the very northern end of the North Pit.

5 LIMESTONE DEPOSIT (ORE BODY)

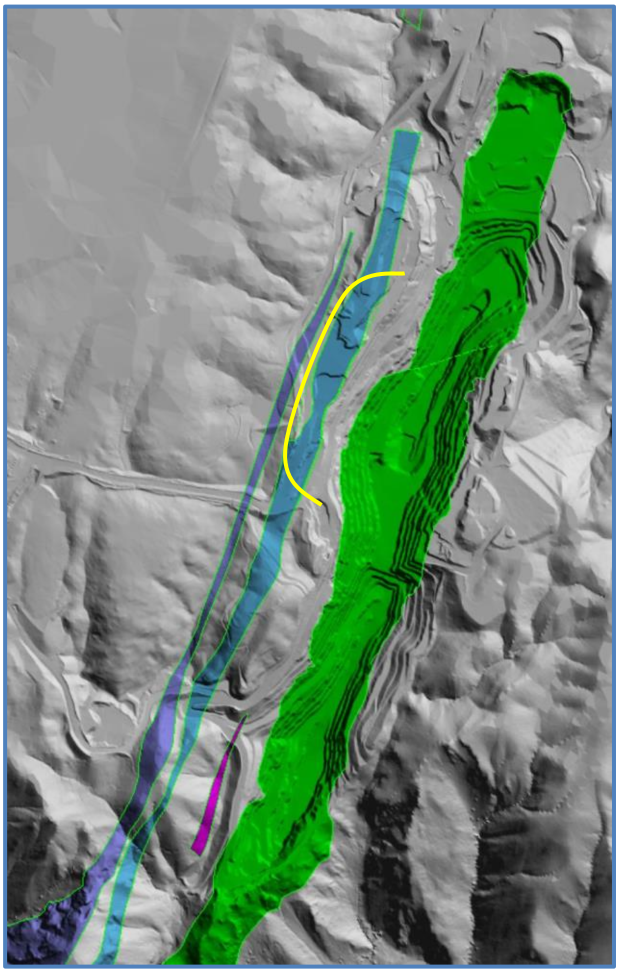
The limestone deposit being mined at Marulan South is virtually synonymous with the shape of the Mine itself (described in Section 1) as the Mine occupies virtually the full extent of the limestone body north of the Bungonia Gorge. Therefore it is convenient to think of the deposit as the ore body and then to describe the ore body.

It is also currently important to appreciate the history of geological exploration (described in Section 0) undertaken at Marulan South and the recent (and on-going) drilling which has considerably improved understandings of the ore body.

5.1 ORE BODY SETTING

The Mine currently extracts limestone overwhelmingly from the massive contiguous almost linear **Eastern Limestone** (EL) ore body. The Mine's rough location in terms of regional geology mapping is marked by the red oval in Figure 2. The Mine is shown in relation to the local limestone ore bodies in Figure 5 (see Figure 8 for coordinates). The pit is distinguished by the sub-parallel benches. The EL ore body is the wide green strip on the east (right). The Mine has also recently begun extracting limestone from the **Mt Frome Middle Limestone** (ML) ore body shown as a thin blue/cyan strip to the west (left) of the EL. The portion being mined is within the yellow line.

Figure 5 Limestone ore bodies



The EL deposit's overall strike is 020° and as the body generally dips steeply to the WNW its horizontal width at ~200 m is nearly equivalent to the bodies' true thickness. At its northern end (~600 RL) the EL ore body is truncated by a granodiorite intrusion upon which the Mine plant sits. At the southern end it crosses the very deeply incised Bungonia Creek Gorge (~175 RL) ~600 m south of the Mine.

The EL is mined along a contiguous strike length of ~2 km ~N/S and over a horizontal width of ~2-300 m E/W. The Mine extends from the northern granodiorite pit edge contact in the north (north end of the North Pit) until the limestone becomes a sharp precipitous ridge ~600 m north of the gorge in the south (south end of the South Pit). The top of the pit in the north is ~575m RL and the base of the South Pit is at 365 m RL – a total vertical height of 210 m. The limestone is flanked roughly conformably by fine grained sediments and the Mine's east and west walls now extend ~100 m into the sediments.

Three thinner (up to ~100 m wide horizontally) sub-parallel Mt Frome Limestone bodies are present ~100-150 m horizontally to the west of the EL. In Figure 5 the short Lower Limestone (LL) in magenta is immediately west (left) of the southern (lower) part of the wide green EL; the thicker and long Middle Limestone (ML) in blue/cyan is further to the west; and the thin Upper Limestone (UL) in mauve is further west again. They exist as far south as the Eastern Limestone does but their northern extents are variable and the Middle Limestone is currently only proved to mid-way north along the North Pit. Mining of the ML commenced in ~2016 from a ~500 m long section west of the North Mine. At its closest point the ML is ~70m west of the EL. The Mt Frome Limestones are separated from each other and from the EL to the east by roughly conformable sediments and they are flanked on the west semi-conformably by dacite.

5.2 LIMESTONE STRUCTURE

Recent drilling (2016 to 2017, see Section 1, collars shown as red dots in Figure 6) has allowed the cross-sectional shapes of the EL and ML units to be considerably refined. The EL is now sub-divided along strike into 6 major '**fault blocks**' (with 2 of them further sub-divided into northern and southern parts) and the ML in to 2. The blocks are variously shaded in Figure 6. The EL on the right is shaded pink to green southwards; the ML on the left is shaded yellow to mauve southwards. The currently undivided UL on the far left is shaded dark blue and the small LL in the south is shaded light blue.

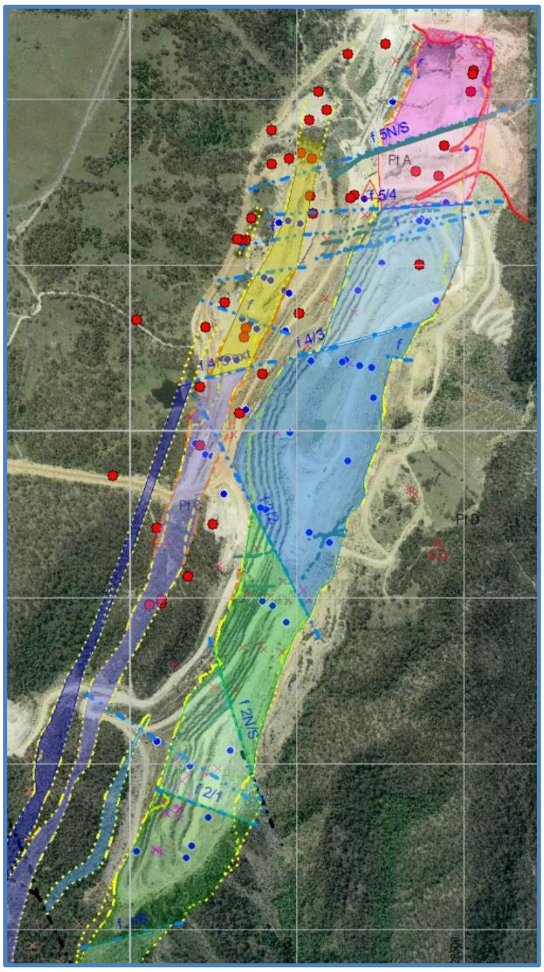
Fault blocks are units which have been structurally rotated relative to each other, and are interpreted as separated by sub-vertical faults with rotation and displacement. Individual blocks have constant (and generally different) dips of the eastern and western contacts, which are different from adjacent blocks. The block boundaries are marked by linear faults cross-cutting the limestones at various orientations. A number of the northern faulted boundaries also mark narrow dykes.

Whilst the EL's eastern contact dip is either steeply to the west or vertical (the northern ⅔ rds interpreted as a sub-vertical faulted boundary) the western contact fairly steep westerly dips vary considerably from block to block along strike.

The eastern and western contact dips are currently interpreted as un-related (the upper and lower surfaces of the deposit are seldom parallel) with the long sub-vertical eastern contact fault being a later event. The contact dip relationship varies block to block and this points to a structural complexity which is currently poorly understood.

Note that current understandings of the western Mt Frome Limestones are still considered to be poor.

Figure 6 Limestone fault blocks



Dips of the various fault blocks are given in Figure 7. Of particular note is the steep easterly (reverse compared to all of the others) dip of the western contact of central Block 3 (blue) and the newly appreciated very shallow westerly dips of the western contacts of Block 5 (red and pink) in the north. The eastern contacts of Block 5 are formed by the late intrusive granodiorite.

The varying dips of the fault blocks are illustrated in the representative E/W cross-sections given in Section 5.3.

NB: For the computer modelling (Section 10) the fault block name numbers (in Figure 7*) were necessarily re-organised slightly as they became identified by unique domain numbers (see* Table 6 *in Section 10.5). EL blocks 0, 1 and 2S became #1, 5S became #5 and 5N became #6. ML block 7S became 7 and 7N became 72.*

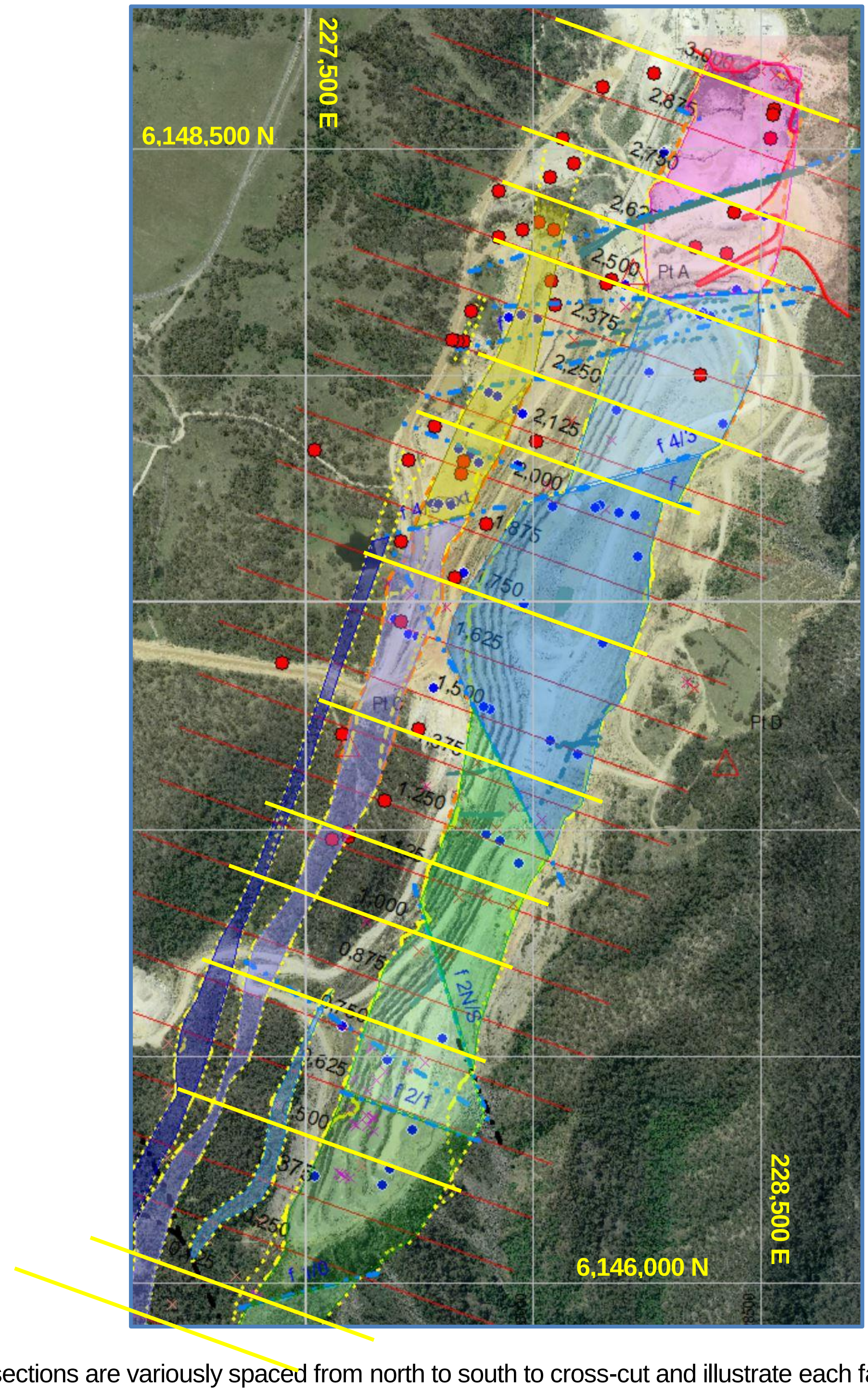
Figure 7 Fault block contact dips

Fault Block	Contact W dip (°)		E dip (°)		Dip Δ (°)
Eastern Limestone:					
5 N	32	W	58	W	-26
Δ	*-16*		*-2*		
5 S	16	W	56	W	-40
Δ	*57*		*25*		
4	72	W	81	W	-9
Δ	*25*		*12*		
3	82	E	88	E	-5
Δ	*-36*		*-19*		
2N	62	W	74	W	-12
Δ	*9*		*-24*		
2S	71	W	50	W	21
Δ	*-8*		*2*		
1	63	W	52	W	11
Δ	*-17*		*7*		
0	47	W	59	W	-12
Mt Frome Middle Limestone:					
7N	35	W	35	W	0
Δ	*32*		*32*		
7S	67	W	67	W	0

5.3 CROSS-SECTIONS

To illustrate the ore body shapes a series of representative vertical cross-sections across the ore body are given for its full length. A plan of the cross-section line locations is given in Figure 8. These section line locations are marked by thick yellow lines (regular 125 m spaced sections are marked by thin red lines). The vertical cross-sections are oriented along 110°approximately normal to the ore body striking at ~020°. Light grey coordinate grid lines are at 500 m spacing with coordinates (MGA94 zone 56) annotated in yellow at the corners.

Figure 8 Cross-section lines



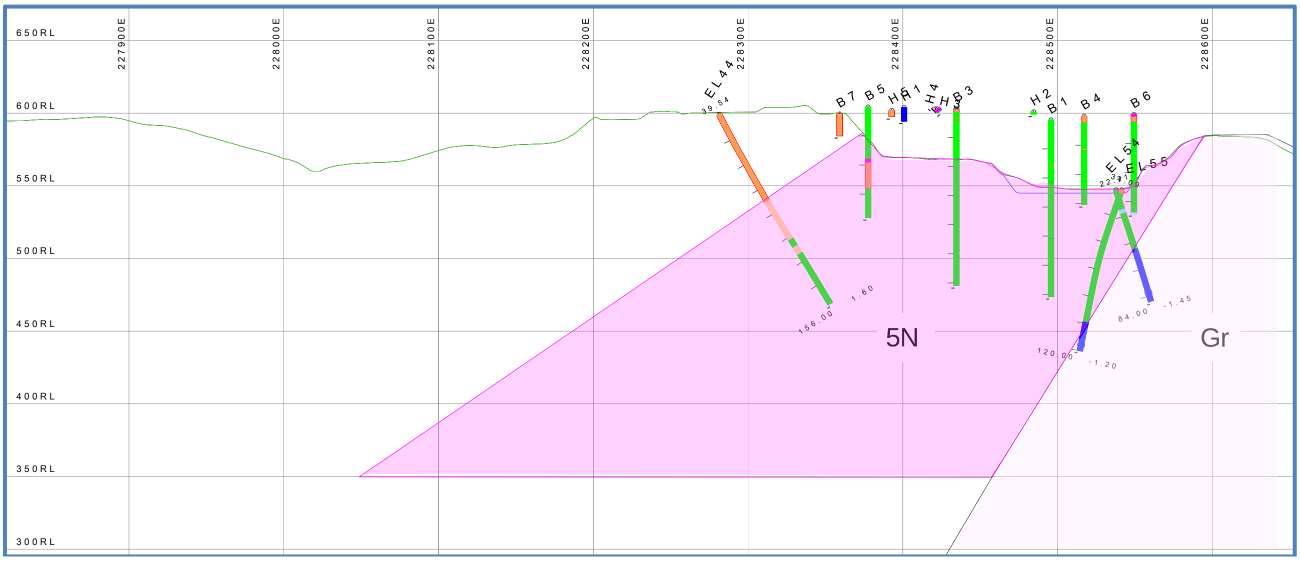
The cross-sections are variously spaced from north to south to cross-cut and illustrate each fault block and some of the contacts between them. Note that all limestone bodies are **open** to depth and are only interpreted to ~50 m below the deepest drill holes. Drill holes have tested the bounding eastern and western contacts with sediments – none have ever encountered a contact which could indicate a termination down dip.

Cross-section legend:

- Only limestone fault blocks are shaded in the cross-sections (with the same colours as in Figure 8) – the interbedded sediments and other rocks are mostly not. Limestone blocks are labelled with the names in Figure 7. The northern granodiorite is shaded (pink) to illustrate its intrusive nature, as are the dykes (olive) at block contacts.
- Surface topography (10/2016) is marked by a green line. The proposed 30 year mine (MP2) design is marked by a blue line. In the South Pit area a potential future back-fill surface is marked by a purple line.
- Drill holes are projected onto section and are coloured on geology. The principal coloured units are limestone (green), limestone contacts (orange), sediments (red), granodiorite (dark blue) and dacite (dark grey). Easting coordinate lines are at 100 m spacing, vertical RLs are at 50 m spacing.

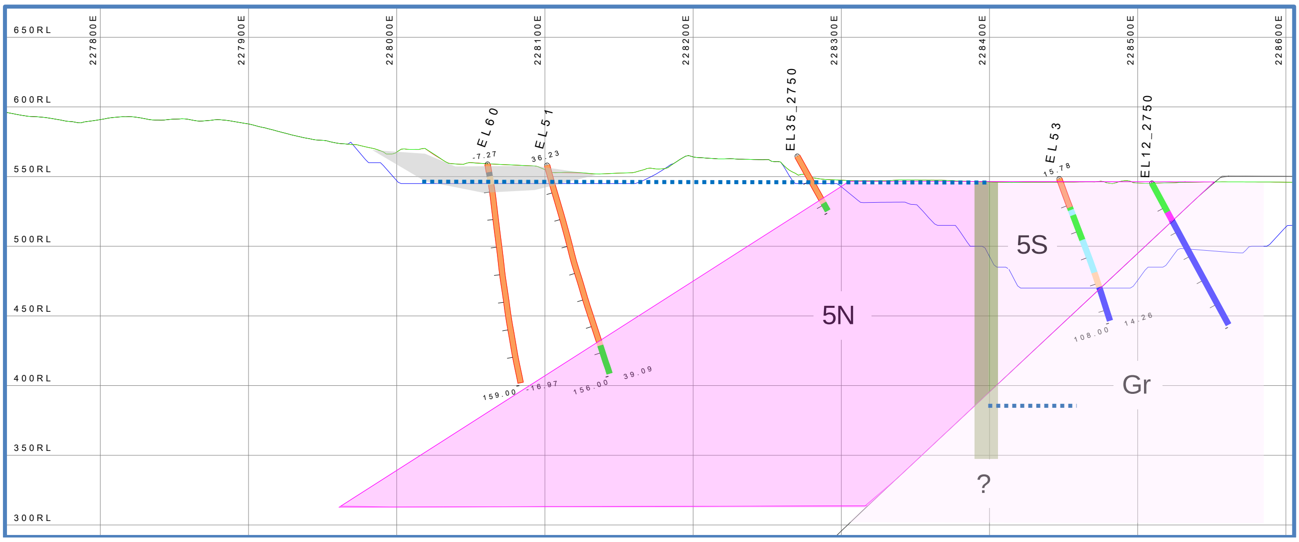
Limestone Block EL 5 North: Figure 9 illustrates northern Eastern Limestone Block EL 5N (purple) and the intrusive granodiorite (Gr, pink) to its east (and north). Block EL 5N became domain 6 during modelling. Of particular note is the moderate westerly dip (~35°W) of the western (left) limestone contact (carried on in several following cross-sections). This newly appreciated feature has very beneficial implications for mining as the overburden stripping ratio is improved, allowing the western pit wall to be pushed westward, in turn giving potential economic access to more limestone at depth.

Figure 9 Cross-section 3,000 – EL 5N and granodiorite



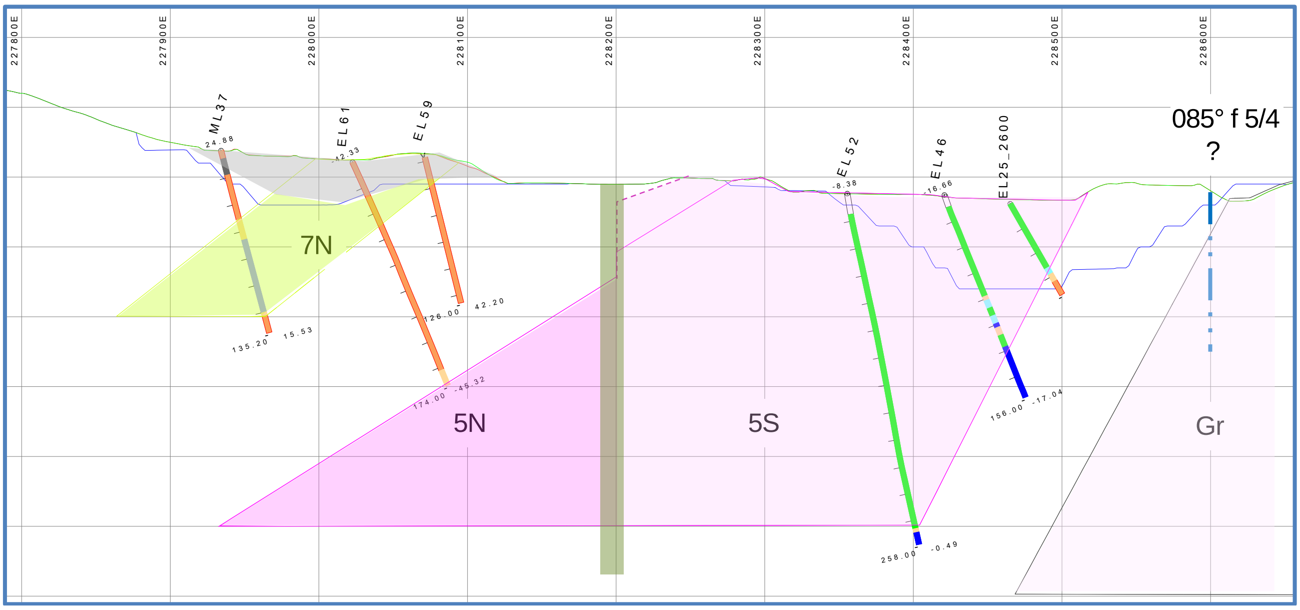
Limestone Blocks EL 5 North and EL 5 South contact: Figure 10 illustrates the vertical contact between northern Blocks EL 5N (purple) and EL 5S (pink). Block EL 5S became domain 5 during modelling. The contact hosts the 'Big Dyke' (olive) which may be ~5 m wide in places.

Figure 10 Cross-section 2,750 – contact between EL 5N and 5S



Limestone Blocks EL 5 South & ML 7 North: Figure 11 illustrates northern Block EL 5S (pink) and the northernmost firmly interpreted Middle Limestone Block ML 7N (khaki/olive green) to the west. Block ML 7N became domain 72 during modelling. The ML is interpreted buried below mine waste (grey). Block EL 5N is interpreted to be only present below surface. The granodiorite is now separated from the limestone by sediments.

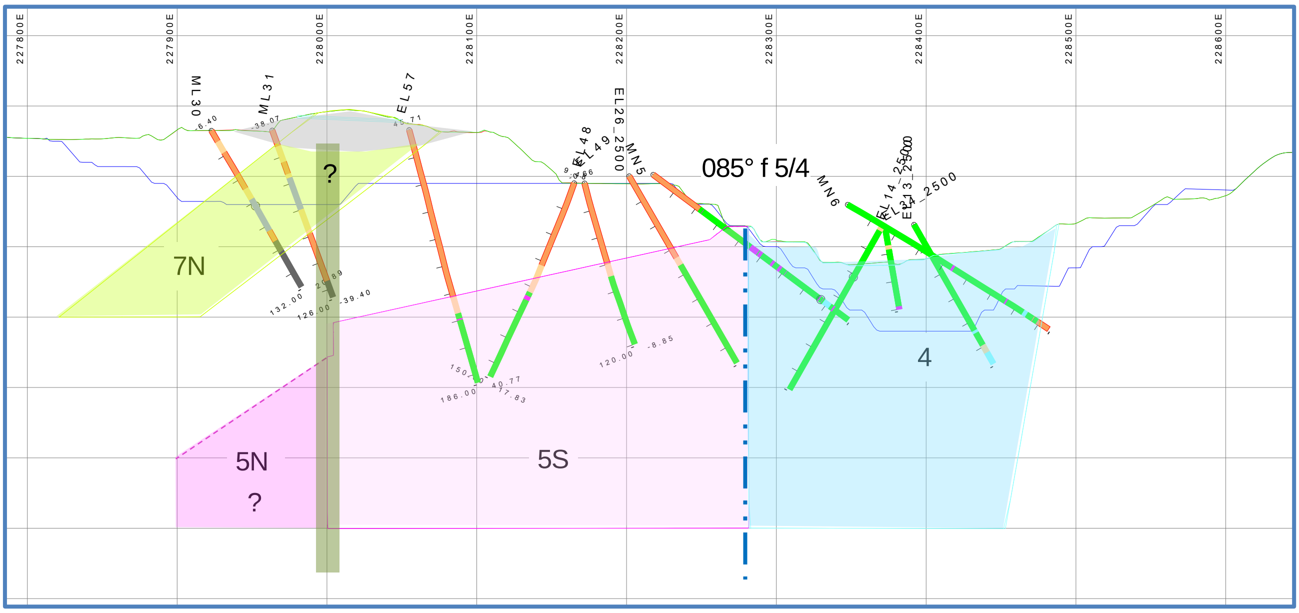
Figure 11 Cross-section 2,625 – EL 5S & ML 7N



Limestone Blocks EL 5 South and EL 4 contact: Figure 12 illustrates the vertical contact between northern Block EL 5S (pink) and Block EL 4 (cyan). Block EL 4 became domain 4 during modelling. The contact fault (blue dot-dash line) is sub-vertical. Block EL 5N is possibly still present at depth – and it is not clear if the contact Big Dyke cuts the Block ML 7N above. The eastern granodiorite is now absent.

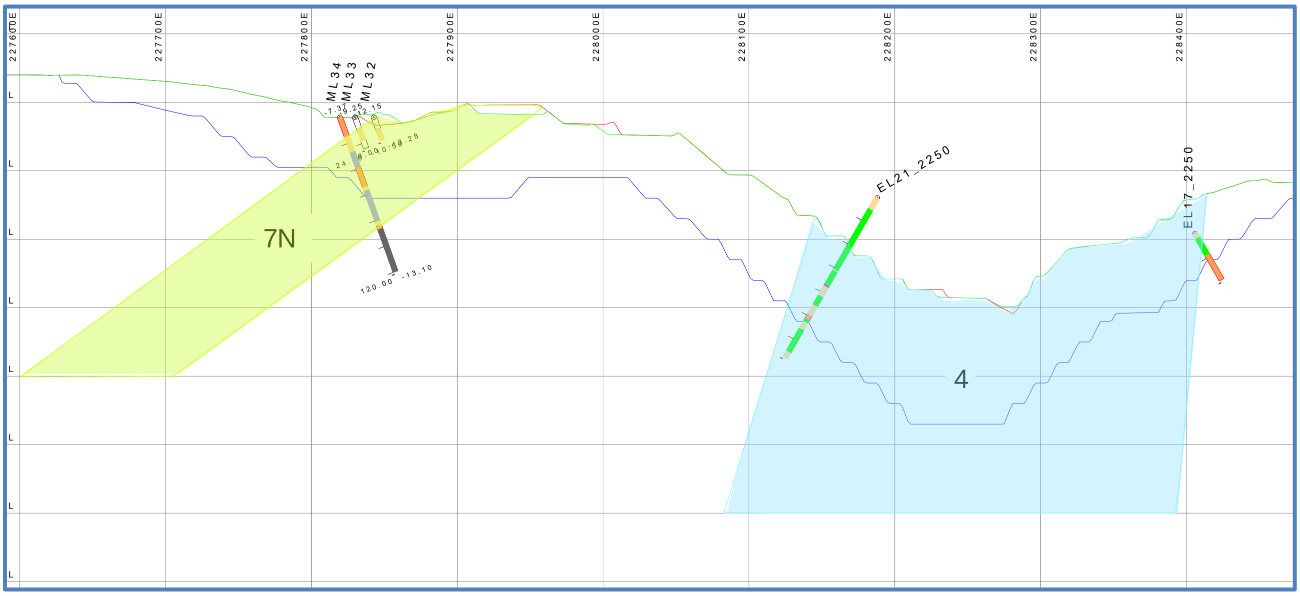
The very flat dip (~15W°) of the western contact of Block 5S is surprisingly even flatter than that of Block 5N to the north. This provides even more support for pushing the western pit wall further west to access the relatively shallow and now very wide limestone. In turn that will have implications for current processing infrastructure located in this area (such as the primary crusher located near the 4 central holes in the section).

Figure 12 Cross-section 2,500 – contact between EL 5S and EL 4



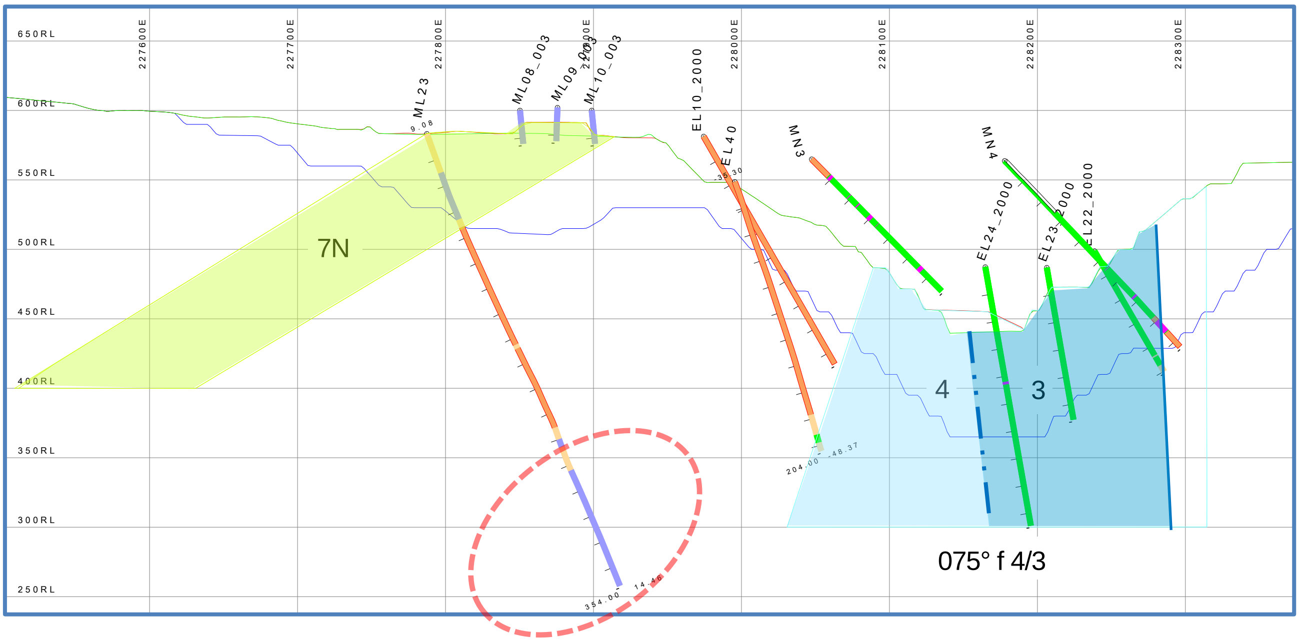
Limestone Block EL 4: Figure 13 illustrates Block EL 4 (cyan). Northern Blocks EL 5N and EL 5S are not absent. Block ML 7N is exposed at surface.

Figure 13 Cross-section 2,250N – EL 4



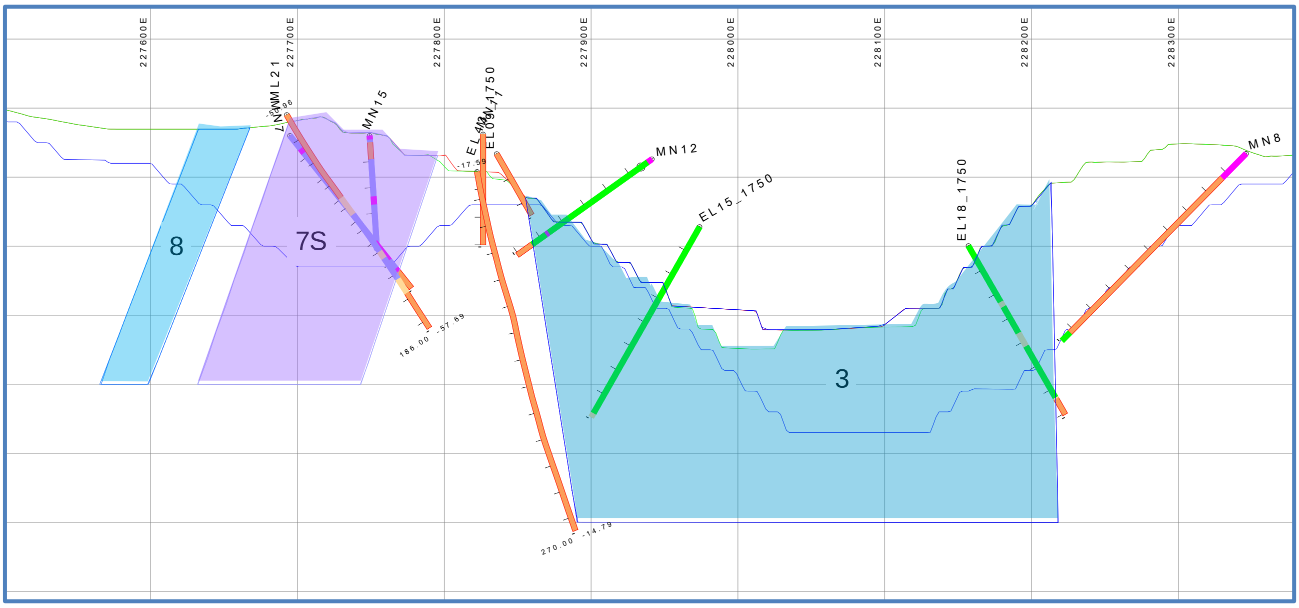
Limestone Blocks EL 4 and EL 3 contact: Figure 14 illustrates the sub-vertical contact between Blocks EL 4 (cyan) and EL 3 (blue). Block EL 3 became domain 3 during modelling. The red dashed oval marks an unidentified long limestone interval – possibly an up-faulted repetition of the EL.

Figure 14 Cross-section 2,075 – contact between EL 4 and EL 3



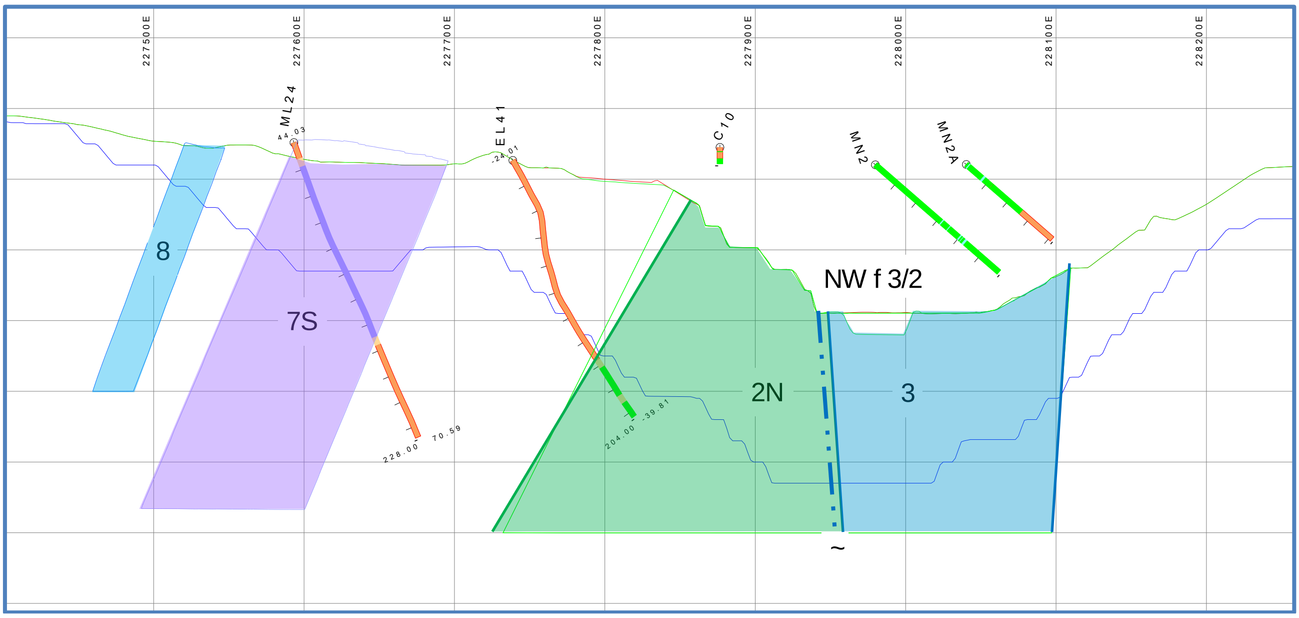
Limestone Blocks EL 3, ML 7S and UL 8: Figure 15 illustrates Block EL 3 (blue) with its a-typical eastern dipping western contact. Block ML 7S became domain 7, and UL 8 became domain 8, during modelling. Block ML 7N is now absent, replaced by the more steeply dipping ML 7S (purple). Upper Limestone UL 8 (light blue) is now present west of ML 7S and dipping sub-parallel to it.

Figure 15 Cross-section 1,750N – EL 3, ML 7S and UL 8



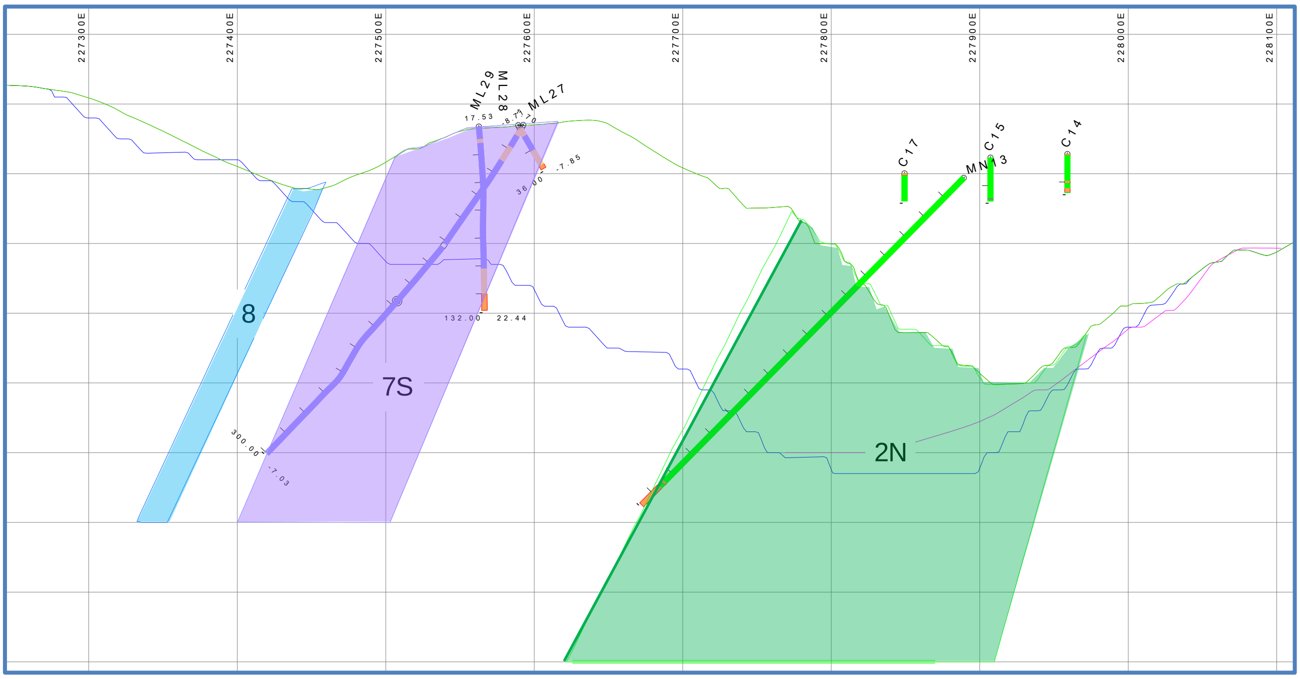
Limestone Blocks EL 3 and EL 2 North contact: Figure 16 illustrates the sub-vertical contact between Blocks EL 3 (blue) and EL 2 North (green). Block EL 2N became domain 2 during modelling. This section is roughly through the old dividing wall between the North and South Pits.

Figure 16 Cross-section 1,400 – contact between EL 3 and EL 2N



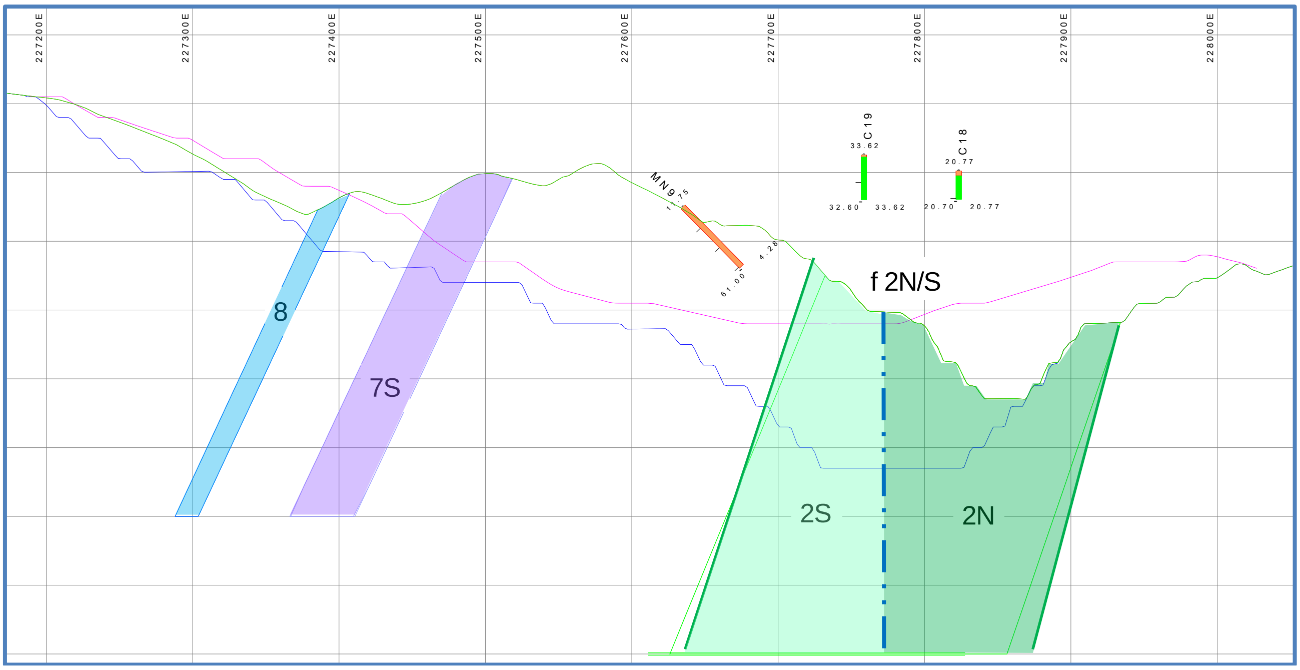
Limestone Block EL 2 North: Figure 17 illustrates Block EL 2N (green) in the South Pit.

Figure 17 Cross-section 1,150 – EL 2N



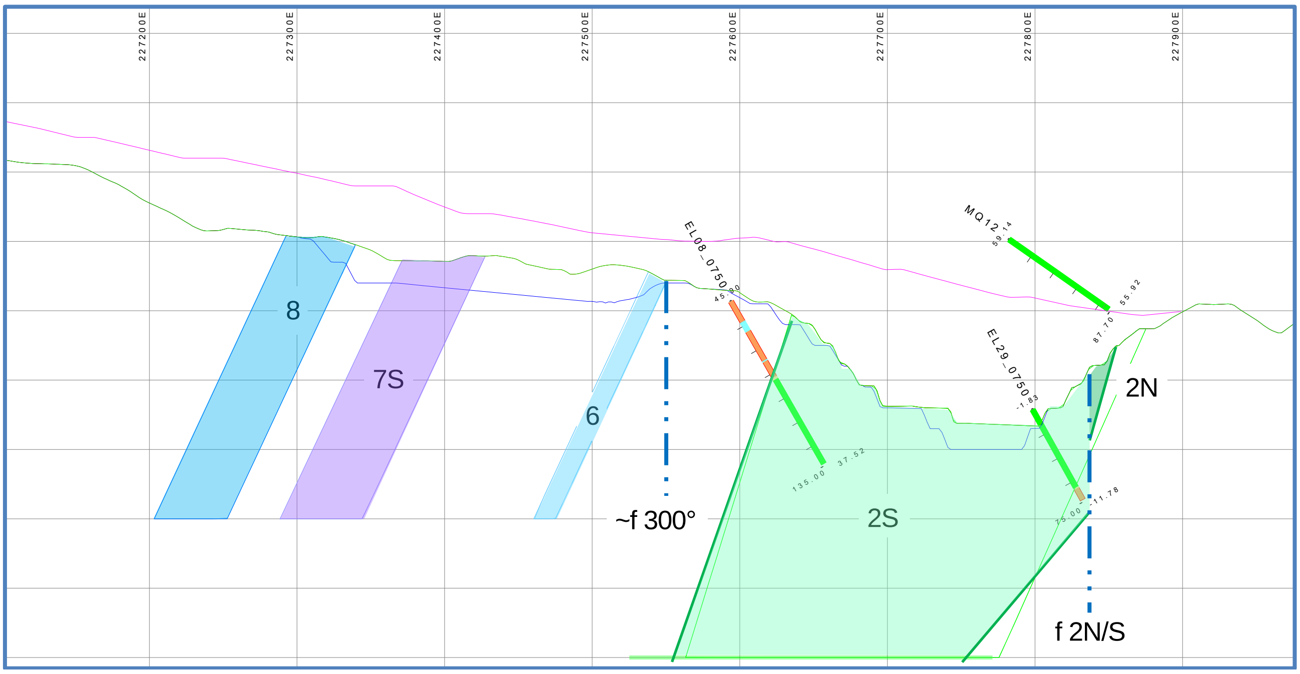
Limestone Blocks EL 2 North and EL 2 South contact: Figure 18 illustrates the vertical contact between Blocks EL 2 North (green) and EL 2 South (light green). Block EL 2S became domain 1 during modelling. Here the western Mt Frome Limestones are thinner.

Figure 18 Cross-section 1,000 – contact between EL 2N and EL 2S



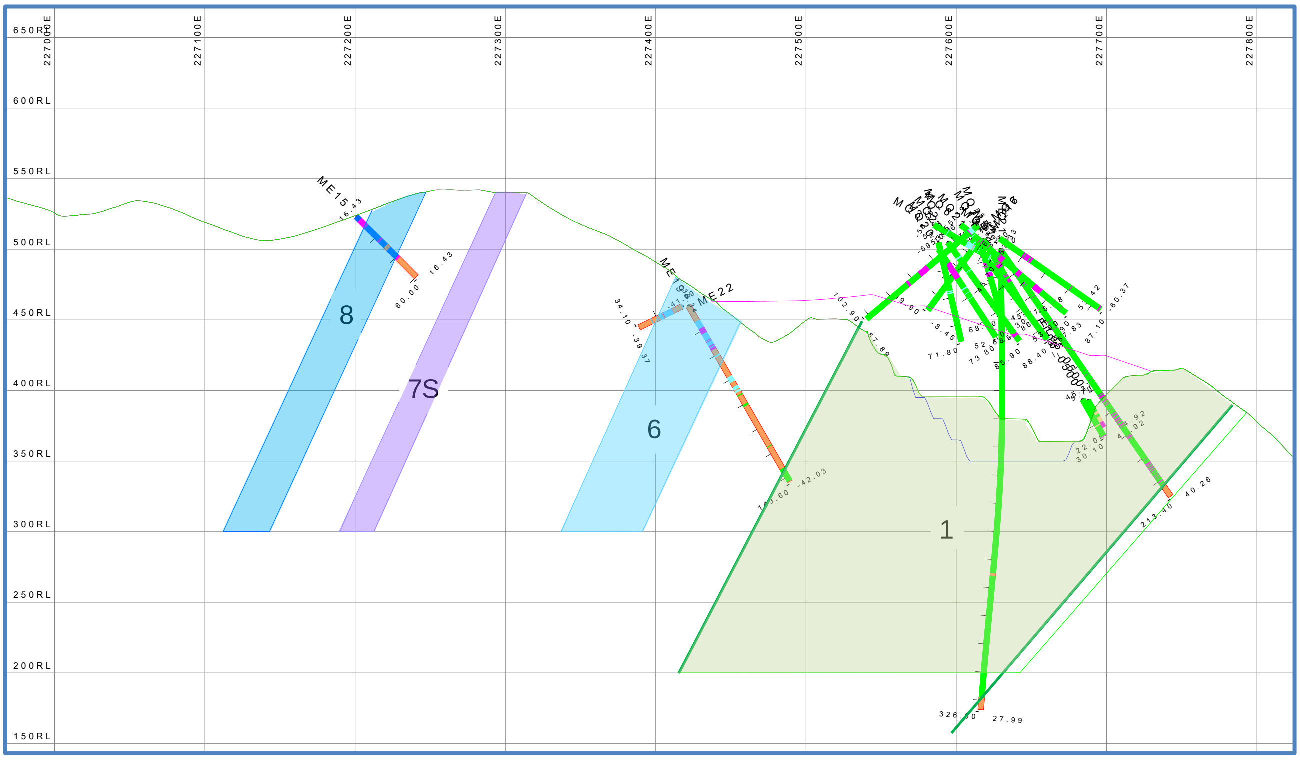
Limestone Blocks EL 2 South and LL 6: Figure 19 illustrates Block EL 2S (light green), apparently distinctly wedge shaped. To the west the very thin Lower Limestone LL 6 is now present, interpreted to be dipping sub-parallel to the other Mt Frome Limestones. Block LL 6 became domain 9 during modelling.

Figure 19 Cross-section 0,800 – EL 2S and LL 6



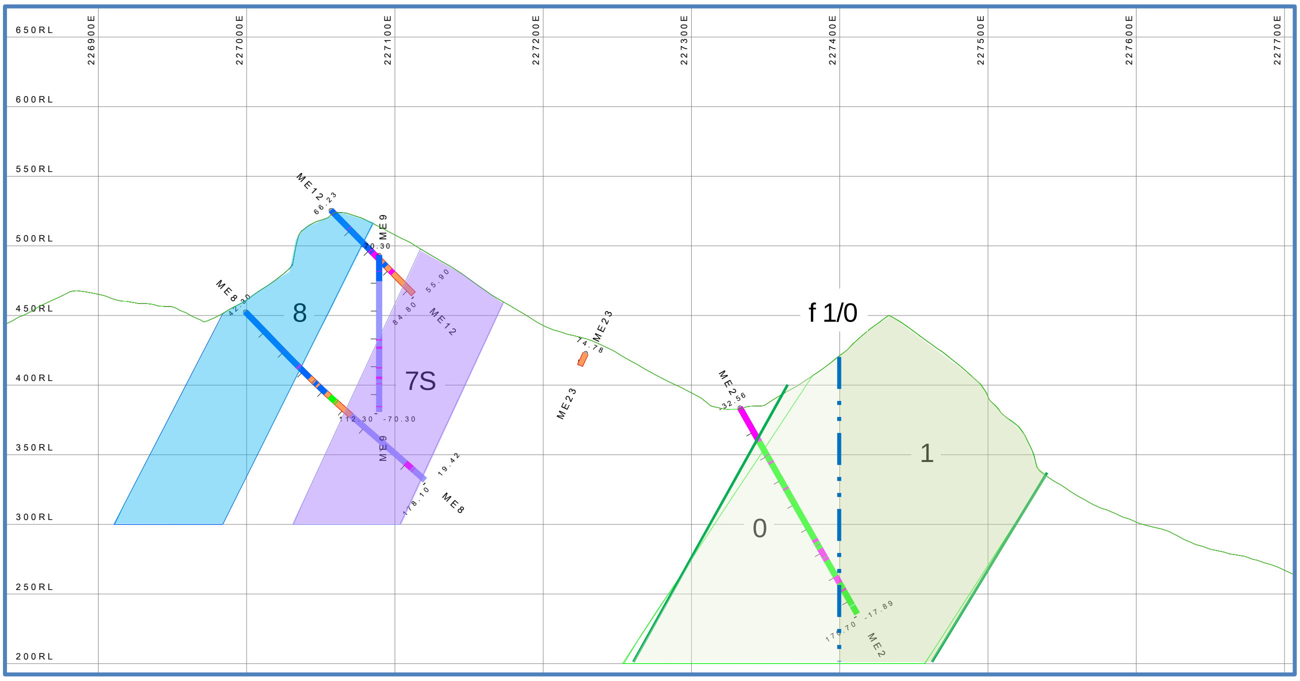
Limestone Block EL 1: Figure 20 illustrates southern Block EL 1 (olive), like EL 2S also apparently distinctly wedge shaped. Block EL 1 became domain 1 during modelling. To the west LL 6 is now appreciably thicker whilst ML 7S and UL 8 are thinner (although they thicken considerably again to the south).

Figure 20 Cross-section 0,500 – EL 1



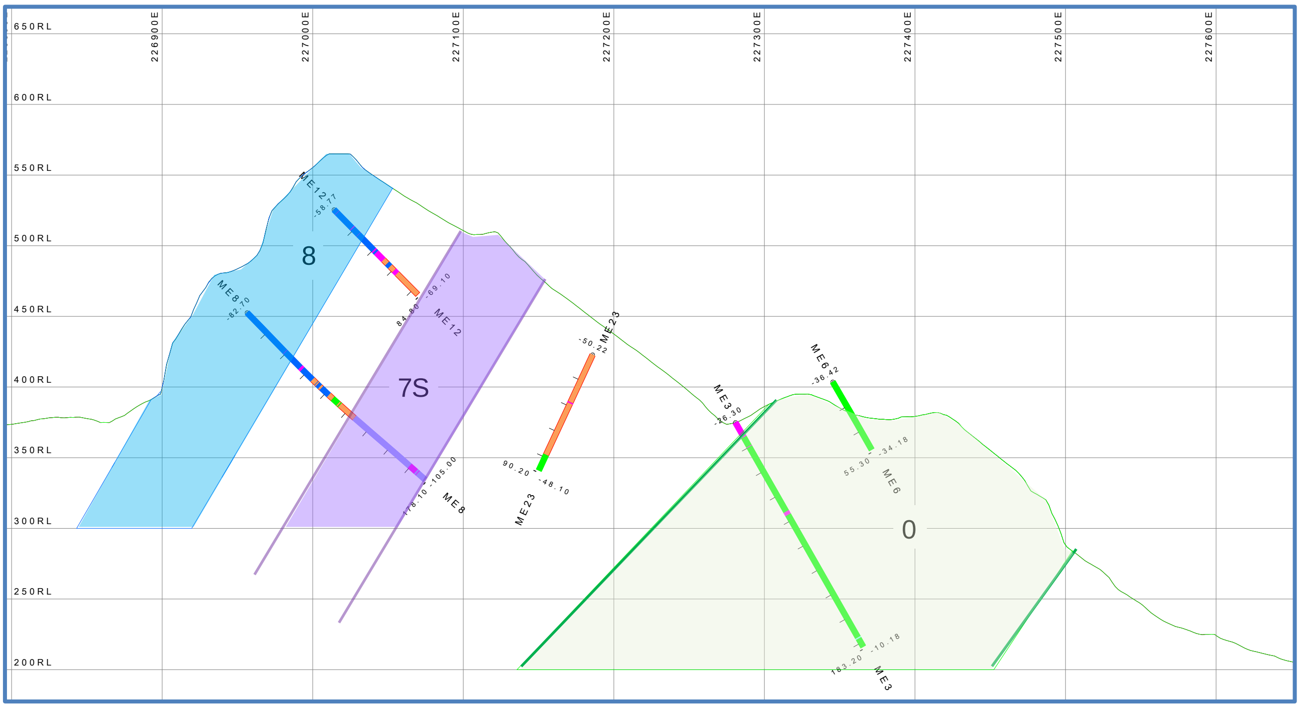
Limestone Blocks EL 1 and EL 0 contact: Figure 21 illustrates the vertical contact between southern Blocks EL 1 (olive) and EL 0 (light olive). Block EL 0 became domain 1 during modelling. This cross-section is immediately south of the southern tip of the South Pit. The change in contact dips in the contact zone changes the apparently distinctly wedge shape from narrowing with depth north of the zone to thickening with depth south of it (see Figure 22). This would conform to the massively wide base to the limestones outcropping in the Bungonia Gorge to the south. And here the LL 6 to the west LL 8 is now absent having either pinched out or been faulted out. ML 7S and UL 8 are considerably thicker, and this section is close to Mt Frome itself where the UL 8 was historically mined.

Figure 21 Cross-section 0,125 – contact between EL 1 and EL 0



Limestone Block EL 0: Figure 22 illustrates the very southern Block EL 0 (light olive), apparently distinctly wedge shaped and thickening with depth.

Figure 22 Cross-section 0,000 – EL 0



5.4 Rock type description (mineralogy)

The mineralogy and description of rocks at the Marulan South Limestone Mine has been described very briefly in many Mine reports but none in a detailed way. This probably went with the limited requirement for this information in a setting where it was very obvious what and where the ore (limestone) was; it was very sharply separated from (not mixed with) overburden rocks; and early on it was established as 'high grade' without a particular need for quality control (other than the identification of 'high magnesium' parts. Consequently the Consultant's descriptions below are generally mostly simple collations from those reports (presented originally with the 2015 geology report), without a particularly academic approach, but with modification through extensive personal observation. They represent physical descriptions only.

The major rock types mentioned in the local geological sequence (3.3.1) are described below, given in order for ore and then overburden and from oldest to youngest.

5.4.1 Limestone

Whilst the following limestone notes apply mostly to the Eastern Limestone because of its scale and mining focus they would also generally apply to the Mt Frome Limestones.

Description: The Eastern Limestone in the pit area is massive, homogenous, crystalline, in parts vitreous, and very hard. It essentially has no other rock types interbedded or included (except for typical cavity fill (see below) and very minor (volumetrically) intruded dyke rock). The main lithological variants are limestone breccias and conglomerates. The breccias are described as slump breccias which have sometimes been sufficiently re-worked to cause rounding of the fragments to form limestone conglomerates (APCM, 1972). Basal conglomerates and rounded fossils possibly indicate a reasonably high energy depositional environment (Geo Survey, 2012, p901). Higher stromatolites and algal beds indicate deposition in the photic zone. Other horizons indicate calm low energy deposition. Corals in some horizons indicate periodic clear water conditions. Although bedded the breccias and conglomerates are discontinuous and occur randomly. The limestone is a generally shallow water depositional sequence of biostromal (bedded rather than mound-like) limestone (Carr et al, 1983; Geo Survey, 2012). The variation in high and low energy environments, laterally and vertically, was interpreted as "fluctuations from biostromal shoal to marine lagoon environments" (Carr et al, 1979; Geo Survey, 2012, p901).

Occurrence & outcrop: The shape of pit benches and the near vertical cliffs of outcrops south of the Mine illustrate the massive competent nature of the limestone. Except for south of the mining area the Eastern Limestone essentially no longer has any original surface outcrop. Outcrop observations are therefore limited to the Mt Frome Limestones. The closest northernmost original undisturbed in-situ outcrop (whitish boulders) of Mt Frome Middle Limestone (?) occur just west of the lime plant. The largest group of rocks showed a clear ~70° dip in agreement with some of the sequence average. In outcrop the most resistive portions may express themselves as very large boulders (up to at least 5 m across). In between the boulders the limestone is presumed completely weathered to clay to at least 15 m in places – a feature that masks much of the existence of the Mt Frome Middle Limestone in its northern reaches. Boulders may float in the clay. In the pit the competency is difficult to see as virtually all of the limestone is shattered to some degree by blasting.

Colour: Limestone colour appearance is variable with the general characterisation being medium to dark grey and less commonly gradations to almost white or black. The vitreous stone (glass rock) is dark grey, less glassy rock the lighter grey. It also has patches of white, cream and buff brown, and is sometimes mottled. Brown ferruginous veins are common, while occasional pink and light brown veins contain iron and magnesium carbonates.
Grain size: Grain size ranges from fine (<0.03 mm) to very coarse (with crystals >30mm), with its usual range fine to medium (0.03-1.00 mm). The granodiorite intrusion to the north of the Eastern Limestone has been assumed by many in the past to apparently cause the coarse recrystallization visible at the contact and in the northern part of the pit. The Consultant is not convinced by this interpretation – seeing re-crystallisation fairly randomly within the full pit length and not necessarily close to the intrusion.

Bedding: Bedding in the limestone is discrete (within the pit), and as the limestone is usually fully crystallised it does not split along original bedding planes (the bedding is not well preserved). Some of the bedding occurs as fossiliferous breccia conglomerates. Bedding is usually difficult to see in the blasted faces in the pit. Blasting shatters the rock and tends to produce a rubbly look in the softer limestone. In harder limestone the splitting along joints often gives the appearance of bedding.

Fossils: Limestone often has a brecciated appearance with fine grained occasionally fossiliferous fragments in a fine to medium matrix. Marine fossils (some 10 cm or more wide) are clearly seen as positive features in the large glass boulders from the Eastern Limestone at the southern rim of the South Pit (Figure 23) where the matrix is weathered slightly by rainfall.

Figure 23 Limestone boulder

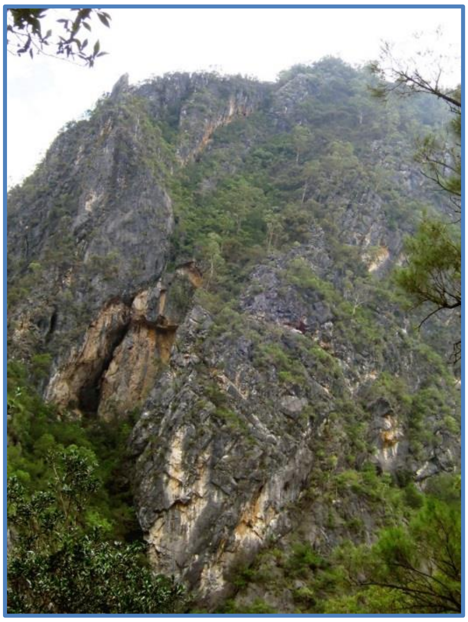
The Mt Frome Middle Limestone also contains glass stone with younger fossils such as coral.

Dolomitisation & other alteration/intrusion: Dolomitic (magnesium richer) limestone horizons and fractures exist within the EL. Although not wide-spread volumetrically they nevertheless can have significant effect on ore as they raise the $MgCO_3$ level considerably. The Consultant has little specific knowledge of this aspect at Marulan South. Re-crystallisation is strong in the northern parts, presumably associated with the granodiorite intrusion (but see earlier comment). However re-crystallisation also occurs in the south, sufficient to obscure primary bedding. Brown ferruginous veins are common, while occasional pink and light brown veins contain iron and magnesium carbonates.

5.4.2 LIMESTONE CAVITIES

Description: A particular feature of the Eastern Limestone (and probably the others) is the presence of cavities. These are frequently clay filled (varied colours, white, red and khaki), but may also be open. Although BCSC stated in 1979 that the Mt Frome Middle Limestone was prone to severe cavitation the Consultant notes they had little drilling information to support that view.

Figure 24 Mt Frome cavity



The Mine's drilling and blasting tends to obscure smaller cavities as they can't be distinguished in the blasted rubble. Often their presence is subsequently noticed by subsidence of blasted rock into the pit floor. Cavities are found randomly along the full pit length. Several records (Barnstone, 1971) mention that cavities could account for 10% of the limestone volume. However the general feeling is that they increase in size in the South Pit. This would be expected as the channels would be more mature and deeper closer to the gorge to the south.

Figure 24 views the massive Mt Frome Limestone from the Bungonia Gorge, looking north. Very large caverns and fissures can be seen in the lower left, and these would drain at least the central vegetated valley just below the top. Similar cave and inter-connected channel systems drain the Eastern Limestone below the pit floor.

The Consultant has observed open cavities in both pits. These have been oval shaped in cross-section, with the long dimension oriented along strike. Dimensions of these have been ~40x20 m in area and +40 m deep, a moderate size in comparison to some according to the miners.

Formation of cavities is interpreted as the typical Karst process common in limestones world-wide – where dissolution occurs along joints or fractures. Extensive (more mature) dissolution leads to wide openings and caves. Where open cavities are formed the original limestone clay may be removed and replaced with other clays (limestone derived or external) and sediments introduced by groundwater running through the inter-connected drainage systems. Here the completely clay filled cavities are interpreted to represent 'completely weathered limestone', possibly commonly known as 'terra rossa' (hence the ubiquitous red colour of the clay). The limestone itself is completely weathered into clay.

5.4.3 LIMESTONE CONTACTS

Description: A particular feature of the limestone boundaries at Marulan South s the development of a 'contact zone' with the bounding sediments alongside them, particularly on the western side. The zone is composed of highly weathered limestone (where it is effectively altered completely to clay) flanked by a narrow zone of discolouration of the adjacent (generally fine grained) sediments. These side boundary contacts are marked in Figure 2 as a thin sinuous semi-continuous zone along the boundaries to the Eastern Limestone. This typically 5-10+ m wide (BCSC, 1979 has it up to 50 m wide) highly disturbed zone is marked by distinct colours (white, khaki, coffee and red (terra rossa)) and the presence of predominant clay and lesser gritty oxides. The Eastern Limestone contact zones are typically twice as wide on the western side as on the eastern. A narrow (0.5-1.0 m) coffee coloured gritty zone is frequently present, and is a useful marker for the contact. Limestone near the sediment contact may also contain clay filled cracks. This gives the limestone an orangey colour and it is dustier when mined. Figure 25 shows a ~5m wide coffee coloured clayey contact zone (red arrow) on the east side of the Middle Limestone. Here the zone is flanked to the left by rubbly limestone (contaminated by near surface weathering (khaki clays) falling down from above) and to the right by soft whitish buff claystone sediments. Because it is now difficult to see a fresh cross-section though the contacts of the Eastern Limestone the best exposures of boundary contact zones are seen in recently opened faces across the top of the Mt Frome Middle Limestone (as is the case in Figure 25).

Figure 25 ML limestone boundary contact

Figure 26 illustrates a contact on the east side of the Eastern Limestone mid-way along the South Pit. Greyish blocky limestone is in the left foreground (above the peg) with the khaki and brown altered sediments (of the normal reddish brown one seen right in the middle distance) to the right. A narrow (~0.3 m) band of the coffee coloured gritty clay is present (bottom middle). The same khaki brown contact zone is also seen in the distance (top near centre, just below the sky line) immediately to the right of the north wall limestone.

Figure 26 EL limestone boundary contact

Another sort of contact zone is deep limestone weathering at surface. Whilst this is generally no longer visible for the Eastern limestone (having been mined) it is very apparent for the newly exposed Middle Limestone. This zone is composed of massive clay, coloured as for the side contacts. It is developed to ~30 m deep over the ML, with the appearance of being thicker below surface stream courses. When newly exposed the clay is damp, plastic and very stiff. It rapidly dries out (1-2 days) and becomes soft and powdery.

The simple presumed cause of the side contact zone formation would be weathering related to lateral and vertical ground water flows. The limestone represents both a barrier to and conduit for flow. Either way the conditions create clays. Another contributing factor could be folding of the sequence, where the less competent sediments deform up against the more competent limestone. The top contact zone cause would appear to be simply created by standing water at surface.

The contact zone may be wet at depth, and frequently presents problems for drilling. It would often appear to possess 'open drain' type conditions for ground water flow. Development of the contact zone is interpreted to be a similar process to that of cavity formation. Along the contact where the limestone itself has turned to clay there would be a commensurate and randomly oriented reduction of rock volume causing the structural disturbances seen.

5.4.4 FOOTWALL (EAST) TALLONG BED SEDIMENTS

Description: The footwall east of the Mine consists of Tallong Bed (*Abercrombie Formation in the Adaminaby Group*) sediments – thinly interbedded quartzose sandstones, siltstones and mudstones (also quartzites and slates, with cherty intervals). In outcrop they appear blocky and rubbly, and adjacent to the Mine are generally light to medium brown. These sediments occur generally unconformably (certainly in the northern part of the Mine, but probably not in the south) below the Eastern limestone and are slightly coarser and harder than the sediments between the limestones. Sediments immediately adjacent to the Eastern Limestone show some considerable deformation and folding in places. The more normal Tallong beds further east of the limestone contact are tightly isoclinally folded.

5.4.5 SEDIMENTS INTER-BEDDED BETWEEN LIMESTONES

Description: Sediments (the non-limestone *Cardinal View and Frome Hill Formations*) interbedded between the limestones are fine grained mudstones, siltstones, shales and occasional sandstones. They appear softer than the Tallong Bed sediments below the Eastern Limestone. The sediments above the Eastern Limestone and below the lowest Mt Frome Limestone are regionally a coarsening upward sequence of siltstones, shales and sandstones (Geo Survey, 2012, p900). A sedimentation hiatus occurred between the Eastern limestone and the sediments above (Bauer 1998), possibly reflecting subsidence of the shallow limestone before deeper water sedimentation of non-limestones recommenced.

Figure 27 Shale bedding

In many places the sediments are highly fissile, in others softer and more clayey. Bedding is generally laminar, as in Figure 27 of shales between the Eastern Limestone and the Mt Frome Middle Limestone (on the western haul road leading into the middle of the South Pit), and conformable and parallel to the limestone orientation.

Deposition of volcanic material begins to be inter-bedded higher in the sequence. Occurrence of tuff within the sediments would agree with the introduction of periodic volcanic events grading up conformably to the higher Tangarang Volcanics. Between the Eastern Limestone and Mt Frome Middle Limestone a portion of the claystone is an air-fall tuff or tuffaceous sediment. Part of this material is bleached almost white and is extracted for clay (for help in making off-white cement). Figure 28 shows this due west of the North/South Pit divide and at the eastern end of the main overburden haul road. The view is looking south and fine bedding dipping to the west is clear (the horizontal feature across the middle of the picture is simply an imprint of an old bench level). It is likely that the shales in Figure 27 are actually tuffs and are a southern extension of the tuffs in Figure 28, making their strike length ~500 m.

Figure 28 Tuffaceous claystone

Colour: The typical sediment colour is a medium brown to khaki. In many places the sediment colours also include light grey to whitish (as in Figure 27 and Figure 28) and also red. A typical example of a khaki brown finely bedded blocky siltstone is shown in Figure 29. This example is from the hanging-wall of (west of) the Eastern Limestone near the south end of the South Pit. It also illustrates the typical ~60°W dip of the sequence. These rocks typically have extremely poor and thin soil developed above them, a diagnostic mapping tool, and in this illustration the soil cover is <10 cm thick.

Figure 29 Siltstone

5.4.6 TANGARANG VOLCANICS (DACITE)

Conformably (or more probably unconformably) higher in the sequence and to the west of the Bungonia Limestone Group rocks are the Tangarang Volcanics (now *Tangarang Formation ((Dkt) of the Bindook Group (Dk)*). These extrusive, air-fall and shallow marine sedimentary rocks consist of dacite and rhyolite ignimbrites, basalt lavas (?), toscanites, ignimbrites, tuffs, tuffaceous volcaniclastic sandstones ('volcanic sandstone'), sandstones and minor limestones. The academic 'type section' of the Tangarang Formation is in Main Gully at the Mine.

Figure 30 shows a typical outcrop of dacite boulders, illustrating their rounded (exfoliated) appearance. This outcrop is well into the dacite, ~150 m west of the volcanics contact. The location is adjacent to the main overburden road and ~150 m from its eastern end where it joins the pit. Figure 31 shows a close-up of the dacite rock, illustrating its fairly uniform texture. The evenly distributed squarish light green phenocrysts weather to a whitish colour on the surface of boulders, giving them a diagnostic spotted appearance.

Figure 30 Dacite outcrop

Figure 31 Dacite

The Tangarang Formation could be characterised as dacites within a shallow marine volcaniclastic succession, with the sedimentary rocks forming the major component (Geo Survey, 2012, p1079). In other words, felsic volcanism and associated sedimentation. Many of the boundaries between the units are unconformable, typical of rapid erosion of unconsolidated material around volcanoes. The Geo Survey describes the 'volcanogenic sequence recording a transition from shallow marine (locally deeper water) into subaerial environments'.

The contact with the lower Bungonia Group is contentious and poorly exposed. However it would seem more likely to be an unconformable boundary as the Geo Survey has the volcanics progressively truncating the limestone units from north to south (Geo Survey, 2102, p1090). The Tangarang Formation is intruded by the Marulan Granite (associated with the Glenrock Granodiorite which cuts the Eastern Limestone in the north).

Earlier geological interpretations (good example McKenzie 1958 (SPC)) described various layers of what is now known as the Tangarang Volcanics as being intrusive in nature, and termed much of it as ‘quartz porphyrite’. This description is now simply assumed to have been a mistaken interpretation of the varied and difficult to understand volcanogenic sequence. Ferruginous contacts with the limestone (up to 10 m wide), put down to alteration of the ‘intrusives’, would now be interpreted as weathered limestone.

5.4.7 GLENROCK GRANODIORITE

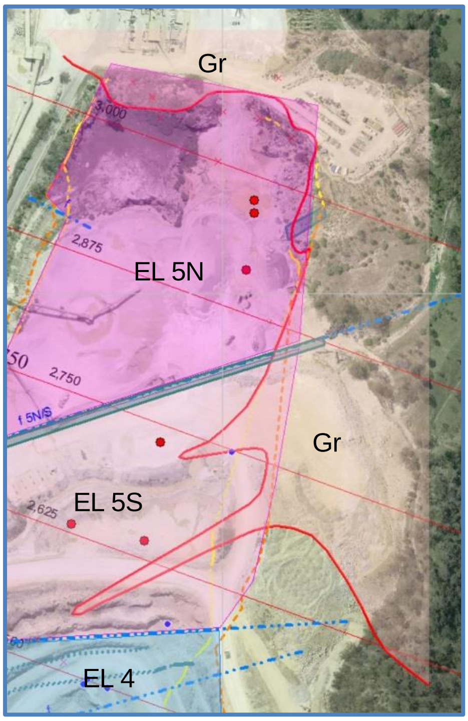
The Glenrock Granodiorite is 1 of 12 intrusive plutons of the *Arthurslie Suite (Da)*. Previously it was grouped with the Marulan Batholith which included intrusive-like rocks now identified as Tangarang Volcanics. These plutons have geochemical characteristics of I-type granites.

Occurrence: The Glenrock Granodiorite intrudes the sediments and Eastern Limestone at the very north and north east of the North Pit. The rock is presumed by the Consultant to be the same as is now being quarried by Boral at the Peppertree Quarry to the north of the Limestone Mine.

Description: The intrusive Granodiorite rock is medium grained, equi-granular, and light grey. It is described as very homogeneous. It is pegmatitic near its margins (Gould, 1966). Locally it contains xenoliths derived from the Tallong Beds.

Contact metamorphism: Carr et al, 1983, mention that the intrusion of the granodiorite into the Eastern Limestone recrystallised part of it into a marble and that the introduction of elements from the pluton also created a skarn (Osborne, 1931). The Consultant is not aware of the location of a skarn, but it seems likely from talk of old copper extraction nearby. Re-crystallisation of the limestones is certainly pervasive, and probably more intense close to the Granodiorite (although it is also present in the South Pit some distance away). The Granodiorite also intrudes the Tangarang Volcanics to the west, and the contact zone used to be described as ‘hybrid rocks’ passing into quartz porphyries. This is now recognised as contact metamorphism of silicic volcanics in the Tangarang Formation.

Figure 32 Granodiorite contact mapping



Outcrop: Small rounded bouldery outcrops, typical of granites, of the granodiorite are widely scattered in the paddock north east of the stores (~200 m north of the pit) and in the gully skirting around the lay-down area east of the stores. Outcrops around the actual northern contact with the limestone are limited and small with the most prominent near the crest (red arrow in Figure 33). This outcrop is only inferred to be granodiorite (it cannot be easily reached) from its dark grey colour and relatively smoothness differentiating it from the limestone appearance there.

Contact: The northern limestone/granodiorite contact is mapped in Figure 2 and displayed in more detail in Figure 32 (red line bounding the pink shading) in relation to the northern EL fault blocks 5 and 4. It has current increased significance to mine planning because of new focus on the northern limestone EL 5.

The irregular contact is hard to verify as the area’s mapping is old and most of the surface is not visible any more (the southern parts being hidden below emplaced overburden). Much of the northern contact position is inferred from a few short holes drilled across and close to the edge of the north wall crest in the late 50s and early 60s. In those holes the granodiorite was only roughly interpreted as present or not (they were probably simply probing the surface weathered zone), with the contact line inferred between holes. Figure 33 illustrates the north wall contact looking west. The blocky limestone within the pit (left and bottom) is off-white.

Determining the dip of the EL’s northern and north eastern contacts with the granodiorite was a specific objective of the P3 drilling. Although the drilling was not able to establish the dip along the E/W trending northern contact it is fairly confidently assumed not to dip back into the pit at any moderate angle but rather to be at least approximately sub-vertical or even have a northerly dip.

Subsequent to the P3 drilling a 1928 topography map was discovered showing the northern part of the Mine (at a date prior to mining in that area). It displays an approximate boundary line around the Eastern Limestone. At its very northern end that line indicates the limestone contact bulging north eastwards ~100 m further than mapped in Figure 32. This is possible and remains a priority objective to resolve.

Figure 33 Granodiorite north wall contact

Drilling on the nearby N/S trending eastern contact (in the north east corner of the pit) showed the intrusive granodiorite contact to be dipping into the pit at ~60°W at its northern end and ~45-50°W at its southern end (see Figure 9 and Figure 10 cross-sections). That contact against the limestone runs for ~350 m southwards before the granodiorite contact veers eastward into the sediments to the east. The two narrow protrusions (Figure 32) mapped SW into the limestone were partially confirmed by the drilling.

The 'Big Dyke' cross-cutting the northern limestone also appears (possibly unreliably) to intrude the granodiorite, as does another to the north nearer the head wall.

Weathering: The upper 10 m of the granodiorite is locally weathered to clay (Barnstone, 1971). The depth of weathering over granodiorite would be expected to vary considerably (with the Consultant estimating it could extend down ~20-30 m).

5.4.8 DYKES

Description: Dolerite dykes intrude the sediment and limestone sequence in places. The visible mapped ones cross-cut the basal Tallong Beds, the Eastern Limestone and at least the adjacent sediments to the west. It is not known if they intrude the higher Mt Frome Limestone sequence. The rocks are fine grained, dark grey and usually weathered greenish. The dykes are generally narrow, in the range 1 to 5 m but range from centimetres up. Several very narrow sub-parallel ones may run along close to a wider one. They are linear and near vertical in dip.

Older mapping (such as Figure 2) has a 25 m wide dyke crossing the very north of the North Pit, apparently older than the granodiorite. However that mapping is now shown to be slightly inaccurate and the dyke is now mapped as the 'Big Dyke' and interpreted as the contact between block EL 5N and EL 5S (see Figure 32). It is only ~5 m wide, linear, sub-vertical, and possibly cross-cuts the granodiorite in the east and certainly cross-cuts the sediments to the west of the EL. Monitoring of water levels during the P3 drilling indicates this dyke to be a good water barrier as the water table close to the south of it is ~150 m lower than to the north (see Section 1).

Figure 34 Dyke

Figure 34 illustrates a typical near vertical dyke cross-cutting limestone near the crest of the east wall of the centre of the pit. The dyke is ~1.5-2 m wide, greenish, and has several narrow sub-parallel stringers. Its contacts with the limestone are typically fairly sharp with negligible contact effects observed. Figure 35 illustrates this with an ~0.5 m dyke in the west wall of the northern part of the North Pit. The dyke rock peeled away smoothly from the limestone when extracted. The pit scale of this dyke is shown in Figure 40.

Figure 35 Dyke edge

Sets & orientation: Dykes are steeply dipping and generally split into two sets based on strike orientation. These were interpreted as of different ages (Mckenzie, 1958 (SPC), and Barnstone, 1971 (APCM)). The more common dykes strike across the limestone at 060° to 090°, are more weathered, and are thought to be older. The less common dykes strike close to along the limestone at 020° and these are younger. These may run along limestone bedding, and may be described as sills. A clear intersection of the two sets is observed in the eastern sediments at the present lookout on the eastern side of the pit at the old dividing bund wall position.

Weathering: Near original surface the dykes are highly weathered to a clayey consistency. Figure 36 illustrates (red arrow) a highly weathered ~1.5 m wide greenish-brown dyke outcropping at surface on the western crest of the North Pit wall. It is cross-cutting khaki coloured siltstone sediments (on the left and right) west of the EL, and both are weathered to a soft crumbly consistency.

Figure 36 Dyke weathering

5.4.9 YOUNGER COVER ROCKS

Although younger unconformable cover rocks are sporadically mentioned in scattered early documents none effectively now remain in the immediate Mine area. These sediments were described as clays (dark grey to greenish and reddish brown, red and white), grits, conglomerates and quartzite boulders (grey) of Tertiary age. Nowhere was their thickness mentioned or mapped, but they were described as originally blanketing much of the south of the lease (presumed to equate to the South Pit area) and being locally thick in the north of the 'quarry' (Barnstone, 1971 (SPC)). It is inferred from the benches mentioned that this cover was at least 30 m thick in places (McKenzie, 1958 (SPC)).

The Consultant considers that the described colours of the clays point to parts of them actually being weathered limestones or limestone contacts.

Large quartzite boulders floating in the clays were described as being silicified quartz conglomerates commonly known in NSW as 'Grey Billy'. The silica was described as having leached from higher horizons (often considered to be Tertiary basalts) and cemented the previously loose quartz grains and pebbles. These boulders occurred mainly at the margins (?) of the cover south of the 'quarry'. The Consultant is not yet aware if these interpretations match current Geo Survey understandings.

6 ORE MINERAL DISTRIBUTION

Ore source: The ore mineral at Marulan South is limestone ($CaCO_3$). Apart from very limited 'high magnesium' zones (discussed in Section 7.1) effectively **all** of the hard crystalline limestone is high enough grade to constitute ore. Apart from small volumes of limestone cavities (Section 5.4.2) and trivial volumes of intrusive dykes (Section 5.4.8) the hard crystalline limestone effectively occupies the full volume of the limestone deposits (as mapped in Figure 2 and then further illustrated and described in detail in Section 1). In other words all of the limestone is 'ore'. Calcium and a few other elements (see Section 1) vary fairly randomly from place to place in the deposit (on a mining unit scale, such as a single blast), allowing various areas or levels of the limestone to be used for different purposes (see blending below).

Figure 5 illustrates all of the potential limestone ore bodies. In modern time (last 50 years) the contiguous Eastern Limestone (wide green body on right) has been virtually the sole source of ore and continues to be so. In very recent times (last 3 years) extraction from the Mt Frome Middle Limestone (thin cyan body to the left of the EL) has begun (within the yellow line). Currently the ML contribution is minimal, but that is expected to grow as overburden above it is removed and it is mined deeper and then extended along strike outside the yellow line at either end.

Overburden/Interburden: The limestone in the Mine is at a sufficient depth along most of the full deposit length that 'non-limestone' overlying overburden material and adjacent interburden material **must** be extracted to allow continued limestone ore extraction. All non-limestone material is generically referred to here as 'overburden'. The vast majority of this material are fine-grained sediments (Sections 5.4.4 and 5.4.5). Limestone contact zone material (predominantly clay) flanking (and also overlying in the case of the ML) each limestone ore body (described in Section 5.4.3 and shown in Figure 2) is treated as overburden. Contact zones are not included in the limestone computer models. Cavity fill and dyke rocks are treated as overburden or 'waste' if they can be sorted out from the limestone.

Having said that a relatively small proportion of the 'clean' shale overburden can be blended (see below) with limestone – and so technically is not overburden. In the future the granodiorite (bounding the limestone in the very NE) and dacite (expected to form a western boundary once the ML is mined to some depth) could potentially represent ore for crushed rock production.

Production: Limestone ore is extracted contemporaneously or sequentially from multiple locations along the ore bodies – as mine planning dictates. The planning is driven largely by fairly constant annual ore (limestone) tonnage production targets (currently ~3 Mtpa) – which translate into roughly equal weekly numbers of trains to load at the plant according to its capacity. The planning is also partly driven by limestone grade variations (see blending below). As all of the ore (and some of the overburden) requires blasting the multi-location mine planning revolves around the operational imperatives of accommodating blasting, trucking, crushing and blending. The Mine operates seven days a week. Ore is generally only trucked to the crusher during the week (and not on weekends) in line with the plant operation.

Overburden is contemporaneously extracted in sufficient quantity to allow the limestone targets to be met. Its extraction has necessarily increased over time as the pit deepens. Over recent times the overburden quantity extraction rate has been similar to that of limestone (giving a ~1:1 stripping ratio).

Blending: The Marulan South Limestone Mine has long (~40 years) had several customers, each with varying product specifications based on 'grade'. Grade is determined by the limestone chemical composition (Section 1) – predominantly by calcium carbonate content and to a lesser extent by 'contaminants'. The biggest customer by volume is the company's own cement plant at (relatively nearby) Berrima. Calcium carbonate levels are lower for cement than for lime and steel making customers.

As grade factors vary from place to place in the deposit the ore from these areas requires blending (effectively mixing to meet an average composition) to make different products. Blending is achieved by undertaking 'grade control' (assaying blast-hole cuttings to know the grade in a particular area) of the extraction and by individual stockpiling of different blended products. Places in the Mine of specific composition are generally of a mining unit scale (a whole or part of a blast). Although they would presumably relate to some specific geology (such as a bedding horizon) they are difficult to identify purely by eye and so they are determined from laboratory analysis of the blast-hole cuttings 'on-the-fly' during mining. Ore from different areas are then either separately stockpiled and then blended or are physically blended from the mining faces to produce the different products. Ore of particularly high calcium content may be blended 'down' by the limited inclusion of overburden shales.

7 ROCK TYPE CHEMICAL CHARACTERISATION (GEOCHEMISTRY)

Chemical characterisation of the limestone deposit and associated rocks is described in terms of:
- Limestone quality – its high grade, contaminants, and ore specifications.
- Individual rock type characterisation.
- Environmental implications of waste rock chemistry

7.1 LIMESTONE QUALITY

Quality of the limestone deposit is described in terms of:
- Uniform high grade of the limestone in terms of calcium carbonate content.
- Contaminants.
- Ore specifications.

7.1.1 HIGH GRADE LIMESTONE

Limestone is a rock type containing >80% calcium and magnesium carbonates, and as such is a 'bag' term for a diverse group of calcareous rocks. The magnesian rich ones are generally termed dolomites. A 'high grade' limestone is one generally taken to contain >95% calcium carbonate ($CaCO_3$) and <1% magnesium carbonate ($MgCO_3$). Silica, alumina and iron minerals would then also individually have concentrations <1%.

Eastern Limestone: This rock is predominantly of high purity. Mining involves systematic sampling and assaying of bench blast-holes. The following average figures are extracted from various Mine or other technical reports based on blast-hole assays. The EL essential element constituents were specified by Read, 1970, as:
- CaO >53%, usually >54%.
- MgO <1%, occasionally higher due to dolomitic veins.
- Al_2O_3 usually 0.5%.
- SiO_2 average 0.7%, rarely >1%.
- Fe_2O_3 < 0.5%, usually <0.1%.

Barnstone, 1971 specified average analyses of recoverable clean limestone as:
- $CaCO_3$ 97.1% (and only insignificant quantity <92.5%).
- $MgCO_3$ 1.1%

Mt Frome Middle Limestone: Phase 1 (P1) of the recent 2015 exploration program on the Mt Frome Middle Limestone produced very encouraging qualities in the pure limestone samples. The straight averages of all the limestone samples were:
- $CaCO_3$ 92.6%
- $MgCO_3$ 0.7%
- Al_2O_3 1.3%
- SiO_2 4.9%
- SO_3 0.007
- K_2O 0.6
- Fe_2O_3 0.8%

All samples were from close to surface and therefore prone to some clay contamination at least.

7.1.2 CONTAMINANTS

Within the bulk of the limestone rock mass the contaminants appear to be variably distributed with no clear correlation with location or lithology. Note that not all clay associated with limestone is 'contamination' as quantities of this material is used for blending. This is to adjust the ore chemical balance to suit different products, particularly cement (where pure limestone is not required).

Dolomitisation contamination: Notwithstanding Barnstone's figure of 1.1% for $MgCO_3$ BCSC, 1979 put the figure at 3%. Within limestone breccias and conglomerates the figure may rise to 6% and occasionally 8%. Secondary dolomitisation which introduces magnesian minerals occurs along joints and fissures normal to the strike, may be up to 5 m wide and vertical, and contain values of 10 to 28% $MgCO_3$. These zones were said to occur mostly in the South Pit.

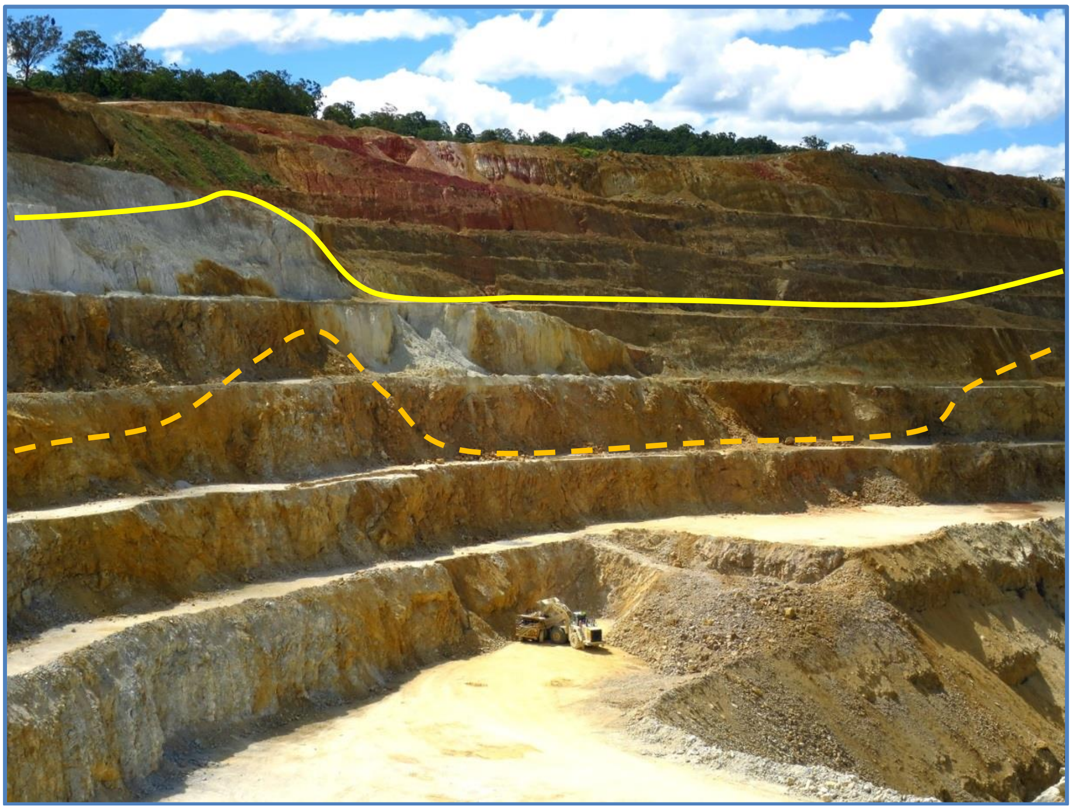
Cavity contamination: The sediments filling the frequent cavities represent contamination to the limestone.

Dyke contamination: Dyke rocks represent contamination to the limestone. During mining these dykes can become difficult to recognise if the limestone is dark, causing their inclusion. The Consultant notes that, if their exclusion was required, dykes could be marked out by a geologist and then visually excluded during excavation (aided by dyke rocks generally peeling away from limestones at their contacts and the contacts generally being sharp).

Surface & contact zone clay contamination: Although near surface material is no longer available for the Eastern Limestone the upper 20 m of limestone often contained clay filled cracks and joints which increased the SiO2. This is certainly evident now for the Mt Frome Middle Limestone from which extraction has commenced from its surface outcrop. By the second bench the limestone is already significantly freer of clay.

This surface clay contamination probably applies to the Eastern Limestone generally in the sense of clay contamination existing for some distance into the limestone away from the upper (western) contact. In Figure 37 the view is NW from the middle of the Eastern Limestone (closest at bottom) towards the footwall sediments (top in distance). The contact between them (solid yellow line) runs across the middle. A zone of buff coloured limestone contaminated with clay exists closest to the contact (above the dashed orange line), whilst further away from the contact (below the dashed orange line) the limestone is cleaner and much whiter (particularly in the foreground).

Figure 37 EL contact clay contamination in west wall



Granodiorite contamination: Quality of Eastern Limestone was said by Read, 1970, to be related to granodiorite proximity. South of the dividing Bund Wall (6,147,200 N), or ~1,500 m from the granodiorite, the ‘lump calcines’ had a stability of 75-85 (the Consultant is unaware of this property or its units). North of that the calcines were weak and friable with excessive fines.

7.1.3 Ore Specifications

The Consultant does not have sufficient comprehensive knowledge of BCL's products to fully describe them or their product specs. Consequently the following details are generalised.

Limestone: Limestone element constituents were given with the description in Section 7.1.1, and essentially describe the limestone as high grade. As such it would directly meet specification for use in typical applications such as cement and lime manufacture (BCL's current uses). Specific other limestone products are sourced from certain parts of the pits based on combinations of local element analyses. Samples from the whole pit area are routinely taken during blast-hole drilling and assayed in the Mine laboratory.

Clays and shales: Minor quantities of clays and shales mined at the Marulan South Limestone Mine represent products in themselves. In general, these products may be blended with limestone to meet limestone specs or represent stand-alone products. These are generally mined as the by-product overburden moved to access the limestone and thus have been typically grouped with the overburden in terms of reporting. This grouping and their minor quantities have generally removed them from the 'Ore Resource' estimation cycle. An example of a specific clay/shale product is the white claystone (now identified as tuff, Figure 28) on the SW crest of the North Pit. This material is blended to create off-white cement.

Consultant notes: Without further discussion with BCL the Consultant would not presume to speak on BCL's behalf with regard to limestone and other material product specifications. However he does make the following general comments with the aim of verifying the limestone's ore grade quality. The Consultant would state that, although BCL ore specifications are commercially confidential, it could be said that the typical high grade limestone chemical constituents exceed the necessary specifications for BCL products. As such the limestone represents a valuable Mineral Resource in a mining context. BCL's specs may be met by direct use (limestone from a specific pit location) or by creating blends of different limestones (from different locations in the pit) and/or other rocks (such as clays). Furthermore, without wanting to attempt to provide a typical spec range of limestone for cement making, it would be typical for different cement plants to be calibrated to the specs of their usual ore sources, and that this is also the case with BCL.

7.2 Individual Rock Type Chemical Characterisation

Chemically characterising all rock types at the Mine is inhibited by the fact that although the limestone has been analysed extensively the 'overburden' rocks have not. However in February 2015, as part of research on environmental issues, a series of 20 samples were taken of different rock types in order to achieve exactly this. They provide the core of the characterisation presented here.

Note:

- The recent P1 to P3 exploration drilling programs (see Section 1) sampled and assayed a great amount of overburden along with all of the limestone. Those results have not yet been compiled for further rock type characterisation.
- These details on rock type geochemistry were previously given in Section 7 of the 2015 geology report.

7.2.1 Samples

The February 2015 rock samples were taken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) with the Consultant's help in identifying different types. Their technical environmental impact analysis was reported by RGS Environmental (RGS). Sampled rock types are listed in Table 2 along with their AGE and RGS sample numbers. The sample locations are shown by the red dots in Figure 38, with two samples taken at each location.

RGS's objective was to assess representative samples of Mine overburden or 'waste rock' materials to determine their potential for generating acid and soluble metals. All samples were analysed by ALS Environmental Laboratory in Brisbane. Samples were crushed to pass 10 mm with sub-samples pulverised. The prepped sample residuals from ALS were then also analysed by BCL's Mine laboratory to acquire results in the usual Mine format.

Table 2 AGE/RGS rock type samples

			Sample numbers		
Pit	Rock type	AGE sample description	RGS		AGE
side	*(Formation)*		#	#	#
W	**Limestone (South Pit, Mg rich)**	Limestone, Mg rich	1	1	RS01-1
W	*(Eastern Limestone)*		2		RS01-2
E	**Limestone (North Pit)**	Limestone	3		RS02-1
E	*(Eastern Limestone)*		4		RS02-2
E	**Dyke** (weathered)	Dyke - highly weathered	5	2	RS03a
E	**Dyke**	Dyke	6		RS03b
E	**Shale** (near lst contact)	Contact - Lst/Shale, ferruginised	7	3	RS04-1
E	*(Eastern Lst lower contact)*		8		RS04-2
E	**Clay** (near lst contact)	Transition zone - weathered clay	9		RS05-1
E	*(Eastern Lst lower contact)*		10		RS05-2
E	**Shale/mudstone**	Shale/mudstone	11	4	RS06-1
E	*(footwall Tallong Beds)*		12		RS06-2
W	**Tuff** (white, sandy)	White sandstone (?), brittle, feldspar, si-rich (?)	13		RS07-1
W	*(seds between ML and EL)*		14		RS07-2
W	**Clay** (lst contact, red, ferric)	Red soil/clay - weathered sst w ferric bands/nodules	15		RS08-1
W	*(Middle Lst lower contact)*		16		RS08-2
W	**Sandstone/claystone** (brown)	Brown sandstone/claystone, blocky, hard	17	5	RS09-1
W	*(seds between ML and EL)*		18		RS09-2
E	**Shale**	Shale, unweathered	19	6	RS10-1
E	*(footwall Tallong Beds)*		20		RS10-2

Figure 38 AGE/RGS sample locations

The 2015 geology report contains illustrations of the sampled rocks.

7.2.2 SIMPLE CHEMICAL CHARACTERISATION

Table 3 presents the BCL Mine laboratory 'whole rock' assay results for the 20 AGE samples. The trace element assays by ALS are available in the RGS report.

Table 3 AGE/RGS rock type assays

		Sample numbers					Location			BCL Mine laboratory assays											
Pit	Rock type	RGS		AGE	BCL	ALS	N	E	RL	$CaCO_3$	$MgCO_3$	Al_2O_3	SiO_2	SO_3	K_2O	Fe_2O_3	TiO_2	MnO	∑	CaO	MgO
side	*(Formation)*	#	#	#	#	#	(m)	(m)	(m)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
W	**Limestone (South Pit, Mg rich)**	1	1	RS01-1	AC 001	EB1513149001	6,146,575	227,712	390.0	93.51	2.48	0.80	2.97	0.185	0.21	0.46	0.042	0.047	100.70	52.360	1.190
W	*(Eastern Limestone)*	2		RS01-2	AC 002	EB1513149002	6,146,575	227,712	390.0	92.66	1.85	1.04	4.28	0.123	0.27	0.47	0.055	0.030	100.78	51.890	0.886
E	**Limestone (North Pit)**	3		RS02-1	AC 003	EB1513149003	6,147,570	228,113	450.6	99.40	0.67	0.06	0.25	0.005	0.01	0.47	0.005	0.097	100.97	55.660	0.322
E	*(Eastern Limestone)*	4		RS02-2	AC 004	EB1513149004	6,147,570	228,113	450.6	99.21	0.60	0.03	0.10	0.003	0.00	0.19	0.004	0.042	100.18	56.100	0.290
E	**Dyke** (weathered)	5	2	RS03a	AC 005	EB1513149005	6,147,230	228,099	624.1	22.21	5.51	11.14	32.17	0.084	2.24	9.54	1.275	0.149	84.32	12.440	2.650
E	**Dyke**	6		RS03b	AC 006	EB1513149006	6,147,192	228,129	536.0	22.65	11.01	15.24	45.35	0.160	0.33	10.58	2.024	0.130	107.47	12.680	5.280
E	**Shale** (near lst contact)	7	3	RS04-1	AC 007	EB1513149007	6,147,169	228,124	538.0	11.67	0.52	4.34	11.26	0.016	0.81	61.71	0.254	3.510	94.09	6.534	0.248
E	*(Eastern Lst lower contact)*	8		RS04-2	AC 008	EB1513149008	6,147,169	228,124	538.0	9.59	2.65	5.17	12.54	0.031	0.62	61.86	0.519	1.434	94.41	5.370	1.270
E	**Clay** (near lst contact)	9		RS05-1	AC 009	EB1513149009	6,147,157	228,132	539.6	4.05	1.90	15.33	39.38	0.003	3.83	5.89	1.001	0.030	71.41	2.270	0.912
E	*(Eastern Lst lower contact)*	10		RS05-2	AC 010	EB1513149010	6,147,157	228,132	539.6	3.76	0.93	10.78	39.84	0.001	2.77	4.96	0.842	0.018	63.90	2.105	0.445
E	**Shale/mudstone**	11	4	RS06-1	AC 011	EB1513149011	6,147,145	228,161	540.9	3.75	1.14	9.75	32.87	0.002	3.48	6.50	0.700	0.015	58.21	2.101	0.545
E	*(footwall Tallong Beds)*	12		RS06-2	AC 012	EB1513149012	6,147,145	228,161	540.9	3.45	0.78	10.57	54.17	0.004	2.15	4.17	0.581	0.012	75.89	1.935	0.374
W	**Tuff** (white, sandy)	13		RS07-1	AC 013	EB1513149013	6,147,266	227,768	566.2	3.40	0.16	6.17	54.28	0.007	0.46	0.36	0.401	0.007	65.25	1.907	0.077
W	*(seds between ML and EL)*	14		RS07-2	AC 014	EB1513149014	6,147,266	227,768	566.2	3.32	0.35	5.66	55.55	0.004	0.76	0.43	0.344	0.008	66.43	1.861	0.170
W	**Clay** (lst contact, red, ferric)	15		RS08-1	AC 015	EB1513149015	6,147,392	227,785	572.5	3.58	0.14	6.98	63.62	0.006	0.51	3.45	0.527	0.013	78.83	2.007	0.067
W	*(Middle Lst lower contact)*	16		RS08-2	AC 016	EB1513149016	6,147,392	227,785	572.5	3.63	0.11	10.22	51.47	0.015	0.55	10.24	0.823	0.012	77.07	2.033	0.055
W	**Sandstone/claystone** (brown)	17	5	RS09-1	AC 017	EB1513149017	6,147,638	227,860	557.1	4.05	0.59	5.23	57.42	0.005	1.09	3.10	0.384	0.013	71.88	2.270	0.282
W	*(seds between ML and EL)*	18		RS09-2	AC 018	EB1513149018	6,147,638	227,860	557.1	3.42	0.25	4.36	67.89	0.003	0.66	1.71	0.288	0.031	78.61	1.915	0.122
E	**Shale**	19	6	RS10-1	AC 019	EB1513149019	6,147,381	228,279	568.9	3.48	0.98	14.68	56.66	0.002	3.28	3.99	0.676	0.012	83.76	1.947	0.473
E	*(footwall Tallong Beds)*	20		RS10-2	AC 020	EB1513149020	6,147,381	228,279	569.9	3.42	1.11	16.48	52.49	0.005	3.83	2.80	0.751	0.010	80.90	1.914	0.534

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7.3 ENVIRONMENTAL IMPLICATIONS OF WASTE ROCK CHEMISTRY

RGS's environmental objective was to assess representative samples of Mine overburden or 'waste rock' to determine their potential for generating acid and soluble metals/metalloids. Four samples of limestone were taken for contrast.

RGS's report (summarised in the 2015 geology report) detailed the:

- Sample analysis.
- Acid forming potential. Tests for pH, Electrical Conductivity (EC), total sulphur; and Acid Neutralising Capacity (ANC) were aimed to determine overall Net Acid Producing Potential (NAPP).
- Metal concentrations.
- Geochemical abundance.
- Potential impacts on water quality.

RGS's geochemical assessment of Mine 'waste rock' indicated overall that:

- It could be considered to have negligible risk for generating Acid Mine Drainage (AMD).
- Classification was as Non-Acid Forming (NAF), barren of sulphur, with a high safety factor.
- Surface water run-off and seepage was likely to be slightly alkaline with low TDS.
- It contained low concentrations of metals/metalloids (below the guidelines for recreational public open spaces), and those found slightly elevated were in limited volume material (thin limestone contact) and were sparingly soluble.
- Geochemically the metals/metalloids were not enriched compared to average crustal abundance.
- Trace metals/metalloids were sparingly soluble in slightly alkaline water and unlikely to impact quality of surface or ground water at the site.

8 GROUNDWATER

Groundwater level and movement understandings have been updated with data from recent exploration drilling (see Section 1) detailed in the 2016/8 exploration report.

Groundwater is described in terms of:

- General observations by the Consultant.
- Groundwater details logging during the 2016/7 drilling.
- Groundwater installations – piezometers installed and the water bore drilled during the 2016/7 drilling.
- Groundwater monitoring.

8.1 CONSULTANT'S GROUNDWATER OBSERVATIONS

Data: The Consultant endeavoured to collect data on groundwater throughout all phases of the 2016/17 exploration drilling program (Section 1). Notes on water encountered in the drilling were collected during the hole logging and are extracted into Table 4. During P2 the Consultant assisted installation of a number of groundwater monitors (piezometers) and the drilling of a water bore (described in Section 8.3). These activities (and the long time spent observing the pit area physically) gave him insights into the groundwater and local water table (WT) which are shared below. The Consultant has not had the opportunity to study any long-term groundwater observations (Section 8.4).

Difficulty collecting data during drilling: During RC drilling with plenty of compressed air (as in this program) it is frequently difficult to determine when groundwater is encountered where the water inflow is limited. One reason is because the air pressure being used may 'keep the water back'. As the hole gets deeper the air has more problem doing that, as the number of fractures (where water may be) increases, and the air increasingly dissipates into the formations. Another reason is that in difficult ground conditions (where the rock may be sticky or in other ways clogs up the system) the driller may begin to inject water to help with drilling. In this case groundwater cannot be differentiated from injected water unless the groundwater flows are high. So discerning when, where and whether groundwater was encountered in any given hole was only successful some of the time.

Limestone: The Consultant's view of the limestone, with respect to groundwater flow through it, is that it contains many internal and external avenues (conduits) allowing almost unrestricted water flow. A simple piece of evidence for this is the rapid pit drainage after heavy rainfall – which must indicate easy water flow though and out of the limestone.

Figure 39 Fissure

These internal conduits are interconnected fault and bedding plane gaps and voids which may be centimetres to metres in width. Ultimately these water conduits are created by the propensity for limestone to slowly dissolve completely in water. During drilling of EL56 in the bottom of the north end of the North Pit, after a period of heavy summer thunder storms on the Mine itself, a recently (days before) exposed NW corner was seen with water pouring freely out of it (orange arrow in Figure 39).The mining had exposed a narrow fissure ~10 cm wide with clean faces from frequent running water. The water flow stopped after approximately a day, presumably having drained all the benches and rock in the west wall above. This fissure also exhibited another often associated feature – partial clay filling of voids (the ~5 m high red brown material above the arrow head in Figure 39). Because of the high flow rate in these fissures there is only a very limited time to observe them actually draining through the floor of the pit (as they would also drain the pit).

The external conduits are the limestone contact zones with adjacent rock, mostly sediments. Here the limestone weathers into impervious red and white clay amongst other things. The clay acts as both a barrier and then a conduit. Initially it presents a barrier to water flow, thus raising the WT and allowing more submerged weathering. Subsequently, as it is relatively weak, any great head of water will break though it in places, thus allowing groundwater to flow from the sediments into the limestone or simply down the irregular contact zone and into the limestone though holes in the clay. And as the contact zone thicknesses vary widely up and down and along the contacts so to do their properties as barriers to water flow.

Water Tables: It became very clear in P3 that the northern 'Big Dyke' across the stockpile area (blue band separating EL 5N and 5S in Figure 32) forms a tight barrier to groundwater flow. To the north of it the local water table (WT) was virtually at surface (shown in hole EL45, 54 and 55), or ~550 RL. This WT appeared to extend to the west and be encountered in the holes drilled on the pad in front of the magazine and on Mt Fuji. To the south of that dyke the WT is far lower, below the bottom of the North Pit and lower than 400 RL. Hole EL53, less than 100 m south of the dyke, was essentially dry to >100 m. And hole EL52, ~100 m south, encountered water at ~210 m down-hole, equivalent to the 340 RL and 210 m below the surface a ~550 RL. Similarly EL46 encountered water at 126 m down-hole, equivalent to ~420 RL and 130 m below surface. This great step in the WT not only illustrates the dyke's barrier properties but also the 'flat' WT in the limestone indicating high transmissivity.

The Consultant does not know how the North Pit WT relates to the South Pit WT but he would expect them now to be similar as the gap between their lowest points becomes less with the North Pit deepening. However if the northern Big Dyke's impermeability is replicated by the similar ~2-3 m wide vertical dyke cutting across the gap between the North and South Pits (Figure 40, virtually directly below the viewing platform and where the old bund wall was) then one would expect a WT step there too.

Figure 40 Dyke cross-cutting mid-pit

South of the northern dyke the WT would appear to step up to the west. Each of the Mt Frome limestones would appear to represent a barrier to ground water flowing eastwards from the west.

8.2 GROUNDWATER LOGGING

The details in Table 4 combine details noted during the Consultant's geological logging of holes during the 2016/7 exploration drilling program and extracted from the driller's plods (rough drilling notes).

Table 4 Groundwater logs

Phase	Drill hole	Wet/ Dry	From (m)	To (m)	Lith	Comments	Piezo (m)
P1	**EL40**	Wet	170		SST		
P1	**EL41**	Dry				Not present. Unsure status.	
P1	**EL42**	Dry				Not present. Unsure status.	
P1	**EL43**	Wet	163		SST		

Phase	Drill hole	Wet/ Dry	From (m)	To (m)	Lith	Comments	Piezo	(m)
P1	**EL44**	Dry ?	69	71	LS/CY	Cavity. Gravel & water. Contact zone		
P2	**EL45**	Wet	4		LS	Water @ 4 m 40 l/m		
P2	**EL45**	Wet	33	36	LS/DY	Water @ 33 m 70 l/m		
P2	**EL46**	Dry	0	126	LS	Slight seepage overnight 108 -126 m.		
P2	**EL46**	Wet	126		GR/CY	Aquifer. Moderate flow		
P2	**EL47**	Dry	0	100	SST		?	
P2	**EL47**	Wet ?	100		SST			
P2	**EL48**	Dry ?						
P2	**EL49**	Dry ?					Y	
P2	**EL50**	Dry				Void 234 m at EOH.		
P2	**EL51**	Wet	18		SST	Water table after standing overnight.		
P2	**EL51**	Wet	135		LS	High flow in limestone from 135 m on.	Y	124
P2	**EL52**	Wet	210	222	LS	High flow		
P3	**EL53**	Dry	24	27	CY/LS/DY	Minor water at top lst contact zone.		
P3	**EL54 (1)**				LS	Void 2.5-6 m.		
P3	**EL54 (2)**	Wet	3			Water from ~3 m from memory		
P3	**EL55**	Wet	4		LS/GR	Water from 4 m. Fractured ground with air coming out at surface.		
P3	**EL56**	Wet	100		LS/CY	Narrow fractured rock zone (void)? In lst @ 99-102 m. Water from ~100 m.		
P3	**EL57**	Wet	139		LS	Void @ 139-140 m. Water (from void?) 139 m on - very low flow.		
P3	**EL58**	Dry ?				Bad ground - mostly fill and clays. Damp clay @ 45-48 m EOH. Water table 42 m ? WT would be same level at north of dyke stockpile area WT @ ~3m.		
P3	**EL59**	Dry	0	42	Fill/CY	Bad ground - clays. Very difficult 42-45 m.		
P3	**EL59**	Wet	42	90	CY/SLST	Difficult drilling, presume because below WT @ 42 m?		
P3	**EL59**	Wet	90		SLST	Water definite. Eventually abandon because dirty water (silt) clogging hammer.		
P3	**EL60**	Dry	0	54	SLST/CY			
P3	**EL60**	Wet	54		SLST	Damp from 54 m.		
P3	**EL60**		90		SLST/SST/CY	More water from~90 m, slowly increasing flow down.		
P3	**EL60**	Wet	145		SST/CYST	Last 15 m ~145-159 m water flow high. Similar to EL51.		
P3	**EL61**	Dry	0	60	SLST/SST			
P3	**EL61**	Wet	60	102	SST	Water @ ~60 m (similar EL60)		
P3	**EL61**	Wet	102	162	SST/SLST	Water flow increases.		
P3	**EL61**	Wet	162	174	CY/LS/SST	Water flow high in lst contact zone. Eventually defeats rig.		
P3	**EL62**	Dry	0	90				
P3	**EL62**	Wet	90	143		Water from ~90 m. Increasing down.		
P3	**EL62**	Wet	143	150	SLST/CY/LS	Water flow high in lst contact zone. Eventually defeats rig.		
P1	**ML20**	Wet	216		SST			
P1	**ML21**	Wet ?	96	102	LS	Cavity. Moisture.		
P1	**ML21**	Wet ?	150	156	LS	Cavity. Moisture.		
P1	**ML21**	Wet ?	180		SST?	Cavity or wet clay bogs rig. Abandon		
P1	**ML22**	Dry ?						

Phase	Drill hole	Wet/ Dry	From (m)	To (m)	Lith	Comments	Piezo	(m)
P1	**ML23**	Wet	63	66	LS	Aquifer. Minor water.		
P1	**ML23**	Wet	177	180	SST/CY	Water		
P1	**ML23**	Wet	~300 ?		LS	Wet sample. Unclear if water injected		
P1	**ML24**	Wet	174		SST			
P1	**ML25**	Dry						
P1	**ML26**	Wet	60	66	LS/CY	Void. Wet. Water 60 m on.		
P2	**ML27**	Dry			LS	Void 105-107m.	Y	107
P2	**ML27**	Wet ?	168		LS	Minor water @ 168 m. Damp sample		
P2	**ML28**	Dry						
P2	**ML29**	Dry ?				Void at lst contact (94 - 95.5 m).		
P2	**ML30**	Dry ?				Void 81 - 84 m.	Y	
P2	**ML31**	Dry ?				Numerous voids with slight water		
P2	**ML32**	Dry						
P2	**ML33**	Dry				Void 9-18m at lst contact.		
P2	**ML34**	Wet	42	45	CY/SLST	Water		
P2	**ML34**	Wet	78	84	LS/CY	Water. Void ?		
P2	**ML35**	Dry				Very minor water at top lst 165-168 m. Very minor water in dacite 228-231 m.	Y	
P2	**ML36**	Wet ?	96	99	LS	Minor water @ 96-99 m 9 m above base lst @ 108 m.	Y	134
P2	**ML37**	Wet	69	72	LS	Moderate water 69-72 m. Lst top@ 66m.		
P2	**ML38**	Wet	123	126	SST	Increase water to high flow which stops hole. Lst base @ 123 m.		
P2	**MW07**	Dry			BAS	Water bore.		

8.3 GROUNDWATER INSTALLATIONS

During Phase 2 of the 2016/7 exploration drilling a specific objective became groundwater with the involvement of AGE. Discussions were held to determine how the drilling could be adapted to achieve groundwater aims. Geophysical down-hole logging was considered but ultimately discarded for various reason, one being the angled holes and another being the expected problems in keeping holes open.

Ultimately the groundwater program became twofold:

- Drilling a dedicated water bore west of the pit in the basalts.
- Install water monitoring piezometers in as many P2 holes as possible.

Water bore: A dedicated water bore (MW07) was drilled during the P2 program. It aimed to be west of the limestones and so was positioned on the ‘Back Road’ to the western overburden emplacements some 250 m west of the access road running ~N/S along the western pit crest. The bore was vertical and 80 m deep.

The hole was cased; included a 12 m section of screens; was gravel packed; was sealed with bentonite; and was ultimately securely capped. New Competitive Drilling (NCD) drilled the hole with a very experienced licensed water well driller (Phil Brown) on site during the drilling. AGE personnel (Bryce McKay) observed the drilling and performed the geological logging.

The rock encountered in the hole was a uniform dacite with little sign of jointing or faulting. Dacite is an extrusive volcanic rock with a similar composition to intrusive granodiorite. The hole was dry when drilled.

Piezometers: Hand slotted PVC piping was run down 6 holes during the P2 drilling program to create water monitoring piezometers. Figure 41 shows the NCD crew running the poly pipe down ML27.

Figure 41 Installing piezometer in hole ML27

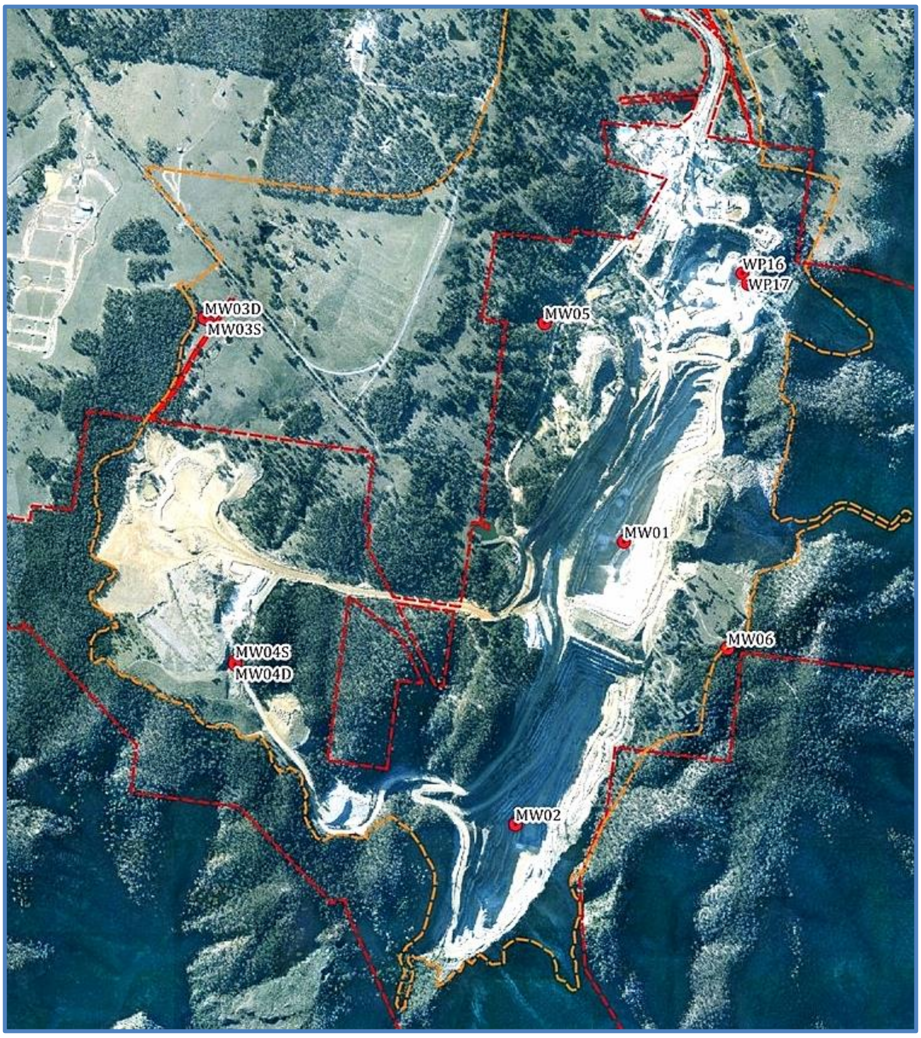
8.4 GROUNDWATER MONITORING

Mine personnel and dedicated water consultants periodically monitor groundwater in water bores, piezometers and at surface at locations scattered around the Mine.

A network of 8 groundwater monitoring bores are maintained within the Mine area. RPS supervised the installation of the eight monitoring bores (MW01 to MW06) in 2014 and undertook a series of hydraulic tests in April and May 2014.

The monitoring bores are located adjacent to and within the pit area and their locations are shown by the red dots in Figure 42 (AGE Fig 6-1, 7/2015). The red dashed line marks the current Mine lease CML16. Two bores within the pit area in the early 1980s have been removed by subsequent mining operations.

Figure 42 Water monitoring bore locations



Surface water quality is also monitored at a series of 12 locations around the Mine. Those locations are listed in Table 5 (coordinates in GDA94, Zone 56).

Table 5 Surface water monitoring locations

Location	Easting	Northing	Elevation
Marulan Creek Upstream	225825	6151504	603.00
Marulan Creek Downstream	228002	6151977	585.50
Barbers Creek Upstream	229518	6148416	250.50
Barbers Creek Downstream	229542	6147306	155.00
SR1 - Shoalhaven River	229183	6145620	120.00
SR2 - Shoalhaven River	229940	6146335	118.00
SR3 - Shoalhaven River	231172	6146891	115.00
Bungonia Creek Upstream	227294	6145485	173.00
Bungonia Creek Downstream	228445	6145589	135.00
Main Gully Sample Point*	227578	6145625	152.00
Main Gully Auto Sampler	227324	6145992	382.80
Blowhole seep sampling point	227432	6145617	179.00

9 RECENT EXPLORATION

Summary: Recent exploration at the Marulan South Limestone Mine is described as background to the comments on Resources given in Section 11, particularly the current non-JORC quantity reporting (Section 11.7).

Setting: A combination of factors have led to a recent surge in exploration on the Mine. Ultimately they all revolve around the same issue – the increasing depth of the mine and therefore the increasing necessity of considering the mining of overburden as the stripping ratio increases. This consideration rests wholly on understanding the shape of the limestone body at depth along the full length of the Mine – effectively the dip of the eastern and western limestone contacts with the sedimentary overburden.

Whilst a large proportion of the limestone was effectively found at or near surface the drilling done up until the 1970s (augmented by a program in the 1990s) was sufficient for mine planning. However with the deepening of the Mine over the last decade the adequacy of past drilling (in predicting the contact dip) has declined, particularly in the North Pit and more particularly on the western side of the North Pit.

Most recently the ML was uncovered west of the North Pit as part of overburden removal for accessing deeper parts of the EL. This added a focus on evaluating the very sparsely drilled ML.

Program 1 (P1): These demands for information initiated in 2015 an exploration program to look at the SW parts of the North Pit. That work combined detailed geological mapping (particularly of the contacts) and a limited 12 hole drilling program. The early 2016 drilling program (subsequently named Phase 1 or P1) utilised the reverse circulation (RC) drilling method to cost effectively drill to the contacts (historically difficult due to bad ground conditions at these weathered, frequently water-logged and clayed contacts) as well as facilitate clean sampling (to allow assaying of the limestone and selected overburden). The P1 program confirmed the presence of potentially considerable ML for mining. It also collected sufficient new data from the North Pit western contact of the EL to prompt re-interpretation of the limestone ore body and indicate the presence of the block faulting.

Programs 2 & 3 (P2 & P3): The P1 results immediately motivated a follow-up drilling program in late 2016 (P2). That program aimed to define a resource of ML (by drilling an adequate strike length of it) and gain definitive contact details of the EL. The P2 program of 20 holes mostly achieved the aim for the ML. However difficult drilling on the ML precluded P2 achieving much on the EL. Consequently an early 2017 program (P3) of 10 holes continued on with the EL objectives. It adequately determined the contact dips at the SW end of the North Pit. It then focussed on the northern end of the North Pit – finding enough information to reasonably interpret the shallow westerly dips of the western contact of fault block EL 5 (mentioned in Section 5).

Future exploration: Interpretation of results from programs P1 to P3 have considerably improved understanding of the EL and ML shapes. The location of the limestone to expected mining depths is now fairly well defined (and markedly different to before in some locations), to a point where major 'surprises' would be somewhat unlikely.

Confirmation of the latest interpretation by drilling is still patchy however – to a point where further drilling is required to improve confidence. Interpretations in some areas rely too heavily on single holes or single lines of holes. In some areas the spacing between holes is too great, both laterally and vertically.

From both a Resource estimation and a mine planning perspective two areas in particular require further drilling in the short term:

- Northern EL – in and around the fault block EL 5. Drilling this area would be necessary if it is to support greater mining, particularly as it also currently hosts crucial infrastructure (crusher, stockpile, conveyors).
- ML – closer spaced along the strike length adjacent to the North Pit.

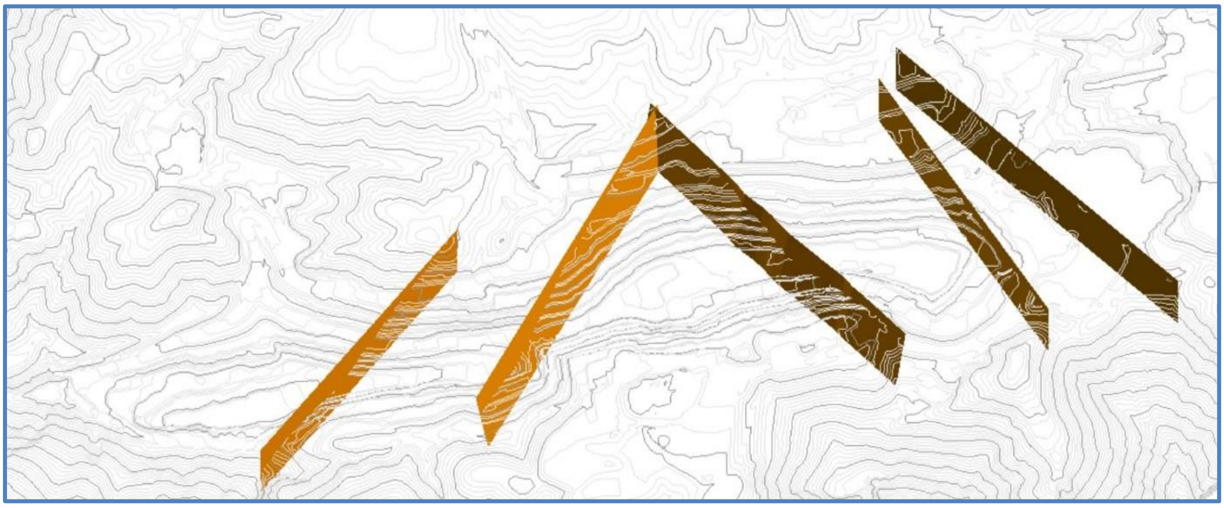
10 COMPUTER MODELS

Each limestone block was computer modelled into a solid using wire-frames. Blocks were wire-framed individually and differentiated by domain numbers. A block model (for grade interpolation, volumetric reporting and other functions) was built from the wire-frames with their domain numbers carrying over into the blocks. The following modelling represents the most recent interpretations of **May 2018**.

10.1 FAULT MODELS

To aid interpretation of cross-sectional outlines of each adjacent block of limestone models of the fault planes separating the blocks were created as wire-framed surfaces or planes. Those fault plane models are shaded brown in the Figure 43, a perspective view looking obliquely downwards towards the WNW (north is on the right) across the strike of the limestone. Surface topography is contoured in grey at 5 m intervals.

Figure 43 Fault plane models



10.2 LIMESTONE MODELS

The limestone bodies were computer modelled using solid wire-framing. Wire-frame solids lend themselves to 3D visualisation. The wire-framing process involved connecting up cross-sectional outlines of each individual limestone fault block. Block numbers were generally used as the basis for the domain numbers, with some rationalised to maintain differentiation (domain numbers are listed in Section 10.5). Pre-existing (2005 and 2015) wire-frames were iteratively adapted as each of the recent 2016 to 2017 drilling programs changed interpretations of the limestone shapes. Figure 44 illustrates the cross-sectional outlines in the same perspective view as above. Fault blocks are generally shown with the same colours used in the plans and cross-sections.

Figure 44 Limestone model cross-sectional outlines (across strike)

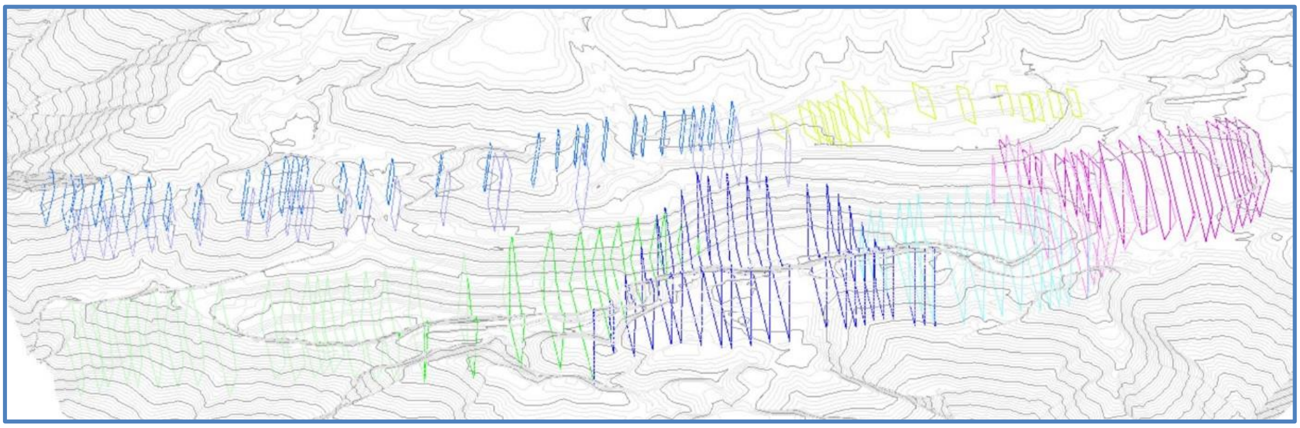


Figure 45 shows the solid shaded wire-frame models of all limestone fault blocks. The 6 modelled Eastern

Limestone fault blocks (light green to purple in the foreground) and the 2 Mt Frome Middle Limestone fault blocks (mauve and yellow in the background) are separated by brown fault planes. The southern (left) light green EL block combines blocks 0, 1 and 2S.

Figure 45 Limestone model wire-frames (across strike)

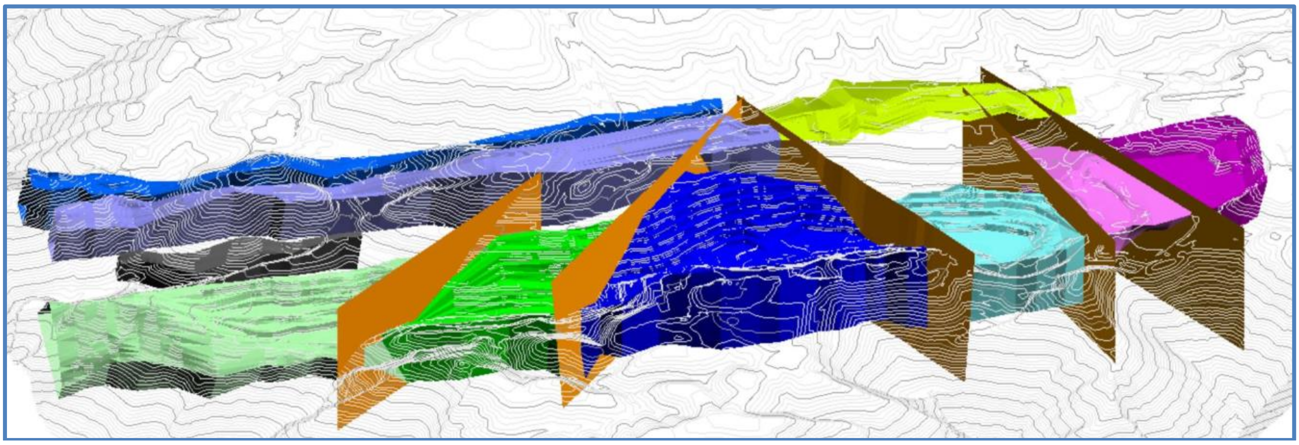


Figure 46 Limestone model (along strike)

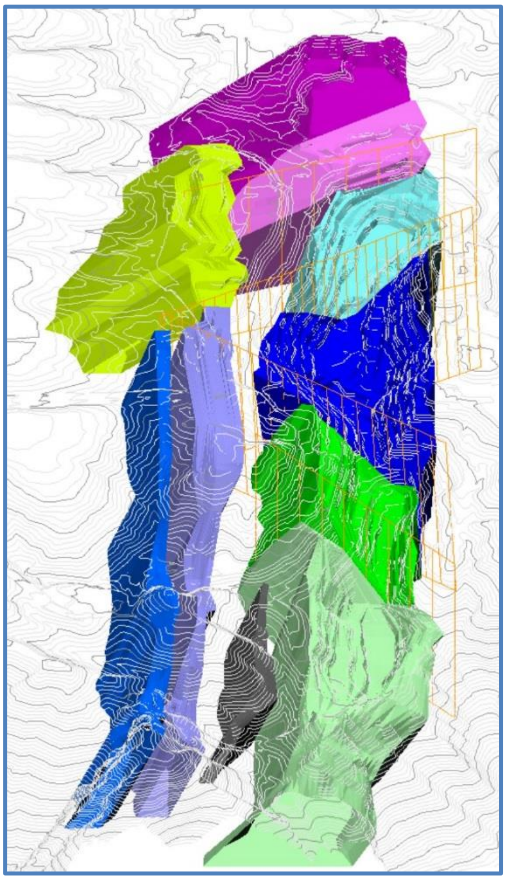


Figure 46 shows the wire-frame models looking along strike towards 020°. This view illustrates the variable block dips, particularly of the western (left) sides.

The distinctly anomalous shallow westerly dips (down to the left) of the western side of the northern (top of Figure) EL blocks 5N (purple) and 5S (pink) and the northern ML block 7N (olive) are apparent. Block EL 5S has a western side dip of only ~16°W. This shallow dip of the northern ML block 7N is however still approximate as understanding of it is still considered to be poor.

Dips of the western sides of blocks to the south of EL 5S are more typically steeply to the west (at ~70°W) – except for the central block EL 3 (blue) which has a steep easterly dip (~85°E).

Dips of the eastern sides of blocks are sub-vertical for most of the strike length of the Mine but turn westward at the southern end.

Artificial truncations: It should also be noted that:

- All limestones are truncated at a depth ~50 m below the base of drilling. They are all assumed to actually extend considerably further to depth.
- All limestones are truncated slightly south of the southern tip of the Mine. All actually extend many kilometres south of the Bungonia Gorge south of the Mine.
- Whilst the EL was generally modelled for its full strike length on the Mine, the NW corner of the northern block EL 5N (purple) was not fully modelled as the contact (direction and dip) with the granodiorite to the north was not known. Similarly old mapping now indicates that the NE corner of the block may extend ~100 m further north than modelled.
- The northern limit of the ML (olive) was truncated adjacent to block EL 5S simply because no drilling exists to the north. This unit possibly connects to an isolated limestone outcrop (at the 'Blue Lagoon') to its north (and NW of EL 5N).

10.3 Granodiorite Model

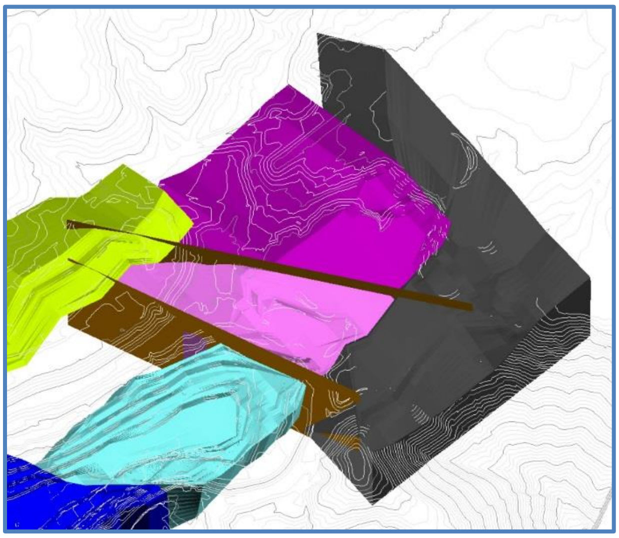
The intrusive granodiorite body in the NE has been separately wire-frame modelled to show its relationship to the limestone. This granodiorite rock is mined in the Peppertree Quarry north of the Mine. The granodiorite wire-frame was assigned the domain number 36.

The granodiorite body wraps around the eastern and northern sides of the northern limestone blocks EL 5N and 5S. It is shown in dark grey in Figure 47, as viewed looking down towards the NW.

The NE corner of limestone block EL 5N (purple) may extent further north into the granodiorite than modelled.

Being younger than the limestone the granodiorite may truncate the faults separating the limestone blocks.

Figure 47 Granodiorite model



10.4 Overburden Models

Wire-frame models of the sedimentary overburden (and inter-burden) either side of the Eastern Limestone were created to facilitate quantity reporting. They extend far enough east and west and to depth to fully accommodate (enclose) long range pit designs. They were subdivided normal to strike along the Eastern Limestone to be identified approximately with the adjacent modelled fault blocks. This would allow a quick comparison of quantities of overburden stripping ratios at different points along the pit. Overburden quantities are differentiated by their domain numbers in the 30 year mine quantity estimates in Section 11.5.2. Identification of overburden adjacent to (either side of) EL blocks was generally by the addition of 30 to the adjacent EL domain number (see the listing Section 10.5).

10.5 Domain Numbers

Domain numbers were used to differentiate limestone blocks, granodiorite, overburden and faults. Limestone numbers were based on the block names (shown on the cross-sections (5.3) and in the listing (Figure 7), slightly re-organised to differentiate the blocks with 'N' and 'S' suffixes. Domain numbers used in the modelling are listed in Table 6 along with the colours used in the cross-sections and 3D illustrations. The limestone model domains are illustrated in Figure 48.

Table 6 Domain numbers

Rock / Feature	Name / Description	Domain #	Colour Cross-section	Colour Wire-frame
Eastern Limestone	EL Block 0	1	Very olive	Light green
	EL Block 1	1	Olive	"
	EL Block 2S	1	Light green	"
	EL Block 2N	2	Green	Green
	EL Block 3	3	Blue	Blue
	EL Block 4	4	Cyan	Cyan
	EL Block 5S	5	Pink	Pink
	EL Block 5N	6	Purple	Purple
Mt Frome Limestone	LL 6	9	Cyan	Grey
	ML 7S	7	Purple	Mauve
	ML 7N	72	Khaki / olive	Light olive
	UL 8	8	Light blue	Blue
Granodiorite		36	Pink	Dark grey
Dykes		-	Dark olive	
Faults	Dom 2 south boundary	42	Blue dot dash line	Brown
	Dom 3 south boundary	43	"	"
	Dom 4 south boundary	44	"	"
	Dom 5 south boundary	45	"	"
	Dom 6 south boundary	46	"	"
Overburden	Adjacent to dom 1 & 2	32	-	-
	Adjacent to dom 3	33	-	-
	Adjacent to dom 4	34	-	-
	Adjacent to dom 5 & 6	35	-	-

10.6 Block Models

A 3D regular block model was created from wire-frame models of the limestone, overburden and granodiorite. A block would allow grade interpolation, volumetric reporting and base-line pit optimisation studies.

The current 2018 quantities reported below (Section 11.5) were derived from the latest **May 2018** block model (version P3.2).

An earlier preliminary August 2017 block model (version P3.1) was created shortly after the P3 exploration drilling and used for preliminary pit optimisation to help in the design of the long term MP2 30 year mine pit shape.

11 RESOURCES

11.1 SEARS REQUIREMENTS

The EIS was to include:

- A Resource/Reserve Statement appropriate to the type of deposit and based on a simple volume and/or quality estimation.
- Estimates of grade ($CaCO_3$ %).
- A statement on the level of confidence, to at least an Indicated or Inferred level (equivalent in intent to JORC Code reporting), covering the next major phase of mining (estimated to be for approximately the next 7 years).
- A volume estimate of the clay/shale present within the previously stated 100 Mt of overburden to be extracted to obtain an equivalent quantity of limestone, along with a statement regarding that material's lithology and nature.

11.2 QUANTITY (RESOURCE/RESERVE) STATEMENT BACKGROUND

Mineral Resources and Reserves in the current JORC 2012 sense (detailed below) have not (to the Consultant's knowledge) ever been reported for the Marulan South Limestone Mine's limestone deposit. They are not reported as such here and instead the term 'quantity' is used. **To prevent any inference of JORC confidence levels to quantities reported here the term 'Resource' is particularly avoided where possible**.

Tonnage quantities at the Mine have long used a universal default density for limestone (described in Section 11.3).

Tonnages and related details have been periodically reported in the past (mostly in historical internal Mine documents). The most relevant and recent are summarised in Section 11.4.

2018 tonnages are reported here in Section 11.5. They were derived using the default limestone density (Section 11.3) applied to the volumes in the recent geological models (Section 10). **Quantities are not stated according to JORC at this time**. Explanation of that reporting position is provided in Section 11.7 on reporting confidence.

JORC Code: The JORC 2012 Code is – *The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (The JORC Code). The JORC Code is produced by the Australasian Joint Ore Reserves Committee (JORC) comprising representatives of each of the 3 parent bodies adopting the Code – The Minerals Council of Australia (MCA), The Australasian Institute of Mining and Metallurgy (The AusIMM), and the Australian Institute of Geoscientists (AIG) – as well representiatives of the Australian Securities Exchange (ASX), the Financial Services Institute of Australasia (FinSIA) and the accounting profession.

11.3 LIMESTONE DENSITY

Typical limestone density: Typical (or average) in-situ densities for a particular rock type are somewhat subjective because they exist in a range and are frequently linked to a particular location. Limestone density varies fairly widely and in the dimension stone industry is sub-divided from low (<2.16 t/m^3) to high (>2.56 t/m^3).

The AusIMM gives average dry densities of limestone and related rocks as:

- Limestone as 2.11 t/m^3 (range 1.74 to 2.76).
- Dolomite as 2.3 t/m^3 (range 2.04 to 2.54).
- Marble (essentially crystallised limestone as generally found at Marulan) as 2.75 t/m^3 (range 2.6 to 2.9).

Marulan Mine limestone density: The Mine has long used a simple single default limestone in-situ density in tonnage estimates, and in the most recent decades that value has been taken as **2.6 t/m^3**.

Old Reserves reported in 1969[1] assumed an in-situ limestone density in Imperial units of 13.5 ft^3/ton. Assuming those units were in long tons that density equates to metric **2.66 t/m^3**. Even older Reserves reported in 1958[2] used

[1] Read, H.W., October 1969. *SPC Marulan Limestone Quarry – geological notes*.

[2] McKenzie, P., August 1958. *Report on the geology of the Marulan Limestone Leases*. Report for SPC.

a fractionally higher 13.6 ft^3/ton value. Reserves reported in 1971[3] and 1972[4] assumed a limestone density in Imperial units of 2.0 tons/yd^3. That density also equates to metric **2.66 t/m^3**. The 1972 report stated that 'certain siltstones and reject limestone have a bulk density slightly higher than normal limestone and certain shales are somewhat less dense'. They then deduced that the stated limestone density was an 'acceptable average'. As a footnote the 1969 report listed a density for 'mullock' of 14.5 ft^3/ton which would convert to 2.86 t/m^3. None of that Reserves reporting detailed how the densities were derived.

More recently the Mine has consistently used a default limestone density of **2.6 t/m^3** for tonnage estimates.

Consultant's knowledge & comments: The Consultant does not know how density was actually originally determined at the Mine. However he presumes that the long existence of an on-site Mine laboratory (NATA accredited now) indicates the Mine's capacity for density measurement and he further presumes that it made the measurements to support the values used. It would seem likely that the old density was simply carried forward over time. The Consultant does not know the basis for the slightly reduced more recent density. He is also unaware of the variability of density over the deposits.

11.4 PAST LIMESTONE QUANTITY STATEMENTS

The past quantities reported here are those of:

- The Mine in 1979 (for past company reporting relevance).
- The Geo Survey in 1986 (for freely available data relevance).
- The Consultant in 2015 (the most recent estimated for the Mine prior to this one).

Those reported in the succession of internal Mine reports are ignored as they cannot be easily reconciled with source areas in the Mine.

11.4.1 1979 ESTIMATE

BCSC reported Reserves in 1979[5] for the South Pit combined with several different proposed North Pit designs. They reported total Eastern Limestone tonnages of either **269 Mt** (Northern development Alternative 1) or **328 Mt** (Northern development Alternative 2). Those quantities were made up of 105 Mt from the Southern Quarry and either 164 Mt (Alternative 1) or 223 Mt (Alternative 2) from the Northern Quarry. They also reported minor quantities of Mt Frome Limestone in the Northern Quarry of either 2 Mt (Alternative 1) or 9 Mt (Alternative 2).

11.4.2 1986 ESTIMATE

The Geo Survey quoted **250-350 Mt** of in-situ limestone in1986 (Lishmund et al, 1986, pp140).

That limestone quantity appears to have remained reasonably static over the last few decades during which time the annual production has been of the order of 2.5-3.3 Mtpa. In other words the remaining in-situ limestone estimate remained roughly constant because the annual (or even total cumulative) production represented a very small fraction of the theoretical volume of the deposit if depths in the Bungonia Gorge were anything to go by. In the nearly 60 years of production 1929 to 1986 the Geo Survey reported extraction of 35 Mt, only ~10% of the remaining Resources.

This presumption of considerable remaining limestone appeared reasonable for several reasons:

- As an industrial mineral, and prior to the JORC era, the reporting of tightly defined mineral deposit quantities was not mandatory under the Mining Act (and mineral quantity estimation was not rigorously linked to specific exploration data such as drilling).
- The regular continuous tabular dipping shape (of roughly constant strike length and width) of the ore body looked likely to remain constant far into the future (i.e. to great depth) with the constant extraction rate. In other words, as the projected remaining limestone was not being significantly depleted the base of the quantity calculation was simply slowly getting deeper.
- With an essentially completely exposed strike length of ~2.5 km and average width of 250 m it only requires a moderate 150 m of depth to produce the 250 Mt often quoted.

[3] Barnstone, November 1971. *South Portland Cement Ltd. - Marulan Quarry : Reserves*. Report by APCM Geological Department.
[4] APCM, July 1972. *Limestone quarry and waste disposal at Marulan – geological report*. Appendix VIII
[5] BCSC,July 1979. *The development of Marulan Quarry*.

- Until recently the relatively shallow depth of the North Pit did not seriously influence or effect mine design through having to carry high pit walls or the removal (or re-handle) of significant overburden (the stripping ratio remained <1). Extraction could still occur at either end without particularly deepening the pit. In addition the South Pit still retained considerable theoretical limestone quantities to depth.

11.4.3 2015 ESTIMATE

The Consultant reported limestone quantity estimates in Section 8.3 of the 2015 geology report. That estimate pre-dated the recent 2016/17 exploration drilling (Section 9) and the new computer modelling (Section 10). The quantum of the 2015 estimate was considerably under-stated and it is replaced by the 2018 estimate given in Section 11.5 here. The 2015 estimate was based purely on assumptions defining the deposit dimensions and therefore its volume.

Volume assumptions: The following deposit dimension assumptions, defining the deposit volume, were based on the 2005 computer model and updated geological understanding of the deposit shape. The volume would be that remaining below the current mine/topography surface.

- Eastern Limestone:
    - 2.5 km full strike length of combined North and South Pits.
    - 280 m width for 1.5 km long North Pit.
    - 220 m width for 1.0 km long South Pit.
    - 120 m depth for full strike length.
- Mt Frome Middle Limestone:
    - 1.0 km strike length.
    - 80 m width.
    - 90 m depth for full strike length.
- Density for all limestone of 2.6 t/m^3.

Tonnages: The 2015 estimates of in-situ limestone quantities were:

- **Eastern Limestone: ~200 Mt**
- **Middle Limestone**: **+18 Mt**

The 200 Mt Eastern Limestone estimate was split in the ratio 2:1 between North and South Pits.

Classification assumptions: Approximations of confidence, using the JORC classification terms, were made using depths below surface:

- Eastern Limestone:
    - 30 m 25% Measured
    - 30-60 m 25% Indicated
    - 60-120 m 50% Inferred
- Mt Frome Middle Limestone:
    - 30 m 34% Indicated
    - 30-90 m 66% Inferred

Classifications: Using the depth proportions the Consultant considered the 2015 estimated tonnages could be approximately classified:

- **Eastern Limestone:**
    - **~50 Mt Measured**
    - **~50 Mt Indicated**
    - **~100 Mt Inferred**
- **Middle Limestone:**
    - **~6 Mt Indicated**
    - **~12 Mt Inferred**

11.5 CURRENT 2018 LIMESTONE QUANTITY STATEMENTS

Data from the recent 2016/17 exploration drilling (Section 1) was used to create new computer models (Section 1) from which new limestone quantities are reported here as at 2018. The following quantity estimates were reported in June 2018 from the May 2018 (version P3.2) block model. In contrast to older models (such as the one reported in 2015) the new models added more definition to the Mt Frome Limestones; subdivided the Eastern Limestone and the Mt Frome Middle Limestone into fault blocks; added the granodiorite; and added separate overburden zones adjacent to the Eastern Limestone fault blocks. All of these features were identified by unique domain numbers (Section 10.5) and those numbers segregate the material in the quantity reports.

Quantities are reported of in-situ limestone for two instances:

- A global quantity – equivalent to a Mineral Resource.
- Within a possible long term 30 year mine design (MP2) – to facilitate BCL's planning.

11.5.1 Global Limestone Quantities

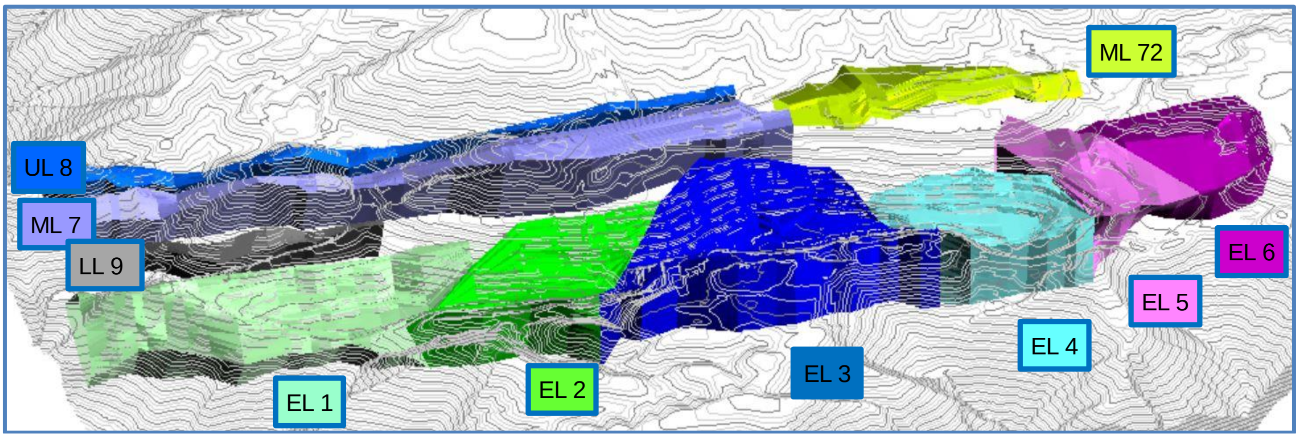
Table 7 reports the 'global' quantities of remaining in-situ limestone at the Marulan South Limestone Mine. If this was JORC compliant these figures would be equivalent to a Mineral Resource. They are reported from the full volume of all modelled limestone below the surface topography as at October 2016. Models were artificially depth limited to ~50 m below the base of the deepest drill holes and all are currently assumed to be open at depth. Limestone blocks are differentiated by domain number. Tonnages were computed from the volumes by applying the mine default average limestone density of 2.6 t/m^3. Quantity totals have been rounded to the nearest 10 Mt.

Table 7 Marulan limestone quantities (6/2018)

Area	In-situ Dom	Ore (Mm3)	SG (t/m^3)	Ore (Mt)
Eastern limestone:				
South Pit - S	1	49	2.6	127
South Pit - N	2	33	2.6	86
North Pit - S	3	35	2.6	91
North Pit - mid	4	23	2.6	60
North Pit - N	5	17	2.6	44
North Pit - stockpile	6	28	2.6	73
		190		**480**
Mt Frome limestone:				
Lower - South pit	9	3	2.6	8
Middle - S pit & N Pit S	7	31	2.6	81
Middle - North Pit N	72	15	2.6	39
Upper - S pit & N pit S	8	14	2.6	36
		60		**160**
Total:		**250**		**640**

The reported limestone is within the solid coloured bodies in Figure 48. The individual body labels are prefixed as EL or ML and the suffixes give the domain number.

Figure 48 Global limestone domains



Comments:

- The estimated in-situ **480 Mt of Eastern Limestone** and the **160 Mt of Mt Frome Limestone** (light grey column) represents a very large Resource.
- Granodiorite modelled around the north of the Eastern Limestone domain 6 (Figure 47) occupies ~80 m^3 and represents ~220 Mt.
- The limestone quantity is considerably greater than previously reported. The Consultant comments below individually on the EL and ML increases.
- Eastern Limestone increase:
    - Part of the tonnage increase was due to a model depth increase (possible through the recent exploration drilling). Although moderate it influenced at least half the strike length and thus had a considerable impact.
    - Part of the tonnage increase was due to a considerably increased quantity of limestone in the north (blocks 5 and particularly 6), effectively a new discovery.
    - Although the increase was large the Consultant considers it fully reasonable as it represents (still conservatively) his volumetric expectation of the long wide contiguous ore body.
- Mt Frome Limestone increase:
    - Effectively the Mt Frome Limestones were not previously fully modelled.
    - +60% of the tonnage comes from the moderately drilled Middle Limestone – and is thus well supported.

11.5.2 30 YEAR MINE LIMESTONE QUANTITIES

Table 8 reports the quantities of in-situ limestone in a long term 30 year open-pit mine design (MP2) designed in late 2017 by Consulting Mining Engineer Gordon Atkinson. The quantities are reported below the surface topography as at October 2016. Limestone blocks and the adjacent overburden (labelled 'waste') sections are differentiated by domain number. Note that overburden domain 32 applies to limestone domains 1 and 2, and overburden domain 35 applies to limestone domains 5 and 6. Tonnages were computed from the volumes by applying the mine default average limestone density of 2.6 t/m^3. Diluted tonnages were computed by subtracting 10% from the un-diluted limestone and adding that to the overburden (waste).

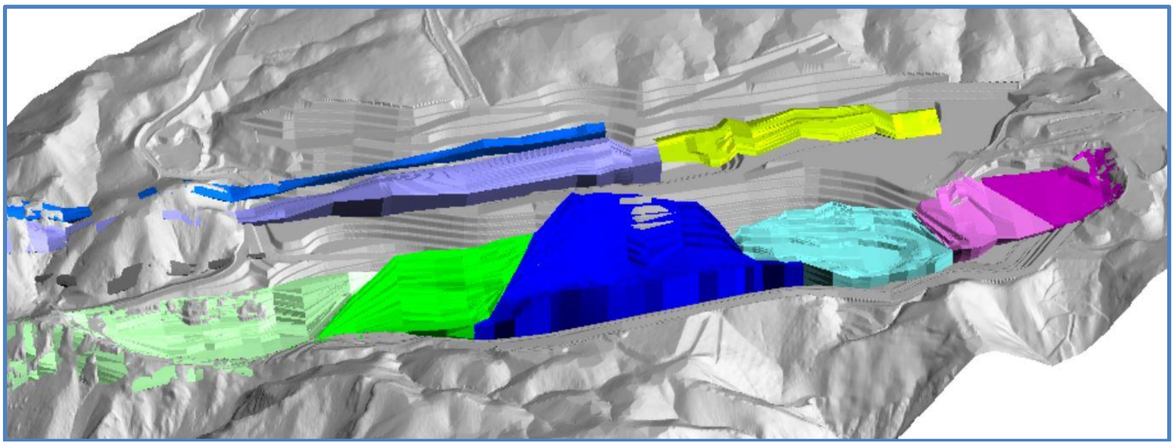
The MP2 open-pit was designed to target ~120 Mt of limestone given a production rate of 4 Mtpa of limestone over 30 years. A further design criteria was to investigate whether a practical mine could be designed with an overburden to ore stripping ratio better than 1. A practical mine would use conservative current bench and mine wall slope parameters (with slopes no steeper than current) and fully provide all necessary haulage roads.

Table 8 Marulan 30 year open-pit mine (MP2) limestone quantities (6/2018)

	Volume (in-situ)						Tonnes (in-situ)		Tonnes (diluted)		
Area	Dom	Waste (Mm3)	SG (t/m^3)	Dom	Ore (Mm3)	SG (t/m^3)	Waste (Mt)	Ore (Mt)	Dil (%)	Waste (Mt)	Ore (Mt)
Eastern limestone:											
South Pit - S	32		2.6	1	4	2.6		10	10%	1	9
South Pit - N	32	18	2.6	2	10	2.6	47	26	10%	50	23
North Pit - S	33	12	2.6	3	15	2.6	31	39	10%	35	35
North Pit - mid	34	8	2.6	4	7	2.6	21	18	10%	23	16
North Pit - N	35		2.6	5	2	2.6		5	10%	0	5
North Pit - stockpile	35	3	2.6	6	1	2.6	8	3	10%	8	3
		41			**39**		**107**	**101**		**117**	**91**
Mt Frome limestone:											
Lower - South pit				9	0	2.6		0	10%	0	0
Middle - S pit & N Pit S				7	8	2.6		21	10%	2	19
Middle - North Pit N				72	5	2.6		13	10%	1	12
Upper - S pit & N pit S				8	0	2.6		0	10%	0	0
					13			**34**		**3**	**31**
Total:		**41**			**52**		**107**	**135**		**120**	**122**

The reported limestone is within the solid coloured bodies in Figure 49 visible above the benched MP2 pit design (light grey shaded surface).

Figure 49 30 year mine limestone domains



Comments:

- The designed open-pit mine contains in-situ undiluted limestone quantities of **101 Mt of Eastern Limestone** and **34 Mt of Mt Frome Limestone** (light grey column).
- For the Eastern Limestone the North Pit contains ~55% of the total.
- On the in-situ undiluted tonnage basis (light grey column) the overall overburden to ore ratio at **0.79** (from 107 Mt of overburden required to access the 135 Mt of ore) is well below 1. And even on a 10% diluted basis (darker grey column) the overall overburden to ore ratio is still below 1 at **0.98**.
- These results effectively show that the target tonnage is achievable in a practical open-pit mine with a better than 1 stripping ratio.
- The northern part of the mine also contains **~3 Mt of granodiorite** (currently included with the overburden). As this is the same product as quarried at the adjacent Peppertree Quarry it is potentially ore.
- Consideration of the granodiorite (and possibly also the dacite which will form the western batters of the mine) as 'ore' would improve the mine economics.

11.6 STATEMENT GRADE

Table 9 lists simple drill hole sample statistics for a series of the important grade minerals (in terms of product specifications) at the Mine. They are each given for the whole Eastern Limestone and for the whole of the Middle Limestone. The samples are from all of the exploration drill hole sampling from the 2005 and 2016/17 programs.

Note that the grades are given from the drill hole samples rather than from estimated blocks. Block grades remain to be interpolated.

Although reported from drill hole samples the Consultant is of the firm opinion that these averages would be extremely close to grade block averages when they interpolated.

Table 9 Sample grade statistics

Element	Lst	Dom	Samples	Min (%)	Max (%)	Av (%)	Med (%)	SD	Var	CV (%)
$CaCO_3$	EL	2	520	73.07	99.59	94.97	96.21	4.0	16.0	4.2
	ML	7	217	5.42	98.73	91.11	93.73	9.7	94.5	9.7
MgCO3	EL	2	520	0.30	14.73	1.30	0.91	1.3	1.6	98.1
	ML	7	217	0.35	4.04	1.03	0.85	0.6	0.3	54.9
Al_2O_3	EL	2	520	0.03	5.05	0.76	0.55	0.7	0.5	96.7
	ML	7	217	0.26	13.70	1.42	1.03	1.5	2.3	103.9
SiO_2	EL	2	520	0.07	26.46	2.26	1.51	2.4	5.9	107.6
	ML	7	217	0.79	61.58	5.31	3.62	6.2	38.1	116.4
Fe_2O_3	EL	2	520	0.03	5.19	0.45	0.31	0.5	0.2	108.7
	ML	7	217	0.15	8.17	0.81	0.50	1.0	1.0	120.3

These grades are very close (negligibly different) to those reported with notes on limestone quality in Section 7.1 and to the whole rock chemical characterisation in Section 7.2.

11.7 Statement confidence

Marulan South Limestone Mine Mineral Resources and Reserves have not previously been reported according to the current JORC 2012 Code. Therefore by definition they have not been formally classified in terms of the JORC Measured, Indicated or Inferred confidence levels. However the Consultant did report his 2015 quantities (Section 11.4) using JORC terms for approximations of confidence. Those classifications were based on depth from surface. He uses similar thinking here, plus other considerations, to make approximations of confidence in JORC terms on the 2018 global limestone estimate (Section 11.5).

Not reporting the current quantities according to JORC is a temporary situation pending completion of current exploration drilling and is specifically addressed below.

11.8 Classification thinking

Until JORC reporting commences the Consultant is prepared to use a similar overall depth from surface method to classify these 2018 model global estimates on a pro-rata basis. The 30 year open-pit mine design estimates are however not classified as the depth method is considered more unreliable in the much smaller (and more randomly shaped) open-pit volume.

Classification methodology and assumptions: Approximations of confidence, using the JORC classification terms, are made using depths below surface and several assumptions:

- Eastern Limestone:
    - The 2015 model depth for the ~200 Mt estimate was taken to be **~120 m**.
        - The upper 30 m or 25% was Measured.
        - The following 30 m or 25% was Indicated.
        - And the lower 60 m or 50% was Inferred.
    - The 2018 model depth for the global ~480 Mt estimate is in the range **150-250 m**, with an average of **~200 m**.
        - Hence the upper 120 m represents ~60% of the 200 m average depth, or ~290 Mt.
        - No Measured quantities will be classified.
        - The upper 60 m will be Indicated.
        - The following 60 m will be Inferred.
        - Deeper material will not be classified.
- Middle Limestone:
    - The 2015 model depth for the +18 Mt estimate was taken to be **~90 m**.
        - The upper 30 m or 34% was Indicated.
        - The following 60 m or 64% was Inferred.
    - The 2018 model depth for the global ~160 Mt estimate is still taken to be **~90 m**.
        - Only the Middle Limestone ~120 Mt estimate will be classified.
        - The upper 30 m or 34%, equivalent to ~40 Mt, will be Inferred.
        - Deeper material will not be classified.

11.9 Confidence classification

Using the methodology above the Consultant considers that **~330 Mt** (~50%) of the 2018 **global** limestone estimate of 640 Mt may be approximately classified as follows:

- **Eastern Limestone:**
    - **~145 Mt** **Indicated** 0-60 m below surface
    - **~145 Mt** **Inferred** 60-120 m below surface
- **Middle Limestone:**
    - **~40 Mt** **Inferred** 0-30 m below surface

11.10 Current non-JORC reporting

Considerable recent exploration (Section 9), comprising geological mapping and drilling of 42 holes, has occurred since 2015 with the aim of better defining the limestone ore bodies. That work has also included an aim to better understand the geological setting, particularly the geological structures apparently shaping the ore bodies. That data feeds directly into quantity estimation and the ability to report a JORC Resource.

At this point in time (June 2018) the very recent (May 2018) interpretations of the structural 'block faulting' of the limestone (Section 5.2) require a degree of further drilling to gain full confidence and a better drilling density distribution. Two areas in particular require additional information – the very northern parts of the Eastern Limestone (blocks 5 and 6) and the Middle Limestone in general. The very shallow westerly dips of the northern fault block 5 and 6 will potentially have a material beneficial impact on mine design there – and therefore on future mine Reserve reporting. A confirmed substantial Resource of Middle Limestone will similarly have the very beneficial impact of reducing stripping ratios for the Eastern Limestone, in turn allowing more of it to be economically accessed.

The effective status of current exploration at the Marulan South Limestone Mine (as far as it supports estimation of Resources) is that whilst all exploration firmly supports a very large potential Resource of limestone (given in Section 11.5) at a low to moderate confidence level (given in Section 11.7), well in excess of +30 years of production at current rates, there is also insufficient drilling to allow estimation of a very large potential Resource at a high confidence level (Measured or Indicated in JORC terms). The moderate classification given in Section 11.7 applies only to ~50% of the global estimate.

It is proposed that until the additional drilling has occurred a JORC Resource estimate will not be made.

11.11 OVERBURDEN VOLUMES

41 Mm^3 or ~107 Mt of overburden is reported here within a long term 30 year open-pit mine design (Section 11.5). The lithology of this overburden in general is described in Sections 5.4.4 and 5.4.5.

In terms of the last SEARs Resources requirement (Section 11) concerning the proportion of 'clay/shale' in the overburden, the Consultant presumes this to refer to the mine's so-called 'white shale', a soft light coloured and very fine grained material with properties lending itself to specific extraction for 'off-white' cement manufacture. This material is described and illustrated (Figure 28) within Section 5.4.5.

The white shale (just south of the eastern end of the western overburden emplacements haul road) is limited in exposure and extent. Its outcrop is estimated at possibly 20-30 m in height, it possibly occurs over a 500 m strike length, and its down-dip extent is unknown. It has not been specifically mapped and its volume has never been accurately estimated. Therefore the Consultant only hazards a rough estimate that such material might constitute up to **~5%** of overburden by volume, which equates to ~5 Mt of the 30 year mine overburden. The dimensions given above with a 50 m down-dip extent would imply a quantity of ~2 Mt.

12 REFERENCES

The 2015 geology document contains a full reference to all past reports directly or indirectly geologically related to the Mine. A number of those are repeated here. Most documents are internal Boral reports.

Carr, P.F. & Jones, B.G., October 1983. *Bungonia field excursion*. University of Wollongong, Department of Geology. Referred to here as 'Carr et al 1983'.

Geological Survey of New South Wales (Thomas, O.D. & Pogson, D.J. compilers), 2012. *Goulburn 1:250,000 geology explanatory notes (sheet SI/55-12, 2nd edition)*. NSW Trade & Investment Resources & Energy. Includes 2 map sheets and detailed text in PDF files on CD. Referred to here as 'Geo Survey 2012'.

Lishmund, S.R., Dawood, A.D., & Langley, W.V., 1986. *The limestone deposits of New South Wales*. Geological Survey of New South Wales Department of Mineral Resources. Mineral Resources No. 25, second edition. Pp134-142. Referred to here as 'Lishmund 1986'.

Longworth & McKenzie Pty Ltd (L&M), May 1976. *Quarry development programme and pit slope design for Marulan Limestone Quarry*. Report for Blue Circle Southern Cement Ltd. Report included multiple Appendices on individual subjects, with Appendix A on geology. Referred to here as 'L&M 1976'.

Rankin, R., May 2005. *Marulan 04/05 Exploration Project*. Report by the Consultant on behalf of SMG Consultants for Blue Circle Southern Cement Ltd. Referred to here as '2005 exploration'.

Rankin, R., 28 September 2015. *Marulan South limestone Mine – CML16 – Geology – for DRE*. Final version V4.2. Referred to here as '2015 geology'.

Rankin, R., 1 August 2016. *Marulan South limestone Mine – Exploration drilling 2016 – Phase 1*. Final version V6. Referred to here as '2016 exploration'.

Rankin, R., 19 February 2018. *Marulan South limestone Mine – Exploration drilling 2016/17 – Phases 1 to 3*. Final draft V2. Referred to here as '2018 exploration'.

Appendix E

Geotechnical assessment

VOLUME 2

Pells Sullivan Meynink
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Our Ref: PSM645-028L

Date: 2 August 2018

Boral Cement Limited
Business Development Manager - Minerals & Mining
Hume Street
MARULAN SOUTH NSW 2579

ATTENTION: LES LONGHURST
By Email: Les.Longhurst@boral.com.au

Dear Sir

RE: GEOTECHNICAL ASSESSMENT OF 30 YEAR MINE PLAN - MARULAN SOUTH LIMESTONE MINE

1 INTRODUCTION

On behalf of Boral Cement Limited (BCL), Mr Gordon Atkinson of Gordon Atkinson & Associates Pty Ltd (GAA) has requested that Pells Sullivan Meynink (PSM) provide an update to the geotechnical assessment for the 30 year mine plan. This letter in essence provides an update to the preliminary assessment presented in PSM645.L17 dated 15th March 2016.

The update has utilised two key aspects:

- Geology updates based on reporting as provided GeoRes
- Updated pit designs provided by GAA in emails of June 14th and 15th.

PSM highlight that the most significant change in understanding has been the geology at the far northern end of the deposit. Based on discussions with GAA, GeoRes and BCL it is understood the east wall will largely comprise Granodiorite.

This study has considered the requirements as noted in PSM645.L17 and in particular, it is understood that BCL is currently in the process of making application for State Significant Development for continued operation of the mine for a 30 year period.

As a result of this application, the Secretary's Environmental Assessment Requirements (SEARs) dated 10 June 2015 has indicated the following requirements:

- "a preliminary geotechnical assessment to identify the likely long term stability risks associated with the proposed remaining high wall(s) and low wall(s) along with associated measures that will be required to minimise potential risks to public",
- Comment in regard "geotechnical stability of the rehabilitated landform", and
- Any other relevant geotechnical advice in regard the proposed 30 Year mine development.

2 PROVIDED INFORMATION

To assist with the PSM assessment, GAA provided the following information:

- 3D digital data in DXF format for each stage of the proposed initial and final 30 year mine operation
- Aerial photography and digital mapping data obtained from Photomapping Services, dated 30 October 2015 and subsequent updates
- Draft report by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE), "Marulan Groundwater Technical Study", G1714, dated November 2015
- Report by Robin Rankin, "Marulan South Limestone Mine, CML 16 Geology", GR1502, dated 28 September 2015
- Report by Robin Rankin, "Marulan South Limestone Mine, CML 16 Proposed Exploration Drilling", GR1502, dated 13 September 2015
- Report by Robin Rankin, "Marulan South Limestone Mine, Exploration Drilling 2016 Phase 1 Program", GR1610, dated 27th June 2016
- Report by Robin Rankin, "Marulan South Limestone Mine, Exploration Drilling 2016/17 Phases 1 to 3", GR1705, dated 19th February 2018
- Report by Robin Rankin, "Marulan South Limestone Mine, Geological Report for DRE's input to SEARs", GR1807, dated 18th July 2018
- The above five reports collectively termed as the GeoRes report for discussion purposes
- 3D digital data in DXF format of geological surfaces developed as part of the RR Geology report
- 3D digital data in DXF format of cross-sections and drill hole locations developed as part of RR Exploration Drilling report
- Copies of letters from SEAR's.

Figures 1 to 5 provide an overview of the pit stages and importantly the location of the interpreted major faults. Figure 5 provides an overview of the final pit, Stage 4, and landform with the external and internal overburden emplacements highlighted.

3 GEOTECHNICAL ASSESSMENT

Since slope stability at Marulan South is largely dictated by the material present in the slope, a key issue with pit design is the definition of the limestone units. Figure 5 provides the interpreted location of the main units in relation to the current 30 year pit plan.

Review of the GeoRes report and recent discussions indicate:

- Two limestone units are present, the Mt Frome Limestone comprising Lower, Middle and Upper members and the Eastern Limestone (the latter referred to previously as the Main limestone). The Lower Mt Frome Limestone is present to the south and is unlikely to be of significance for future pit development. The Middle and Upper members are currently being defined in the northern pit area and are of significance for future pit development.
- Drilling to better define the Eastern limestone contact has indicated faulting non-parallel to the broad contact shape and suggesting there will be undulations in the contact along the western boundary.
- Fault Blocks have been defined, Figure 1 to 5, and with variations in the limestone bedding dip in each block
- Occurrence of Granodiorite in the far north and which will be encountered in the northern and eastern walls
- Being younger than the limestone the Granodiorite may truncate the faults separating the limestone blocks
- The Eastern limestone near the contact, and over a 5 to 10m wide zone, is highly disturbed, marked by distinct colours (white, khaki, coffee and red) and the presence of clay and gritty oxides.
- What appears to be a wide zone of altered limestone at the southwestern end of the North pit is actually a tuff unit within sediments of Bungonia Limestone Group. The tuff is of moderate to high intact strength and non-slaking.

PSM have previously provided criteria for slope design, PSM645.R3 dated 24 January 2011, and these parameters are summarised within Table 1.

Figure 6 provides an overview of the 30 year mine design which has been developed by GAA, the extent of the limestone units and the slope design parameters utilised within the current 30 year mine plan. PSM appreciate that owing to the undulations in the limestone contact there is difficulty in strictly applying the parameters provided in Table 1. However, comparison of the design with the PSM recommendations highlights areas of both steeper and shallower design and these are highlighted in Figure 7.

TABLE 1

PSM 2011 RECOMMENDED SLOPE DESIGN

UNIT	BENCH SLOPE ANGLE	BENCH HEIGHT	BERM WIDTH	INTER-RAMP SLOPE ANGLE
Extremely Weathered Sediments	50°	15m	9m	35°
Eastern & Western Sediments	60°	15m	9m	40°
Highly Weathered Limestone*	65°	15m	8m	45°
Eastern Limestone East wall North of 614 7300 N	65°	15m	8m	45°
Eastern Limestone elsewhere to above	75°	15m	7m	54°

* Essentially contact zones with sediments

PSM highlight that the extent/depth of the extremely weathered sediments is somewhat unknown. For discussion purposes PSM have assumed that the depth adopted by GAA in the designs, nominally 30m deep below topography, is appropriate. However, this aspect will need to be confirmed as part of future studies.

PSM also highlight that at present there are no design parameters for the Granodiorite which is anticipated to occur in the north and east walls of Fault Block 5 at the far north. It is anticipated this will become exposed in the Stage 2 pit, Figure 3. Experience at the nearby Peppertree quarry indicates the Granodiorite has several steep to moderate defect sets and therefore design angles, in keeping with the "Eastern Limestone, East wall North of 614 7300 N" in Table 1 would be appropriate. However, PSM note this area of the pit design has three haulroads traversing the area coupled with a wide berm at RL470which suggests a low risk to large scale wall instability.

Review indicates that the areas of steeper design relate to areas of sediments and where the PSM limestone slope design parameters have been utilised. For the east wall the failure mechanism is somewhat unknown as there has been very little exposure of the eastern sediments. However, based on the limited intersection to date PSM anticipate the concern will be the presence of deep weathering coupled with bedding near parallel to the bench faces leading to the potential for bench to multi-bench scale failures within the sediments.

The area of shallower design, Figure 7, relates to areas of limestone where a steeper batter design could be utilised by BCL if so desired. As such, these areas are unlikely to be at risk of failure and simply indicate areas of opportunity for recovery of additional limestone resource.

PSM anticipate that as mining progresses at Marulan South, geotechnical review of the behaviour of materials, review of structural patterns in the rock mass and extent of weathered materials will be better defined. The results of both the geological and geotechnical programs would result in refining and revision of the geological model and slope design parameters. As such, it would be expected that the pit designs would be revised to reflect these updates and to limit or altogether remove the extent of areas of risk evident in Figure 7. The current extent of mining, particularly at the north, lies inside the 30 year pit. This indicates that ample time remains to address the requisite studies and revise design to ensure the risk of pit stability and potential risks to public are kept low.

Although not indicated as part of the designs, additional measures that would be anticipated to be used to minimise potential risks to the public following mining would include bunding (and or fencing) beyond the pit crest. The locations of the bunds/fencing would be placed in cognisance of final stable landforms and in keeping with published guidelines (for example the Western Australian pit closure guidelines).

4 STABILITY REHABILITATED LANDFORM

A number of overburden emplacements, comprising of mine waste, are planned at various locations around the perimeter of the proposed mining lease, Figure 5. These overburden emplacements will be constructed to the North, West and South of the currently proposed pit shell. Review of the landforms for the North and Western overburden emplacements indicates overall angles of 10.5° or less and such angles are considered to pose a very low risk of geotechnical instability.

The Southern emplacement will be constructed by backfilling the South pit and also by placing material on the natural surface directly to the west. The in-pit portion of the Southern emplacement consists of a south-east facing slope and a north facing slope into the final pit void. The south-east facing slope will have a final height of up to 190m, however, the relatively shallow slope angle (16°) and favourable foundation conditions formed by in-pit dumping are expected to produce a low risk of emplacement instability. The north facing slope will be up to 170m high and is comprised of a series of batters varying in height and up to 45m high at the natural rill angle producing an overall slope angle of about 26°. Although such a configuration is not considered to be stable in the long term, the risk to the public is considered low as any erosion or instability would report to the pit void and unlikely to impact outside the pit footprint.

The portion of the Southern emplacement to be constructed on the natural surface (to the west of the in-pit portion) will be between 60 and 70m high and at an overall slope angle of nominally 12°. This portion of the Southern emplacement is considered to pose a low risk of geotechnical instability.

5 OTHER ADVICE

The Brief has requested "*any other relevant geotechnical advice in regard the proposed 30 Year mine development*".

As noted in the above discussions it should be apparent that there are uncertainties that require future studies to ensure the final pit designs appropriately mitigate risk. PSM anticipate these studies will be carried out in future and in recognition of timing of pit development. The anticipated scope of studies would include, but potentially not be limited to:

- Better definition of the extent/depth of the extremely/highly weathered sediments (may require a program of open hole drilling in future)
- Definition of the bedding dip with the eastern sediments adjacent to the Eastern limestone (preferable if understanding developed through exposures but may require drilling of core and Acoustic Televiewer (ATV) interpretation)
- Ongoing update of the structural patterns in the rock mass (preferable if understanding developed through exposures but may require drilling of core and ATV interpretation)
- Better definition of the structural pattern in the Granodiorite which will form part of the final slopes at the far north
- Study to define the locations of bunds/fencing for the final pit (although such studies are best addressed near the end of mining and in recognition of actual final pit).

Ongoing geotechnical reviews would be utilised to observe the behaviour of different materials/units as well as confirming structural patterns and with refinement of designs as appropriate.

6 CLOSURE

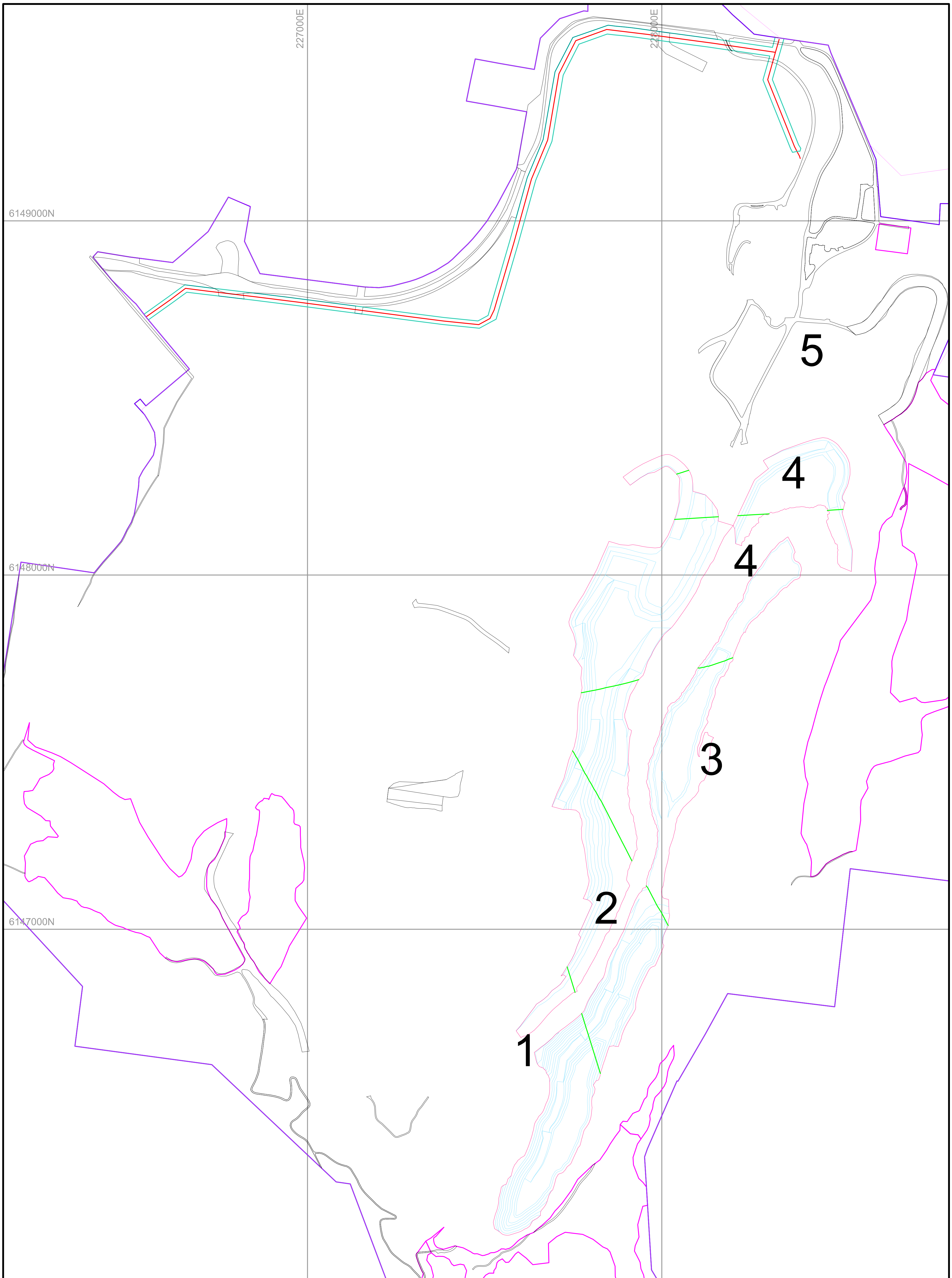
We trust the above meets your immediate requirements and please contact the undersigned if you have any queries in relation to any aspect.

For and on behalf of
PELLS SULLIVAN MEYNINK

ALEX DURAN
Principal

CHARTERED PROFESSIONAL
AusIMM
AUSTRALASIAN INSTITUTE OF MINING & METALLURGY
•GEOTECHNICAL•
ALEX DURAN

Encl. Figures 1 to 7



LEGEND

- 2018 30 Year Pit Shell
- Limestone Contacts
- Faults
- 1 Fault Block

0 100 200 300 400 500

Scale (m)

PSM

Pells Sullivan Meynink

Boral Cement Limited

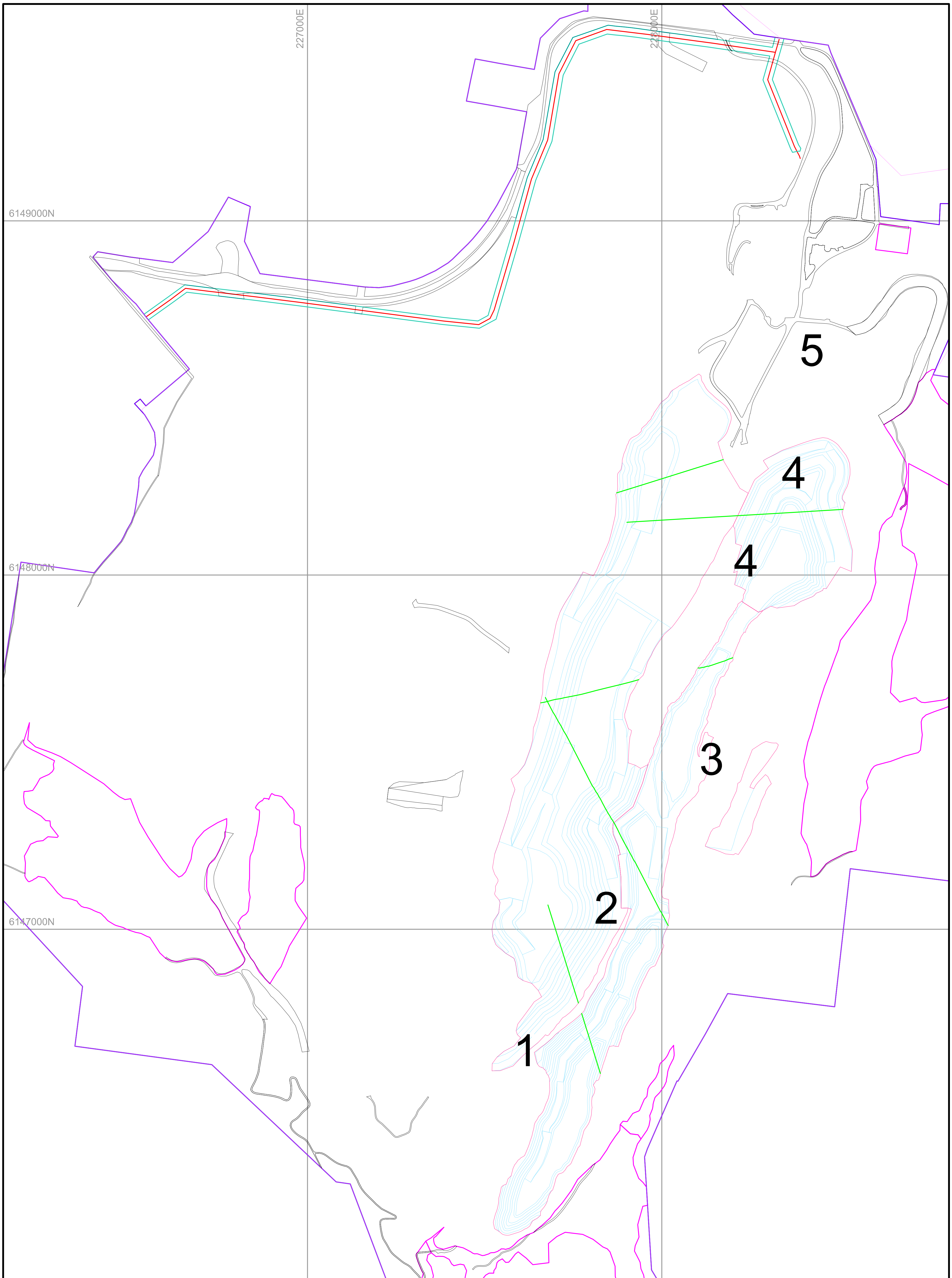
2018 Geotechnical Assessment

30 Year plan - Marulan South Limestone Mine

STAGE 0 PIT & FAULT BLOCKS

PSM 645-028L

Figure 1



LEGEND

2018 30 Year Pit Shell

Limestone Contacts

Faults

1 Fault Block

0 100 200 300 400 500

Scale (m)

PSM

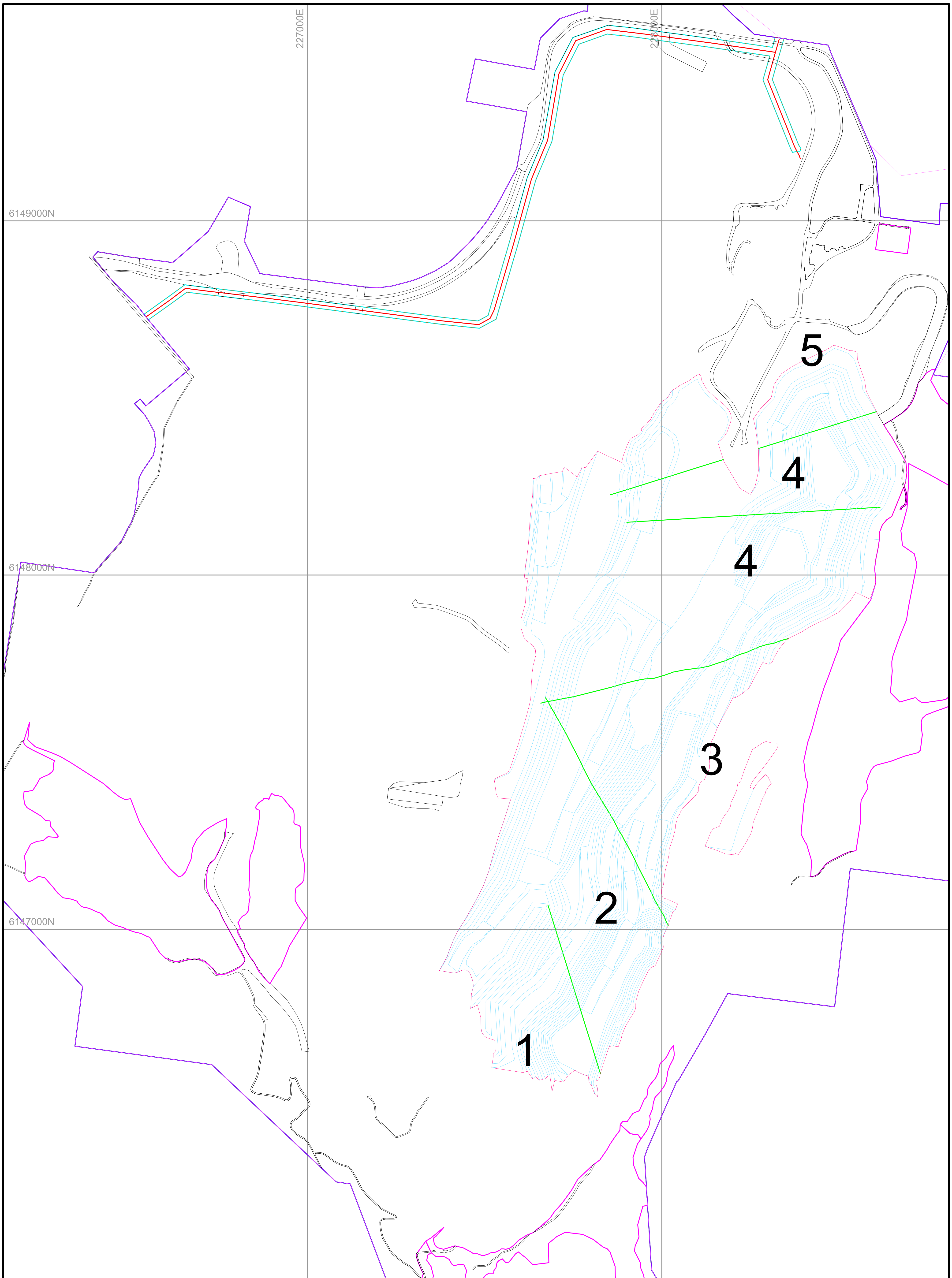
Pells Sullivan Meynink

Boral Cement Limited
2018 Geotechnical Assessment
30 Year plan - Marulan South Limestone Mine

STAGE 1 PIT & FAULT BLOCKS

PSM 645-028L

Figure 2



LEGEND

- 2018 30 Year Pit Shell
- Limestone Contacts
- Faults
- 1 Fault Block

0 100 200 300 400 500

Scale (m)

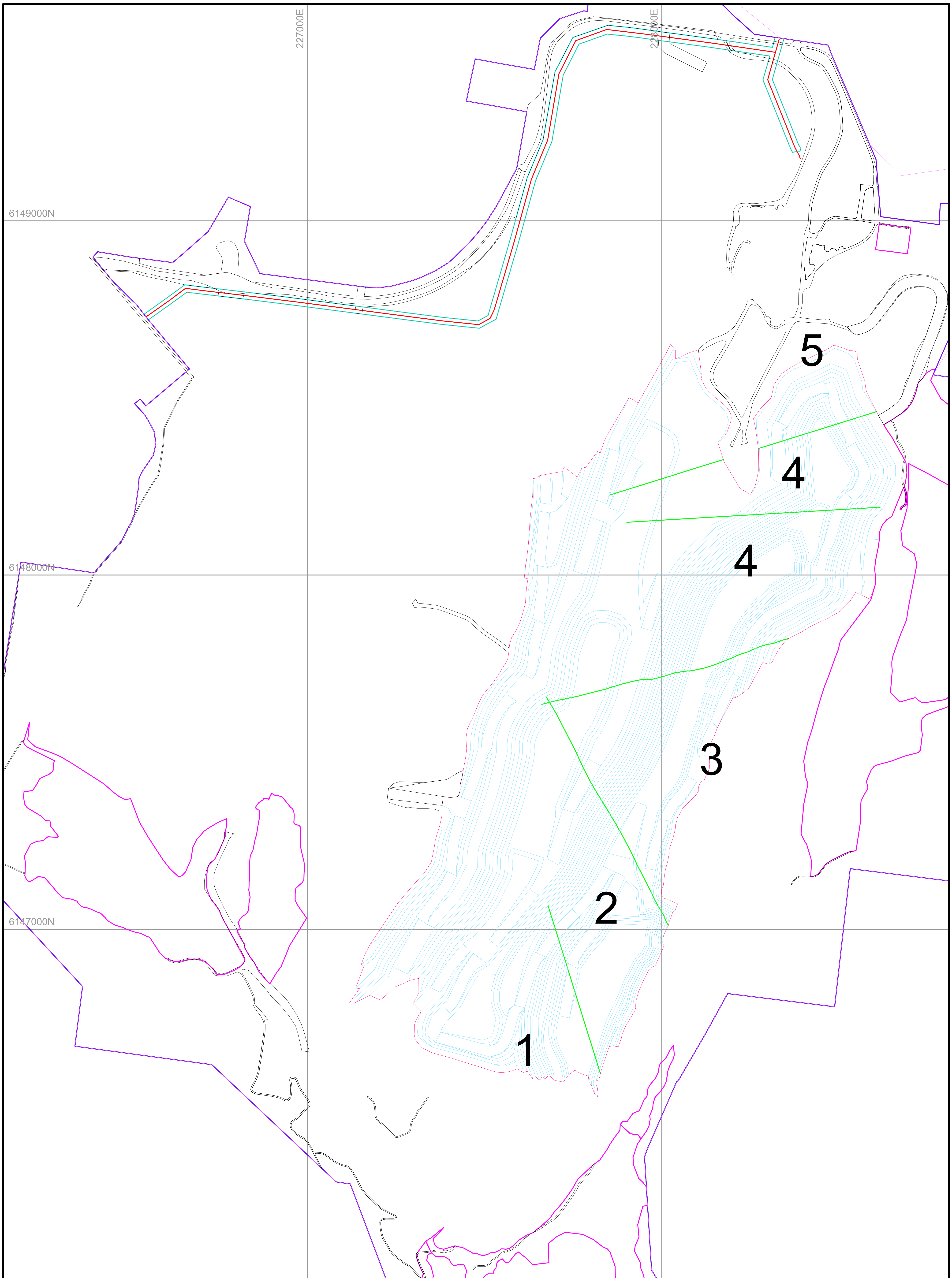
PSM

Pells Sullivan Meynink

Boral Cement Limited
2018 Geotechnical Assessment
30 Year plan - Marulan South Limestone Mine

STAGE 2 PIT & FAULT BLOCKS

PSM 645-028L | Figure 3



LEGEND

- 2018 30 Year Pit Shell
- Limestone Contacts
- Faults
- 1 Fault Block

0 100 200 300 400 500

Scale (m)

PSM

Pells Sullivan Meynink

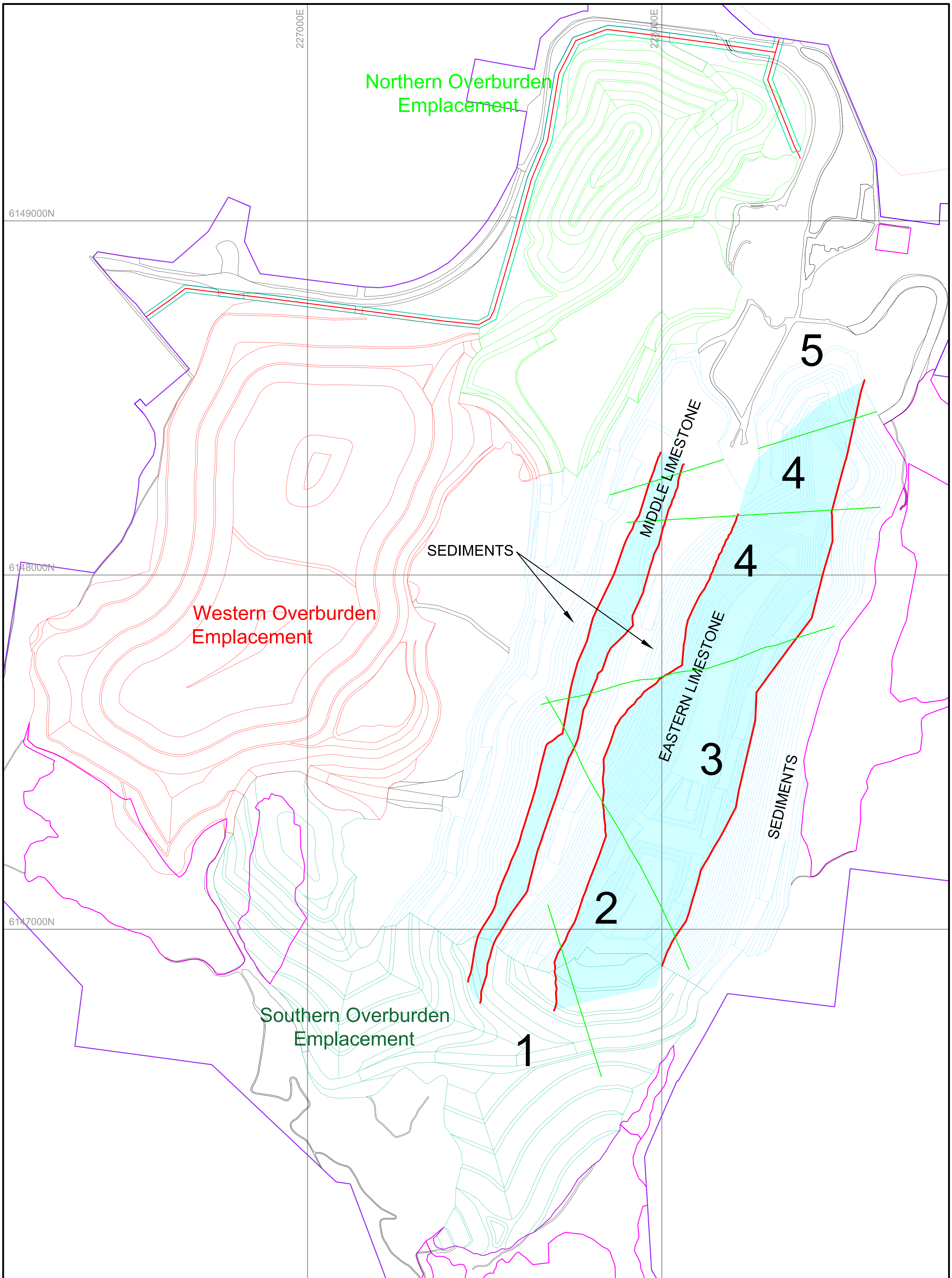
Boral Cement Limited

2018 Geotechnical Assessment

30 Year plan - Marulan South Limestone Mine

STAGE 3 PIT & FAULT BLOCKS

PSM 645-028L	Figure 4



LEGEND

- 2018 30 Year Pit Shell
- Limestone Contacts
- Faults
- 1 Fault Block

0 100 200 300 400 500

Scale (m)

PSM

Pells Sullivan Meynink

Boral Cement Limited

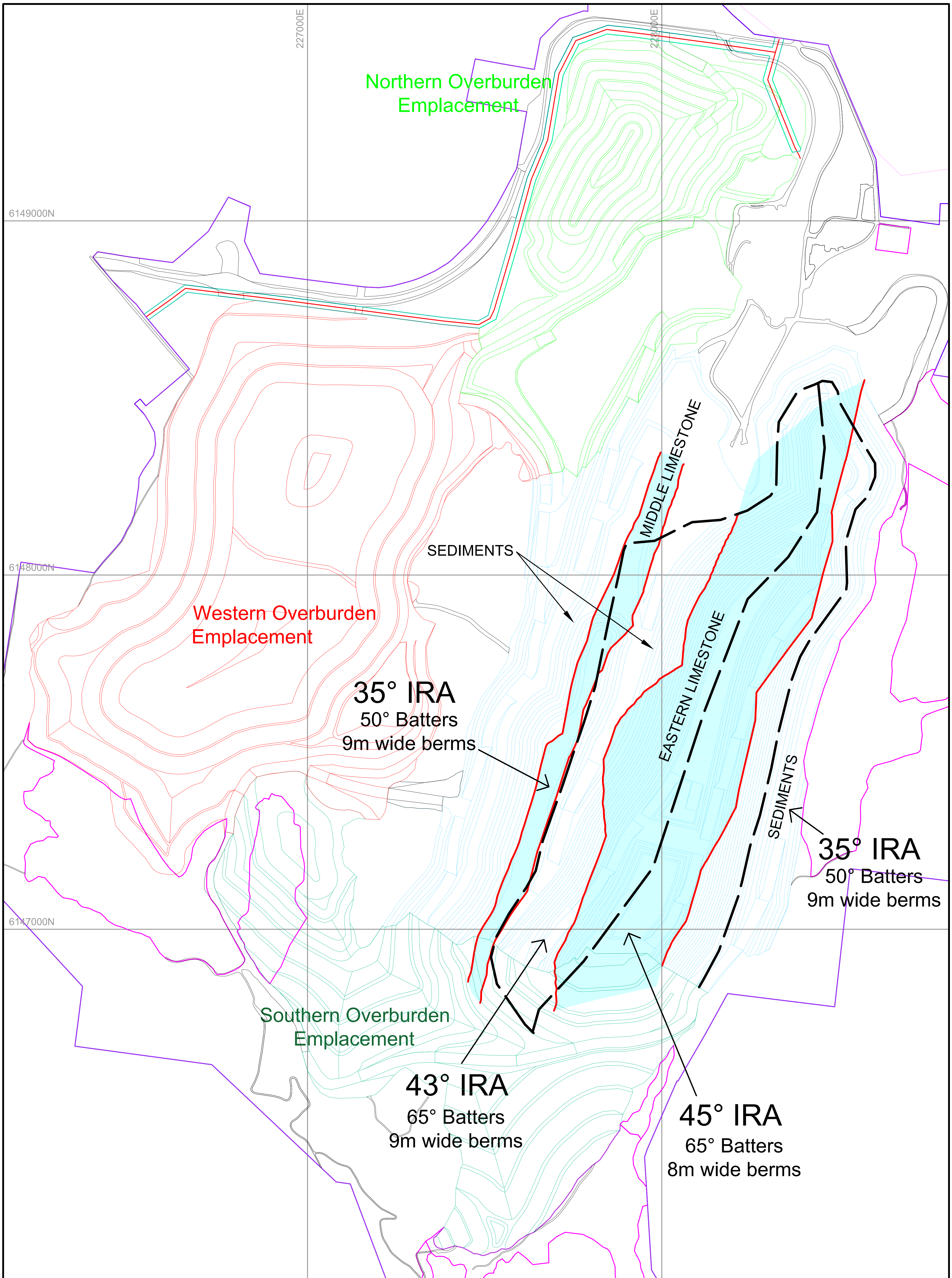
2018 Geotechnical Assessment

30 Year plan - Marulan South Limestone Mine

STAGE 4 PIT, FAULT BLOCKS & OVERBURDEN EMPLACEMENTS

PSM 645-028L

Figure 5



LEGEND

- 2018 30 Year Pit Shell
- Limestone Contacts
- 43° IRA — Inter ramp slope angle

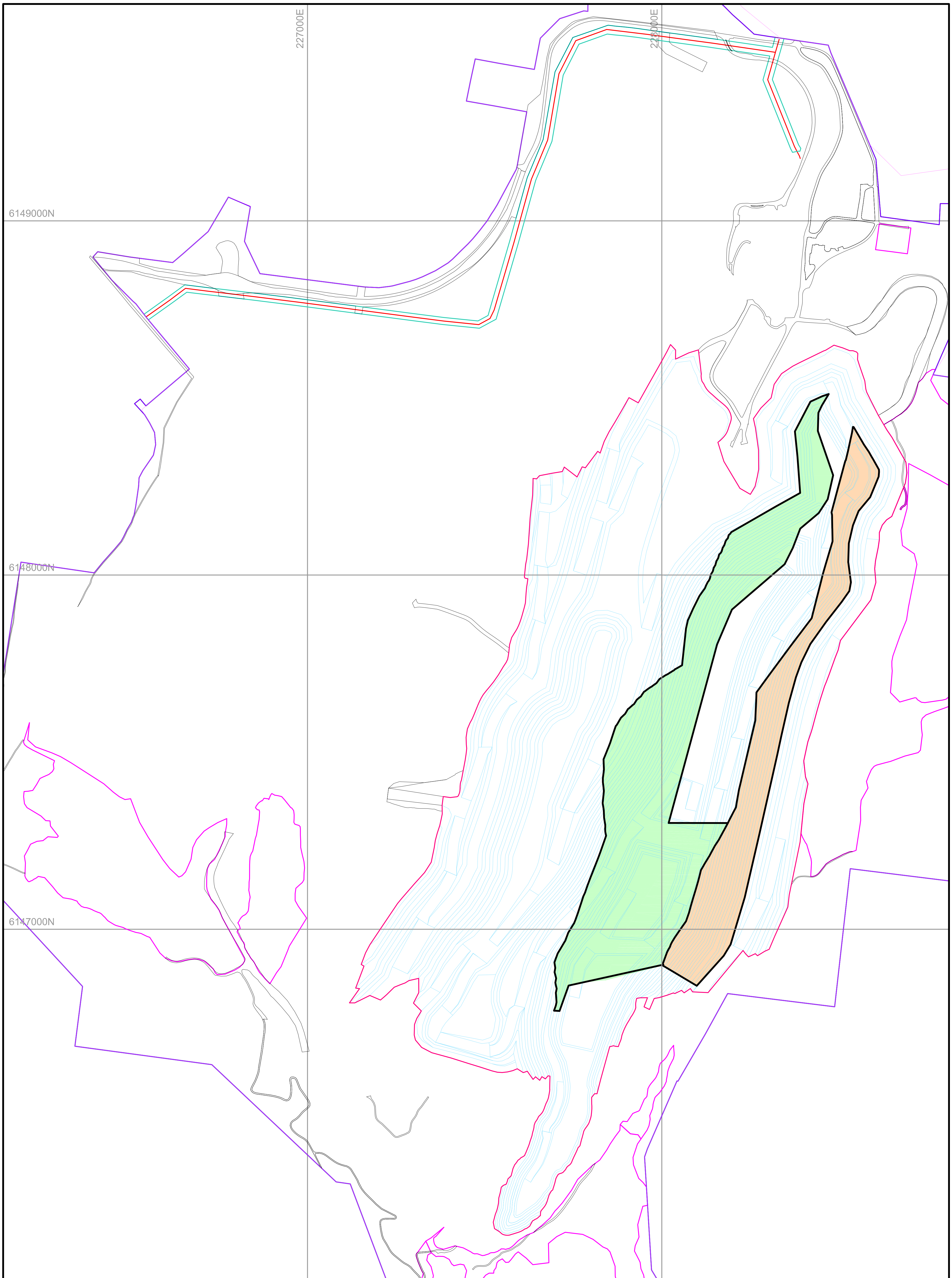
Scale (m): 0, 100, 200, 300, 400, 500

PSM — Pells Sullivan Meynink

Boral Cement Limited
2018 Geotechnical Assessment
30 Year plan - Marulan South Limestone Mine

STAGE 4 PIT
PIT DESIGN PARAMETERS

PSM 645-028L | Figure 6



LEGEND

Steeper than PSM recommendations

Shallower than PSM recommendations

0 100 200 300 400 500

Scale (m)

PSM

Pells Sullivan Meynink

Boral Cement Limited
2018 Geotechnical Assessment
30 Year plan - Marulan South Limestone Mine

STAGE 4 PIT
DESIGN VERSUS PSM RECOMMENDATIONS

PSM 645-028L | Figure 7

Appendix F

Marulan Creek dam concept design report

VOLUME 2

Pells Sullivan Meynink
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Rock-Soil-Water

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Our Ref: PSM1492-146R REV 3

9 August 2016

Boral Cement Limited
Clunies Ross St
PROSPECT NSW 2148

ATTENTION: ROD WALLACE
By email: Rod.Wallace@boral.com.au

Dear Sir

RE: CONCEPT DESIGN FOR THE PROPOSED MARULAN CREEK DAM, MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS

We are pleased to submit our concept design report for the proposed Marulan Creek Dam for at Marulan South Limestone Mine Continued Operations, New South Wales.

Please do not hesitate to contact the undersigned if you have any queries.

For and on behalf of
PELLS SULLIVAN MEYNINK

GARRY MOSTYN

Distribution: 1 electronic copy to Boral Cement Limited
Original held by PSM

Boral Cement Limited

CONCEPT DESIGN

FOR THE PROPOSED MARULAN CREEK DAM, MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS

PSM1492-146R REV 2   AUGUST 2016

CONTENTS

FIGURES

APPENDICES

1 INTRODUCTION

This report presents the concept design for the proposed Marulan Creek dam at Marulan South Limestone Mine Continued Operations, New South Wales.

The work was performed in accordance with our proposal email to Rod Wallace of Boral dated October 2014.

As part of the work, David Piccolo of PSM visited the site in the presence of Rod Wallace of Boral on 20 January 2015. Selected photos from the site visit are included in Appendix A.

2 BACKGROUND

Between 2010 and 2012 PSM was involved in the investigation, design and construction of the quarry infrastructure at Peppertree Quarry located 1 km south of the proposal dam location.

The infrastructure included a dam and rail embankment of similar characteristics of that proposed at Marulan Creek. We have incorporated the knowledge and experience from Peppertree Dam design as part of this concept design.

3 DAM CONCEPT

3.1 Dam configuration

It is proposed to adopt a homogeneous earth fill dam with a chimney drain and toe drain as per the Peppertree Dam.

A typical cross section through the dam is provided as Figure 1. Levels in the figures and this report are shown relative to AHD. The dam crest level is shown at RL600 m, full storage level (FSL) is shown at RL597 m and the batter slopes at 2.5H:1V. It may be possible to steepen the downstream face at the detailed design stage.

The crest and downstream face of the dam embankment will be landscaped upon completion to control erosion. The upstream face will need to be protected by means of rip rap.

Figure 2 presents a plan view showing a summary of the dam configuration, showing the preferred dam location (Location D see Section 3.2.1 for details) and spillway options.

Figure 3 presents the same plan view overlaid to an aerial photo showing the reservoir extent for a FSL of 597 m.

3.2 Dam locations

3.2.1 Options study

We have investigated four dam locations (Location A, B, C and D) as shown on Figures 4, 5, 6 and 7. We note:

- Location A requires removal of some of the trees located within Marulan Creek dam and impacts on the Marulan women's site, but maximises the storage volume.
- Locations B and C do not require removal of the trees but impact on the Marulan women's site.
  - Location B maximises the storage volume for no tree removal. The spillway outlet would still impact on the trees.
  - Location C has a lesser dam embankment volume and storage volume when compared to B and locates the dam over the shortest distance across the valley for no tree removal. The spillway outlet would have a lesser impact on the trees.
- Location D does not require removal of trees and does not impact on the women's site.

Figure 8 presents, for the four dam locations, the:

- Storage volume versus RL curves.
- The dam embankment material volumes.

3.2.2 Preferred Location D

The advice herein assumes that the dam will be located at Location D. At this stage, we consider this to be the preferable location as:

- It requires the minimum volume of earthworks.
- Locates the dam where the trees and Marulan women's site area are not impacted by neither the embankment or the spillway outlet.

The final location would need to be assessed at detailed design stage. The dam configuration in Figures 2 and 3 assume the dam embankment located at Location D. The advice which follows should vary only slightly should the dam location be changed to either location A, B or C.

3.3 Foundation preparation

At this stage it is proposed to found the dam on the decomposed granite at a depth of approximately 1.0 m below the current surface.

Given the observed creek bed geometry it is likely that between 1 to 2 m of alluvium is present in the creek bed that will need to be removed below the dam footprint.

Some rock breaking below footprint where rock does not allow compaction of the Dam Fill material.

Requirements for foundation grouting or a partial upstream blanket will need to be assessed at detailed design stage. We note that at Peppertree no such grouting was required.

3.4 Materials

The concept design of the dam assumes that the following materials will be used:

- **Dam Fill** as defined in the Peppertree Quarry Technical Specification. We can provide a copy of this document at Boral's request. This essentially comprised Decomposed Granodiorite (DG) won from the borrow areas at Peppertree Quarry, after clearing, grubbing and stripping of topsoil. It was able to be won and placed without processing. Given the large exposures now present in the quarry it may be worth targeting some of the more clayey portions of the DG.
- **Drainage Fill** as defined in the Peppertree Quarry Technical Specification. This is essentially a manufactured material that needs to comply with strict grading specification. It was able to be produced on site by crushing site won material and blending with imported material.
- **Upstream Face Rip Rap** as defined in the Peppertree Quarry Technical Specification. This comprises fresh granodiorite rock fragments of size between 5 kg and 70 kg.
- **Outlet Rip Rap i**s defined in the Peppertree Quarry Technical Specification. This material comprises fresh granodiorite boulders with weight between 1200 kg and 2000 kg.

3.4.1 Dam spillway

3.4.2 Design flows and surcharge

Based on the preliminary flood study completed (refer to Section 4) the design flow for the spillway is approximately 120 m^3/s (i.e. the 100 ARI peak flows for Marulan Creek Dam Catchment).

We have adopted a spillway level of RL597.0 m.

The spillway design will need to balance the following requirements:

1. The FSL, and thus the storage capacity.
2. The flow velocities, and thus the requirement and extent of lining of the spillway.
3. The frequency and duration at which the rail bridge located some 950 m upstream of the dam will be flooded.

The proposed configuration as discussed in Section 3.4.3 provides an initial proposal for the spillway configuration. At detailed design this can be finessed to better match Boral's requirements.

3.4.3 Proposed configuration

The spillway concept and arrangement is shown in Figures 2 and 8. The proposed spillway comprises:

1. FSL of RL597 m has been adopted.
2. A 20 m to 30 m wide spillway channel (shown as 20 m wide in figures). This would be excavated in the granodiorite to the north of the dam. Material excavated from the spillway is likely to be suitable for use as Dam Fill.
3. The spillway channel will need to be lined either with rocks or concrete:
   a. Should overtopping of the rail bridge on rare conditions be tolerable (e.g. for 1 in 100 yr flood event), the spillway can be designed to flow up to 2.0 m deep with flow velocities between 1.5 m/s and 2.0 m/s. At these velocities, a rock lined channel may be possible. It may still be desirable to minimise maintenance by concreting the channel.
   b. Should a higher FSL be desired (say RL598 m) and/or frequency of inundation of the bridge reduced, the depth of flow would need to be controlled and the spillway design would result in shallower faster flowing water. This in turn would require concrete lining of the spillway channel.
4. Outlet rip rap, in the order of 1.0 m diameter will be required at the downstream end of the spillway.
5. A reinforced concrete inlet structure with some rip rap may be required at the upstream end of the spillway.

3.5 Quantities estimates

Table 3.1 presents quantity estimates derived for the reservoir, dam and spillway as shown in Figures 1, 2 and 3. Rip rap is provided in terms of surface area.

TABLE 3.1
QUANTITY ESTIMATES (approximate)

ITEM	VOLUME (m^3)	AREA (m^2)
Storage at RL597 m	118,300	-
Reservoir surface at RL597 m	-	58,800
Dam Fill	13,550	-
Drainage Fill	550	-
Upstream Face rip rap	-	1,600
Outlet rip rap	-	2,600

ITEM	VOLUME (m^3)	AREA (m^2)
Crest and downstream face landscaping	-	2,300
Spillway excavation	5,300	-
Spillway surface area requiring concrete or rock lining	-	2,500 – 4,000

3.6 Dam and spillway construction issues

The following are some of the construction issues that should be considered when assessing the viability of the Marulan Creek dam:

- Temporary diversion. Provision for a temporary diversion or bypass will need to be set in place prior and during construction of the dam and spillway. A solution may comprise a temporary embankment upstream, and the provision and maintenance of a low flow channel over the dam as it is constructed.
- Road crossing. At the time of the site inspection Boral raised the issue of the road crossing. We consider that the most appropriate place to relocate the road crossing is across the spillway (with low flow provision) and over the dam crest. Any other solution would require an embankment upstream of the proposed dam location.
- Rock excavation in spillway. Some rock excavation as well as dealing with large buried fresh grandiorite boulders may be required as part of the spillway excavation.

4 PRELIMINARY FLOOD STUDY

4.1 Catchment details

Marulan Creek catchment is a small catchment in the Southern Tablelands of NSW. The catchment includes a mix of rural and uncleared areas and several small farm dams have been constructed across the main creek and some of its tributaries. The catchment is immediately north of the Peppertree Gully catchment and both flow into Barbers Creek, a tributary of the Shoalhaven River. The catchment area upstream of the proposed dam site is 20.25 km^2.

4.2 Design flows

Design flows have been estimated for Marulan Creek at the proposed dam location. The estimates have been developed using the Regional Rational Method as set out in Australian Rainfall and Runoff (1987).

The time of concentration was estimated as 2.4 hours, with a runoff coefficient for the 10 year event (C_{10}) of 0.5, based on the catchment being in frequency factor zone C with an elevation greater than RL500 m. The resulting flow estimates for a range of annual exceedance probabilities (AEP) are listed in Table 4.1. The table includes equivalent average recurrence intervals (ARIs).

TABLE 4.1
FLOW ESTIMATES

AEP	ARI (YEARS)	FLOW ESTIMATE (m^3/s)
1	1	29
0.5	2	39
0.2	5	52
0.1	10	63
0.05	20	76
0.02	50	101
0.01	100	120

The 0.01 Annual Exceedence Probability (AEP) flood has been used to estimate spillway width requirements at the dam. The estimate assumed an initial condition of the water level at the spillway level of RL597 m. Inflows were estimated as a triangular hydrograph with a total event length being four times the time of concentration. Outflows were controlled by the spillway geometry, which was assumed to behave as an open channel governed by the Manning's equation. The estimate considered the storage effect of the dam in attenuating peak flows, but not routing within the dam.

The adopted spillway design is for a channel with between 20 metre and 30 m wide base, a 0.1% to 1.5% longitudinal slope. The resulting depths are between 1.0 m and 2.5 m and velocities between 6 m/s and 2.5 m/s respectively.

Such a channel will require drop structures/rip rap at the downstream end to tie into the natural creek level.

4.3 Flooding of rail during storm events

A rail bridge crossing of the Marulan Creek is located 1km upstream of the proposed dam. Hydraulic modelling of this waterway crossing was undertaken to assess whether the dam construction would have any adverse impact on the level of service of the bridge. Modelling was completed using the HEC-RAS hydraulic modelling software package.

4.3.1 Assumptions

The main part of the Marulan Creek catchment lies upstream of the rail bridge. Therefore the same flows were adopted for assessment of the rail hydraulics. In the absence of detailed survey of the bridge, the bridge was idealised as a 35 metre crossing, with 5 sets of 7 metre spans. The deck assumed to be 600mm high with 4 piers each 800mm thick. Indicative levels for the top and underside of the deck are RL598.7 m and RL598.1 m respectively. While the top of rail is indicated to be at RL599.1 m, this assessment considers that the rail is inundated once water is flowing over the top of the embankment (ie. through the ballast). The model adopted a skew of approximately 30 degrees for the bridge normal to the direction of flow.

Two scenarios were considered – the Existing Scenario and Dam Scenario, where the dam spillway is set at RL597 m and designed to jeep water at the spillway below RL598 m for all flows up to the 100 year flood event.

In the Existing scenario, downstream boundary conditions of the hydraulic model are governed by the natural channel slope.

For the Dam Scenario, the downstream boundary is governed by the flow over the spillway.

4.3.2 Results

The model predictions of water levels immediately upstream of the bridge for the Existing Scenario are listed in Table 4.2 for each AEP. Long sections of the reach upstream and downstream of the bridge are shown in Appendix B. The results indicate that under the existing conditions flows greater than the 100 year flood can pass below the bridge without inundating the rail. This is consistent with anecdotal evidence from Boral.

For the Dam Scenario and the 0.01 AEP (100 year flood) event, the hydraulic modelling suggest that the bridge is not subject to inundation. The analysis indicates a 0.5 m increase in water level upstream of the bridge compared to the scenario when the dam is not in place.

That is, the preliminary assessment indicates that for FSL below RL598 m, the inundation of the rail bridge is likely to be controlled by the spillway design. In other words, the hydraulic modelling suggest that the bridge is not subject to inundation for flows up to the 0.01 AEP provided that the spillway is designed with adequate capacity as not to raise the water above the rail level.

TABLE 4.2
RESULTS OF PRELIMINARY FLOOD ASSESSMENT

AEP	WATER LEVELS UPSTREAM OF BRIDGE Existing Scenario (m AHD)
1	596.53
0.5	596.69
0.2	596.89
0.1	597.02
0.05	597.19
0.02	597.46
0.01	597.66

4.3.3 Discussion

In assessing the FSL for the dam and the spillway design, Boral need to balance the storage volume, with the frequency and duration of flooding of the railway and the cost of the spillway.

However, for the concept spillway configurations provided in this report the preliminary flood study suggests that the rail bridge is not subject to inundation for events up to the 0.01 AEP (100 year ARI) flood for either the Existing Scenario or the Dam Scenario with FSL at RL597 m.

Furthermore, we consider that concrete lining the spillway, designing the spillway for higher velocities, and accepting that on occasion the rail may be inundated for short durations will allow the FSL to be raised above RL597 m (and as high as RL598 m).

The effect of inundation of the rail and embankments can be addressed by raising the rail and reshaping/protecting the embankments if necessary. This is a matter for detailed design.

5 DETAILED DESIGN

5.1 Geotechnical site investigation

Prior to detailed design a geotechnical site investigation would need to be completed. We consider that this would entail two days of test pitting at dam footprint and proposed spillway locations. A 25 tonne excavator would be adequate for this work. Test pits should be logged by a suitably qualified geotechnical engineer.

5.2 Detailed flood and yield study

Detailed flood and yield study to confirm the preliminary study and provide predictions of water availability versus time. Review of Peppertree Dam performance (inflows, outflows and losses) would greatly improve these predictions.

This would also need to consider the interaction between the existing dams and spilling from these dams and the proposed Marulan Creek dam.

The flood study should include a survey of the bridge structure to confirm advice regarding flow below the bridge.

5.3 For construction drawings and technical specification

Detailed design would require PSM to prepare the minimum number of drawings to allow construction of the dam and spillway by others. Typical cross sections shall be provided where appropriate. The drawings would be prepared and provided in the format required by Boral.

In addition, a dam specification will need to be prepared to comprise the following sections and subsections:

1. Earthworks Specification. This will include:
    a. Stripping and grubbing

b. Materials. We have identified the following materials:

   i. Dam embankment fill, (i.e. decomposed granite)

   ii. Chimney and toe drain (and filters if required)

   iii. Rip rap

   iv. Topsoil

   v. Temporary roads materials (by contractor)

c. Material placement. This will detail:

   i. Layer thickness

   ii. Compaction requirements

   iii. Moisture control requirements

   iv. Other requirements

d. Inspection and testing requirements. This will include details of:

   i. Role and responsibilities of Geotechnical Testing and Inspection Authority (GITA).

   ii. Level of site presence.

   iii. Type of testing

   iv. Frequency of testing

   v. Inspection requirements

   vi. Reporting requirements

   vii. Certification requirements

   viii. Witness and hold points

e. Audit role. This will include details of inspections and certificates to be provided by geotechnical consultant and site supervisor including witness and hold points.

2. Landscaping Specification. This will include:

   a. Topsoiling

   b. Seeding/hydromulching details

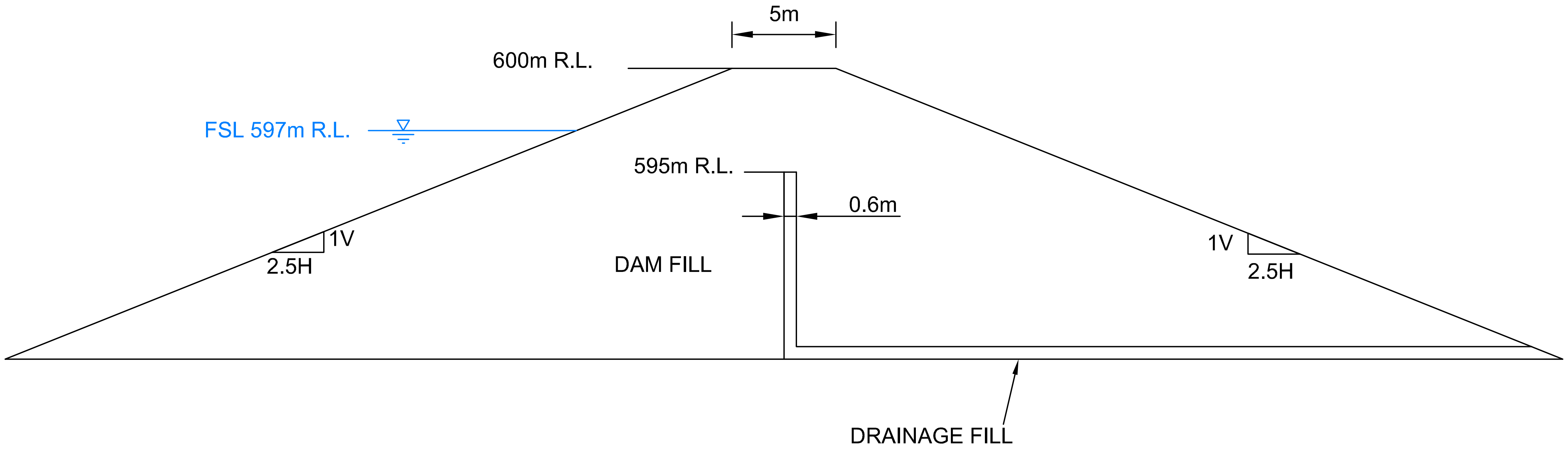
   c. Witness and holdpoint requirements

PSM provided such documentation for the Peppertree Dam that allowed for an economic and, we understand, a dispute free construction.

For and on behalf of
PELLS SULLIVAN MEYNINK

DAVID PICCOLO
Principal

GARRY MOSTYN
Principal



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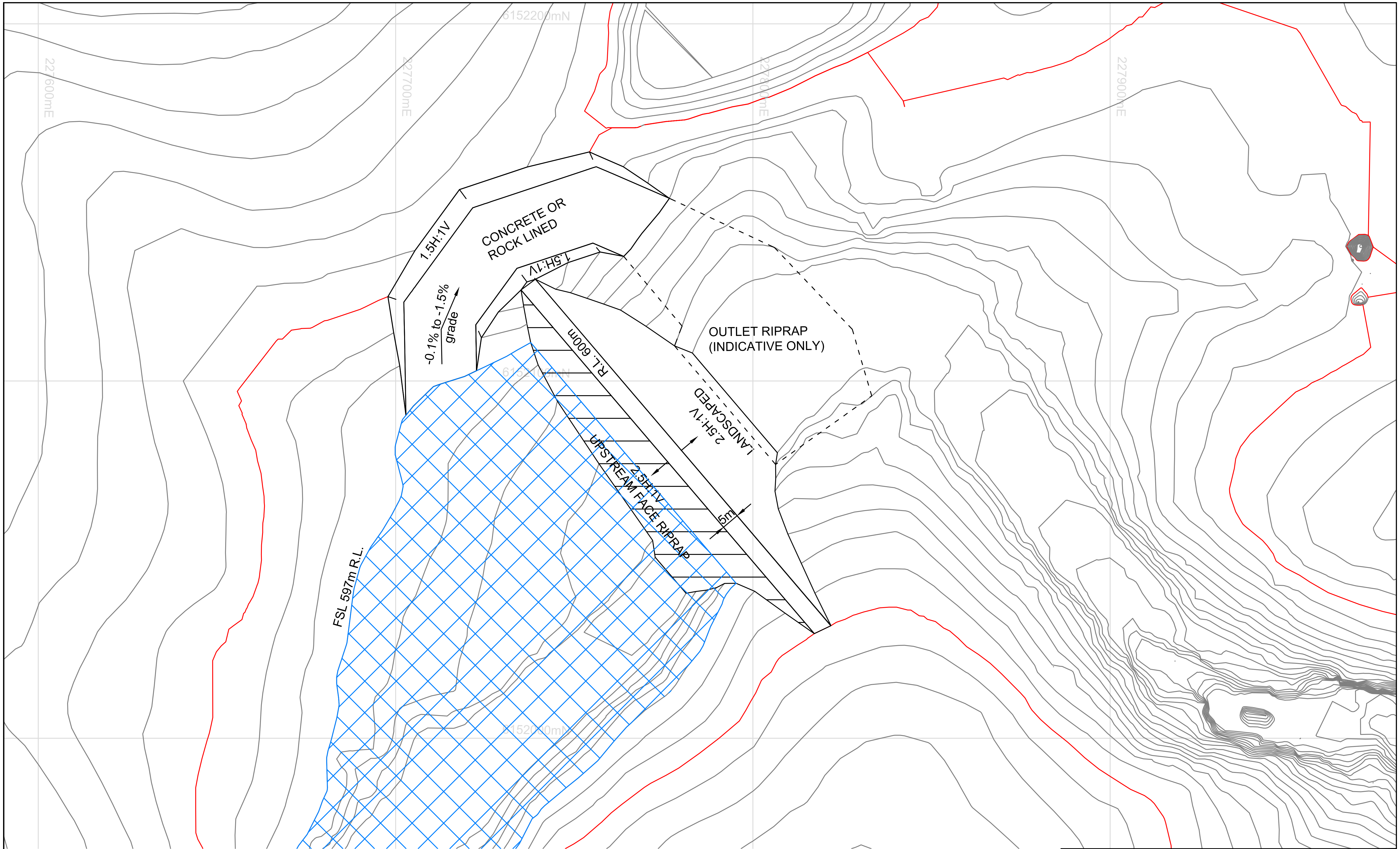
Scale (m)

PSM
Pells Sullivan Meynink

Boral
Marulan Creek Dam
Concept Design

TYPICAL CROSS SECTION

PSM1492 - 146R	Figure 1



0 10 20 30 40 50

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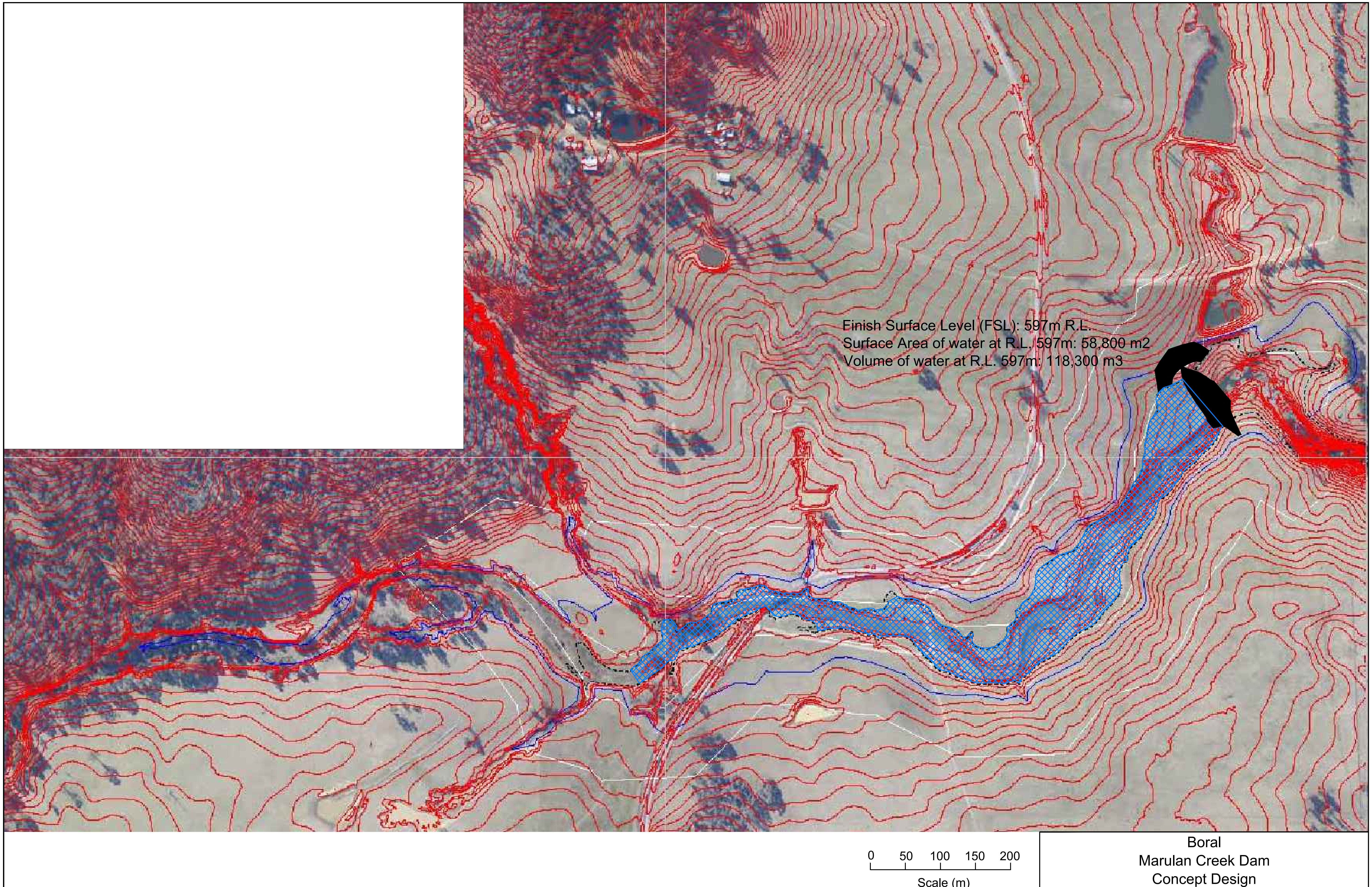
Concept Design

DAM AND SPILLWAY CONFIGURATION

PSM1492 - 146R	Figure 2



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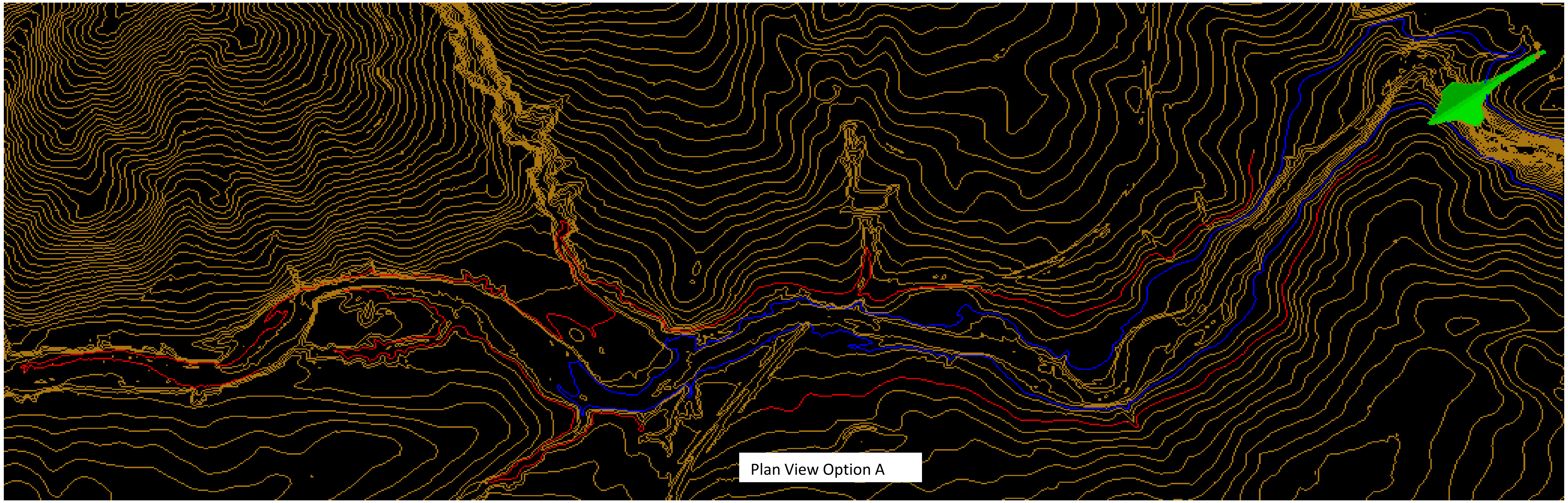
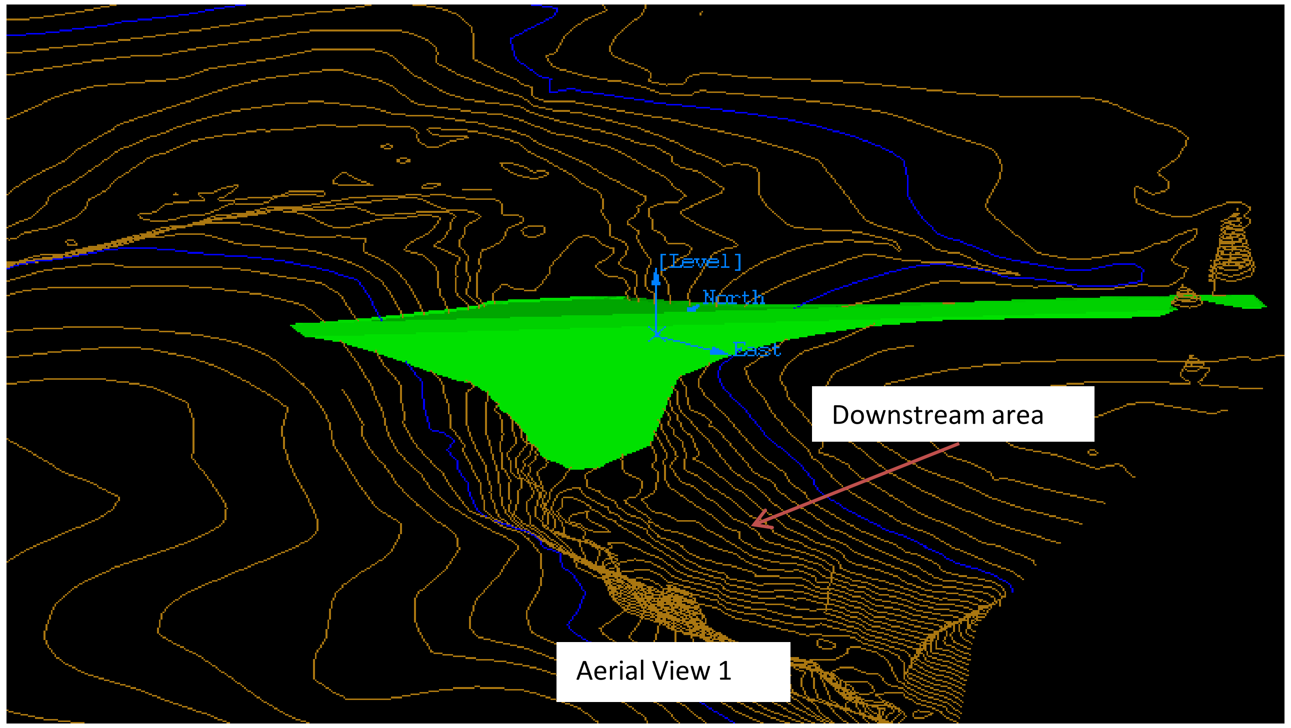
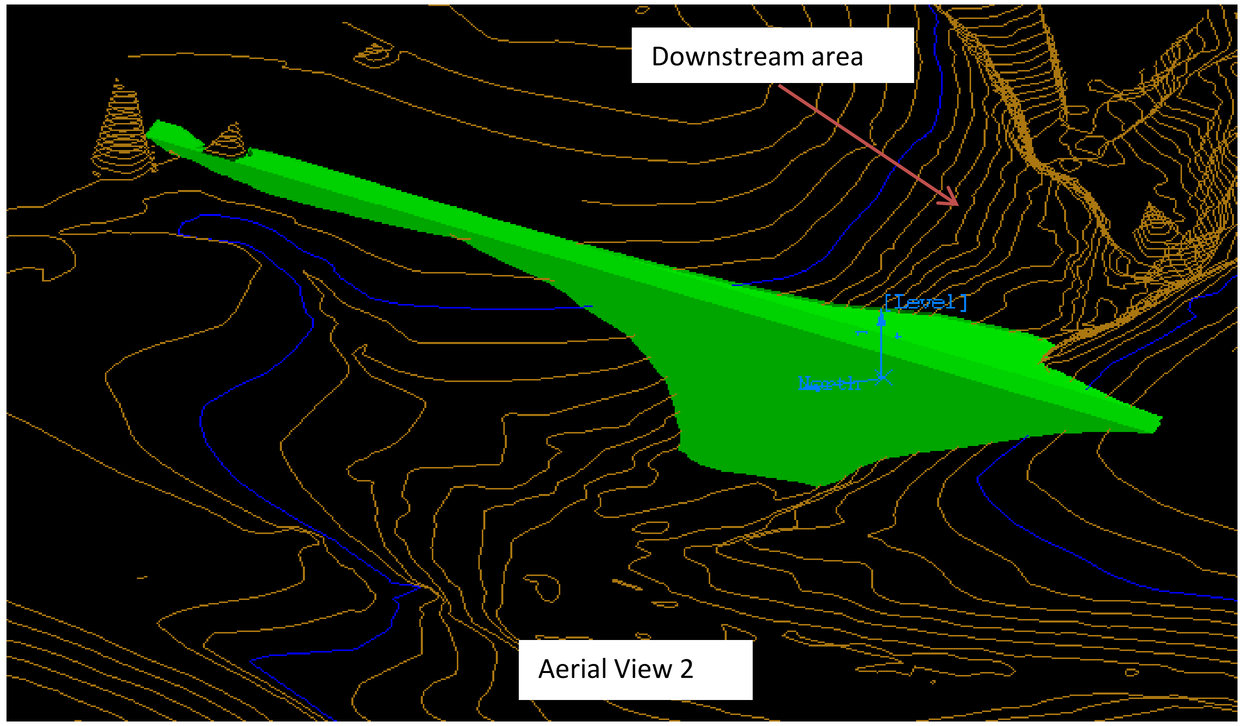
Marulan Creek Dam
Concept Design

RESERVOIR CONFIGURATION

PSM1492 - 146R | Figure 3







Pells Sullivan Meynink

Boral Marulan Creek Dam Concept Design OPTIONS STUDY DAM EMBANKMENT OPTION A	
PSM1492 - 146R	Figure 4

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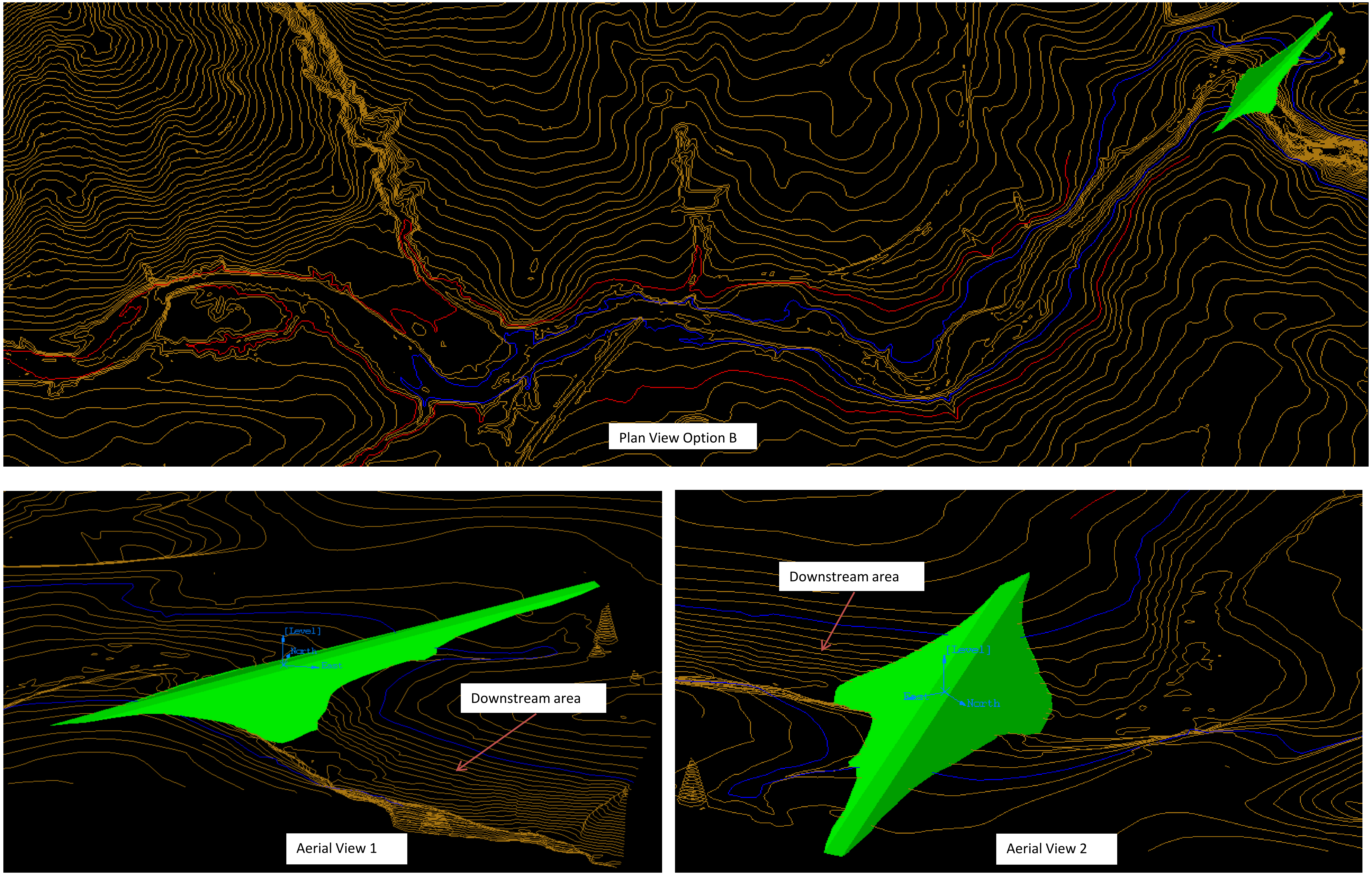
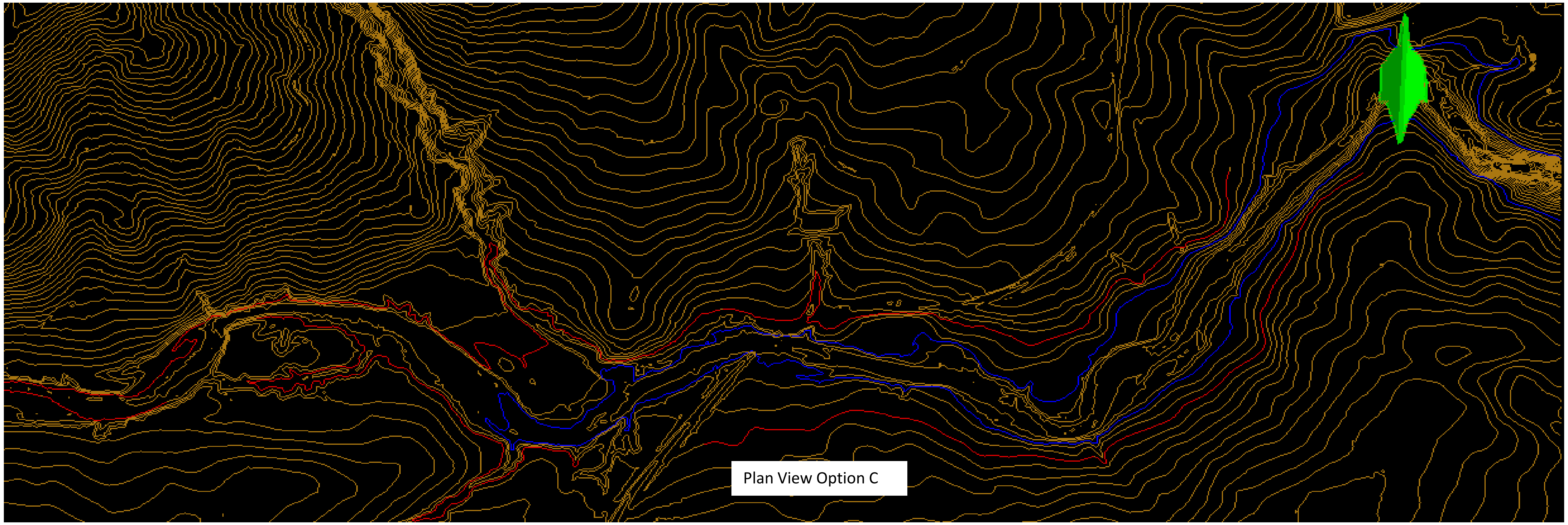
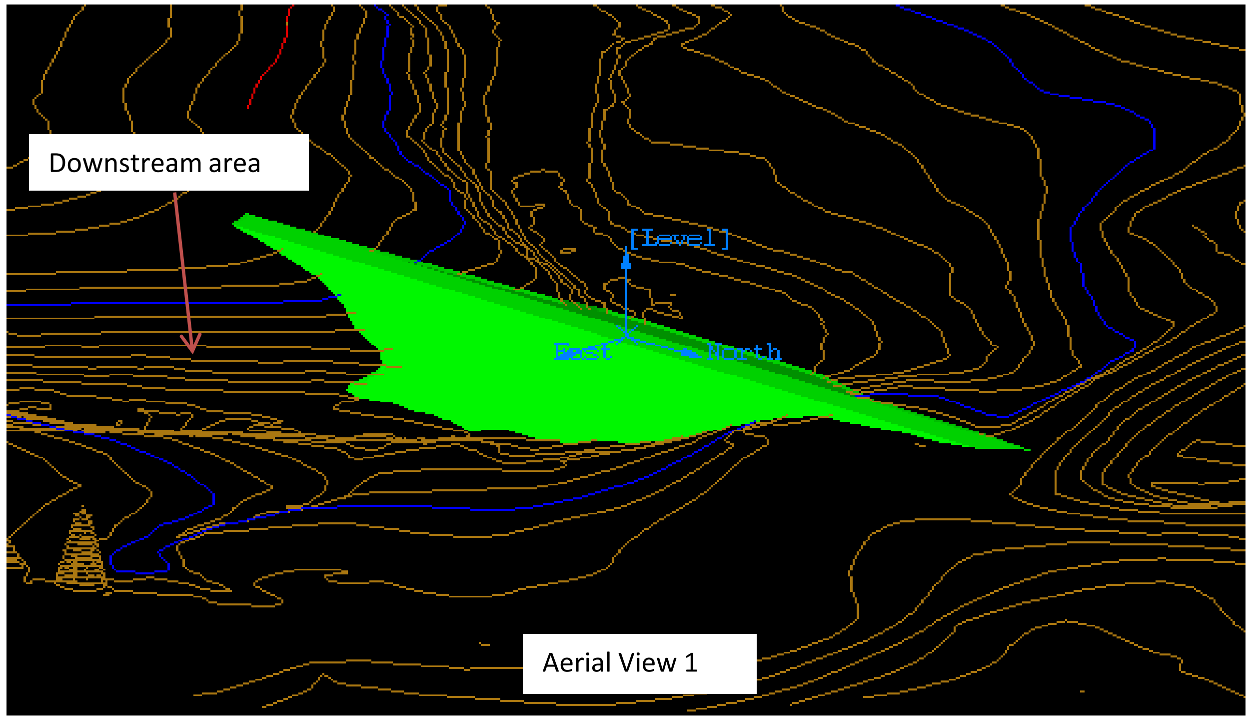


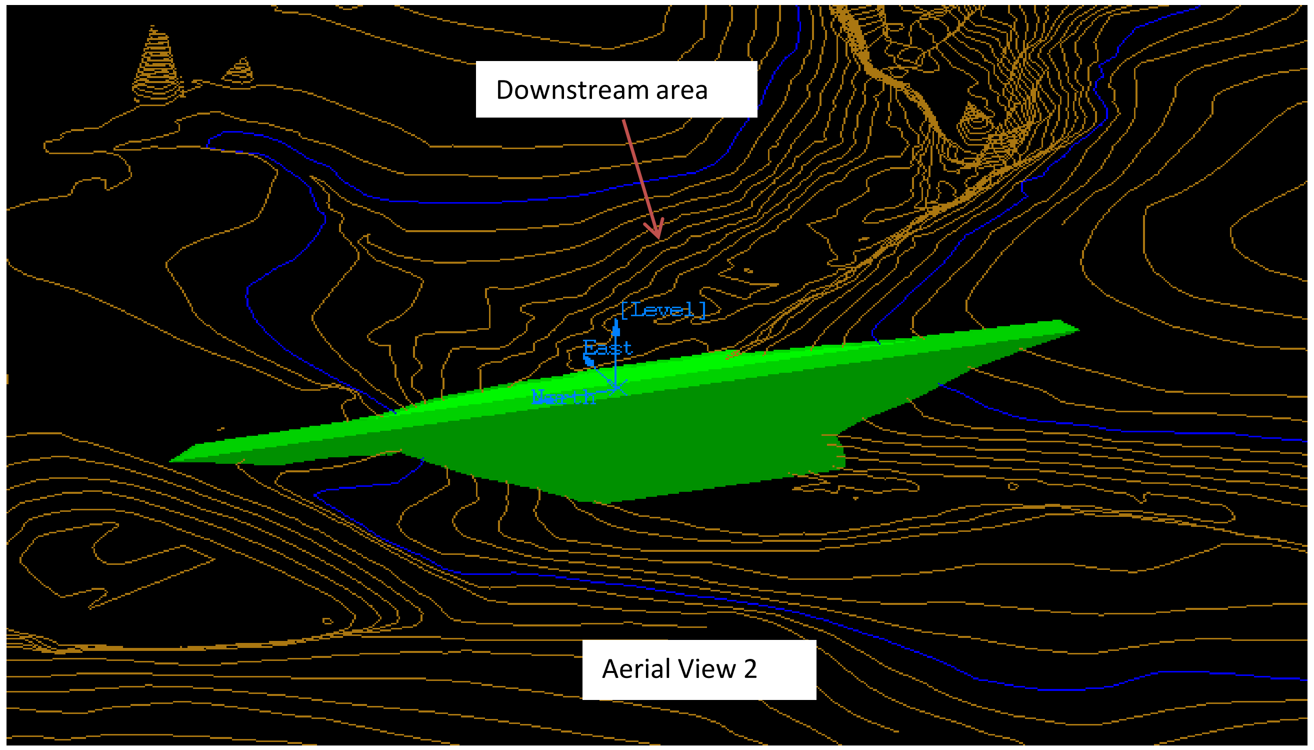
Boral
Marulan Creek Dam
Concept Design
OPTIONS STUDY
DAM EMBANKMENT OPTION B

PSM1492 - 146R	**Figure 5**

Pells Sullivan Meynink

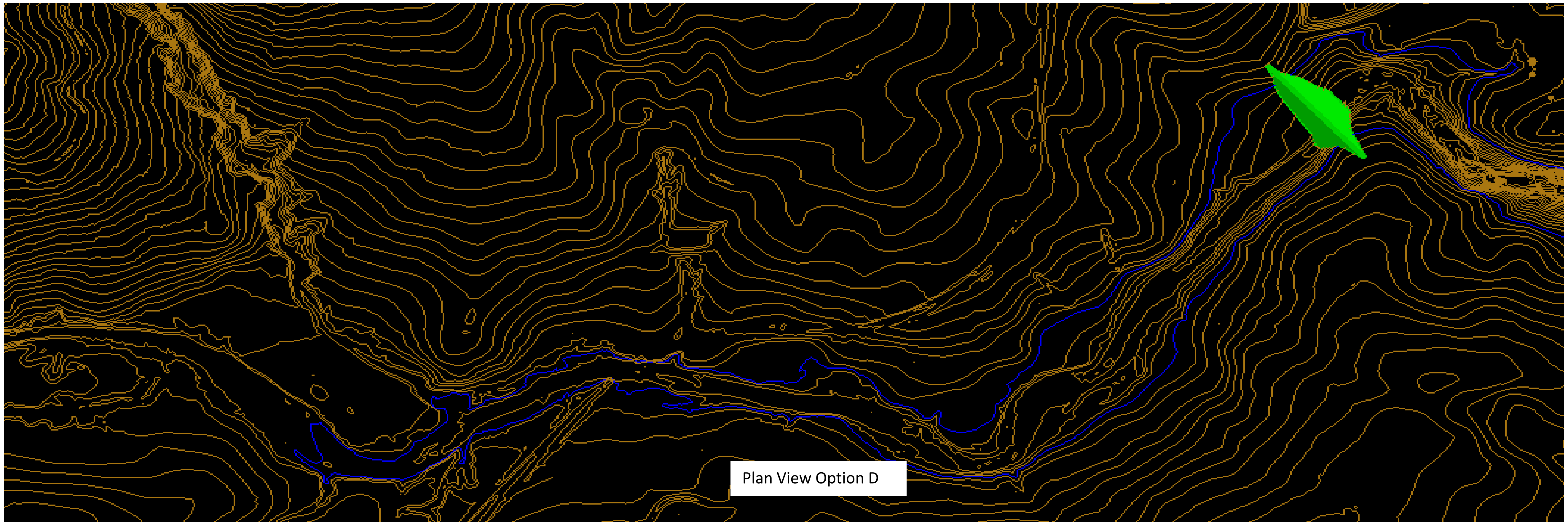


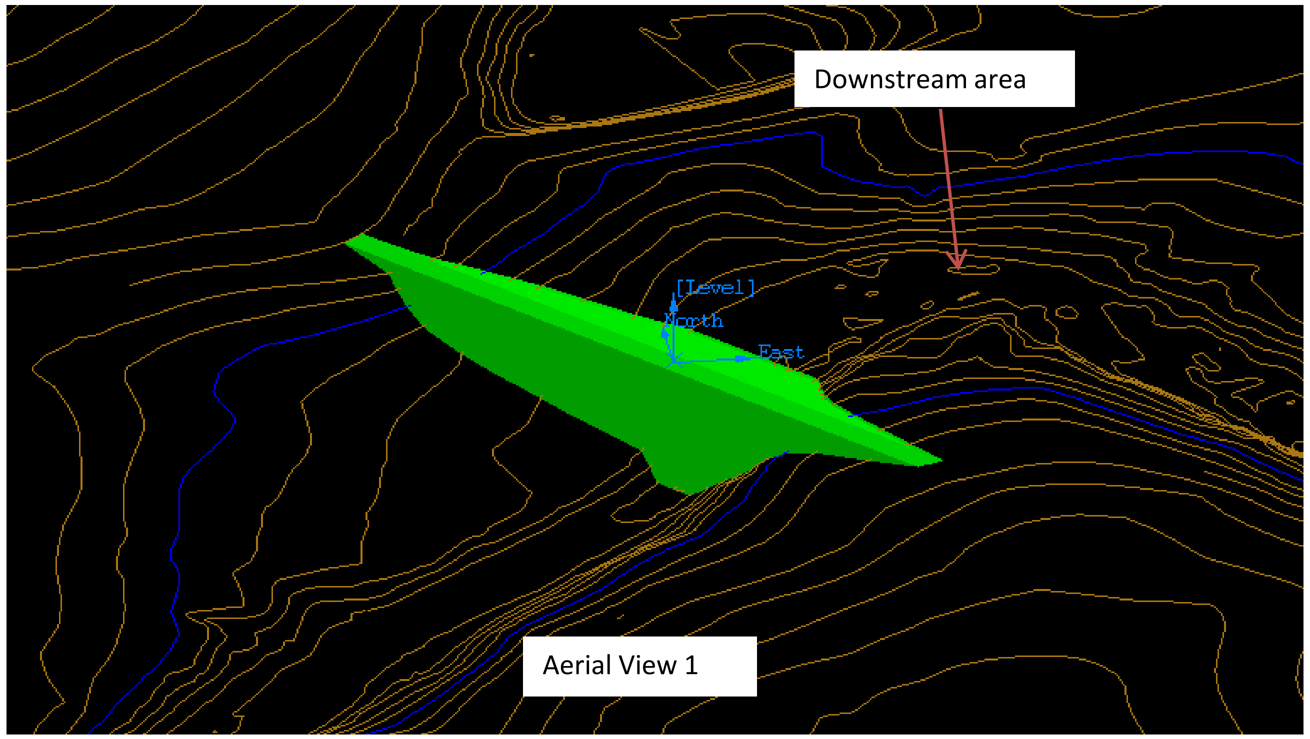


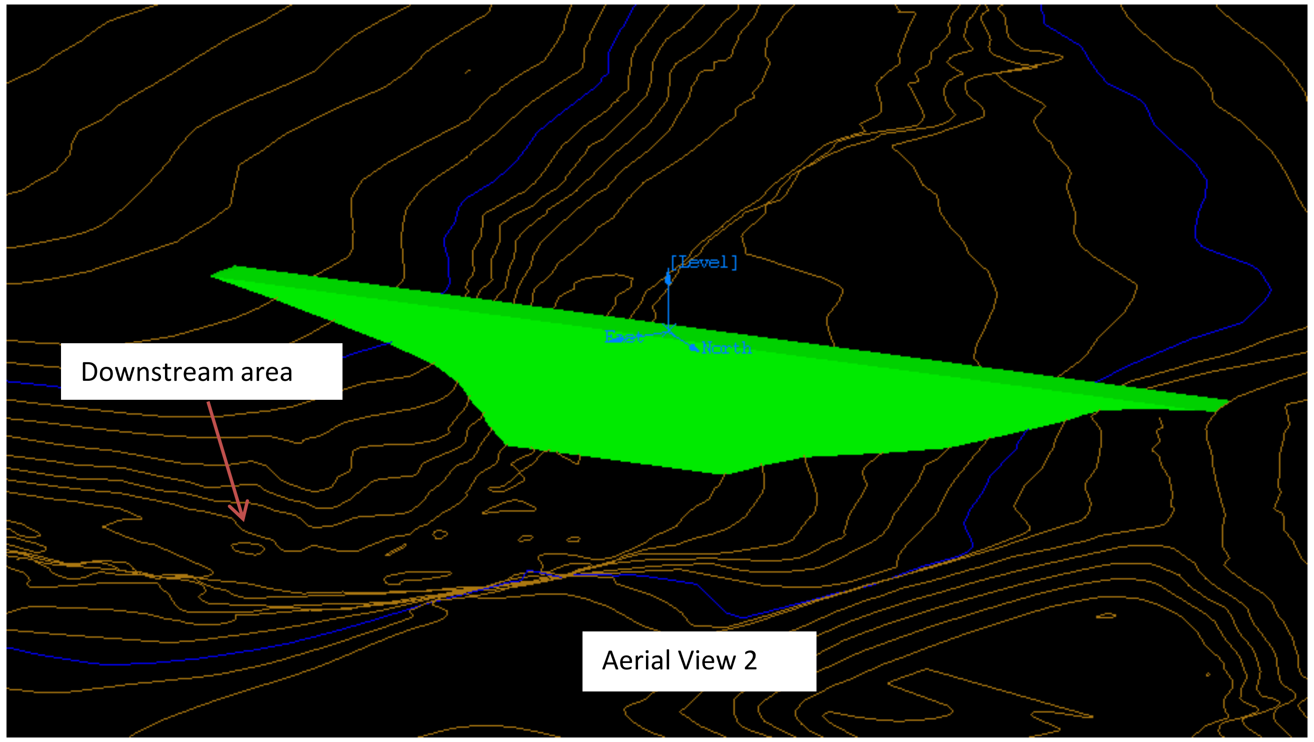


Boral Marulan Creek Dam Concept Design OPTIONS STUDY DAM EMBANKMENT OPTION C	
PSM1492 - 146R	Figure 6

PSM Pells Sullivan Meynink







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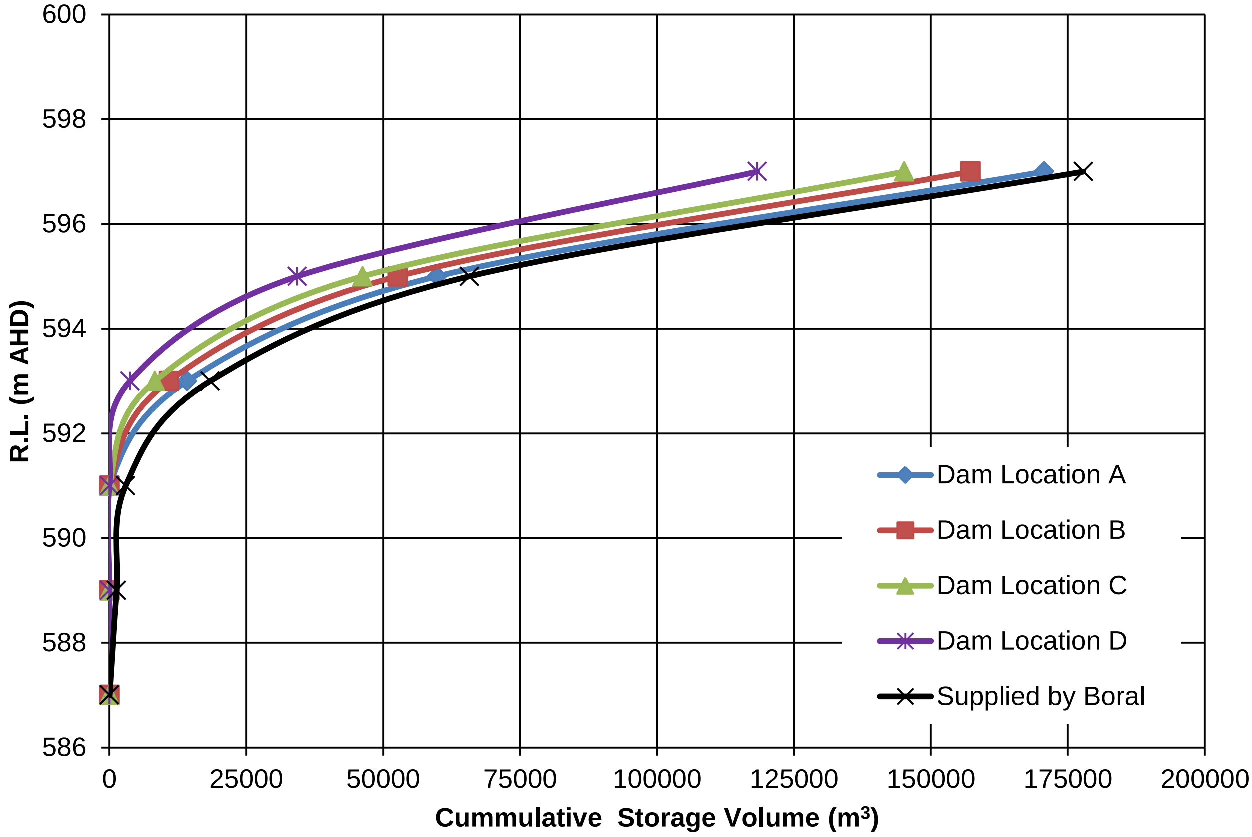
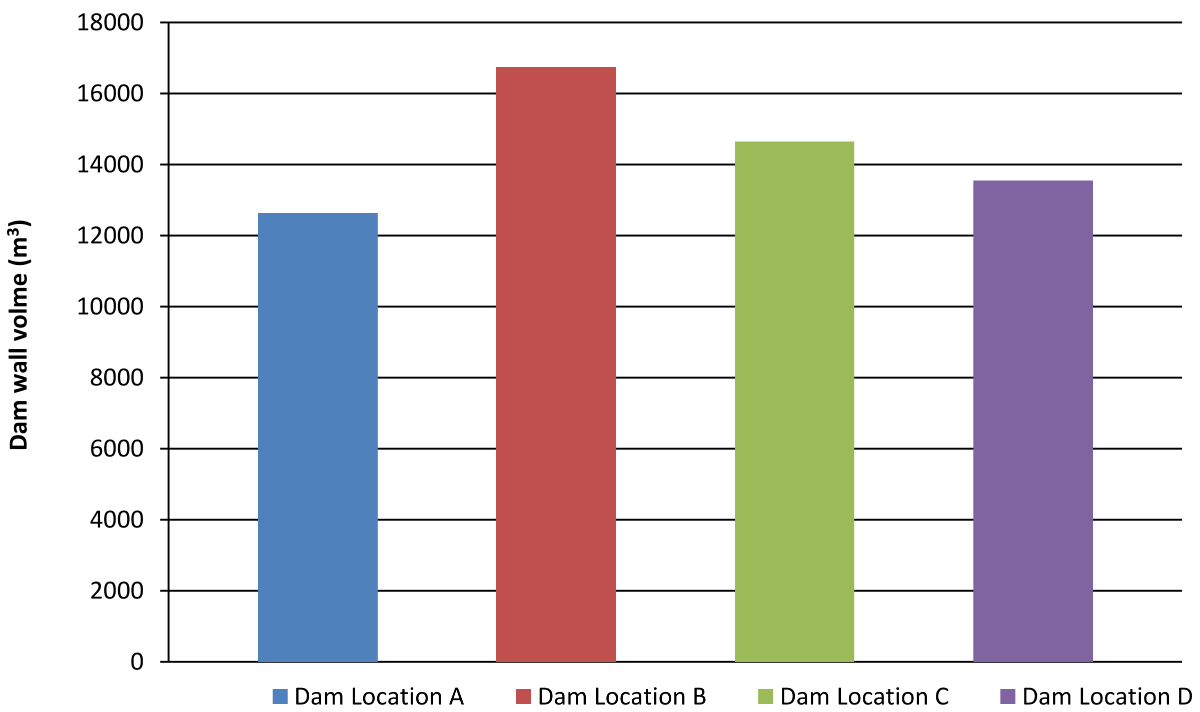
Boral Marulan Creek Dam Concept Design OPTIONS STUDY DAM EMBANKMENT OPTION D	
PSM1492 - 146R	**Figure 7**





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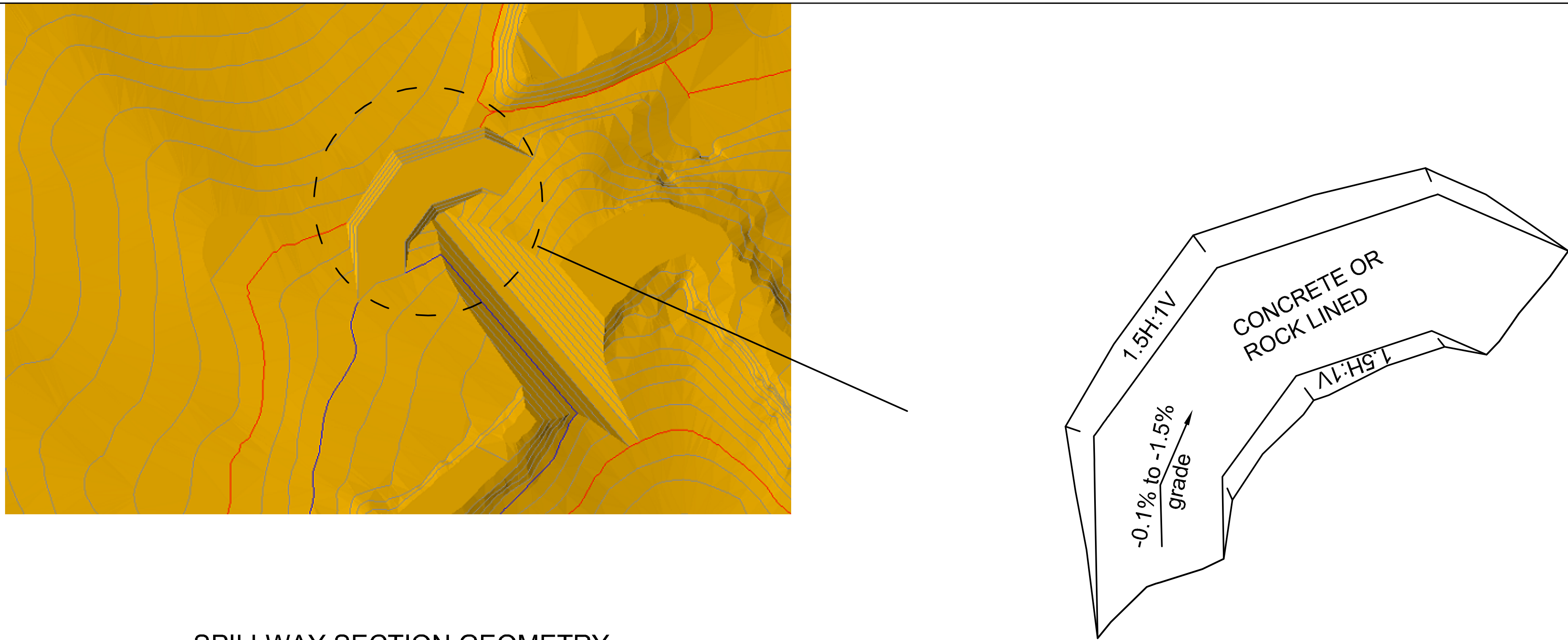
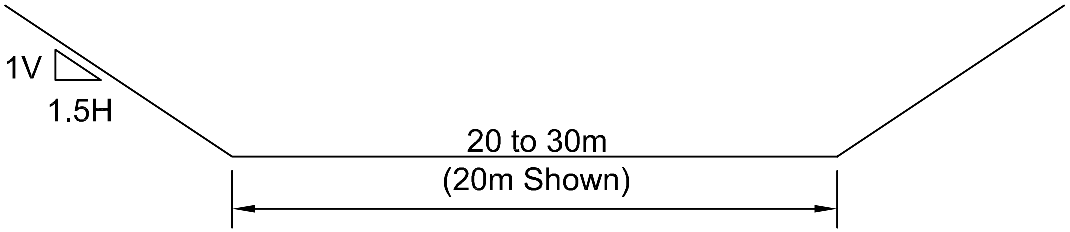
Boral Marulan Creek Dam Concept Design OPTIONS STUDY VOLUME ESTIMATES	
PSM1492-146R	Figure 8

S:\PSM1492\Engineering\Concept Design\Marulan Dam 2015\[Dam volumes.xlsx]Figure 8



SPILLWAY SECTION GEOMETRY



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Marulan Creek Dam
Concept Design

SPILLWAY CONFIGURATION

PSM1492 - 146R	Figure 9

APPENDIX A

SELECTED PHOTOGRAPHS SITE VISIT JANAURY 2015

Photo 1: Rail bridge south abutment

Photo 2: Rail bridge – South abutment – White paint mark is RL597.0 m, measured height to top of concrete is 1.7 m

Photo 3: Rail bridge from downstream end

Photo 4: Rail bridge from upstream end

Photo 5: Rail bridge – North Abutment

Photo 6: Marulan creek – Wide flat alluvium channel

Photo 7: Marulan creek – Wide flat alluvium channel

Photo 8: Marulan creek – Weathered granodiorite on south bank, fresh boulders present

Photo 9: Marulan creek – Approaching dam location C

Photo 10: Marulan creek – Approaching dam location C

Photo 11: Marulan creek – Dam location C panorama– Trees can be seen at right of photos. Dam Location C centre line approximately at centre of photo. Note rocky foundation

Photo 12: Rail bridge panorama

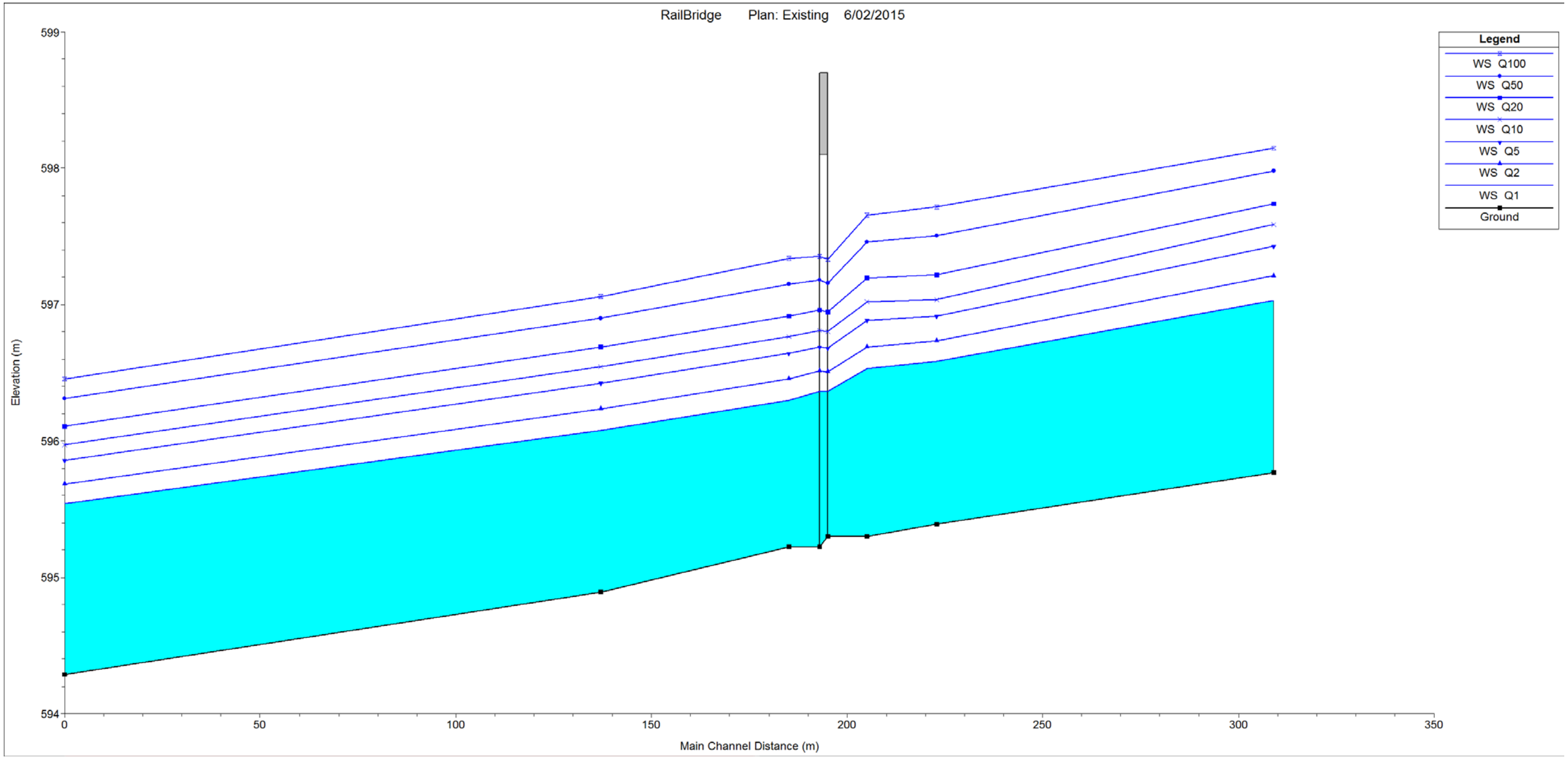

Figure 1 River Water Level Profiles for the Existing Scenario

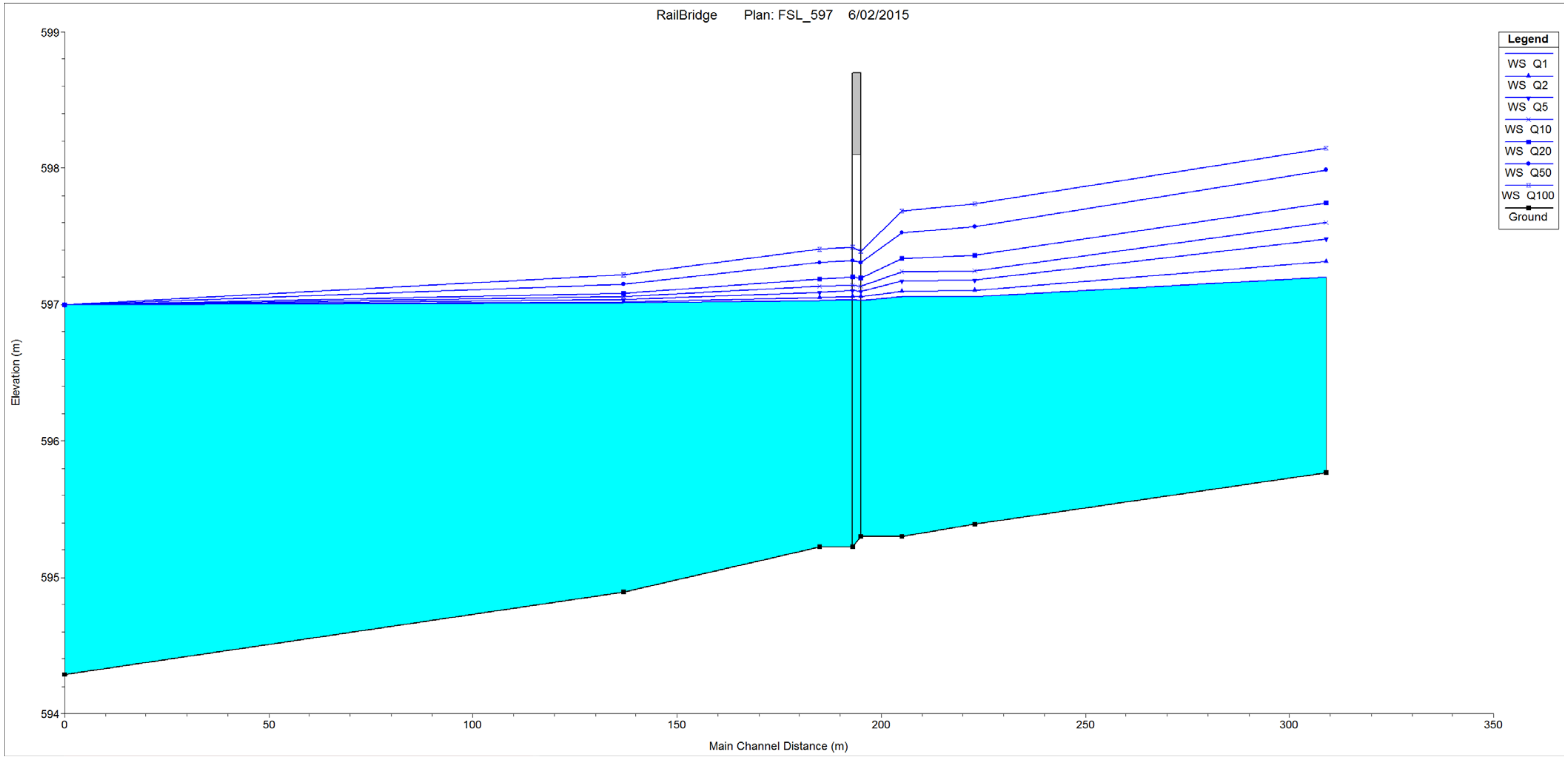

Figure 2 River Water Level Profiles for the FSL597 scenario

APPENDIX B

FLOOD ANALYSIS RESULTS

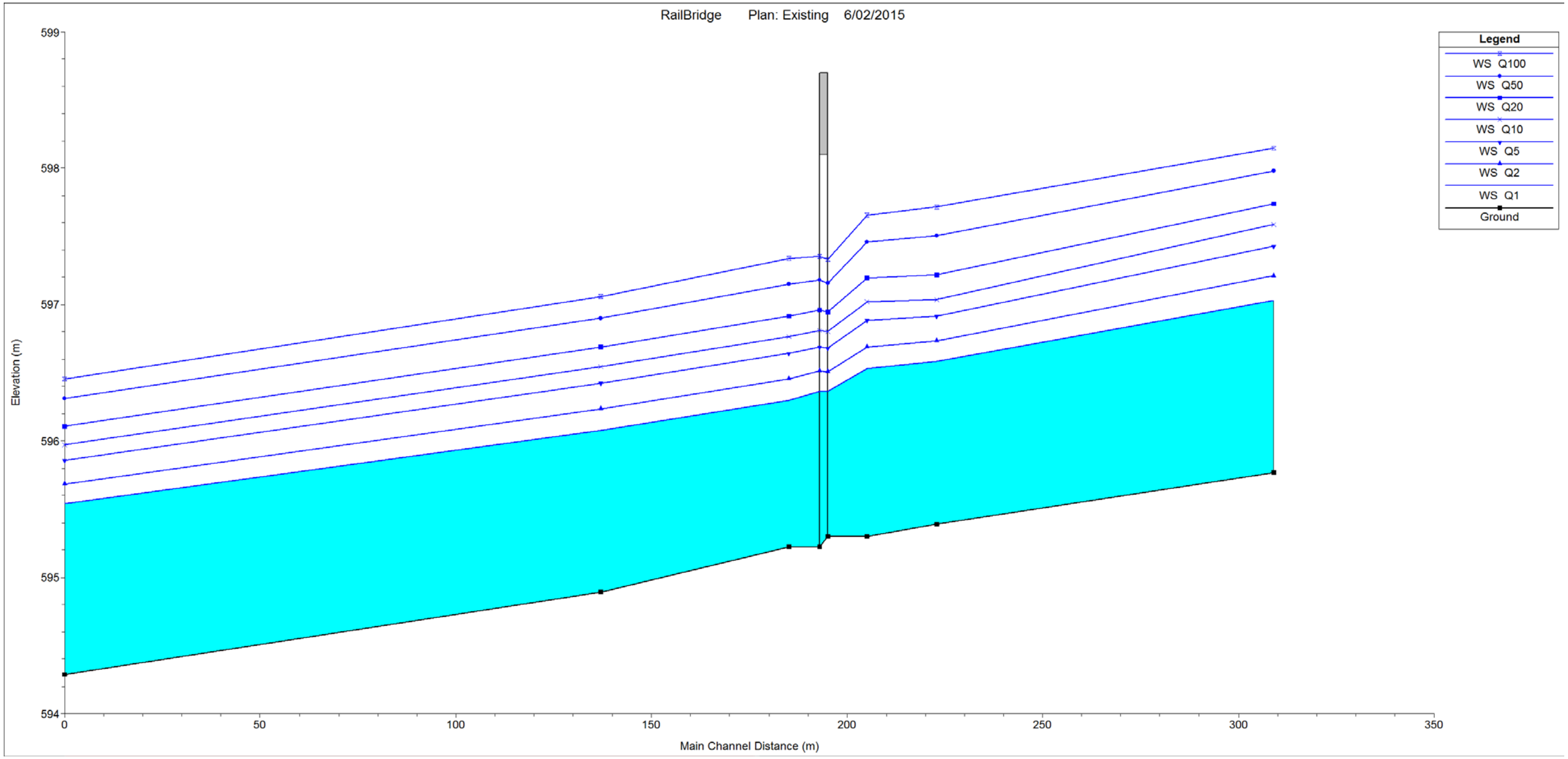

Figure 1 River Water Level Profiles for the Existing Scenario

Appendix G

Surface water assessment

VOLUME 2

Boral Cement Limited

Marulan South Limestone Mine Continued Operations

Surface Water Assessment

March 2019

www.advisian.com

Disclaimer

Project No: 201015-50004
Marulan South Limestone Mine Continued Operations: Surface Water Assessment

Revision	Description	Author	Review	Date
1.0		A Tourle	M Butcher	23/10/2018
2.0	Address DP&E adequacy comments	M Butcher	N Hattingh	8/03/2019

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List of Abbreviations

AEMR	Annual Environmental Management Report
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
ARR	Australian Rainfall and Runoff
AWBM	Australian Water Balance Model
Boral	Boral Cement Limited
BoM	Bureau of Meteorology
CAP	Catchment Action Plan
CMA	Catchment Management Authority
CML	Consolidated Mine Lease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPE	Department of Planning & Environment
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
EP&A Act	*NSW Environmental Planning and Assessment Act 1979*
EPL	Environmental Protection Licence
ET	Evapotranspiration
GCM	Global Climate Model
GFRGS	Goulburn Fractured Rock Groundwater Source
HRC	Healthy Rivers Commission
IESC	Independent Expert Scientific Committee
IFD	Intensity-Frequency-Duration
IPCC	International Panel on Climate Change
MOP	Mine Operations Plan
NARCliM	NSW and ACT Regional Climate Modelling
NorBE	Neutral or Beneficial Effect
NOW	NSW Office of Water
NWQMS	National Water Quality Management Strategy
PET	Potential Evapotranspiration
PoEO Act	*NSW Protection of the Environment Operations Act 1997*
RCP	Representative Concentration Pathway

SCA	Sydney Catchment Authority
SCL	Stochastic Climate Library
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SILO	Scientific Information for Landowners
SSD	State Significant Development
SWMOP	State Water Management Outcomes Plan
SWA	Surface Water Assessment
the mine	Marulan South Limestone Mine
the Project	Marulan South Limestone Mine Continued Operations
WAL	Water Access Licence
WMA	*NSW Water Management Act 2000*
WSP	Water Sharing Plan

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1 Introduction

1.1 Overview

This Surface Water Assessment has been prepared by Advisian on behalf of Boral Cement Limited (Boral). This document is an appendix to the Environmental Impact Statement (EIS) for the proposed Marulan South Limestone Mine Continued Operations Project ("the Project").

Boral Cement Limited (Boral) owns and operates the Marulan South Limestone Mine (the mine). It is a long standing open cut mine that has produced up to 3.38 million tonnes of limestone based products per year for the cement, steel, agricultural, construction and commercial markets.

The mine is a strategically important asset for Boral, as it supplies the main ingredient for the manufacture of cement at Boral's Berrima Cement Works. This is also a strategically important operation for Sydney based consumers of these products as this represents around 60% of the cement sold in NSW and feeds into more than 30% of concrete sold in Sydney.

The mine operates under Consolidated Mining Lease No. 16 (CML 16), Mining Lease No. 1716, Environment Protection Licence (EPL) 944 and a combination of development consents issued by Goulburn Mulwaree Council and continuing use rights.

Due to changes between the *Mining Act 1992* and the *Environmental Planning & Assessment Act 1979* (EP&A Act), when mining moves beyond the area covered by the current Mining Operations Plan, a development consent under the EP&A Act will need to be in place.

An EIS has been prepared by Element Environment Pty Ltd on behalf of Boral for submission to the Department of Planning and Environment (DP&E) to satisfy the provisions of Part 4 of the EP&A Act. Boral is seeking approval for continued operations at the site through a development application for a State Significant Development (SSD) including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam (hereafter referred to as 'the Project').

1.2 Site Description

1.2.1 Site Location

The mine is in Marulan South, 10 kilometres (km) southeast of Marulan village and 35 km east of Goulburn, within the Goulburn Mulwaree Local Government Area in the Southern Tablelands of NSW (Figure 1.1). Access is via Marulan South Road, which connects the mine and Boral's Peppertree Hard Rock Quarry (Peppertree Quarry) with the Hume Highway approximately 9 km to the northwest (Figure 1.2). Boral's private rail line connects the mine and Peppertree Quarry with the Main Southern Railway approximately 6 km to the north (Figure 1.2).

1.2.2 Land Use and Ownership

CML 16 (which encompasses ML 1716) covers an area of 616.5 hectares (ha), which includes land owned by Boral (approximately 475 ha), Crown Land (adjoining to the south and east) and five privately owned titles (Figure 1.3). There is also Boral owned land surrounding the mine that does not fall within CML 16.

Land use surrounding the mine is a mixture of extractive industry, grazing, rural residential, commercial/industrial and conservation.

The mine is separated from the Bungonia State Conservation Area to the south by Bungonia Creek and is separated from the Shoalhaven River and Morton National Park to the east by Barbers Creek.

Peppertree Quarry, owned by Boral Resources (NSW) Pty Limited, borders the mine to the north. The site of the former village of Marulan South is between the mine and Peppertree Quarry on land owned by Boral. The village was established principally to service the mine but has been uninhabited since the late 1990s. The majority of the village's infrastructure has been removed and only a village hall and former bowling club remains. The bowling club has been converted into administration offices for the mine and the hall is used by the mine services team.

A small number of rural landholdings surround the Boral properties to the north and west, including an agricultural lime manufacturing facility, fireworks storage facility, turkey farm and rural residential (a number of these properties are actively grazed). The main access for these properties is via Marulan South Road. Rural residential properties are also located to the northeast of the mine along Long Point Road. These properties are separated from the mine by the deep Barbers Creek gorge. Sensitive receivers are shown in Figure 1.2.

1.2.3 Zoning

The majority of the site is zoned RU1 - Primary Production zone under the Goulburn Mulwaree Local Environmental Plan (LEP) 2009. Mining and extractive industries are permissible in this zone with consent.

The remaining area is zoned E3 - Environmental Management. Under this zone mining and extractive industries are prohibited development, although historically mining has occurred within these areas under "existing use rights" as mining and processing operations commenced well before the commencement of the Mulwaree Planning Scheme Ordinance on 15 May 1970.

Notwithstanding that both mining and extractive industries are prohibited in the E3 zone, these activities are permissible pursuant to *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*. In accordance with Clause 7(1)(b)(i) of this SEPP mining can be carried out with consent in any zone which has agriculture as a permissible land use (with or without consent). Agriculture is permitted with consent in the E3 - Environmental Management zone under the Goulburn Mulwaree LEP 2009. Similarly Clause 7(3)(a) of this SEPP makes it clear that extractive industries can be carried out with consent in any zone which has agriculture as a permissible land use (with or without consent). Therefore, both mining and extractive industries are land uses which can be carried out provided development consent is granted.

Boral operates the mine pursuant to Section 109 of the EP&A Act and the continuance of an existing use and its expansion is possible provided the necessary approvals are in place. Therefore, there are no environmental planning issues that would prohibit approval of expanded operations at the mine.

Importantly, the Project aims to improve the stability of existing overburden emplacements and improve rehabilitation outcomes over the entire site.

1.2.4 Topography and Hydrology

The Southern Highlands, similar to the Blue Mountains to the north-west, are predominantly comprised of a level plateau with the occasional high intrusive volcanic remnant mountains, such as

Mount Jellore, Mount Gibraltar and Mount Gingenbullen. On the seaward side they decline into a steep escarpment that is heavily divided by the headwaters of the Shoalhaven River.

The Project site and surrounds is characterised by rolling hills of pasture and grazing lands interspersed with woodland to the west, contrasting with the heavily wooded, deep gorges that begin abruptly to the east of the mine, forming part of the Great Escarpment and catchment of the Shoalhaven River. As such, local relief of Marulan South ranges from around 130 metres (m) Australian Height Datum (AHD) to over 630 m AHD.

The Project site is drained by a number of minor ephemeral drainage lines into Barbers Creek to the east and Bungonia Creek to the south. These creeks are tributaries of the Shoalhaven River, which is 1.5 km from the mine (at its closest point) and flows eastwards into Lake Yarrunga, approximately 20 km downstream and enters the Pacific Ocean approximately 15 km east of Nowra (approximately 100 km downstream). Further details of the regional and local hydrology are provided in Section 4.2.

1.2.5 Geology

The Marulan South limestone deposit lies within the Lachlan Geosynclinal Province. During the Palaeozoic Era (500 to 300 million years ago) thick sedimentary formations were laid down in the region. The formations included sediments, volcanic lavas and ash, and limestone reefs.

A reef complex formed the Bungonia Limestone Group, which was later folded and faulted by crustal collisions and then subsequently levelled by substantial erosion. About 65 million years ago the area was again uplifted giving way to a rejuvenated river system leading to the landscape of today.

The Bungonia Limestone formations around Marulan South consist of a number of generally parallel and north-south striking beds dipping to the west. The Bungonia Limestone includes

- Eastern Limestone, which is the oldest, easternmost and thickest unit and
- Mt. Frome Limestone, which is the younger unit that lies to the west of the Eastern Limestone and is made up of three sub-parallel sub-units including the Upper Limestone (furthest west), Middle Limestone and Lower Limestone (furthest east).

Separating the limestone units are fine grained sediments including shales, mudstones, siltstones and minor fine sandstones.

The total horizontal width of the Bungonia Limestone is approximately 670 m east-west. The true depth of the Bungonia Limestone is not known as the termination of the limestone is not visible either in the mine or at the bottom of the Bungonia gorge to the south. To date even the deepest drill holes (approximately 300 m) in the mine have ended in limestone.

The Eastern Limestone has the highest grade and was therefore selected for the commencement of mining. The Eastern Limestone is still the focus of current mining operations, however mining of Mt. Frome Middle Limestone commenced in approximately 2016.

The Bungonia Limestone Group is bound to the east by the older Tallong shale beds and in the west by the Tangarang Volcanics (younger shales, volcanic and associated sedimentary rocks). A north-south and various east-west dolerite dykes penetrate the limestone from beneath and the limestone bed is cut off in the north by the Glenrock Granodiorite intrusion, which is extracted by Peppertree Quarry.

1.2.6 Groundwater-Surface Water Connectivity

As reported in the *Marulan Groundwater Technical Study* (AGE, 2018), groundwater – surface water connectivity occurs via two mechanisms:

- groundwater recharge where surface water seeps into the ground and becomes groundwater and
- groundwater discharge when groundwater becomes surface water.

The level of connectivity between surface water and groundwater systems in the Project area is high because of the unique conditions presented by the topography (steep gradients from the plateau towards Bungonia Gorge) and the type of bedrock (fractured limestone with karst features).

The main zones of groundwater recharge are in topographically elevated areas on top of the plateau. The local topographic depression of the mine presents a major groundwater recharge zone due to the exposed limestone, runoff concentration and lack of surface water attenuation in the (removed) topsoil layer.

The discharge areas are in low-lying alluvial zones of the Shoalhaven River, Bungonia Creek and Barbers Creek. These alluvial zones play a key role by removing groundwater from the system. Another important discharge area is on the slopes of Bungonia Gorge where the groundwater daylights in the form of springs or seeps. An example of this process can be observed in two small caves known as Main Gully Spring (B68 - locally referred to as the 'Blowhole') and Main Gully Spring Too (B128), located within the northern escarpment of the Bungonia Gorge, south of the mine.

The alluvial zones receive water from:

- the surface water streams associated with the alluvium in the form of the leakage through the stream bed to the alluvial sediments
- groundwater seeping upwards or sideways from underlying bedrock, or flowing from upstream sections of alluvium
- rainfall related recharge, which depends on the area of the alluvium and is quite small compared to the other two sources.

In terms of outflow, the groundwater loss from the alluvium occurs:

- to the rivers or creeks in the form of baseflow
- to the underlying bedrock or in the form of flow within the alluvial sediments to a downstream section of alluvium
- through evapotranspiration.

1.2.7 Soils

Soil survey, investigation and mapping in the vicinity of the Project, including the proposed disturbance area, has been undertaken and is reported in the *Soils, Land Resources and Rehabilitation Assessment* report (LAMAC 2018). The investigations showed that texture contrast soils dominate much of the proposed disturbance footprint but, other than the heavy clay and moderately to strongly acidic B horizons, no particularly hostile soils were identified as requiring specific management.

Alternative materials have been trialled as surface growth media in previous onsite rehabilitation. These materials include decomposed granite (from the adjacent Peppertree Quarry) and a weathered shale material from the open cut mine. Both materials have demonstrated measured success, and the potential use of these materials is discussed in the report.

The report recommends that topsoil recovery from texture contrast soils should be restricted to the A1 horizon (100 – 150 mm). Below the A1 horizon, soils are limited by soil chemical and physical properties, such as increased sodicity in the A2 horizon, moderate to strongly acidic B horizon and heavy clay in the B horizon. Geochemical and erosion potential testing of geological strata from the open cut mine identified transitional weathered material of high erosion potential. The report recommends that characterisation testing is undertaken before any material from the open cut mine is used as a growth medium in rehabilitation.

1.2.8 Geochemical Characteristics of Overburden

A report on a geochemical assessment of the waste rock materials from the mine (RGS, 2015) forms Appendix C to the *Marulan Groundwater Technical Study* (AGE, 2018).

Six composite samples of limestone and overburden or "waste rock" were tested for soluble metals/metalloids and major cations and anions. The results of the testing indicated that:

- pH ranges from 8.3 to 9.5 and is typically slightly alkaline, indicating that these materials are likely to contribute alkalinity to initial surface runoff and seepage
- the acidity values are very low, ranging from <0.2 to 2 mg/L
- the alkalinity ranges from 23 to 1,426 mg/L (median 50 mg/L), and is typically well in excess of the measured acidity leading to positive net alkalinity values
- EC in the water extracts ranges from 79 to 983 µS/cm and is typically low (median 125 µS/cm), confirming that most materials exhibit low salinity and low concentrations of dissolved solids when in contact with water
- the concentrations of the major cations and anions are typically very low for all but the shale/ mudstone sample
- the concentration of all trace metals/metalloids tested is below the laboratory level of reporting in most samples. Minor exceptions include aluminium and chromium which have concentrations slightly above trigger values for aquatic ecosystems (95% species protection level). However, the concentrations of these and other metals/metalloids are at least an order of magnitude below the applied livestock drinking water guideline values (ANZECC and ARCANZ, 2000).

The geochemical assessment concluded that:

- waste rock materials are classified as non-acid forming and are essentially barren of sulphur. The waste rock materials therefore have a high factor of safety with respect to potential acid generation
- surface runoff and seepage from waste rock materials is likely to be slightly alkaline and contain low concentrations of dissolved salts
- the waste rock materials contain relatively low concentration of metals/metalloids in solids. Whilst the concentration of arsenic, cobalt and manganese may be elevated compared to average crustal abundance in some of the contact material between limestone and shales, these elements are sparingly soluble in contact water
- most trace metal/metalloids in waste rock are sparingly soluble in slightly alkaline contact water and are unlikely to impact upon the quality of surface and groundwater resources at the site.

The results indicated that dissolved metal/metalloid concentrations in initial surface runoff and seepage from most overburden or waste rock materials at the overburden emplacement or waste rock storage facility would be unlikely to impact on the quality of surface and groundwater resources at the site.

1.2.9 Climate

The mine is in Australia's cool temperate climatic region, which is characterised by mild to warm summers and cold winters, with common frost and occasional snow fall.

Long term climatic data was obtained from the Bureau of Meteorology (BoM) automatic weather station at Goulburn Airport, approximately 25 km west-southwest of the mine.

The BoM weather station shows that January is the hottest month with a mean maximum temperature of 27.9 degrees Celsius (ºC) and July is the coldest month with a mean minimum temperature of 0.3ºC.

Average annual rainfall is 551.9 mm. Rainfall peaks during the summer and the month of June. June is the wettest month with an average rainfall of 60.9 mm over 7.0 days and April is the driest month with an average rainfall of 25.6 mm over 4.0 days.

Relative humidity levels exhibit variability and seasonal flux across the year. Mean 9 am relative humidity levels range from 65% in October and December to 88% in June. Mean 3 pm relative humidity levels vary from 39% in December to 63% in June. Wind direction is predominantly from the west in winter and from the east in summer.

Wind speeds have a generally similar spread between the 9 am and 3 pm conditions. The mean 9 am wind speeds range from 12.2 km/h in March to 19.8 km/h in September. The mean 3 pm wind speeds vary from 19.8 km/h in April to 26.5 km/h in August.

1.3 Existing Operations

The mine is sited on a high grade limestone resource. Subject to market demand, the mine has typically produced 3 to 3.8 million tonnes of limestone and 120,000 to 200,000 tonnes of shale per annum.

The mine currently produces a range of limestone products for internal and external customers in the Southern Highlands/Tablelands, the Illawarra and Metropolitan Sydney markets for use primarily in cement and lime manufacture, steel making, agriculture and other commercial uses. Products produced at the mine are despatched by road and rail, with the majority despatched by rail.

Historically limestone mining was focused on the approximately 200-300 m wide Eastern Limestone and was split between a North Pit and a South Pit. A limestone wall (referred to by the mine as the 'centre ridge') rising almost to the original land surface, divided the two pits. The North and South Pits were recently joined in 2016/2017 by mining the centre ridge to form a single contiguous pit, approximately 2 km in length. However, the North Pit/South Pit nomenclature remains important as current mining operation locations continue to be reported with respect to one or other of the old pits.

Limestone and shale are extracted using open-cut hard rock drill and blast techniques. Material is loaded using front end loaders and hauled either to stockpiles or the processing plant using haul trucks. Oversized material is stockpiled and reduced in size using a hydraulic hammer attached to an excavator.

Limestone processing facilities including primary and secondary crushing, screening, conveying and stockpiling plant and equipment are in the northern end of the North Pit. Kiln stone grade limestone is also processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment. Overburden from stripping operations is emplaced in the Western Overburden Emplacement, west of the open cut pits.

The current operations are 24 hour, 7 days per week with personnel employed on a series of 8, 10 and 12 hour shifts to cover the different operational aspects of the mine. Blasting is restricted to daylight hours and on weekdays, excluding public holidays.

1.4 The Proposed Project

1.4.1 Mining Operations

Boral proposes to continue mining limestone from the mine at a rate of up to 4 million tonnes per annum (mtpa) for a period of up to 30 years. This represents an increase in extraction rate from historic levels (peak of 3.38 mtpa) due to forecast increased demand from the construction industry. Shale would continue to be extracted at a rate of up to 200,000 tonnes per annum (tpa).

The proposed 30 year mine plan accesses approximately 120 million tonnes of limestone down to a depth of 335 m AHD. The mine footprint focuses on an expansion of the North Pit westwards to mine the Middle Limestone and to mine deeper into the Eastern Limestone. As the Middle Limestone lies approximately 70 m to 150 m west of the Eastern Limestone, the 30 year mine plan avoids mining where practical the interburden between these two limestone units thereby creating a smaller second, north-south oriented West Pit with a ridge remaining between. The North Pit will also be expanded southwards, encompassing part of the current South Pit for overburden emplacement and a visual barrier (Figure 1.5).

In addition to mining approximately 5 million tonnes of shale, the extraction of the limestone requires the removal of approximately 108 million tonnes of overburden over the 30 year period. This material will be emplaced within existing and proposed overburden emplacement areas (Figure 1.5).

Limestone will continue to be mined using drilling and blasting methods. Shale will continue to be mined by excavator / front end loader. Limestone, shale and overburden will be transported to the primary crusher, stockpile areas and overburden emplacements respectively, using the load and haul fleet of trucks.

Products produced at the mine will continue to be despatched by road and rail, with the majority despatched by rail.

The limestone sand plant produces a crushed and air classified limestone sand for use in concrete. The mine currently produces 500,000 tpa for Peppertree Quarry and proposes to increase production of manufactured sand to approximately 1 million tpa.

Boral's adjoining Peppertree Quarry currently has approval to emplace some of its overburden in the South Pit mine void. As the South Pit is required for the emplacement of over 30 million tonnes of overburden from the mine after removal of accessible limestone. Boral proposes to emplace up to 15 million tonnes of overburden from Peppertree Quarry within the Northern Overburden Emplacement (Figure 1.5).

1.4.2 Associated Infrastructure

1.4.2.1 Processing

The existing facilities for processing limestone will continue to be utilised to produce a series of graded and blended limestone products that are despatched from site for use primarily in cement manufacture, steel making, commercial and agricultural applications.

Limestone processing facilities (Figure 1.5) include primary and secondary crushing, screening, conveying and stockpiling plant and equipment located north-west of the North Pit and extending to the tertiary crushing, screening, bin storage and despatch (rail and road) systems that form part of the main processing facilities.

Kiln stone grade limestone will also continue to be processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment.

Processing infrastructure and the reclaim and stockpile area at the northern end of the North Pit will be relocated during the life of the 30 year pit to enable full development of the mine plan. The timing and location of this is presented in the EIS.

Shale and white clay will not be processed and will be stockpiled directly from the pit, ready for dispatch by road to the Berrima and Maldon cement operations.

1.4.2.2 Water Supply

Water supply for the Project, including dust suppression, processing activities and some non-potable amenities will be from existing and new on-site dams and a proposed new water supply dam on Marulan Creek (Figure 1.5). This dam would be located on Boral owned land north of Peppertree Quarry and utilises the adjoining Tallong water pipeline to transfer water to the mine. This dam would require the purchase of water entitlements.

Mine water demand will also be supplemented by Tallong Weir via the Tallong water pipeline.

1.4.2.3 Rail

No changes are proposed to the existing rail infrastructure. A 1.2 km long passing line was constructed at Medway Junction during construction of the Peppertree Quarry, which will also be used by the mine to enhance access to the Main Southern Railway.

1.4.2.4 Road

Road access from the mine to the Hume Highway is via Marulan South Road. The proposed Western Overburden Emplacement extends northwards over Marulan South Road. Boral propose to realign a section of Marulan South Road, to accommodate the northern portion of the proposed Western Overburden Emplacement (Figure 1.5).

All public roads within the former village of Marulan South as well as the section of Marulan South Road between Boral's operations and the entrance to the agricultural lime manufacturing facility will be de-proclaimed.

1.4.2.5 Power

Power supply to the mine is via a high voltage power line that commences at a sub-station on the southern side of Marulan South Road, immediately west of the Project boundary. A section of this power line will be relocated to accommodate the proposed Northern Overburden Emplacement (Figure 1.5).

1.4.3 Transport

The majority of limestone products will continue to be transported to customers by rail for cement, steel, commercial and agricultural uses. Boral seeks no limitation on the volume of products transported by rail.

Manufactured sand will continue to be transported by truck along a dedicated internal road, across Marulan South Road and into Peppertree Quarry for blending and dispatch by rail.

Agricultural lime, quick lime and fine limestone products will continue to be transported by powder tanker, bulk bags on trucks or open tipper trucks along Marulan South Road.

Shale, limestone aggregates, hard rock aggregates, sand and tertiary crushed products will be transported by road predominantly using truck and dog.

The adjoining Peppertree Quarry is currently approved to transport all products by rail. Boral will seek to transport approximately 150,000 tpa of Peppertree Quarry's products from the mine to customers via Marulan South Road. This could be achieved by back loading to a new shared road sales product stockpile area by the trucks carrying the limestone sand to Peppertree Quarry. A new shared road sales product stockpile area is proposed on the northern side of Marulan South Road, immediately west of the mine and Peppertree Quarry entrances (Figure 1.5). This shared finished product stockpile area includes a weighbridge and wheel wash and will service both the mine and Peppertree Quarry.

In total, Boral is seeking to transport up to 600,000 tpa of limestone and hard rock products along Marulan South Road to the Hume Highway, as well as 120,000 tpa of limestone products to the agricultural lime manufacturing facility.

1.5 Water Management and Supply

Current operations rely on water for processing activities and some non-potable amenities sourced from Tallong Weir via Boral's water pipeline which also supplements surface runoff collected in water storage dams that is used for dust suppression (refer Section 6.1.3). Runoff from land to the west of the mine pits that is not collected in the water storage dams drains into the mine pits from where it subsequently drains into the limestone in the base of the pits. Runoff from the steep historical overburden emplacements to the east of the pit (referred to in the EIS as the 'eastern batters') cannot be captured because of the steep terrain and drains via gabion filter dams into Barbers Creek. Further details of the existing water management system are provided in Section 6.1.

The proposed water management system for the Project is described in Section 6.2 and the simulated performance of the system is described in Section 7. The Project would involve cessation of overburden emplacement to the east of the mine pits, and the construction of the Southern Overburden Emplacement by backfilling the southern part of the South Pit and the placement of overburden in an out of pit extension to the west of the South Pit. In addition, two out-of-pit overburden emplacements would be progressively constructed to the north (Northern Overburden Emplacement) and west (Western Overburden Emplacement) of the mine pit.

Runoff from all out-of-pit emplacements would be directed to one of seven sediment basins as listed in Table 6.9 and shown on Figure 6.7 that would be sized and operated in accordance with *Managing Urban Stormwater: Soils and Construction*. Water captured in the sediment basins would be transferred to one of four water storage dams (including three new dams and one existing dam to be enlarged as listed in Table 6.5) for reuse for on-site purposes, principally dust suppression. Three of the sediment basins (W1, N2 and S2) may discharge off site in the event of rainfall in excess of the design rainfall event. A variation to the existing Environmental Protection Licence (EPL No. 944) to specify conditions for water quality monitoring and discharge from these basins would be required.

The Project includes the proposed construction of a water storage dam on Marulan Creek to provide an alternative to the current supply from Tallong Weir (Figure 1.5). This dam would be located on Boral owned land north of Peppertree Quarry and would utilise the adjoining Tallong water pipeline to transfer water to the mine. This dam would require the purchase of additional water entitlements to those currently held for supply from Tallong Weir. Further details of the proposed Marulan Creek Dam are provided in Section 8.

As part of the assessment, a review of historic maps and aerial photographs has been undertaken to determine the likely pre-mining natural catchments draining to Barbers Creek and Bungonia Creek. To the extent practical, off-site drainage would seek to restore pre-mining catchment areas draining off site.

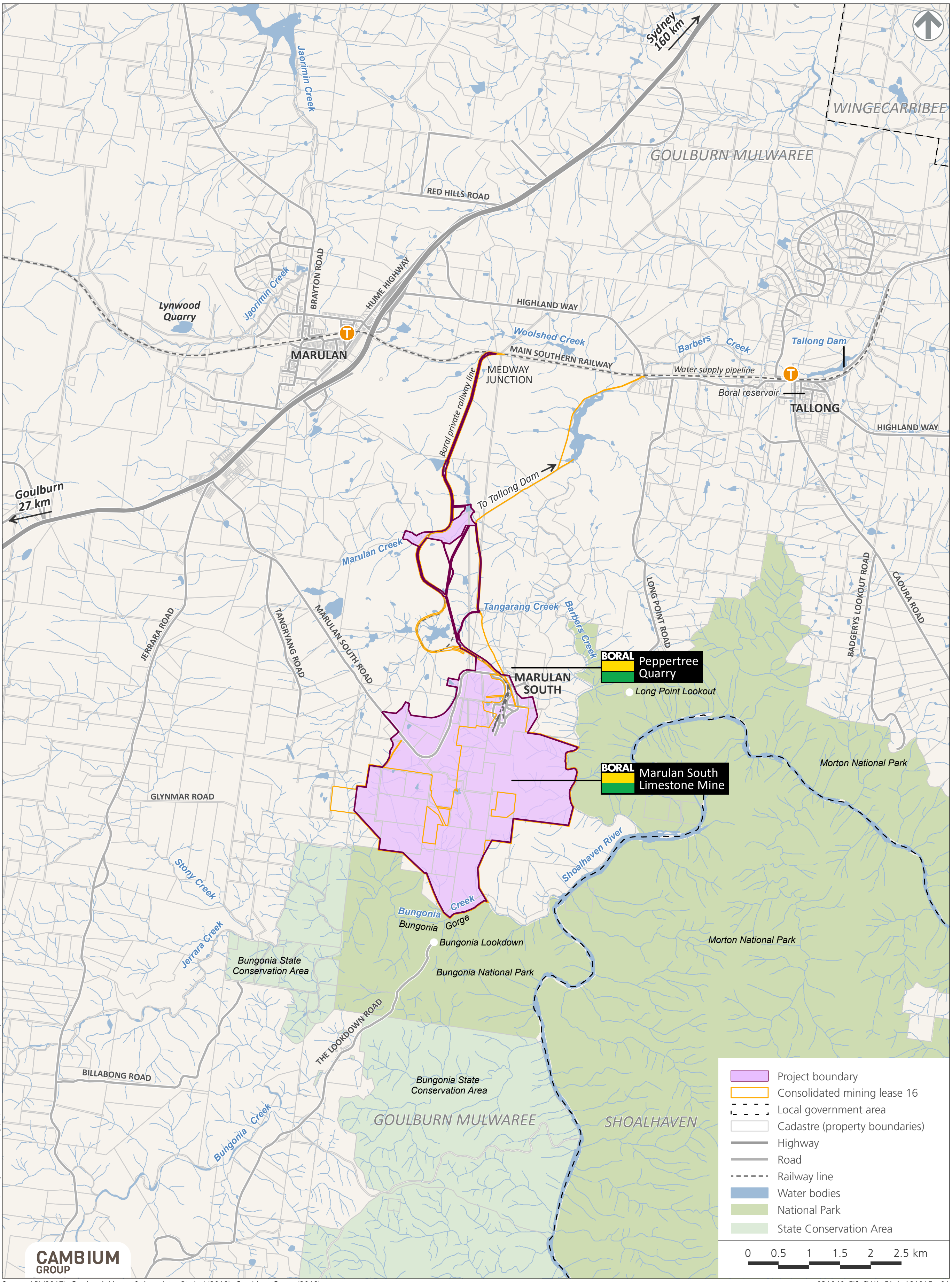
1.6 Objectives

The objectives of this Surface Water Assessment are to:

- address the surface water related Secretary's Environmental Assessment Requirements (SEARs) (Section 2 and Annexure A)
- identify legislation, policy and guidelines relevant to the Project (Section 3)
- document the existing catchment conditions and the flow regime and water quality in the creeks and rivers draining through and from the Project area, including regulated water sources (Sections 1, 4, and 5 and Annexures C and D)
- describe the proposed site water management system for the Project, including water supply and demand requirements (Sections 6 and 7) and the provision of a dam on Marulan Creek to provide a supplementary supply (Section 8)
- assess the potential impacts of any changes in the flow and water quality resulting from the proposed Project, and the proposed mitigation actions to minimise any potential residual impacts (Sections 9 and 10 and Annexures C and D)
- identify appropriate monitoring and management measures necessary to verify the predicted impacts of the Project and initiate any additional mitigation measures required (Section 11) and
- identify licencing and approval requirements for the Project (Section 11.6).

Figure 1.1
Regional context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

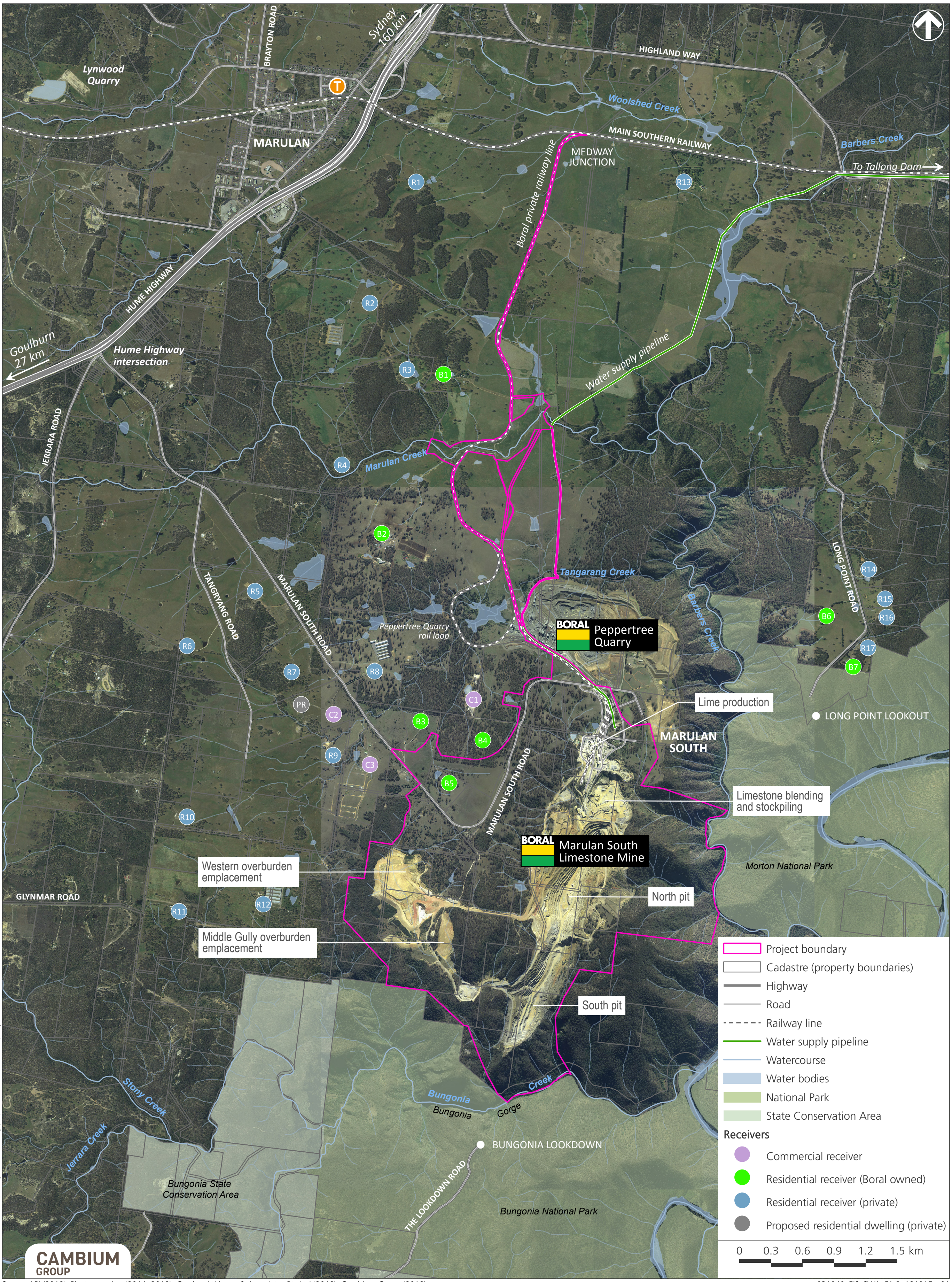


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_SWA_F1-1_181015_v01

Figure 1.2
Local context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

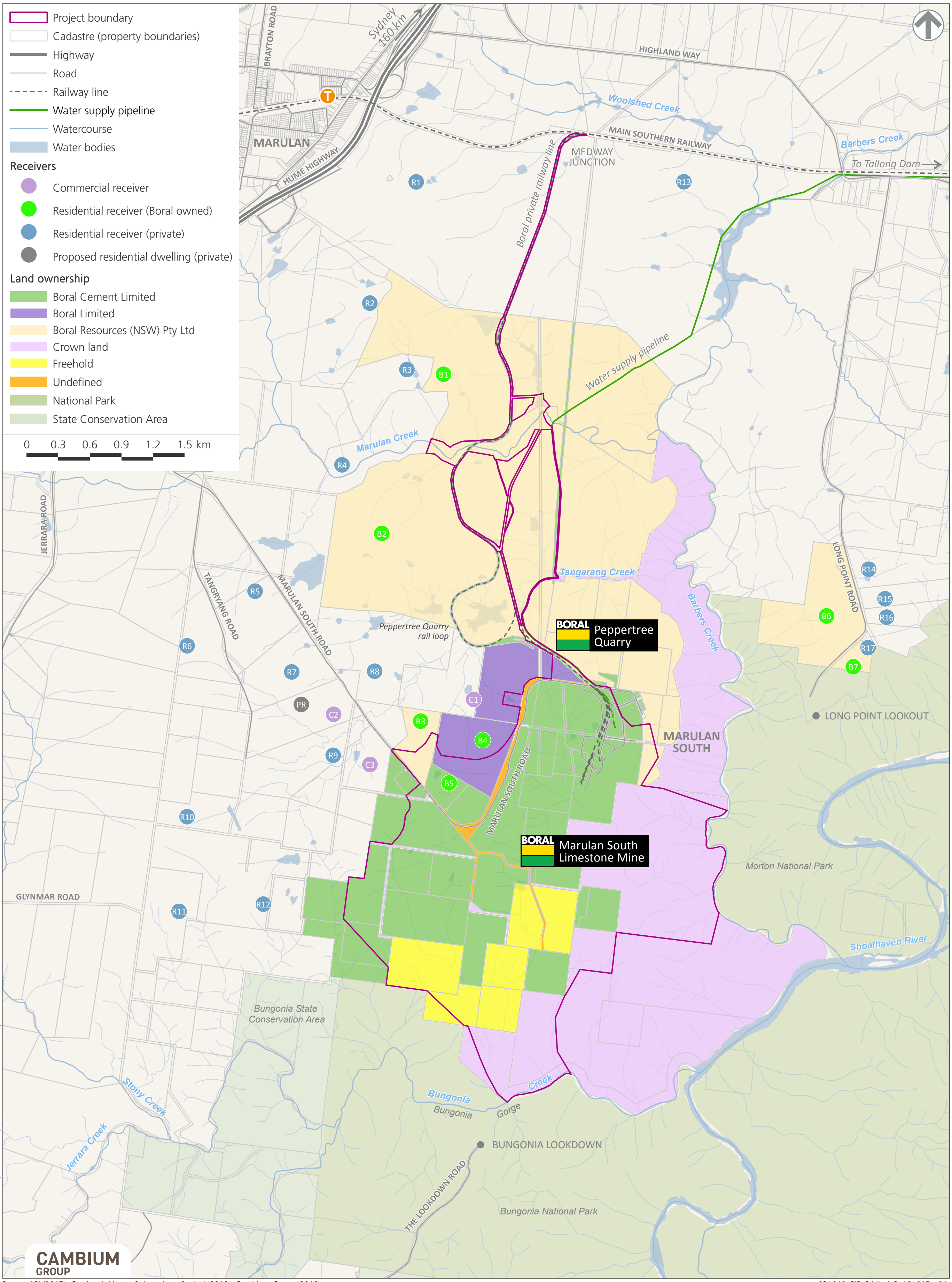


Source: LPI (2018), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_SWA_F1-2_181015_v01

Figure 1.3
Land ownership

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

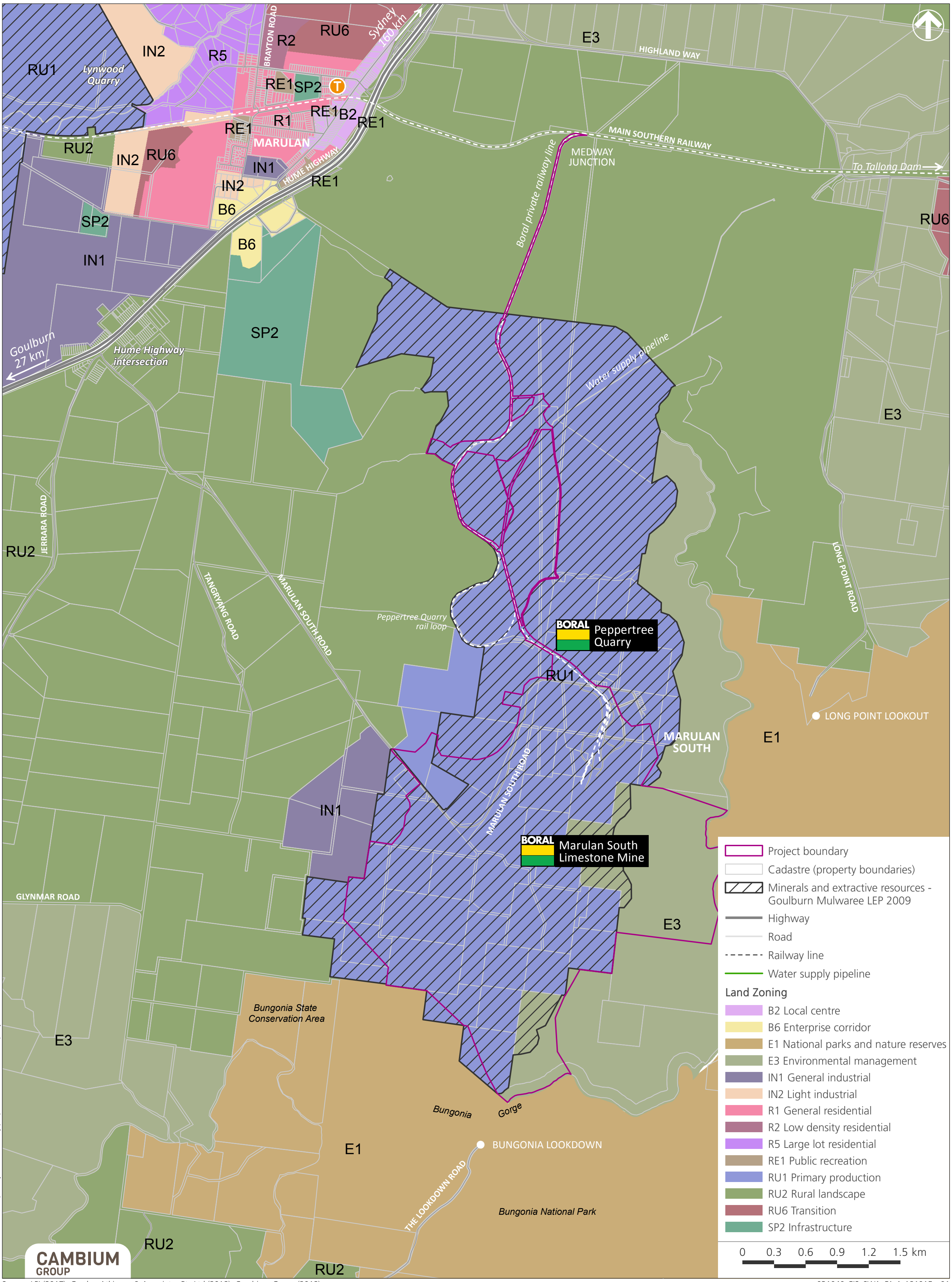


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_SWA_1-3_181015_v01

Figure 1.4
Land zoning

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

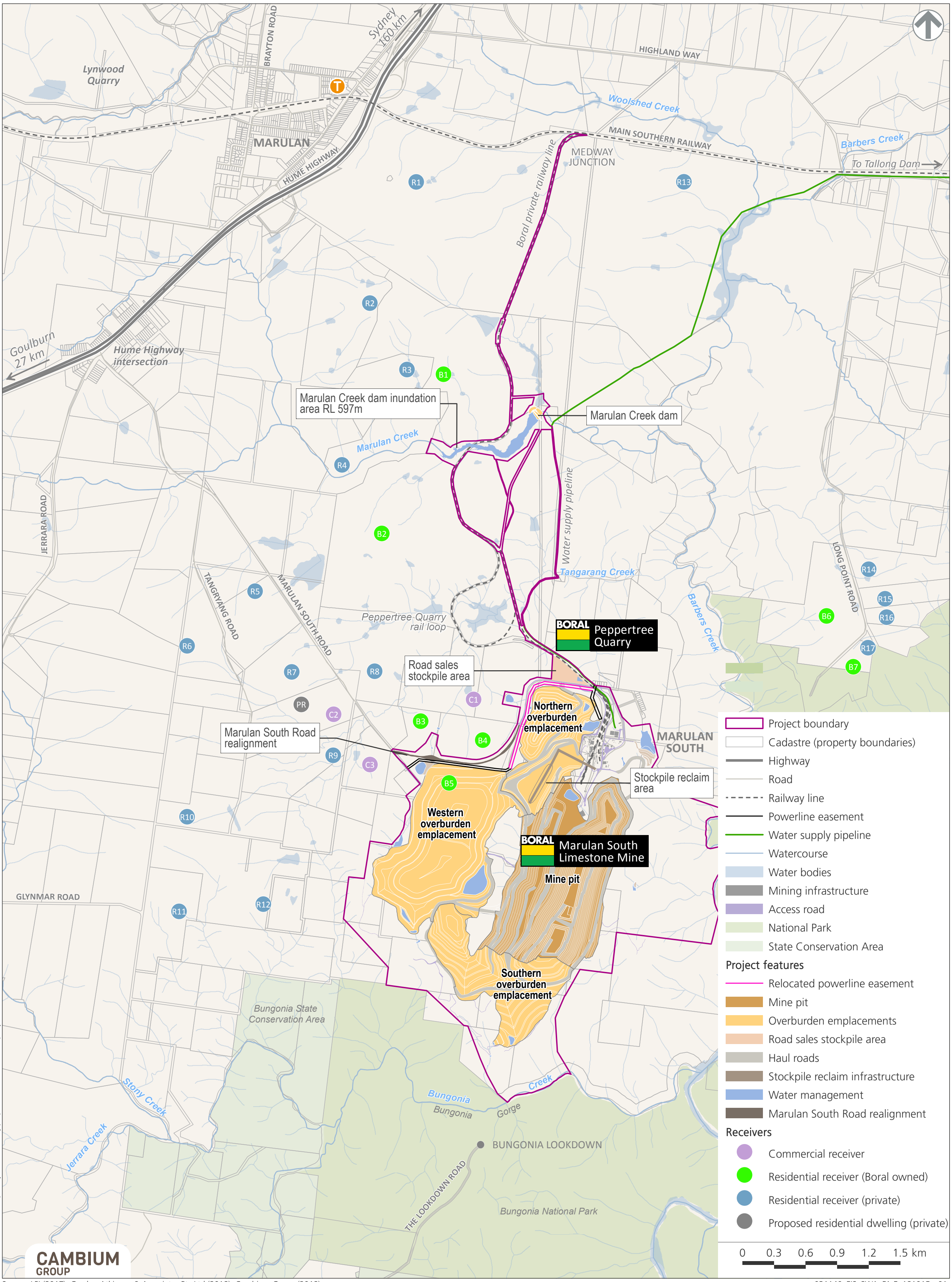


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_SWA_F1-4_181015_v01

Figure 1.5
The Project

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_SWA_F1-5_181015_v01

2 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (SEARs) for the Project were issued under Section 78A(8A) of the *Environmental Planning and Assessment Act 1979* on 10 June 2015.

Table 2.1 lists the surface water related SEARs and the corresponding section of this Surface Water Assessment where the requirement is addressed.

The detailed requirements of the agencies are included as attachments to the SEARs and have been tabulated in Annexure A to this Surface Water Assessment, with a cross-reference to the location in this Surface Water Assessment where the requirement has been addressed.

Table 2.1: SEARs Relevant to Surface Water

SEA Requirement	Section (for aspects relevant to Surface Water)
General Requirements	
The EIS must include: A full description of the development, including:	
• a water management strategy, having regard to the EPA's, NSW Office of Water's and WaterNSW's requirements	Section 6.2 Annexure A identifies requirements of the Agencies and the corresponding section in this Surface Water Assessment where the requirement is addressed
• a list of any approvals that must be obtained before the development may commence	Sections 3 and 11.6
• an assessment of the likely impacts of the development on the environment, focusing on the specific issues identified below, including:	Section 9
– a description of the existing environment likely to be affected by the development, using sufficient baseline data	Sections 1, 4, 5, 8 and Annexures B and C
– an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant laws, environmental planning instruments, guidelines, policies, plans and industry codes of practice	Sections 3 and 9
– a description of the measures that would be implemented to mitigate and/or offset the potential impacts of the development, and an assessment of:	Section 10
o whether these measures are consistent with industry best practice, and represent the full range of reasonable and feasible mitigation measures that could be implemented	Section 10
o the likely effectiveness of these measures and	Section 10
o whether contingency plans would be necessary to manage any residual risks	Section 10
– a description of the measures that would be implemented to monitor and report on the environmental performance of the development if it is approved	Section 11

SEA Requirement	Section (for aspects relevant to Surface Water)
Key Issues – Water	
The EIS must address the following specific issues:	
• an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, NSW Office of Water's and WaterNSW's requirements and the *NSW Aquifer Interference Policy*	Section 9 (To the extent that these issues relate to surface water. Groundwater related issues are addressed in the *Groundwater Technical Study* (AGE, 2018))
• an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users	Section 9
• a 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 7 and Annexure B
• 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	Section 7.11
• 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 and	Section 9.3
• a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts	Sections 6, 7, 8, 9, 10 and 11

3 Relevant Legislation, Policy and Guidelines

A range of legislation, policies, regulations and guidelines contain relevant considerations for the assessment of the surface water related aspects for the Project as set out below.

3.1 Legislation

3.1.1 Water Management Act

The aim of the *Water Management Act 2000* (WMA) is to provide for the sustainable and integrated management of the water sources of NSW for the benefit of both present and future generations. The WMA contain provisions for the licensing of water capture and use, and if/how water allocations can be traded. If any dams are proposed as part of a water management system, consideration must be given to whether the dams need to be licensed.

Water sharing plans (WSPs) have been developed under the WMA for rivers and groundwater systems across NSW. The WSPs relevant to the Project are described in further detail in Section 3.2.5 below.

The WMA provides for three types of approvals:

- Management works approvals:
  - water supply work approval
  - drainable work approval and
  - flood work approval (Section 90).
- Water use approval – which authorises the use of water at a specified location for a particular purpose, for up to 10 years (Section 89).
- Activity approvals comprising:
  - controlled activity approval (for works within riparian protection zones of watercourses (40 m)) and
  - aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years (Section 91).

Controlled activities include the carrying out of building work, such as erecting buildings and other structures, the installation of infrastructure and the excavation or depositing of material. A controlled activity approval under the WMA is typically not required for surface mining activities approved as State Significant Developments.

If the Project is approved, Boral would apply for a new Water Supply Works Approval and Water Use Approval to construct and operate the Marulan Creek Dam.

3.1.1.1 Harvestable Rights

Harvestable rights orders made by the Minister under Section 54 of the WMA give a landholder the right to capture 10% of the average regional rainwater runoff on their land by means of a dam or dams having not more than the total capacity calculated in accordance with Schedule 1 of the orders, providing such structures are located on minor streams only (i.e. first and second order streams). This water can, in most cases, be used for any purpose. Water take in excess of the maximum harvestable right requires licencing.

The *Water Management (General) Regulation 2011 (Schedule 1)* excludes certain types of water storage structures from Harvestable Rights considerations:

1. Dams solely for the control or prevention of soil erosion:

a. from which no water is reticulated (unless, if the dam is fenced off for erosion control purposes, to a stock drinking trough in an adjoining paddock) or pumped, and

b. the structural size of which is the minimum necessary to fulfil the erosion control function, and

c. that are located on a minor stream.

...

3. Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority (other than Landcom or the Superannuation Administration Corporation or any of their subsidiaries) to prevent the contamination of a water source, that are located on a minor stream.

The DP&I (Water) Guideline "*Dams in NSW - Do you need a licence*" (2016) indicates that the following dams do not require a licence:

- dams that capture water under a harvestable right
- dams built before 1999
- dams up to one megalitre on small properties and
- dams without a catchment, including turkey nest dams which operate to store water only.

The Guideline states that landholders may construct and use a dam to store different kinds of water taken under different rights and licences in addition to their harvestable right, providing the landholder holds:

- a licence for the volume of water that exceeds the MHRDC, unless the water is taken under a domestic and stock right or native title right
- a water supply work approval for a dam which exceeds the MHRDC.

The Guideline also states that special dams which are not included in harvestable right calculations include:

- dams for the control or prevention of soil erosion (gully control structures)
- dams for flood detention and mitigation
- dams for the capture, containment and recirculation of drainage
- dams endorsed by the Minister for specific environmental management purposes
- dams without a catchment
- dams licenced under the *Water Act 1912* before 1 January 1999.

Therefore, any mine water dams that collect runoff from the open cut, haul roads, stockpiles and infrastructure areas are defined under provision three above and are not included in harvestable rights calculations. They also apply to sediment basins constructed to control runoff from overburden emplacement areas until such time as the vegetation has established to the point when sediment runoff is minimal. There are no restrictions on the use of water from dams that comply with these provisions.

Section 9.3.2 provides further information on the Project's MHRDC.

3.1.2 Protection of the Environment Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (PoEO Act) and the NSW *Protection of the Environment Operations (General) Regulation 2009* set out the general obligations for environmental protection. The PoEO Act is relevant to the Project as it contains requirements relating to the prevention of the pollution of waters, and requires licensing of 'scheduled activities' for environmental protection, including water pollution. Conditions set under Environmental Protection Licences (EPL) typically include, but are not limited to, volumetric limits and water quality criteria for any licenced discharges, and environmental monitoring requirements.

The existing Marulan South Limestone Mine undertakes the activities listed in Schedule 1 of the PoEO Act being: "cement or lime production" and "mining for minerals". Boral holds EPL 944 for the existing mining operations at Marulan South, as detailed further in Section 6.1.5.

If the Project is approved, Boral would apply for a variation to EPL 944 to allow for potential offsite discharge from sediment basins following rainfall when there is not capacity in onsite storages to allow for the transfer of water or when design criteria are exceeded.

3.1.3 Environmental Planning and Assessment Act, 1979

The EP&A Act is administered by the NSW Department of Planning and Environment (DP&E), and provides the primary statutory framework in NSW for integrated planning and development under which development proposals are assessed and approved. The Project is a State Significant Development (SSD) listed under Schedule 1, Clause 5 of the State Environmental Planning Policy (SEPP) (State and Regional Development) 2011.

This report provides the results of a surface water impact assessment in accordance with the environmental impact considerations under Section 4.12 (8) of the EP&A Act.

Section 3.26 of the EP&A Act requires a SEPP to require consent authorities to refuse consent to development applications relating to any part of the Sydney drinking water catchment unless the consent authority is satisfied that the proposed development would have a neutral or beneficial effect (NorBE) on water quality. SEPP (Sydney Drinking Water Catchment) 2011 was prepared to satisfy this obligation.

3.1.4 SEPP (Sydney Drinking Water Catchment) 2011

SEPP (Sydney Drinking Water Catchment) 2011 aims to provide for healthy water catchments, delivering high quality water while permitting development that is compatible with that goal. The Policy also aims to support the maintenance or achievement of the water quality objectives for the Sydney drinking water catchment. In accordance with Section 3.26 of the EP&A Act, SEPP (Sydney Drinking Water Catchment) 2011 sets out the planning and assessment requirements for all new developments in the Sydney drinking water catchment to have a NorBE on water quality, incorporating Current Recommended Practices or performance standards relating to water quality endorsed/published by WaterNSW. WaterNSW has established guidelines for defining NorBE in assessments of various classes of activities as discussed further in Section 3.2.6 below.

The Marulan South Limestone Mine is located within the catchments of Bungonia and Barbers Creeks that drain to the Shoalhaven River, which is part of the Tallowa Dam catchment. Tallowa Dam provides drinking water supplies for Sydney and the Illawarra and therefore Barbers and Bungonia Creeks are managed by WaterNSW.

The Water Management System for the Project has been developed to provide for a NorBE on water quality. This is discussed further in Section 9.5.3.

3.1.5 WaterNSW Act 2014

The *WaterNSW Act* establishes and defines the objectives of WaterNSW, as an amalgamation of the former SCA and State Water. For this Project, the relevant objectives of the Act include:

- 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 conduct its operations in compliance with the principles of ecologically sustainable development.

Implementation of the Act to satisfy these objectives through related guidelines and water quality objectives for surface and groundwater is discussed further in Section 3.2.

3.1.6 Dam Safety Act, 2015

The *Dam Safety Act 2015* establishes the role of Dams Safety NSW (replacing NSW Dams Safety Committee that was established under the *Dam Safety Act 1978*) to achieve objectives relating to the safety of dams, including ensuring that any risks that may arise in relation to dams (such as any risks to public safety and to environmental and economic assets) are of a level that is acceptable to the community. Dams Safety NSW can declare a dam or proposed dam to be a 'declared dam' under the *Dams Safety Act 2015*.

One of the functions of Dams Safety NSW is to make recommendations on the development, implementation and modification of the dam safety standards, to keep owners of declared dams informed about dam safety standards and to regulate compliance with those standards. Determination of whether a dam is a declared dam is based on an assessment of its consequence category, which considers potential downstream impacts of dam failure.

Under the *Dam Safety Act 2015*, a 'notification area' can be declared covering an area around the dam structure and the impoundment. Any proposal to mine within the notification area requires consultation with Dam Safety NSW. The Project is not located within the notification area of any of the dams shown on the map '*Prescribed Dams in NSW, July 2015*'.

At the time of detailed design, all water storages and sediment basins would be assessed against the criteria published by Dams Safety NSW and would be referred if necessary.

3.2 Policies, Plans and Guidelines

The NSW State Government natural resource management policies and guidelines that have been considered in relation to surface water management for the Project are set out below.

3.2.1 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) is a joint national approach to improving water quality in Australian and New Zealand waterways. The NWQMS aims to protect the nation's water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main mechanism for promoting this aim has been the publication of a number of water quality guidelines, including the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) (commonly referred to as the *ANZECC Guidelines*), which are discussed in Section 3.2.2 below. For the Shoalhaven River catchment, the specific requirements of the *Independent Inquiry to Shoalhaven River System* (Healthy Rivers Commission, 1999) take precedence as described in Section 3.2.3 below.

3.2.2 ANZECC Guidelines for Fresh and Marine Water Quality 2000

The ANZECC Guidelines set out a range of water quality criteria for assessment of the suitability of water for protection of ecosystem health, recreational amenity, drinking water, irrigation and stock water use, and potential toxic effects on aquatic fauna.

The main aspects of the ANZECC Guidelines that relate to matters covered in this report are the default 'trigger values' for common water quality characteristics for ecosystem protection for which there is minimal risk of ecosystem harm. The trigger values are based on 20^{th} and 80^{th} percentile data derived for appropriate reference systems (as set out in Tables 3.3.2 and 3.3.3 of the Guidelines). It is important to note that the default trigger concentrations are frequently misinterpreted as water quality targets. As noted in Section 3.3.2.3 of the ANZECC Guidelines:

> *'The guideline trigger values are the concentrations (or loads) of the key performance indicators, below which there is a low risk that adverse biological effects will occur. The physical and chemical trigger values are not designed to be used as 'magic numbers' or threshold values at which an environmental problem is inferred if they are exceeded.'*

The NSW guideline *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (Department of Environment and Conservation, 2006) specifically notes that trigger values are not 'pass/fail/ compliance criteria'.

The ANZECC Guidelines recognise that the water quality values quoted in Tables 3.3.2 and 3.3.3 for south-eastern Australia are default values to be used in the absence of local data for a particular watercourse, and provide the following advice (Section 3.3.2.4) in relation to the derivation of locally specific data:

> *'For naturally occurring stressors, use data for appropriate reference systems to determine the low-risk trigger value for each key indicator. For these Guidelines, data collected after two years of monthly sampling are regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values'.*

Further discussion relating to the water quality data in the watercourses in the vicinity of the site is contained in Section 5 and proposed trigger values applicable to local watercourses are presented in Section 11.2.1.

A further aspect of the ANZECC Guidelines relates to the use of trigger values for regulatory purposes. Section 2.2.1.9 of the ANZECC Guidelines provides the following advice in relation to the use of the trigger values for regulatory purposes:

> *'The Guidelines have not been designed for direct application in activities such as discharge consents, recycled water quality or stormwater quality, nor should they be used in this way. (The exception to this may be water quality in stormwater systems that are regarded as having some conservation value.) They have been derived to apply to the ambient waters that receive effluent or stormwater discharges, and protect the environmental values they support.'*

This advice is reflected in the Department of Environment and Conservation (2006) guideline '*Using the ANZECC Guidelines and Water Quality Objectives in NSW*', which notes:

> *'The NSW WQOs [Water Quality Objectives] are the environmental values and long-term goals for consideration when assessing and managing the likely impact of activities on waterways. They are not intended to be applied directly as regulatory criteria, limits or conditions but are one factor to be considered by industry, the community, planning authorities or regulators when making decisions affecting the future of a waterway.'*

3.2.3 Healthy Rivers Commission

Bungonia and Barbers Creeks are sub-catchments of the Shoalhaven River. The Healthy Rivers Commission's (HRC) *Independent Inquiry into the Shoalhaven River System* (HRC, 1999) endorsed the following environmental values for the Shoalhaven River and its tributaries:

- healthy waters – protection of aquatic ecosystems
- recreation – protection of primary and secondary recreation and visual amenity
- water supplies – protection of livestock, irrigation and farmstead water
- protection of drinking water to be treated with coarse screening and disinfection, within sections of stream where water is extracted for use in urban water supply.

HRC (1999) recommended that the water quality criteria specified in the prevailing water quality guidelines published by NHMRC/ARCANZ/ANZECC for primary and secondary contact recreation and for drinking water supplies should be adopted as water quality objectives throughout the Shoalhaven catchment. Further details on the ANZECC Guidelines and environmental performance criteria to achieve these water quality objectives are outlined in Section 3.2.2 above.

The HRC also provided the following commentary and advice in relation to water quality objectives for nutrients:

> *"The criteria specified in Table WQ2 (taken from Table 3.2) should be adopted as indicative water quality objectives for nutrients throughout the catchment to be used in the initial phases of an adaptive management regime for water quality.*
>
> *The recommended objectives generally should not be used for regulatory purposes. They are indicative and only should be used in policies and planning instruments, as criteria for the first round of strategic planning. Further monitoring and evaluation may demonstrate the need for their revision.*

Table WQ2. Recommended indicative water quality objectives for nutrients

Location	Dry weather	Wet weather
Total Phosphorus (µg/L)		
Upper and middle catchment	40	60
Kangaroo Valley	30	60
Estuary	50	
Total Nitrogen (µg/L)		
Upper and middle catchment	500	500
Kangaroo Valley	500	500
Estuary	400	

While nitrogen derivatives from ammonia based explosives are the only potential source of nutrients within the Marulan South Limestone Mine, the principles contained in this advice have been taken into account in developing proposed water quality trigger values specific to Barbers Creek and Bungonia Creek adjacent to the mine (see Section 11.2).

HRC (1999) also provides river flow management recommendations, including the following recommendation specific to the Blue Circle Southern Cement Company (previous owner of Marulan South Limestone Mine):

> *'Licence development and review processes should incorporate assessment leading to environmental flow criteria for Bundanoon Dam and Tallong Weir.'*

Further, HRC (1999) notes that:

> *'Relatively low level assessments are called for these small storages. DLWC [Department of Land and Water Conservation] should undertake them, with involvement of… the Blue Circle Southern Cement Company for Tallong Weir'.*

3.2.4 Southern Rivers Catchment Action Plan

Catchment Action Plans (CAPs) are statutory, non-regulatory plans under the *Catchment Management Authorities Act 2003*. CAPs provide strategic direction for collaborative action and investment by government, community and industry partners for natural resource management within respective catchment areas, and provide a framework to prioritise and implement management decisions at both local and catchment scales. The CAPs are intended to align with NSW and Australian government objectives, policies, plans and targets for natural resource management.

The *Southern Rivers CAP 2013 – 2023* is an overarching 10-year plan that has been developed by the Southern Rivers Catchment Management Authority (CMA) in collaboration with a range of partners, to guide the implementation of natural resource management in the Southern Rivers region, which includes the Shoalhaven River catchment. The CAP lists a number of objectives and targets for the region including the following objectives for surface water:

- private and public land and water managers make well-informed decisions about use and care of natural resources
- private and public land and water managers effectively respond and adapt to change
- diverse, healthy, connected and productive natural environments
- health and integrity of natural habitat supports people and the environment and
- fresh water, estuarine and marine assets support people and the environment.

The *Southern Rivers CAP 2023 Paper – Water* describes the desired state of rivers within the region that supports water quality, quantity and movement:

- good geomorphic condition, close to reference condition for the particular River Style
- natural hydraulic function-balance for surface and base flows
- functional connectivity within stream, to adjacent floodplains, between surface and groundwater
- healthy and diverse native aquatic fauna
- water quality supports community uses and values suitable for human consumption that meet ANZECC guidelines 100% of the time and
- sufficient riparian buffers to manage pollution sources.

The objectives of the *Southern Rivers CAP 2013 - 2023* are consistent with the policies and plans for water quality and runoff within the catchment. The assessment of water quality impacts for the Project is detailed in Section 9.

3.2.5 Water Sharing Plans

WSPs are used to set out the rules for the sharing of water between water users and the environment and rules for the trading of water in a particular water source. Each WSP provides rules on access, managing water allocation, rules for the use and granting/amending of water supply works approvals, limitations to availability of water, and rules for trading of water.

3.2.5.1 Surface Water

The Project is located within the area of the Greater Metropolitan Region Unregulated Area WSP and the following three surface water sources within the WSP:

- Bungonia Creek Management Zone (commenced July 2011)
- Barbers Creek Management Zone (commenced July 2011) and
- Shoalhaven River Gorge Management Zone (commenced July 2011).

Table 3.1 lists Boral's existing WALs that would be available for the Project.

Table 3.1: Summary of existing Water Entitlements

WAL No	Works Approval	Water Source	Management Zone	Entitlement (ML)
Unregulated River				
WAL25207	10WA102352	Shoalhaven River Water Source	Barbers Creek Management Zone	76
WAL25373	10WA102377	Shoalhaven River Water Source	Barbers Creek Management Zone	10
			Total: Unregulated River	86
Domestic and stock				
WAL25352	10WA102352	Shoalhaven River Water Source	Barbers Creek Management Zone	1
Aquifer				
WAL24697	10WA116142	Goulburn Fractured Rock Groundwater Source		12
WAL41976		Goulburn Fractured Rock Groundwater Source		838
			Total: Aquifer	850

Table 3.2 summarises the licenced water entitlements and access rules for the Bungonia Creek, Barbers Creek and Shoalhaven River Gorge Management Zones. Further information to characterise the existing environment in these areas is provided in Section 4.6.

The proposed Marulan Creek Dam would also be located within the Barbers Creek Management Zone. Section 8 details the assessment of the proposed Marulan Creek Dam and identifies that a total annual surface water entitlement of up to 183 ML/year would be sought. Table 3.2 shows that water licence trading is permitted within the Barbers Creek Management Zone, and that sufficient surface water entitlements exist within the management zone for a proposed Marulan Creek Dam. Boral would seek to acquire additional Water Access Licence entitlements within the Barbers Creek Management Zone to account for water extraction of 183 ML/year from the proposed Marulan Creek Dam.

Table 3.2: Surface Water Entitlements and Access Rules

	Bungonia Creek	Barbers Creek	Shoalhaven River Gorge
Licenced Water Entitlements			
Total surface water entitlement	43 (ML/year)	1,176 (ML/year)	5
Number of water licences	7	11	1
Peak daily demand	1.54 (ML/day)	2.8 (ML/day)	N/A
Access Rules			
A Class	Cease to pump flow <0.2 ML/day	N/A	Cease to pump flow <40 ML/day
Commence to pump (A Class)	Flow exceeds 0.2 ML/day for 24 hours	N/A	Flow exceeds 77 ML/day
Environmental flow protection rule	N/A	Pumping prohibited when there is no visible flow	N/A
Reference point	Bungonia Creek gauge (215014)	Pump site	Shoalhaven River @ Fossikers Flat (215207
Trading Rules			
Trading into management zone	Not permitted	Not permitted	Permitted up to a maximum entitlement of 2,198 ML
Trading within management zone	Permitted	Permitted subject to assessment	Permitted subject to assessment
Conversion to high flow access licence	Not permitted	Not permitted	Not permitted

3.2.5.2 Groundwater

Groundwater in the Project Area is managed under the *2011 Greater Metropolitan Region Groundwater Sources Water Sharing Plan* (the plan). The plan covers 13 groundwater sources on the east coast of NSW and is divided into management zones based on geology and aquifer properties. The Project Area is located within the Goulburn Fractured Rock Groundwater Source (GFRGS). The provisions in the plan are intended to provide water to support the ecological processes and environmental needs of high priority groundwater dependent ecosystems and rivers, and direct how the water available for extraction is to be shared. Water sharing is intended to protect the groundwater source and its dependent ecosystems through reserving portions of stored groundwater and recharge as planned environmental water, and establishing rules for the granting and amendment of water supply works approvals.

Under the plan, groundwater extraction requires an authorisation under a water access licence or some form of exemption. This provision is exclusive of water extracted for basic landholder rights. Basic landholder rights include water for domestic and stock purposes extracted from a water source fronting a landholder’s property or from any aquifer underlying the landholder’s property, and for native title rights. Groundwater extracted for basic landholder rights does not require a licence, however, the bore must be approved by the NSW Department of Industry (Water).

Upon plan commencement, on 1 July 2011, the licensing provisions of the WMA 2000 came into effect in the plan area. Licences issued under the *Water Act 1912* were converted to WMA 2000 water access licences, and water supply works and use approvals. The water access licences are therefore separated from land.

Boral holds entitlement to extract 12ML/year (WAL24697) from two bores (10WA116142) for water supply on site. Boral also owns groundwater Water Access Licence (WAL41976) for 838 ML, which was issued in September 2017.

3.2.6 Neutral or Beneficial Effect on Water Quality Assessment Guideline 2015

The *Neutral or Beneficial Effect on Water Quality Assessment Guideline* (SCA, 2015), is a revised version of guidelines first published in 2011, developed in response to SEPP (Sydney Drinking Water Catchment) 2011. The Guideline responds to the requirement for all development in the Sydney drinking water catchment to have a neutral or beneficial effect (NorBE) on water quality, and provides clear definition for assessment and management of water quality, including provision of a standard Assessment Tool. The Guideline requires assessment commensurate with project risk, and promotes source management and control strategies over 'end of pipe' control solutions.

A NorBE for water quality is satisfied if the development:

- 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 where it is treated and disposed of to standards approved by the consent authority.

Table A2 of the Guideline provides a checklist for identifying potential impact occurring to water quality for project activities where:

- flow of water is concentrated on part of the site during construction or operation
- flow of water is impeded on part of the site during construction or operation
- proposed development during construction or operation will involve a discharge of effluent, dust, stormwater or other pollutants
- any other matter considered to result in an identifiable impact on water quality.

Minimum information requirements to assess development applications have been established by WaterNSW (*Developments in the Drinking Water Catchment – Water Quality Information Requirements*, 2015) which define water quality as comprising both surface and groundwater in characterising the existing environment.

For the purposes of WaterNSW and the above guidelines, the Project falls within Module 5, requiring referral to WaterNSW. Consultation with WaterNSW (Jim Caddey pers com, 29/11/2015) indicated that erosion and sediment controls that complied with the requirements for discharge to 'sensitive' environments (as defined in Table 6.1 of *Managing Urban Stormwater: Soils and Construction, Volume 2E – Mines and Quarries*) for rainfall events in excess of the design rainfall would be considered to comply with the requirements of NorBE. The design and operating requirements specified in these guidelines have been adopted for the Project sediment basins which may discharge off site.

The elements of the NorBE Guideline Checklist as recommended for extractive industries (Module 5) applied to the Project are summarised in Table 3.3.

Table 3.3: NorBE Assessment Checklist

Documentation Requirements (as per Table A3, SCA, 2015)	Specific Requirements	Where addressed in this Report
On site water management report	Where on-site wastewater management is proposed.	On-site wastewater management systems currently exist on the site as outlined in Section 6.1.4. No new on-site wastewater management systems are proposed as part of the Project. Therefore, no further assessment is required.
Conceptual erosion and sediment control plan (ESCP)	For a construction area > 250 m^2 and < 2,500 m^2	The proposed maximum area of disturbance due to overburden emplacement and associated haul roads is greater than 2,500 m^2. Proposals for managing runoff from overburden emplacements are an integral part of the proposed drainage systems described in Section 6.2.
Conceptual Soil and water management plan (SWMP)	For construction or impervious areas > 2,500 m^2	A conceptual Water Management System for the Project is described in Section 6, which details the proposed drainage system and sediment controls for the emplacement areas. Section 10.7 and Section 10.8 detail the management and mitigation measures proposed for surface water and erosion and sediment control.
Small scale stormwater quality modelling	For < 2,500 m^2 impervious area	The proposed realignment of Marulan South Road would involve a new road of about 1,220 m to replace about 1,950 m of the existing road. The impervious surface would, therefore be reduced by about 4,500 m^2. Standard erosion and sediment controls would be implemented during construction (see Section 10.4) to minimise water quality impacts.
MUSIC stormwater modelling	For > 2,500 m^2 impervious area	See above for proposed road realignment and measures to minimise water quality impacts.
Contamination report	Where historical land use of the development area indicates potential contamination	Appendix to the EIS.
Flood study	Where the development area is within or potentially within the AEP and the water sensitive parts of the development are located in the flood area	The Project is located in the upper reaches of minor tributaries and gullies that drain to Barbers and Bungonia Creeks. The water sensitive parts of the development are not located within a flood-liable area. Potential flood impacts of the proposed Marulan Creek Dam are considered in Section 8.5
Any SEPP1 (Development Standards) objection		Not applicable, as the Project is State Significant Development.

3.2.7 Erosion and Sediment Control Guidelines

Managing Stormwater: Soils and Construction, Volume 2E – Mines and Quarries (DECC, 2008) provides guidelines to specifically address requirements for erosion and sediment control on mines and quarries based on the principles set out in *Managing Stormwater: Soils and Construction, Volume 1* (Landcom, 2004).

Specific aspects of the guidelines applicable to the Project include the recommended minimum design criteria for erosion and sediment control measures set out in Table 6.1 of *Volume 2E – Mines and Quarries*. These guidelines have been adopted for the design and operation of all sediment basins and runoff conveyance structures as described in Section 6.2.

Appendix D of *Managing Stormwater: Soils and Construction, Volume 2D – Main Roads* (DECC, 2008) provides guidelines to specifically address requirements for erosion and sediment control for road construction based on the principles set out in *Managing Stormwater: Soils and Construction, Volume 1* (Landcom, 2004). Relevant aspects of these guidelines have been adopted for the erosion and sediment controls for the realignment of a short section of Marulan South Road as referenced in Section 10.4.

3.2.8 Controlled Activity Guidelines

In accordance with Division 2 of the *Water Management (General) Regulation 2011*, a controlled activity approval under the WMA is typically not required for surface mining activities approved as State Significant Development under the EP&A Act. However, the general standards used by the Natural Resources Access Regulator (NRAR) (previously Department of Industry (DoI) Water) in implementing the WMA still need to be adhered to. Consideration of the following guidelines has been included in this Surface Water Assessment:

- *Guidelines for Controlled Activities on Waterfront Land - Riparian Corridors (NRAR, 2018)*
- *Guidelines for Instream Works on Waterfront Land (DPI Water, 2012a)*
- *Guidelines for Laying Pipes and Cables in Watercourses on Waterfront Land (DPI Water, 2012b*
- *Guidelines for Outlet Structures on Waterfront Land (DPI Water, 2012c)*
- *Guidelines for Vegetation Management Plans on Waterfront Land (DPI Water, 2012d)*
- *Guidelines for Watercourse Crossings on Waterfront Land (DPI Water, 2012e)*.

The requirements for controlled activity approval have been considered in the layout and assessment of the following features of the Project:

- construction of the proposed Marulan Creek Dam
- construction of overburden emplacements and sediment basins on first order tributaries of Tangarang Creek
- discharge from sediment basins to first order tributaries of Tangarang Creek and Main Gully
- a road crossing of a first order tributary of Tangarang Creek.

3.2.9 NSW State Rivers and Estuaries Policy (1993)

The *State Rivers and Estuaries Policy* is based on the principle that government agencies, private landholders, resource users and the community in general must all share responsibility for managing natural resources. It recognises that a critical factor in achieving the policy objectives is the coordination and resolution of disparate State agency objectives, and their integration with Total Catchment Management principles and activities. The Policy provides management objectives and principles which reflect the State's commitment to resource sustainability balanced against other social and economic objectives in resource management decisions.

The objectives of the *State Rivers and Estuaries Policy* are to:

- manage the rivers and estuaries of NSW in ways which slow, halt or reverse the overall rate of degradation in their systems
- ensure the long term sustainability of their essential biophysical functions
- maintain the beneficial use of these resources.

The surface water management of the Project has been designed in accordance with the objectives of the Policy. The key aspect of this would be to demonstrate that there is no degradation of Tangarang Creek, Bungonia Creek or Barbers Creek as a result of mining activities.

3.2.10 NSW Water Extraction Monitoring Policy (2007)

This Policy sets out roles and responsibilities for DoI (Water), WaterNSW and holders of water extraction licences. The Policy applies to extraction from water sources in NSW under the WMA. This includes extraction of water from regulated rivers, unregulated rivers (includes lakes, estuaries) and groundwater sources, and extends to the measurement of return flows under Section 76 of the WMA.

DoI (Water) determines which licensees need to be monitored, and the form of monitoring, on the basis of the following:

At the water source level

- water extractions will be metered in stressed water sources (those with limited water availability and very high competition for water), and high conservation value water sources
- the WSP areas are the priority areas for the Policy

At the individual level

- those licence holders who extract sufficient volumes of water to impact adversely on the environment or other licence holders should be monitored
- licence holders that want to trade account water must be monitored, preferable by flowmeter, but with the approval of the DoI, by electricity, hour or revolution meter
- inactive licences or works need not be monitored, but the DoI must be notified if the licence and/or the works are to be activated.

The proposed extraction from Marulan Creek Dam is not expected to trigger the need for monitoring under the *Water Extraction Monitoring Policy* based on the criteria above.

4 Surface Water Environment and Hydrology

4.1 Climate

Background information on climate is provided in Section 1.2.9. The following sections describe the detailed climate data used for the water balance modelling presented in Section 7 of this Surface Water Assessment.

4.1.1 Rainfall

4.1.1.1 Daily Rainfall

The daily rainfall records for Marulan, George St (Station 070063) were obtained from the Scientific Information for Landowners (SILO) climate database for use in the water balance model. The patched data record for Marulan (George St) for the period 1 July 1889 – 30 June 2017 was obtained from SILO for the analysis for the site water balance assessment. The record comprised 77% historic station data. Missing data in this record was infilled with interpolated daily observations. Table 4.1 contains the monthly and annual rainfall statistics for the patched data record for Marulan (George St). Figure 4.1 provides the statistics graphically.

Table 4.1: Monthly Rainfall Statistics for Marulan (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	70	70	70	50	52	51	48	45	46	58	59	63	696
Minimum	1	0	0	0	0	0	0	0	0	1	0	0	288
10th %ile	14	7	10	8	7	9	9	10	15	16	8	13	473
Median	62	52	49	39	30	42	33	33	38	47	50	53	663
90th%ile	145	160	140	114	116	131	98	101	91	115	121	128	960
Maximum	222	273	330	233	406	382	319	224	166	263	248	220	1469

The statistics show that average annual rainfall in the vicinity of the Project is approximately 696 mm. Peak rainfall occurs in the summer months, with slightly lower rainfall in winter. On average, however, there is little variation in monthly rainfall between winter and summer.

On average, January, February and March are the wettest months of the year and August is the driest. Rainfall is highly variable ranging from a minimum of zero in a month up to a maximum of 406 mm. In wet (90th percentile) years the annual rainfall can be up to 960 mm while in a dry (10th percentile) year it can be as low as 473 mm.

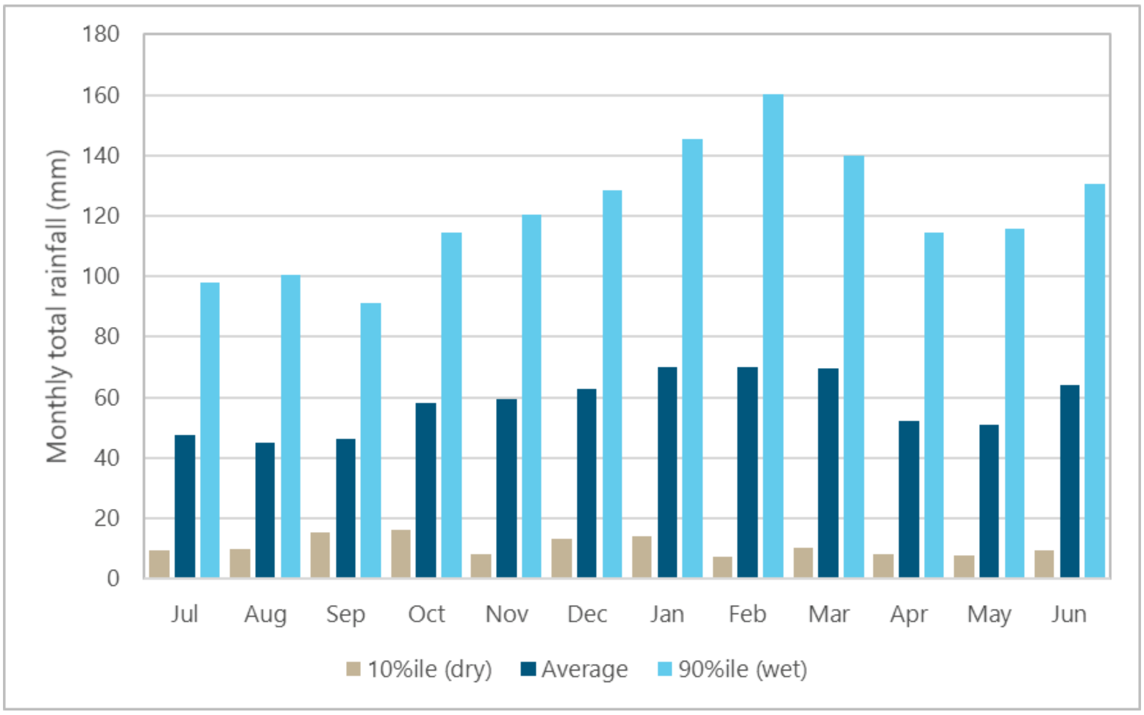


Figure 4.1: Monthly Rainfall Analysis (1889 - 2017)

Figure 4.2 shows the cumulative departure of rainfall from the long term average of the 128 year daily rainfall sequence. Figure 4.2 shows that the area has experienced extended drought periods (graph sloping downwards to the right), particularly an extended drought in 1900 – 1948. Although it contained some drier years, the period 1948 – 1978 was predominantly wetter than the long term average.

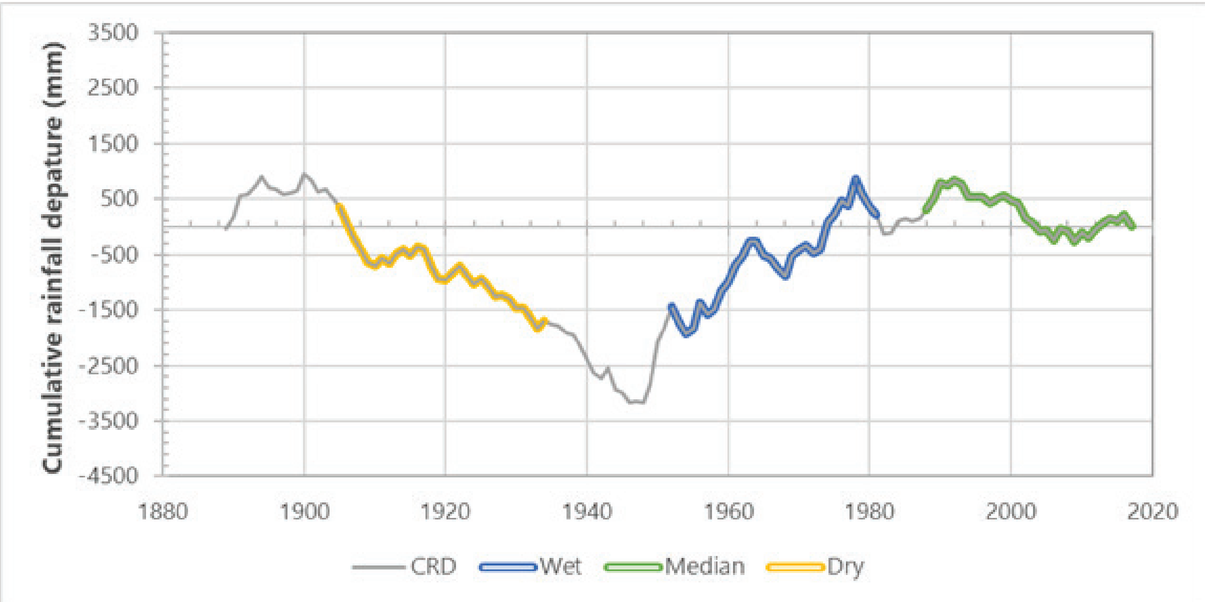


Figure 4.2: Residual Rainfall Analysis (1889 - 2017)

Figure 4.2 also shows the dry, median and wet 30 year rainfall sequences adopted for presentation of the water balance modelling results. The climate sequences adopted are:

- dry: 1905-1935
- median: 1986-2016
- wet: 1952-1982.

4.1.1.2 Rainfall Intensity

For purposes of assessing the required capacity of structures to convey peak flows in water management structures for the Project, the updated rainfall intensity-frequency-duration (IFD) data published by BoM in 2016 for use in conjunction with the 2016 edition of Australian Rainfall and Runoff (ARR2016) has been used. Design rainfall depths applicable to the design of site water conveyance structures based on the IFD data are summarised in Table 4.2.

Table 4.2: Design Rainfall Depths (mm) Data for Marulan

Duration	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
5 min	6.3	8.5	10.1	11.7	13.8	15.5
10 min	9.9	13.6	16.3	19.0	22.7	25.6
15 min	12.2	16.9	20.2	23.6	28.2	31.9
30 min	16.4	22.4	26.7	31.0	36.9	41.5
1 hour	20.7	27.8	32.8	37.8	44.6	49.9
2 hour	25.9	34.2	40.0	45.8	53.6	59.8
3 hour	29.7	39.1	45.6	52.2	61.0	68.0

Source: Bureau of Meteorology - http://www.bom.gov.au/water/designRainfalls/revised-ifd/ (accessed April 2018)

4.1.1.3 Five Day Rainfall

For purposes of determining the required capacity, the sediment basins have been provisionally sized to comply with the requirements for capture of fine and dispersive sediments as set out in Table 6.1 of Managing Urban Stormwater: Soils and Construction: Volume 2E Mines and Quarries (DECC, 2008). The table specifies the adoption of the 95th percentile rainfall as the basis for sizing sediment basins that would overflow into 'sensitive' receiving environments and the 90th percentile rainfall for a standard receiving environment sensitivity. Table 4.3 lists the 90th and 95th percentile five-day rainfall depths for various durations for Mittagong and Goulburn (as set out in Table 6.3 of Managing Urban Stormwater: Soils & Construction – Volume 1). The value for Marulan has been derived on the basis of the relative proximity of the mine to Mittagong and Goulburn.

Table 4.3: Five-day rainfall depths (mm) for Marulan

Rainfall percentile	Mittagong	Goulburn	Marulan
90th	49.0	28.6	35.7
95th	75.2	40.8	52.8

4.1.2 Evaporation

Two evaporation datasets have been used for different aspects of the water balance modelling undertaken for the Project:

- evapotranspiration data to account for surface water loss to vegetation
- pan evaporation for the purpose of accounting for evaporation from water storages and for dust suppression water requirements.

4.1.2.1 Evapotranspiration

For the purposes of modelling catchment runoff, Boughton (2010) recommends the use of areal potential evapotranspiration (PET) data. Areal PET is the evapotranspiration that would take place, if there was an unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average.

Average daily areal PET (by month) for Marulan was derived by interpolation of the spatial data from the digital version of the *Climatic Atlas of Australia – Evapotranspiration, (*BOM, 2002), and is detailed in Table 4.4. Daily potential evaporation data was also generated for input to the Australian Water Balance Model (AWBM) runoff modelling, (Boughton, 2003).

Table 4.4: Average daily areal potential evapotranspiration (mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.7	4.1	3.3	2.4	1.6	1.3	1.3	1.9	2.7	3.7	4.4	4.7

4.1.2.2 Pan Evaporation

The SILO patched daily pan evaporation dataset for Marulan George St (Station No. 70063) was obtained to correspond with the daily rainfall record for Marulan South for the period 1 July 1889 to 30 June 2017 for use in the water balance model. The data comprised long term average monthly data from 1889 to the end of 1968 and daily data from 1969 to current. Statistics for the patched pan evaporation data for Marulan (1969 – 2017) are provided in Table 4.5.

Table 4.5: Monthly Evaporation Statistics for Marulan (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	185	142	122	79	53	37	43	66	93	126	148	185	1278
Minimum	137	95	86	48	39	24	29	48	62	86	100	121	1017
10th %ile	146	111	97	61	43	28	34	52	76	98	116	143	1088
Median	189	143	121	78	51	36	43	64	91	122	146	174	1257
90th %ile	223	175	151	96	66	47	54	82	112	159	179	236	1478
Maximum	267	215	178	120	78	51	71	98	165	186	261	296	1752
Pan Factor	0.785	0.791	0.770	0.801	0.802	0.849	0.881	0.879	0.873	0.883	0.852	0.811	0.785

Table 4.5 also includes mean monthly 'pan factors' for Canberra Airport which is the nearest station with high quality Class-A pan evaporation data (McMahon et al, 2013). These pan factors were used to convert the daily pan evaporation data to estimates of open water evaporation from water storages.

4.1.3 Climate Change

The NSW and ACT Regional Climate Modelling (NARCliM) Project (a multi-agency research partnership between the NSW and ACT governments and the University of NSW) prepared high spatial resolution climate projections for NSW and the ACT in 2014. *The South-East and Tablelands Region Climate Change Snapshot* (OEH, 2014) provided the climate change projections for the near future (2030) and far future (2070+). Projections for the annual average rainfall range from a decrease (drying) to an increase by 2030 and also span both drying and wetting scenarios by 2070.

In 2015, Commonwealth Scientific & Industrial Research Organisation (CSIRO) updated the 2014 predictions in *Climate Change in Australia Projections for Australia's Natural Resource Management (NRM) Regions* (CSIRO, 2015). The Project is located in the East Coast cluster and East Coast South sub-cluster (CSIRO, 2015 *Climate Change in Australia Projections – Cluster Report- East Coast*). The projections are based on current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and aerosol emissions.

The Global Climate Model (GCM) simulations presented in the report represent the full range of emission scenarios, as defined by the Representative Concentration Pathways (RCPs) used by the IPCC. Projections for three RCP scenarios are provided:

- RCP2.6 – representing a low emission scenario
- RCP4.5 - representing a pathway consistent with intermediate emissions, which stabilise the carbon dioxide concentration at about 540 ppm by the end of the 21st century
- RCP8.5 - representing a high-emission scenario, for which the carbon dioxide concentration reaches about 940 ppm by the end of the 21st century.

Projections are given for two 20-year time periods: the near future 2020–2039 (referred to as 2030) and 2080–2099 (referred to as 2090). The spread of model results are presented as the range between the 10th and 90th percentile in the model output. For each time period, the model spread can be attributed to three sources of uncertainty: the range of future emissions, the climate response of the models, and natural variability.

The key predictions for the East Coast likely to impact on the water balance are:

- average, maximum and minimum temperatures are projected to continue to increase with very high confidence
- the temperature reached on the hottest days, the frequency of hot days and the duration of warm spells are projected to increase with very high confidence
- average winter rainfall is projected to decrease with medium confidence and a range of changes are projected in other seasons
- increased intensity of extreme rainfall events is projected with high confidence
- there is high confidence in little change in relative humidity for the near future and medium confidence in a decrease for late in the century
- projections for potential evapotranspiration indicate increases with high confidence in all seasons by late in the 21st century.

Further details of these predictions are provided in Annexure B.

Table 4.6 below summarises the CSIRO's seasonal rainfall and potential evapotranspiration projections for the near future and far future for the three RCP scenarios. The table provides the 10th and 90th percentile predictions as well as the median (50th percentile).

Table 4.6: Seasonal Rainfall and Evaporation Projections for the East Coast south

Season	Near Future (2030)						Far Future (2090)					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Rainfall (% change)												
Summer DJF	1	-13 to 18	1	-10 to 15	2	-13 to 14	-2	-22 to 10	0	-15 to 19	11	-12 to 27
Autumn MAM	-2	-16 to 8	-3	-22 to 15	-3	-13 to 14	-6	-23 to 12	-1	-22 to 18	-2	-28 to 20
Winter JJA	-2	-19 to 10	-5	-18 to 14	-8	-20 to 12	-3	-16 to 8	-8	-24 to 7	-17	-31 to 1
Spring SON	-3	-18 to 18	-1	-19 to 12	-3	-20 to 11	0	-19 to 10	-6	-23 to 9	-8	-30 to 14
Annual	-2	-9 to 7	-3	-10 to 6	-1	-11 to 6	-2	-16 to 8	-2	-16 to 9	-3	-20 to 16
Evapotranspiration (% change)												
Summer DJF	4.2	2.0 to 6.0	3.1	1.6 to 5.7	4.4	1.9 to 6.8	6.6	4.6 to 8.4	7.6	5.3 to 10.7	13.0	8.5 to 17.5
Autumn MAM	4.5	-0.4 to 8.8	3.6	0.5 to 7.4	5.2	2.3 to 9.4	6.3	3.9 to 9.8	9.1	6.1 to 13.2	19.3	12.8 to 24.0
Winter JJA	4.1	2.0 to 7.3	3.9	2.1 to 8	5.7	1.7 to 8.1	5.4	2.4 to 6.7	8.7	5.5 to 14.1	20.6	13.2 to 25.6
Spring SON	3.6	1.0 to 7.1	3	-0.3 to 4.1	3.0	1.0 to 6.2	3.8	1.4 to 7.1	7.2	2.6 to 8.2	11.4	7.4 to 15.4
Annual	3.9	2.7 to 5.9	3.4	2.3 to 4.4	4.2	2.3 to 6.0	5.9	4.2 to 6.8	7.8	5.3 to 9.5	14.3	10.1 to 18.1

Source: Climate Change in Australia Projections - Cluster Report: East Coast (CSIRO, 2015)

The predictions in Table 4.6 were used as the basis for assessing the sensitivity of the water balance results to uncertainties in future climate.

4.2 Regional Hydrology

The Project site is located within the catchment of the Shoalhaven River (NSW Drainage Basin 215), within the headwaters of Barbers Creek and Bungonia Creek tributaries, as shown on Figure 4.3.

Barbers Creek is bounded by the Morton National Park to the east for a distance of about 4 km upstream of the Shoalhaven River. Bungonia Creek runs through a section of the Bungonia State Conservation Area for a distance of about 4 km upstream of Boral owned land and is then bounded by the Bungonia National Park for the remaining 2 km to the confluence with the Shoalhaven River.

The Project site is drained by a number of minor ephemeral drainage lines into Barbers Creek to the east and Bungonia Creek to the south. These creeks are tributaries of the Shoalhaven River which, at its closest point, is located 1.5 km from the mine and flows eastwards into Lake Yarrunga, approximately 20 km downstream and enters the Pacific Ocean approximately 15 km east of Nowra (approximately 100 km downstream).

4.3 Local Hydrology

Figure 4.4 shows the extent of the Project boundary area together with the named watercourses:

- Marulan Creek
- Tangarang Creek
- Barbers Creek
- Bungonia Creek and
- Shoalhaven River.

Prior to mining, the natural runoff generally drained in easterly and southerly directions across the site to Barbers Creek and Bungonia Creek respectively. Historical natural catchments have been identified using the earliest available archived aerial photography of the mine area from 1963 (NSW Department of Lands) and 1:250,000 topographic maps (Figure 4.4).

The drainage pattern has been altered in places by mining activities over time. On the eastern and southern sides of the mine, steep batters have been constructed in external sections of both the North and South Pits above the steep ravines below.

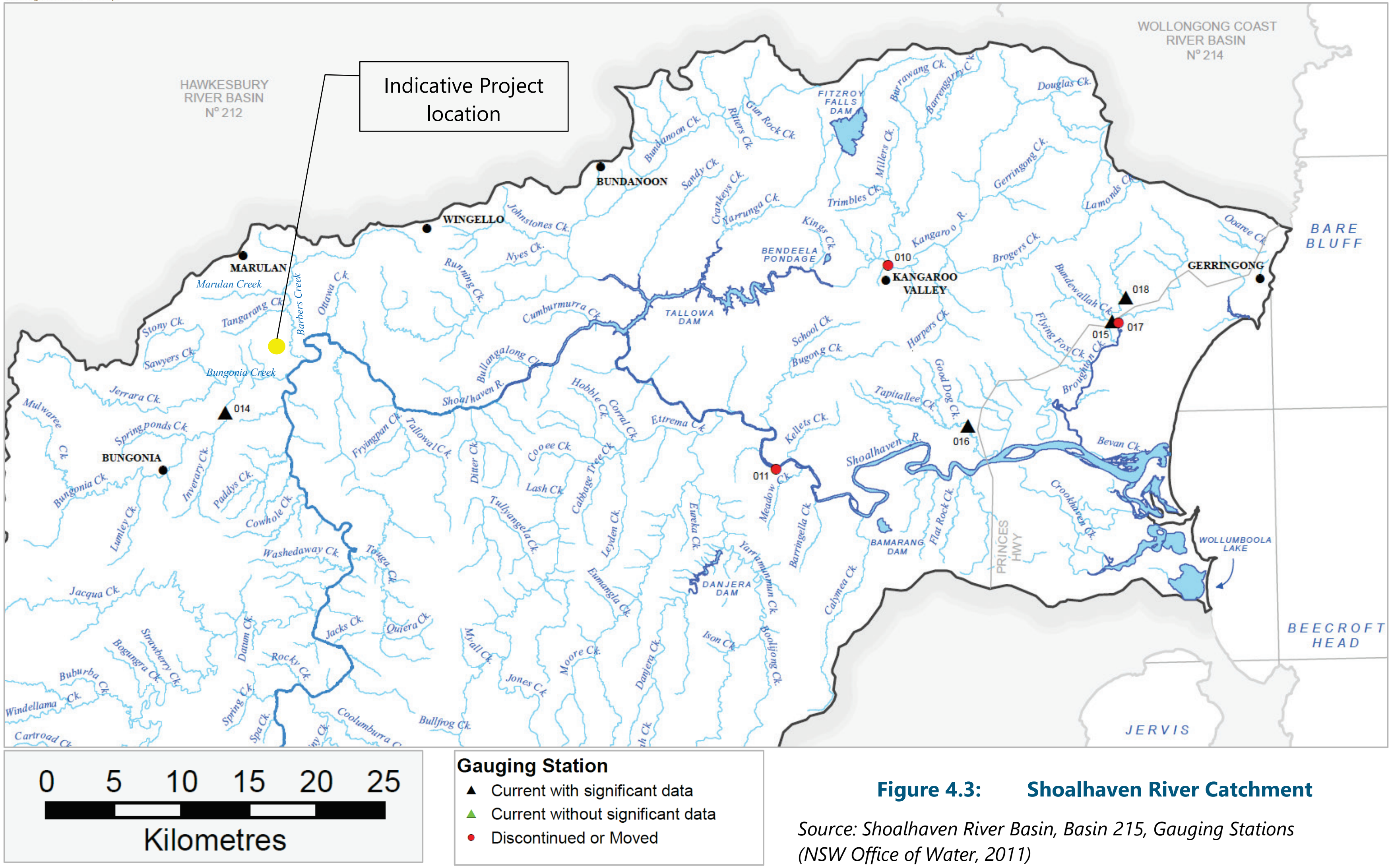
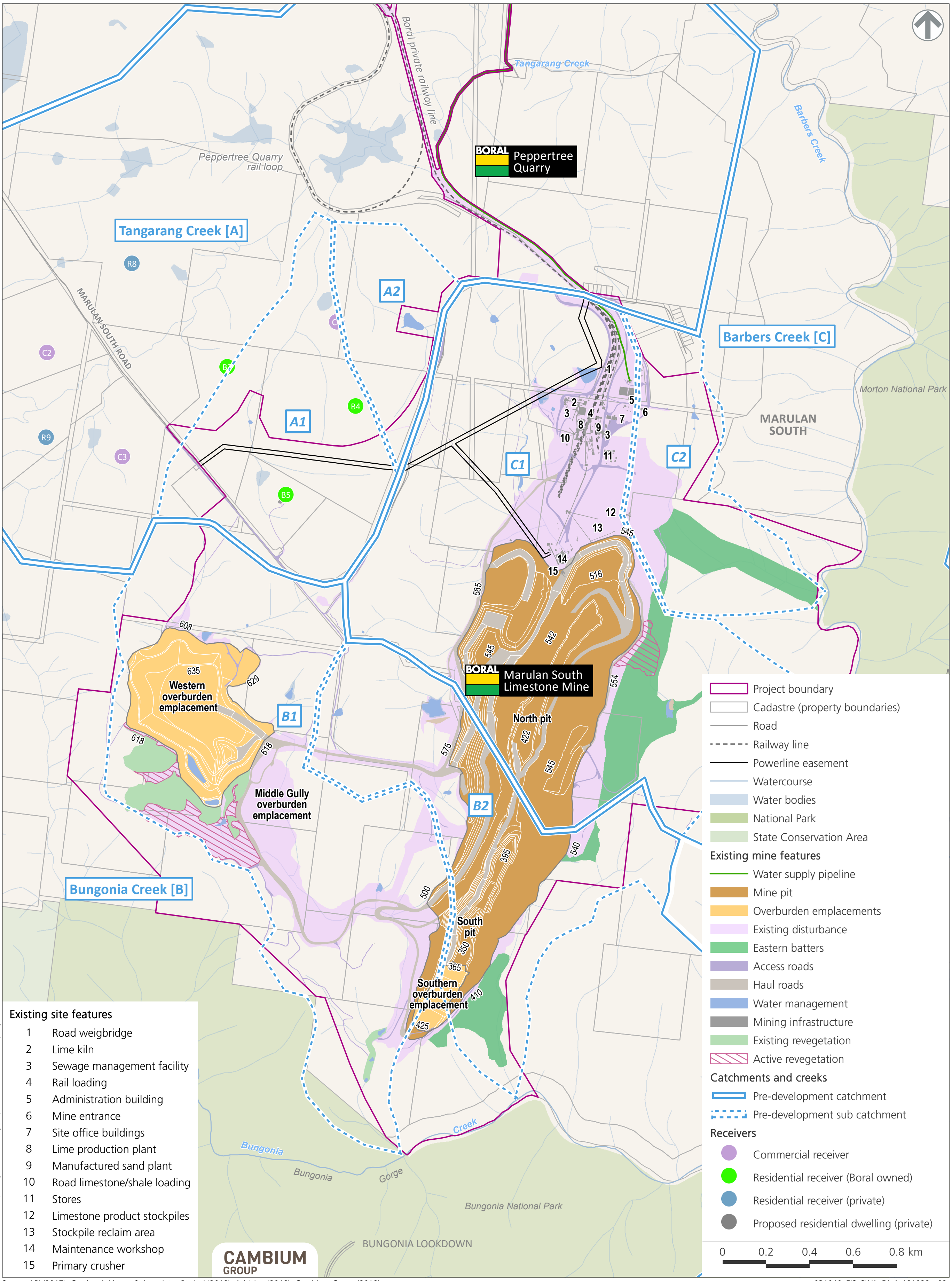


Figure 4.3: Shoalhaven River Catchment

Source: Shoalhaven River Basin, Basin 215, Gauging Stations (NSW Office of Water, 2011)

Figure 4.4
Pre-development catchments and creeks

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

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Runoff from revegetated eastern batters drains to Barbers Creek.

The southern end of the mine area drains naturally towards Bungonia Creek. Incised gullies in the vicinity of the mine drain into Barbers and Bungonia Creeks before discharging into the Shoalhaven River immediately south-east and east of the mine respectively. A number of small farm dams currently exist on ephemeral creeks on the site and appear to retain water with little seepage. Main Gully is a drainage line that, prior to mining, had a catchment area of 230 ha, much of which has been subsumed by prior mining or overburden emplacements, but remains the main drainage line for the southern part of the Project area.

Marulan Creek and Tangarang Creek are ephemeral drainage lines located within the Barbers Creek catchment. The catchments of both creeks contain several farm dams and Tangarang Creek has been dammed to supply water for Peppertree Quarry.

4.4 Stream Order and Catchment Size

Barbers Creek and Bungonia Creek are fifth order streams at their junctions with the Shoalhaven River, based on the Strahler Stream Order system. Marulan Creek and Tangarang Creek are fourth order streams and drain to the Shoalhaven River via Barbers Creek. The catchment areas and Strahler stream order are provided in Table 4.7.

Table 4.7: Catchment Areas

Creek	Total Catchment Area (km^2)	Strahler Stream Order
Barbers Creek	90 [a]	5
Bungonia Creek	275 [b]	5
Marulan Creek at proposed dam site	20^2	4
Tangarang Creek at existing dam site	7.5^2 [a]	4
Shoalhaven River at Fossickers Flat	$4{,}667^2$ [c]	7[e]
Shoalhaven River at Tallowa Dam	$5{,}750^2$ [d]	8[e]

Sources:
a ERM (2011).
b Southern Rivers Catchment Management Authority (2008a).
c Data provided by WaterNSW for gauging station 215207
d WaterNSW (http://www.waternsw.com.au/supply/visit/tallowa-dam)
e Estimated from Geoscience Australia (2018)

4.5 Watercourse Characteristics

4.5.1 Marulan Creek

The proposed dam on Marulan Creek and the existing dam on Tangarang Creek are located near the edge of the escarpment where the creeks drain down into steep rock gorges. On the escarpment, creek gradient is of the order of 0.5% to 1% with grass forming the majority of the vegetation cover in the bed of the creek (see Figure 4.5). The Marulan Creek dam site has a catchment of about 20 km^2 of primarily open grazing land.

Figure 4.5: Marulan Creek Upstream of the Dam Site

Downstream of the dam site the creek gradient increases to as much as 10% in a steep rocky gorge upstream of Barbers Creek as shown on Figure 4.6.

Figure 4.6: Marulan Creek Downstream of the Dam Site

4.5.2 Barbers Creek

About 1.5 km upstream of the confluence with Marulan Creek, Barbers Creek enters a steep sided gorge which extends for a distance of about 8 km down to the Shoalhaven River. In this section, Barbers Creek is characterised by a rocky boulder-strewn channel with rock pools (see Figure 4.7). The channel gradient ranges from about 5% to 6% in this section of Barbers Creek. At the confluence with Shoalhaven River the catchment area is about 90 km^2.

Figure 4.7: Barbers Creek at Water Quality Monitoring Point '*Barbers Creek Up*'

4.5.3 Bungonia Creek

The channel of Bungonia Creek is similar in many respects to that of Barbers Creek in that it comprises a rocky boulder-strewn channel with pools (see Figure 4.8). Like Barbers Creek, Bungonia Creek runs through a steep sided narrow gorge for about 8.5 km upstream of the confluence with the Shoalhaven River. For the Project, water quality monitoring locations have been established in Bungonia Creek upstream and downstream of a creek named 'Main Gully' which drains from the southern boundary of the Project area. Channel slope in Bungonia Creek adjacent to the Project is of the order of 4%. The Bungonia Creek catchment (275 km^2) is about three times larger than that of Barbers Creek and therefore has sufficient flow during large floods to mobilise the larger boulders shown in Figure 4.8.

Figure 4.8: Bungonia Creek near confluence with 'Main Gully'

4.5.4 Shoalhaven River

The Shoalhaven River has a catchment area of about 4,400 km^2 at the confluence with Barbers Creek. As shown in Figure 4.9 (located about mid-way between Bungonia Creek and Barbers Creek) the river in this reach has a wide channel with sandy banks indicating significantly lower velocities than those experienced in Bungonia Creek and Barbers Creek.

Figure 4.9: Shoalhaven River at Water Quality Monitoring Point SR2

4.6 Regulated Surface Water Sources

As discussed in Section 3.2.5, the Project is located within the area of the Greater Metropolitan Region Unregulated Area Water Sharing Plan, which commenced in July 2011. Three surface water sources within the WSP applicable to the Project area are:

- Bungonia Creek Management Zone
- Barbers Creek Management Zone and
- Shoalhaven River Gorge Management Zone.

Table 3.2 in Section 3.2.5.1 summarises the licenced water entitlements and access rules for the Bungonia Creek, Barbers Creek and Shoalhaven River Gorge Management Zones.

4.7 Baseline Flow Regime

This section reviews the flow characteristics of the watercourses that would potentially be impacted either by extraction of water (such as the proposed Marulan Creek Dam) or by discharge from the mine (such as runoff from the south-western area of the disturbance footprint which currently drains to the South Pit).

Apart from the Shoalhaven River, the creeks in the vicinity of the Project are all ephemeral. This is illustrated by the flow statistics for three watercourses shown in Table 4.8 and the flow duration graphs in Figure 4.10, Figure 4.11 and Figure 4.12 for:

- Marulan Creek at the site of the proposed Marulan Creek Dam (within the Barbers Creek Management Zone)

- Bungonia Creek at Bungonia (DPI Water gauge 215014), (1981 – 2015) (Bungonia Creek Management Zone) and
- Shoalhaven River at Fossickers Flat (WaterNSW gauge 215207), (1977 – 2015) (Shoalhaven River Management Zone).

The estimated flow regime at the dam site on Marulan Creek has been derived from rainfall:runoff modelling using an AWBM model (described in Annexure D) calibrated using the flow data for DPI Water gauge sites at Bungonia Creek at Bungonia (215014), Kialla Creek at Pomeroy (212040) and the WaterNSW gauges at Wingecarribee River at Berrima Weir (212272) and Wingecarribee River at Greenstead (212009).

Key aspects of the hydrologic behaviour illustrated by the flow regime in Table 4.8 and Figure 4.10, Figure 4.11 and Figure 4.12 include:

- similar annual runoff expressed as depth over the catchment area for Marulan Creek and Bungonia Creek (53.3 mm/year compared to 54.9 mm/year) but a much longer flow recession for Bungonia Creek attributable to baseflow contribution
- significantly higher flow per unit area in the Shoalhaven River (117.8 mm/year – twice that of the flow in Bungonia Creek) mainly attributable to higher rainfall in the southern section of the catchment.

Table 4.8: Flow Statistics for Marulan Creek, Bungonia Creek and Shoalhaven River

Statistic	Marulan Creek at Dam Site		Bungonia Creek at Bungonia (215014)		Shoalhaven River at Fossickers Flat	
Catchment Area (km^2)	19.2		164		4,667	
Average Annual Runoff (ML)	1,023		9,009		549,184	
Average Annual Runoff (mm)	53.3		54.9		117.8	
Average Daily Runoff	**ML/day**	**mm/day**	**ML/day**	**mm/day**	**ML/day**	**mm/day**
January	54	2.8	164	1.0	24,832	5.3
February	79	4.1	428	2.6	29,114	6.2
March	105	5.5	786	4.8	50,736	10.9
April	75	3.9	905	5.5	39,721	8.5
May	118	6.1	533	3.3	42,948	9.2
June	212	11.0	1,259	7.7	85,392	18.3
July	145	7.6	1,112	6.8	60,517	13.0
August	81	4.2	1,799	11.0	73,744	15.8
September	36	1.9	510	3.1	40,039	8.6
October	43	2.2	536	3.3	33,287	7.1
November	38	2.0	379	2.3	31,142	6.7
December	44	2.3	398	2.4	31,746	6.8

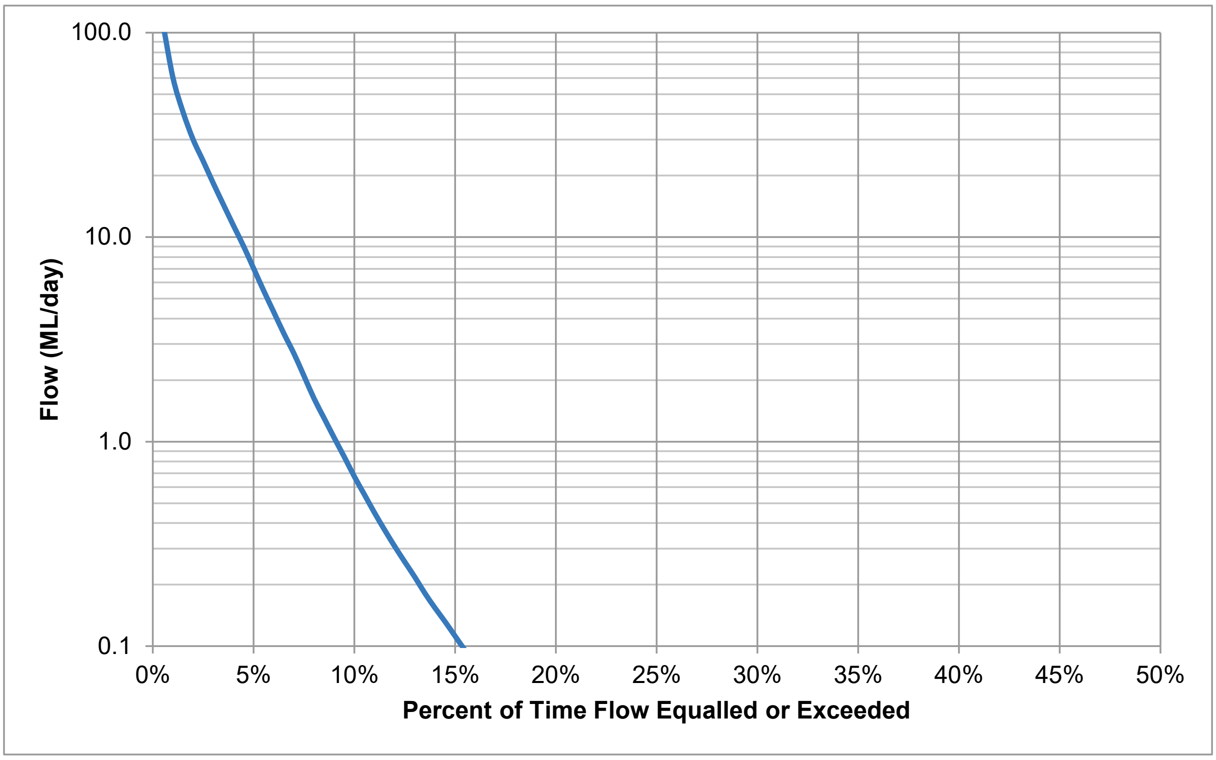


Figure 4.10: Flow Duration Graph for Marulan Creek at proposed Marulan Creek Dam

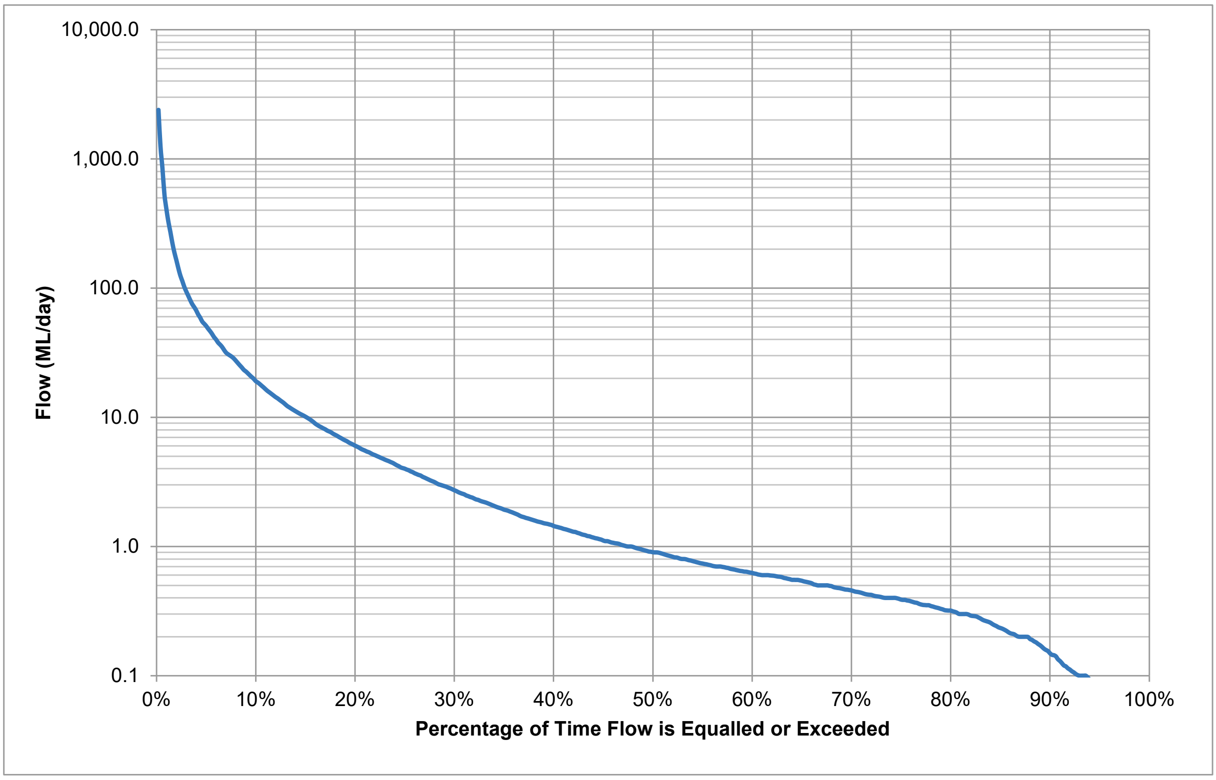


Figure 4.11: Flow Duration Graph for Bungonia Creek at Bungonia

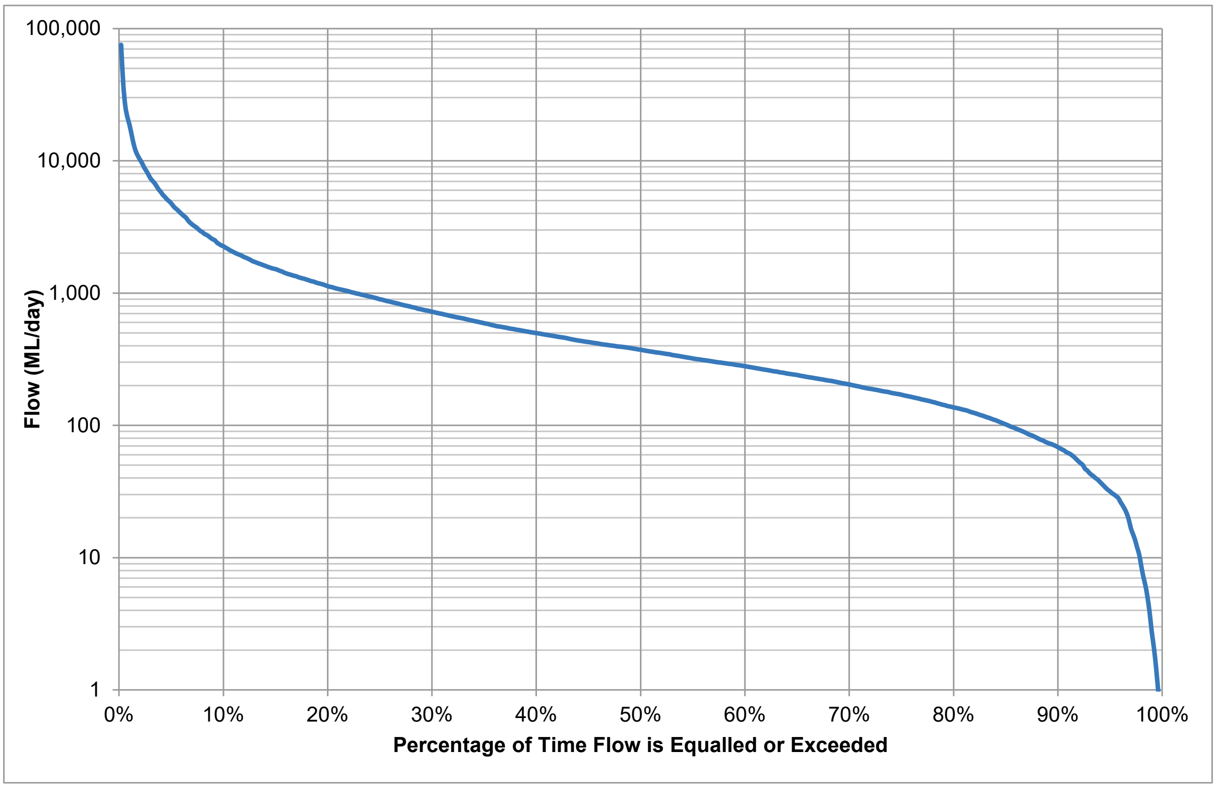


Figure 4.12: Flow Duration Graph for Shoalhaven River at Fossickers Flat

5 Surface Water Quality

Surface water quality information has been collected within the mine site area and the creeks surrounding the mine. This section summarises the available surface water quality information in the vicinity of the Project area. Detailed water quality data and analysis is provided in Annexure C.

5.1 Mine Site Surface Water

5.1.1 Monitoring Locations

In 2009, DECCW acknowledged that the North and South pit 'voids' were '*considered adequate to monitor water quality entering the limestone*' (GSS Environmental, 2009). As such, the February 2009 variation to EPL944 required monitoring of water quality at three sampling locations within the mine site:

- EPL Monitoring Point 13 – North Pit Bore
- EPL Monitoring Point 14 – South Pit Bottom Level
- EPL Monitoring Point 15 – Main Gully Sample Point.

Water quality monitoring undertaken for EPL Monitoring Point 13 – North Pit Bore is considered to be groundwater monitoring and as such is not discussed in this Surface Water Assessment.

A subsequent variation to EPL944 (June 2012) removed the licence requirement for monitoring at EPL Monitoring Points 14 and 15 as the historical data collected from these points does not appear to indicate any connectivity between the activities undertaken at the premises and the previously observed instances of sediment laden water in Bungonia Creek. However, Boral has voluntarily continued to undertake monitoring at these locations and at the Main Gully Auto Sampler point beyond EPL requirements. The mine site surface water monitoring locations, including the historical EPL sites, are described below and summarised in Table 5.1:

- ***South Pit Bottom Level*** – this monitoring location (historically known as EPL Monitoring Point 14) was the lowest point in the south pit where runoff from within the mine is currently collected. Surface water collected in the base of the south pit seeps through the base and is filtered as it reaches the groundwater system. This surface water runoff is uncontrolled and untreated but the South Pit Bottom Level acts as a sediment collection area. Samples from this location were collected between 2008 and 2012. However, the sampling at this location is not considered representative of runoff from the landscape and therefore this data has not been included in the analysis of baseline surface water quality in watercourses draining from the site or external to the site.
- ***Main Gully Sample Point*** – this monitoring location (historically known as EPL Monitoring Point 15) is located downhill from a natural feature known as the "Blow Hole". The Blow Hole is a ground water seep or spring (also known as B68 Main Gully Spring) and is located at an elevation that is below the base of the South Pit. It is possible that water seeping from the Blow Hole is representative of groundwater that includes seepage through the base of the South Pit. Due to the very steep terrain, access to the Blow Hole is not practical and therefore Boral voluntarily carries out sampling at the Main Gully Sample Point in Main Gully, a tributary of Bungonia Creek. Sampling at this location was undertaken approximately monthly from March 2008 to June 2012 and then both monthly and quarterly from November 2014 to September 2017. Since September 2017 sampling has been carried out quarterly.
- ***Main Gully Auto Sampler*** – surface water at this location currently comprises runoff from a small area of the haul roads (about 5 ha) and surrounding vegetated areas. The water sampled at this

location would be typical of runoff from the haul roads and the overburden emplacement areas within the site. Surface water runoff pools in the lower of three sediment basins (Figure 5.1) from where a sample is taken by the Main Gully Auto Sampler (Figure 5.2). Sampling is undertaken when water velocity is sufficient to trigger the auto sampler.

Figure 5.1: Main Gully Auto Sampler Collection Point

Figure 5.2: Main Gully Auto Sampler

Table 5.1: Routine Mine Site Water Quality Monitoring Sites and Locations

Site	Description	Easting (mMGA)	Northing (mMGA)	Site specified in EPL 944	Monitoring Period	Frequency
South Pit Bottom Level	Lowest point of South Pit (previously EPL monitoring point 14)	227763	6146492	February 2009 – December 2011	October 2008 – June 2012	Approximately monthly
Main Gully Sample Point	Downhill of "Blow Hole" (previously EPL monitoring point 15)	227578	6145625	February 2009 – December 2011	March 2008- June 2012 Nov 2014 – to Sep 2017 Sep 2017 →	Approximately monthly Monthly/Quarterly Quarterly
Main Gully Auto Sampler	Auto sampler	227325	6145992	N/A	February 2008 →	When water velocity sufficient to trigger auto-sampler

Other Supplementary/Opportunistic Sampling Locations - Additional and opportunistic sampling and analysis was also undertaken in 2009 (GSSE, 2009) including:

- two sites that receive runoff from relatively undisturbed catchments (Main Mine Dam 2 and a farm dam upstream of the Western Emplacement) and
- two sites that receive runoff from overburden emplacement areas (Main Mine Dam 1 – previously located within the Western Emplacement and the lower south-east sediment basin on Main Gully).

Water quality data from this opportunistic sampling is summarised in Table 5.2. Based on this sampling GSSE concluded:

> *Review of the data collected shows that suspended sediment loads in all storages were well below typically recognised trigger levels for industry best practice (50 mg/L), indicating that coarse sediment loads(>1.2 micron) to these dams is satisfactory. No pollution from plant and machinery was detected in the sampled dams (no oil and grease detected). The pH levels varied from slightly alkaline to moderately alkaline as a reflection of the limestone geology of the area.*

Table 5.2: Water Quality in Storages in 2009

Parameter	Main Mine Dam 2	Farm Dam	Main Mine Dam 1	SE Sediment Basin
pH	8.08	7.41	7.55	7.74
Suspended Solids (mg/L)		10	8	8
Oil & Grease (mg/L)		<5	<5	<5

5.1.2 Water Quality Data

Prior to November 2014, the sampling regime (i.e. analytes and frequency) changed a number of times due to changes in EPL licencing requirements, as described in Section 5.1.1 above. Since November

2014, sampling for the analytes listed in Table 5.3 has been undertaken at the Main Gully Sample Point.

Table 5.3: Analytes Monitored at Main Gully

pH	Sodium Adsorption Ratio	Electrical Conductivity
Total Dissolved Solids	Suspended Solids (from May 2015)	Total Hardness as CaCO3
Bromide	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3
Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulphate as SO4
Chloride	Calcium	Magnesium
Sodium	Potassium	Aluminium (dissolved & total)
Arsenic (dissolved & total)	Beryllium (dissolved & total)	Barium (dissolved & total)
Cadmium (dissolved & total)	Chromium (dissolved & total)	Cobalt (dissolved & total)
Copper (dissolved & total)	Lead (dissolved & total)	Manganese (dissolved & total)
Molybdenum (dissolved & total)	Nickel (dissolved & total)	Selenium (dissolved & total)
Strontium (dissolved & total)	Vanadium (dissolved & total)	Zinc (dissolved & total)
Boron (dissolved & total)	Iron (Dissolved and Total)	Mercury (Dissolved and Total)
Silicon as SiO2	Fluoride	Nitrite + Nitrate as N
Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P
Total Anions	Total Cations	Ionic Balance
Total Organic Carbon	Dissolved Oxygen	Biochemical Oxygen Demand

A summary of the data for key analytes is provided in Table 5.4. The ANZECC default trigger levels for ecosystem protection are provided for comparison purposes. Detailed monitoring results are provided in Annexure C.

Table 5.4: Summary of Main Gully Site Water Quality Statistics

Analyte	Unit	Statistic	Main Gully Sample Point	Main Gully Auto Sampler	ANZECC Default
pH	pH value	Count	21	87	6.5 – 7.5
		20th %ile	8.0	8.1	
		Median	8.1	8.2	
		80th %ile	8.2	8.3	
Electrical Conductivity @ 25°C	µS/cm	Count	21	87	350
		20th %ile	590	400	
		Median	610	484	
		80th %ile	630	570	
Total Dissolved Solids	mg/L	Count	21	33	N/A
		20th %ile	356	313	
		Median	369	350	
		80th %ile	390	400	
Suspended Solids	mg/L	Count	15	119	N/A
		20th %ile	1.8	78.2	
		Median	8.1	166	
		80th %ile	9.2	620	

Key aspects of the Main Gully Sample Point water quality monitoring results are:

- **pH** is slightly alkaline, with the 20th – 80th percentile pH values ranging between 8.0 and 8.2, with a median value of 8.1. This range is consistent with the observed pH range in Bungonia Creek
- **salinity** (as indicated by EC) 20th – 80th percentile values ranging between 590 and 630 µS/cm, with a median value of 610 µS/cm. This range is consistent with the observed salinity range within Bungonia Creek (447 – 682 µS/cm)
- **suspended solids** 20th – 80th percentile concentrations range between 1.8 and 9.2 mg/L, with a median value of 8.1 mg/L. This is consistent with the observed suspended solid concentrations within Bungonia Creek (<5 mg/L).

Key aspects of the Main Gully Auto Sampler water quality monitoring results are:

- **pH** is slightly alkaline, with 20th – 80th percentile values pH values ranging between 8.1 and 8.3, with a median value of 8.2. This median value is consistent with the observed pH in Bungonia Creek
- **salinity** (as indicated by EC) 20th – 80th percentile values range between 400 and 570 µS/cm, with a median value of 484 µS/cm. The median EC value is less than the median observed salinity in Bungonia Creek
- **suspended solids** 20th – 80th percentile concentrations range between 78 and 620 mg/L, with a median value of 166 mg/L. This is much higher than the results observed in Bungonia Creek (median value of <5 mg/L).

The data collected at the site monitoring locations indicate that under existing conditions, the surface water and groundwater discharges are resulting in a water quality discharge that is consistent with the existing water quality of the receiving waters (Bungonia Creek).

The data collected at the Main Gully auto sampler also indicates that the level of treatment of runoff from haul roads and emplacement areas within the site in the three sediment basins upstream of the auto sampler are sufficient to meet the water quality objectives for the Shoalhaven River catchment being that a neutral or beneficial effect will result.

5.2 Existing Creek and River Water Quality

5.2.1 Overview

Baseline surface water quality monitoring in the vicinity of the Marulan South Limestone Mine commenced in July 2014. In order to increase the dataset to provide a sufficient baseline, data from additional 'off-site' monitoring locations have been assessed. As such, the following surface water quality monitoring data has been considered in this Surface Water Assessment:

- Marulan South Limestone Mine monitoring (Shoalhaven River, Bungonia Creek, Barbers Creek and Marulan Creek)
- Peppertree Quarry monitoring (Tangarang Creek)
- WaterNSW monitoring (Shoalhaven River).

5.2.2 Monitoring Locations and Programs

5.2.2.1 Marulan South Limestone Mine Baseline Monitoring

Baseline surface water quality monitoring undertaken in the vicinity of the Marulan South Limestone Mine is summarised in Table 5.5. The sample sites on Bungonia Creek and Barbers Creek were chosen to represent surface waters both upstream and downstream of the mine to provide a statistically representative baseline data set and identify any existing mining induced impacts.

Water quality monitoring at Tangarang Creek has also been undertaken for Peppertree Quarry since February 2012 and is included in this assessment as Tangarang Creek is a tributary of Barbers Creek. The location and monitoring period for the monitoring sites on Tangarang Creek are listed in Table 5.5.

The monitoring sites on the Shoalhaven River were chosen to represent the incremental catchment inflows from Barbers Creek and Bungonia Creek that include the Project area. Also, as the Shoalhaven River is the main conveyance supplying Tallowa Dam, this dataset would also be used to demonstrate the variability of water quality from the contributing catchments (Barbers and Bungonia Creeks) and the corresponding potential impact, if any, on water quality in the Shoalhaven River attributable to mining activities. This dataset is important in demonstrating the ongoing effectiveness of the mine water management system in achieving a Neutral or Beneficial Effect (NorBE).

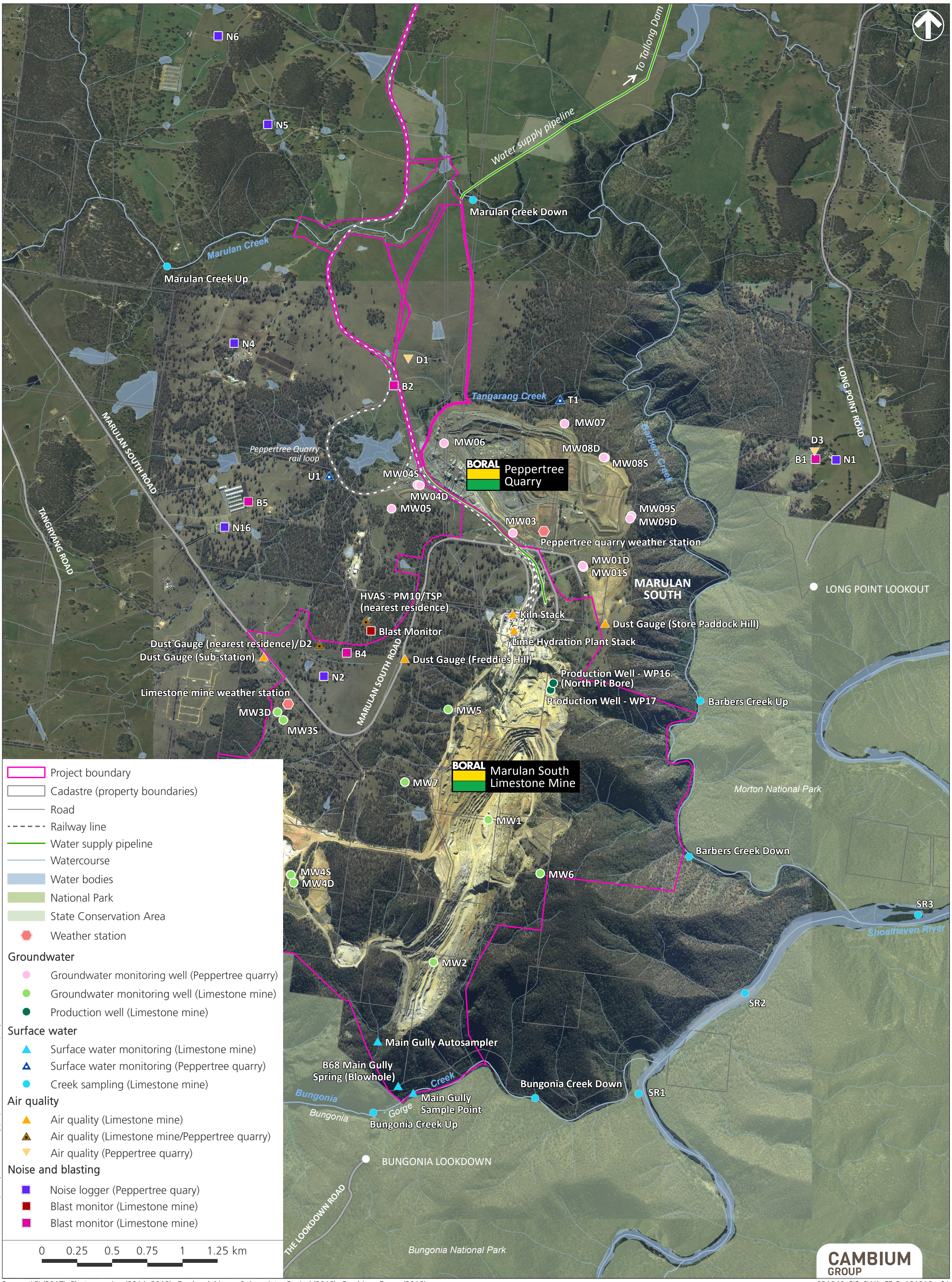
The locations of all surface water monitoring sites relevant to the Project are shown on Figure 5.3.

Table 5.5: Routine Creek Water Quality Monitoring Sites and Locations

Site	Description	Easting	Northing	Commencement of Monitoring	Monitoring Frequency
Marulan Up	Marulan Creek upstream of proposed dam	225825	6151504	November 2014	Monthly until Sep 2017, quarterly since Sep 2017
Marulan Dn	Marulan Creek downstream of proposed dam	228002	6151977		
Tangarang Up (U1)	Tangarang Creek upstream of Tangarang Dam (Peppertree Quarry monitoring site)	226950	6149970	February 2012	Quarterly during a flow event
Tangarang Down (T1)	Tangarang Creek downstream of Peppertree quarry (Peppertree quarry monitoring site)	228730	6150550		
Barbers Up	Barbers Creek upstream of mine	229518	6148416	September 2014	Monthly until Sep 2017, quarterly since Sep 2017
Barbers Dn	Barbers Creek downstream of mine	229542	6147306		
Bungonia Up	Bungonia Creek upstream of mine	227294	6145485	July 2014	Monthly until Sep 2017, quarterly since Sep 2017
Bungonia Dn	Bungonia Creek downstream of mine	228445	6145589		
SR1	Shoalhaven River site 1	229183	6145620	July 2014	Monthly until Sep 2017, quarterly since Sep 2017
SR2	Shoalhaven River site 2	229940	6146335		
SR3	Shoalhaven River site 3	231172	6146891		

Figure 5.3
Existing environmental monitoring locations

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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Access to the monitoring sites along the steep gorges along Barbers Creek, Bungonia Creek and the Shoalhaven River is difficult in dry weather conditions and hazardous in wet weather or bushfire conditions. Accordingly, data is not available for all months since monitoring commenced.

5.2.2.2 WaterNSW Baseline Monitoring

As part of their Water Monitoring Program for the Sydney catchment area, WaterNSW (formerly Sydney Catchment Authority) monitors surface water quality in the Shoalhaven catchment, which is reported on an annual basis. The monitoring site E847 on the Shoalhaven River at Fossickers Flat (Site E847 shown on Figure 2.4 of Annexure C) is located approximately 15 km south-east (downstream) of Marulan South Limestone Mine and is the monitoring site closest to the mine site. This is also the same location as the "Fossickers Flat" flow gauging station referred to in Section 4.6.

5.2.3 Baseline Water Quality

The suite of parameters analysed for each water quality sample for Marulan South Limestone Mine is listed in Table 5.3.

A summary of the statistical analysis for key analytes (for data collected by both Marulan South Limestone Mine and Peppertree Quarry) is provided in Table 5.6 and detailed monitoring results are provided in Annexure C. For comparison, the ANZECC default trigger levels for south-east Australia (upland rivers in NSW) for slightly disturbed ecosystems are also provided.

Five years (2010 to 2015) of monitoring results reported by WaterNSW for the Shoalhaven River at Fossickers Flat are summarised in Table 5.7.

Table 5.6: Summary of Existing Water Quality and Default ANZECC Default Trigger Values

Analyte	Unit	Statistic	Marulan Up	Marulan Dn	Tangarang Up (U1)	Tangarang Down (T1)	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	ANZECC* Default
pH	pH	Count	25	25	3	24	28	27	31	31	30	30	30	6.5 - 8.0
		20th %ile	7.6	7.8	7.5	7.7	7.8	7.9	7.6	7.9	7.3	7.2	7.2	
		Median	7.8	8.0	7.6	8.1	8.0	8.0	7.7	8.1	7.4	7.4	7.4	
		80th %ile	7.9	8.2	7.8	8.3	8.1	8.1	7.9	8.2	7.5	7.5	7.5	
Electrical Conductivity @ 25°C	µS/cm	Count	25	25	0	0	28	27	31	31	30	30	30	350
		20th %ile	451	648			414	445	447	481	84	89	94	
		Median	1160	1000			541	553	589	581	103	105	110	
		80th %ile	1556	1248			853	933	743	682	139	143	146	
Total Dissolved Solids	mg/L	Count	25	25	3	24	28	27	31	31	30	30	30	NA
		20th %ile	293	421	98.4	339.8	269	290	290	313	55	58	61	
		Median	754	650	159.0	444.0	352	359	383	378	67	69	72	
		80th %ile	1014	811	175.2	583.4	555	607	483	443	90	93	95	
Suspended Solids	mg/L	Count	16	16	3	24	18	17	22	18	18	18	18	NA
		20th %ile	3	3	5.5	<5	3	3	3	3	3	3	3	
		Median	7	3	10.0	4.4	3	3	3	3	3	3	4	
		80th %ile	10	6	20.8	40.6	3	3	5	6	8	6	8	
Total Nitrogen as N	mg/L	Count	25	25	0	0	28	27	28	31	30	30	30	0.25
		20th %ile	0.48	0.40			0.34	0.20	0.50	1.50	0.28	0.20	0.30	
		Median	0.80	0.60			0.40	0.50	0.80	2.30	0.45	0.40	0.45	
		80th %ile	1.02	0.80			0.66	0.60	1.36	3.60	0.60	0.50	0.62	
Total Phosphorus as P	mg/L	Count	25	25	3	24	28	27	28	31	30	30	30	0.02
		20th %ile	0.02	0.01	0.13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Median	0.03	0.01	0.26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		80th %ile	0.08	0.02	0.50	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02	

** ANZECC Default Trigger Value for ecosystem protection, South East Australia, slightly disturbed ecosystems in upland rivers*

Table 5.7: WaterNSW Monitoring Results – Shoalhaven River at Fossickers Flat (Site E847)

Analyte		2010/11	2011/12	2012/13	2013/14*	2014/15
Conductivity (uS/cm)	Sample No	11	8	12	11	11
	Median	107	93	134	110	100
pH (field)	Sample No	11	8	12	11	11
	Median	7.5	7.5	7.5	7.0	7.2
Suspended Solids (mg/L)	Sample No	11	8	12	11	11
	Median	5	3.5	1	4	4

** Note - physio-chemical parameters were not monitored at E847 in 2013/14, results from station DTA5 quoted instead*

Key aspects of water quality monitoring results for each of the watercourses referenced in the Water Sharing Plan are summarised below.

5.2.3.1 Shoalhaven River

For the Shoalhaven River, based on a data set of 30 samples collected for the Project, it can be seen that the water quality in the river, in terms of electrical conductivity, decreases very slightly between the upstream sampling point (SR1) and the furthest downstream point (SR3). This slight decrease occurs consistently across all analytes. Both pH and electrical conductivity are within the ANZECC ecosystem protection trigger ranges recommended for slightly disturbed upland rivers in South-eastern Australia. Annexure C provides a more detailed analysis of the Shoalhaven River water quality data including the additional analytes as listed in Table 5.3.

WaterNSW monitoring results between 2010 and 2015 for the river at Fossickers Flat are similar to those reported for the sites monitored for the Project and confirms that the Project monitoring adequately represents baseline water quality in the Shoalhaven River.

5.2.3.2 Bungonia Creek and Barbers Creek

The water quality data in Table 5.6 is similar for both Barbers Creek and Bungonia Creek. Both creeks demonstrate a small water quality decline similar to the Shoalhaven River when comparing upstream and downstream results. This indicates that water quality generally declines through this system possibly due to broader land-use and runoff quality issues.

The difference between the observed upstream and downstream water quality for Barbers Creek and Bungonia Creek is not significant, indicating that under existing operational practices the Marulan South Limestone Mine has no impact on surface water quality.

In late January 2016, an EPA officer observed discolouration of the water in Bungonia Creek near locations referred to as 'Main Gully' and the 'Blow Hole' and this was subsequently reported to Boral. Subsequent investigation by Boral concluded that the discolouration identified was not caused by surface runoff from any disturbed areas that drain to Main Gully. The discolouration was attributed to an overflow event from the 'Blow Hole' cave (fed by groundwater) due to the 30 mm rainfall event on the weekend of 23 and 24 January 2016. The EPA accepted Boral's assessment and noted that:

It seems unlikely that there was a significant incident involving poor sediment and erosion control on the Boral Limestone mine site which may have caused the observed increased sediment load in Bungonia Creek.

It is noted from your report and previous correspondence between the EPA and Boral, that links between high sediment loads in Bungonia Creek and the operations at the mine remain inconclusive, but could be attributed to the intricacies of the limestone karst system and overflows from within this system.

Although the routine water quality monitoring in Bungonia Creek shows no evidence of ongoing water quality impact from episodic events such as that observed by the EPA in January 2016, fine light brown sediment in the bed of Main Gully was observed prior to January 2016, even though the water appeared clear at the time. This observation suggests that episodes of sediment discharge from the Blow Hole have occurred in the past.

5.2.3.3 Marulan Creek and Tangarang Creek

The Marulan Creek water quality data indicates that water quality improves for some parameters as it moves downstream. Also, the water quality for both Marulan Creek and Tangarang Creek indicate that this water is diluted in Barbers Creek, as demonstrated by the better water quality of Barbers Creek.

6 Mine Water Management System

This section describes the historical water management system and the proposed mine water management system which has been developed to comply with accepted best practice principles for mine site water management and to satisfy the Project's specific objectives and design criteria. A wide range of alternatives for drainage layout, dam sizing and discharge locations have been examined with a view to providing security of supply for mine operations and minimisation of overflow (in the event of rainfall in excess of the design rainfall) from sediment basins to the external environment.

A water balance model has been developed to assess the performance of the water management system. The results of the simulated performance of the water management system are summarised in Section 7 and described in more detail in Annexure B.

6.1 Historic Water Use and Management

The Marulan South Limestone Mine has operated since 1869. During that time the mine pit has excised portions of a number of catchments that previously drained to Barbers Creek and Bungonia Creek. In particular, the drainage patterns inferred from the earliest available aerial photography (see Figure 4.4) indicate that prior to mining, a large catchment (about 350 ha) drained in an easterly direction towards a drainage line in which the existing gabion wall sediment filter is located.

The mine pit now cuts across the original drainage line and, as a result, approximately 104 ha of land to the west and north of the pit drains into the pit (about 138 ha). In addition:

- the mine pit has encroached into the area that originally drained to tributaries of Main Gully
- the Western Emplacement has created a 'closed' catchment (about 20 ha) that is now excised from the catchment that originally drained to Main Gully and
- drainage works have diverted a large proportion of the original Main Gully catchment into the South Pit.

6.1.1 Water Use and Management for Limestone Processing and Office Facilities

The existing limestone processing, workshops and office facilities are located adjacent to, and within, the land formerly known as Marulan South village. Water supply for lime hydration, kiln cooling and non-potable uses in this area of the site has been provided by pipeline from Tallong Weir. Potable water supply is provided in 15 litre water bottles issued to the site by the store.

Effluent from the office and workshop facilities is treated by licenced on-site wastewater treatment systems and treated effluent is disposed of by irrigation onto a designated effluent irrigation area as described in Section 6.1.4.

6.1.2 Overburden Emplacement and Drainage

Historically, the Marulan South Limestone Mine had three major drainage systems:

The Eastern System
For many years, overburden from the mine was placed on the eastern side of the mine forming steep unconsolidated batters. As shown on Figure 4.4, prior to mining in the area the natural topography in the north-east of the site generally drained eastward/southeast toward Barber's Creek from the edge of the plateau into the gorges below. The North Pit has intercepted a number of the upper tributary

ephemeral drainage lines in this area and flows from the north and west, including the limestone processing area. Natural gullies to the east of the North Pit have been used for overburden emplacement in the area known as the Eastern (Barbers Creek) Emplacement. Overburden emplacement in this area has now ceased and the remaining disturbed areas are being rehabilitated.

A sediment filter dam constructed with gabion baskets (by helicopter due to steep terrain) is located downstream in the main drainage line prior to entry to Barbers Creek. Maintenance of the filter dam is very difficult to undertake due to the rugged steep terrain in which it is located. As part of the Project, rehabilitation works will continue on the Eastern Emplacement (see *Soils, Land Resources and Rehabilitation Assessment,* LAMAC 2018).

An upstream drainage line in the north-east of the site previously drained southward toward the North Pit and was diverted east of the North Pit into the natural drainage line feeding to Barbers Creek via the filter dam. This upper catchment, which now drains predominantly to the North Pit, includes both upstream clean water runoff from vegetated areas mixed with sediment laden runoff from the operations area.

The Northern System

The northern system drains the area around the process plant, workshop, administration building and lime plant. This catchment drains via a series of sediment basins into the North Pit and subsequently seeps into the local groundwater system. Water management infrastructure comprises Main Plant Dam 1 to the north of the processing plant area and Main Plant Dam 2 directly to the west of the processing plant area. Runoff from the processing plant area and process water from the processing plant is directed towards a triple interceptor sediment trap and a minor sediment basin, before being discharged to Main Plant Dam 2 for subsequent recycling.

The Southern System

The southern system drains the Western Overburden Emplacement and haul roads. Matrix (2005) describes a drainage channel directing runoff from the Western Overburden Emplacement along the southern haul road into the sump of the South Pit where it subsequently drained into the local groundwater system. Matrix (2005) identified that, at the time, the channel along the haul road was undersized and some flow was diverted along a haul road into the adjacent main gully area and Bungonia Gorge. The precise location of this drainage system is not clear. However, this channel was upgraded in late 2005 to ensure that a design flow of 18 m^3/s could be directed into the South Pit. This ensured that, at the time of writing of the 2009 *Surface Water Assessment* (GSS Environmental, 2009), all sediment-laden surface runoff from the southern system was diverted to the South Pit via the southern haul road and the sediment check dam.

A small area of the site on the western side of the South Pit down-slope of the mine disturbance area drains towards Bungonia Creek via Main Gully which contains three sediment basins. Table 6.1 summarises the approximate capacity and contributing catchment areas of the existing sediment basin.

Table 6.1: Existing Sediment Basins

Dam	Estimated Volume (ML)	Approximate Catchment Area (ha)	Notes
Southern Haul Road Check Dam	~0.08	6.5	Pre-treatment sediment check dam in roadside drainage near Main Gully diversion of Southern Haul Road, prior to entry to South Pit.
Main Gully Primary Sediment Basin 1	~5.8	~2 mainly haul road	Large sediment basin wall. First dam in Main Gully series of 3 sediment basins. 2008 AEMR lists as 5.8 ML. Estimated by GSS Environmental (2009) at 5 ML.
Main Gully Sediment Basin 2 (Lower SE Sediment Basin)	~0.2	~2 mainly haul road	2nd in-line sediment basin in Main Gully prior to discharge via the auto-sampler point into Bungonia Creek gorge.
Main Gully Sediment Basin 3	~0.8	~2 mainly haul road	Final sediment basin in Main Gully series prior to discharge.
Plant Sediment Basin	0.3	N/A	Completed late 2007 when Main Plant 1 Dam diversion works undertaken.

6.1.3 Existing Site Water Supply Dams

Historically, the main clean water source for the mine was the 'external' source of Tallong Weir via a pipeline, in addition to two on-site groundwater bores. An agreement was also in place with a local landholder to supply water from a large farm dam, Glenrock Dam, should the site ever reach a minimum onsite supply level. This agreement has never been implemented. Table 6.2 summarises existing mine water supply dams.

Table 6.2: Existing Mine Water Supply Dams

Water Supply Dam	Estimated Dam Volume (ML)	Catchment/ Water Source	Notes
Main Plant Dam 1 (Kiln Dam)	27	Limited catchment, used for storage of flows transferred from the Tallong Weir.	
Main Plant Dam 2	11	Runoff from processing plant area	Pollution control dam that controls/recycles runoff from the lime plant.
Main Mine Dam 1	12	Limited catchment from north-east.	Historically, this provided a source of water for dust suppression prior to being subsumed within the Western Emplacement.
Main Mine Dam 2	43	0.21 km^2 catchment	This dam was previously fed by water pumped from Main Mine Dam 1 and water was utilised periodically for dust suppression by the mine.

6.1.4 Sewage Treatment

Boral operates six sewage treatment facilities at the Marulan South Limestone Mine:

- one main Envirocycle unit that receives effluent from main offices, laboratory, bathrooms, store and conference room
- two lime plant Envirocycle units servicing the kiln control room, hydration, dispatch and workshop areas
- three septic tanks, one located at the "machine shop"/primary crusher, one adjacent to the "Fettlers' shed" and the other services the former "Club" facility, north of the main office.

Effluent from the office and workshop facilities is treated by a licenced on-site wastewater treatment system. Treated effluent is disposed of by irrigation onto a designated effluent irrigation area. The "machine shop"/primary crusher septic tank is inspected and pumped out weekly by an accredited waste disposal contractor. The "Fettler's shed" and "Club" units are serviced by adsorption trenches.

6.1.5 Environment Protection Licence for Existing Operations

The current Environment Protection Licence (EPL) (No 944 dated 17 August 2014) does not contain any requirements for monitoring of on-site surface water quality or discharge.

6.2 Proposed Water Management System

The following sections outline the proposed water management system and the input data to the water balance model described in Section 7.

6.2.1 Objectives and Design Criteria

The Project specific objectives and design criteria for the proposed site water management system are to:

- minimise impacts on the receiving environment by retaining all overburden emplacement runoff on-site except where the rainfall exceeds the specified design storm
- separate runoff from undisturbed, rehabilitated and mining affected areas
- design and manage the system to operate reliably throughout the life of the mine in all seasonal conditions, including both extended wet and dry periods
- design permanent drainage infrastructure to be stable in storms up to the 1% AEP
- maximise site water supply using runoff from the overburden emplacement areas, and thereby minimise the requirement for external water supply
- minimise the number of licensed discharge points
- design post-mining drainage systems and a final landform to reflect pre-mining catchment areas and flows where practicable.

6.2.2 Overview of Proposed Water Management System and Overburden Placement

To develop an effective water management system that addresses the above objectives and design criteria, the proposed strategy for the management of water for the Project is based on the separation of water from different sources based on anticipated water quality as follows:

- wherever possible, 'clean' surface runoff would be diverted around disturbed areas and released from site
- no further overburden would be placed on the Eastern Emplacement (eastern batters) and any remaining disturbed areas would be rehabilitated in line with the recommendations in the *Soils, Land Resources and Rehabilitation Assessment* (LAMAC, 2018)
- overburden would be used to:
  - backfill the South Pit and subsequently extend the emplacement of overburden to the west to create a single Southern Overburden Emplacement (final area 76 ha)
  - extend the existing Western Overburden Emplacement to the north (final area 132 ha)
  - construct a Northern Overburden Emplacement (final area 63 ha)
- except for the section of the Southern Overburden Emplacement that drains directly to the South Pit, overburden and haul road drainage (termed 'dirty water' for purposes of this report) would be directed to a series of sediment basins that have been provisionally sized (see Section 6.2.8) to comply with the requirements for capture of fine and dispersive sediments as set out in *Managing Urban Stormwater: Soils and Construction: Volume 2E Mines and Quarries* (DECC, 2008)
- runoff collected in the sediment basins would either be pumped to one of the mine water dams for reuse in limestone processing or dust suppression, or would drain to the mine pit. In the event that there is insufficient capacity in the mine water dams to retain water pumped from the sediment basins, water quality in the sediment basins would be tested and flocculant added if necessary to achieve total suspended solids of 50 mg/L for discharge
- areas that would continue to drain to the mine pit are:
  - lime production facilities
  - limestone blending and stockpiling
  - the northern face of the Southern Overburden Emplacement
  - other areas immediately adjacent to the western side of the mine pit.
- any excess water in the mine water dams would overflow to the mine pit
- to the extent possible, post mining catchment areas draining from the site would be comparable to the pre-mining catchment areas draining to the following discharge locations:
  - the Southern Emplacement and the southern section of the Western Emplacement would drain to Main Gully
  - the northern section of the Western Emplacement and the north-west corner of the Northern Emplacement would drain to tributaries of Tangarang Creek upstream of the water supply dam for Peppertree Quarry.

6.2.3 Progressive Development of the Mine and Water Management System

Figure 6.1 illustrates the mine layout prior to the commencement of the Project.

The progressive development of the water management system, as depicted in Figure 6.2 to Figure 6.5, accounts for the ongoing development of the open cut and mine areas, as well as the continuing prompt rehabilitation of sections of the overburden emplacements once the final level and landform has been achieved. The progressive development of the mine as depicted in these figures provides the basis for the final landform and associated drainage systems depicted in Figure 6.2 to Figure 6.5. Water management structures, such as sediment basins, storage dams and drains, as well as indicative drainage pathways, are detailed on each figure. A schematic of the water management system is provided in Figure 6.7.

Stage 1 – (5 years) (Figure 6.2) would involve:

- Construction of the new Marulan Creek, Central and Eastern Gully water storage dams, enlargement of the existing Kiln Dam, revegetation of all new dam walls
- Upgrade Tallong Weir to Marulan pipeline to allow connection of the Marulan Creek Dam to the Reservoir
- Pipeline connecting Eastern Gully Dam to Kiln Dam via the Reservoir
- Construction of the North Pit Sump towards the end of Stage 1 following north west mine development
- Construction of Sediment Basins N1 and N2 in preparation for emplacement of overburden in the Northern Overburden Emplacement
- Installation of pipelines to connect N1 and N2 to Kiln Dam, Eastern Gully Dam to Kiln Dam via the Reservoir, and W1 and W2 to Central Dam
- Completion of the Northern Overburden Emplacement including overburden emplacement to create southern stockpile/reclaim area. Commencement of rehabilitation of western section of Northern Overburden Emplacement
- Construction of Sediment Basin P1 to receive runoff from the new shared road sales stockpile area
- Completion of construction of Sediment Basin W1 to control runoff from the upper slopes of the Western Overburden Emplacement that progresses northwards toward Marulan South Road
- Completion of rehabilitation of the lower slopes of the Western Overburden Emplacement
- Progressive "in-pit" filling of the Southern Overburden Emplacement and commencement of western "out-of-pit" section. Progressive rehabilitation of the lower south-eastern slopes of the Southern Overburden Emplacement.

Stage 2 – (8 years) (Figure 6.3) would involve:

- Complete rehabilitation of the Northern Overburden Emplacement (northern section) and complete construction of new stockpile/reclaim area infrastructure (southern section of Northern Overburden Emplacement) to allow northern mine pit development
- Progressive filling and rehabilitation of the southern section of the Western Overburden Emplacement
- Progressive filling of the Southern Overburden Emplacement above current South Pit rim. As the level of overburden rises above the level of the South Pit rim, Sediment Basin S1 would be constructed at approximately 440 m AHD. Water captured in this sediment basin would be used for revegetation purposes and dust suppression in the immediate area. Any overflow to be directed along the contour to limestone benches to drain to the base of the South Pit.
- A small area in the Southern Overburden Emplacement (0.8 ha) which would be at a lower elevation than Sediment Basin S1 would drain towards Main Gully where the existing sediment control facilities would be enlarged (to 1 ML) to form Sediment Basin S2 to treat any runoff from the emplacement and natural catchment before it discharges towards Bungonia Creek.

- Progressive rehabilitation of the lower southern and south-eastern slopes of the Southern Overburden Emplacement and upper slopes of the western "out-of-pit" section.

Stage 3 – (6 years) (Figure 6.4) would involve:

- Decommissioning of Sediment Basins N1 and N2 as actively managed sediment basins once rehabilitation of the Northern Overburden Emplacement (northern section) is well established, but would likely be retained for water storage and transfer as required for ongoing land management.
- Relocation of existing Marulan South Road to permit construction of the complete northern section of the Western Overburden Emplacement. Construction of new section of Marulan South Road including required erosion and sediment controls. Progressive rehabilitation of the lower slopes of the northern section of the Western Overburden Emplacement
- Rehabilitation of the batter slopes of the southern section of the Western Overburden Emplacement would be completed. If runoff water quality is appropriate, overflow from Sediment Basin W2 could be redirected directed by pipe or into a channel that discharged into the western tributary of Main Gully
- Mining progressing to west within the main pit, creating a smaller west pit. Runoff collected in the west pit will seep into groundwater, with any overflow reporting to the south pit
- Continued filling of the Southern Overburden Emplacement to join western "out-of-pit" section with the initial southern "in-pit" fill area. Rehabilitation of the upper batters of the western section and lower slopes of the southern and south-eastern sections of the Southern Overburden Emplacement.

Stage 4 – **(11 years)** (Figure 6.5) would involve:

- Completion of rehabilitation of the northern section of the Western Overburden Emplacement. Sediment Basins W1 and W2 to be decommissioned as actively managed sediment basins once rehabilitation was well established but would likely to be retained for water storage and transfer as required for ongoing land management.
- Completion of filling and rehabilitation of the outer slopes of the Southern Overburden Emplacement. Once rehabilitation has been well established, the drainage arrangements would be modified so that all runoff from the western section of the emplacement would be allowed to drain directly off site via Main Gully. Drainage from Sediment Basin S1 would also be directed to Main Gully via the existing S2 series of sediment basins.
- Assuming limestone mining did not continue beyond the proposed 30 year mine plan period the final mine pit floor configuration includes two large sediment retention basins, a northern basin at about 365/355 m AHD and southern basin at about 350/335 m AHD. These basins will provide an estimated storage capacity of 70 ML and 400 ML respectively.

Conceptual Final Landform Design – (Figure 6.6) would involve:

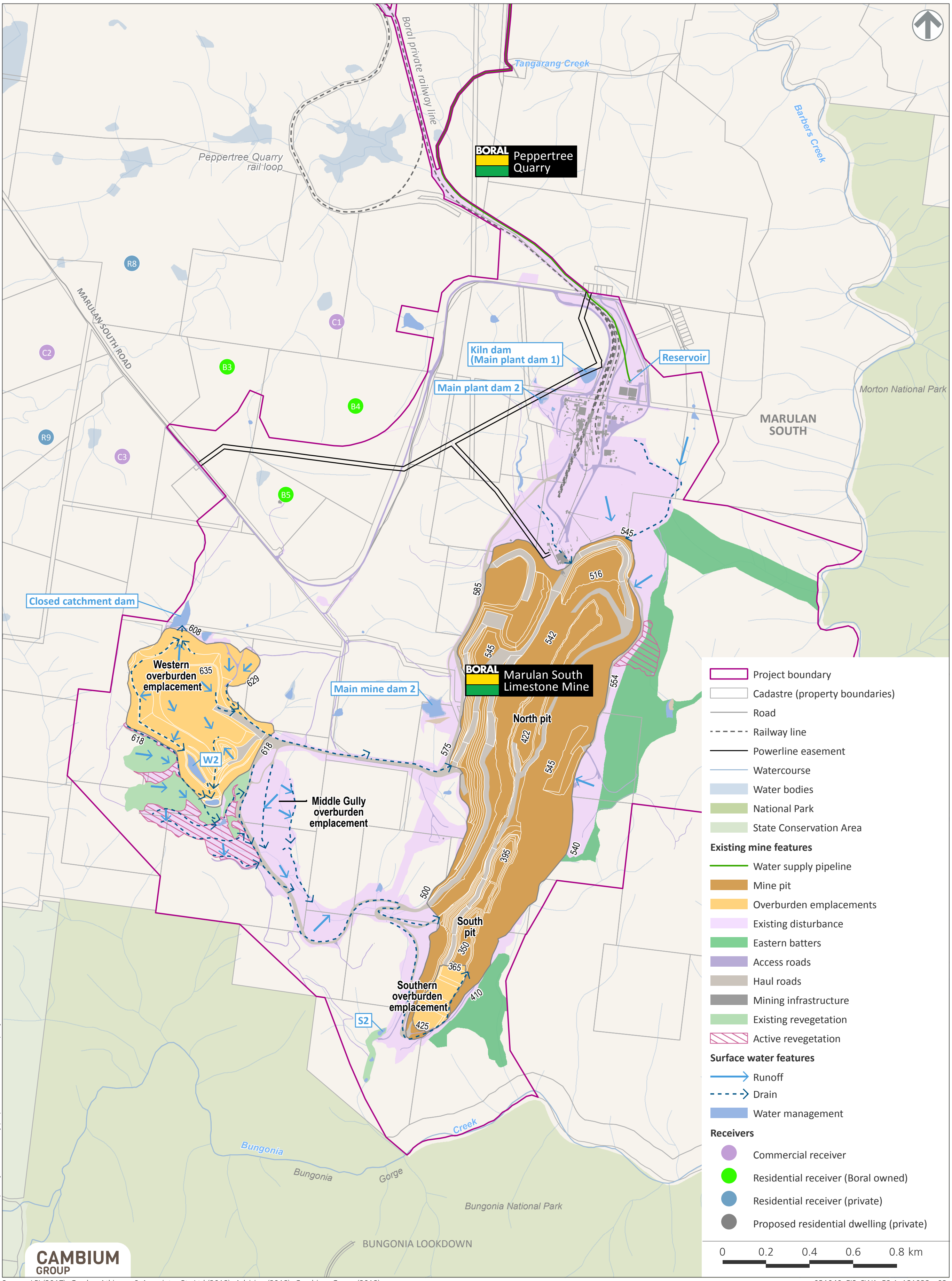
A conceptual layout of the mine drainage facilities post Stage 4 is shown in Figure 6.6 and would involve:

- Maintenance of established rehabilitation on all emplacements.
- Establishment of revegetation on available upper "inner" facing slopes of the Southern Overburden Emplacement to minimise erosion and sedimentation following final landform construction.
- Establishment of revegetation on select upper mine benches and infrastructure areas to minimise erosion and sedimentation.

- Completion of the modified drainage arrangements undertaken toward the end of Stage 4 including:
  - runoff from the Western Overburden Emplacement and western section of the Southern Overburden Emplacement would be allowed to drain directly off site via Main Gully
  - drainage from Sediment Basin S1 would also be directed to Main Gully via the existing S2 series of sediment basins
  - mine pit floor sediment basins and associated drainage works.
- Decommissioning of any water storage dams and sediment basins no longer required for final land use requirements.

Figure 6.1
Indicative mine layout - Stage 0 (pre SSD approval)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

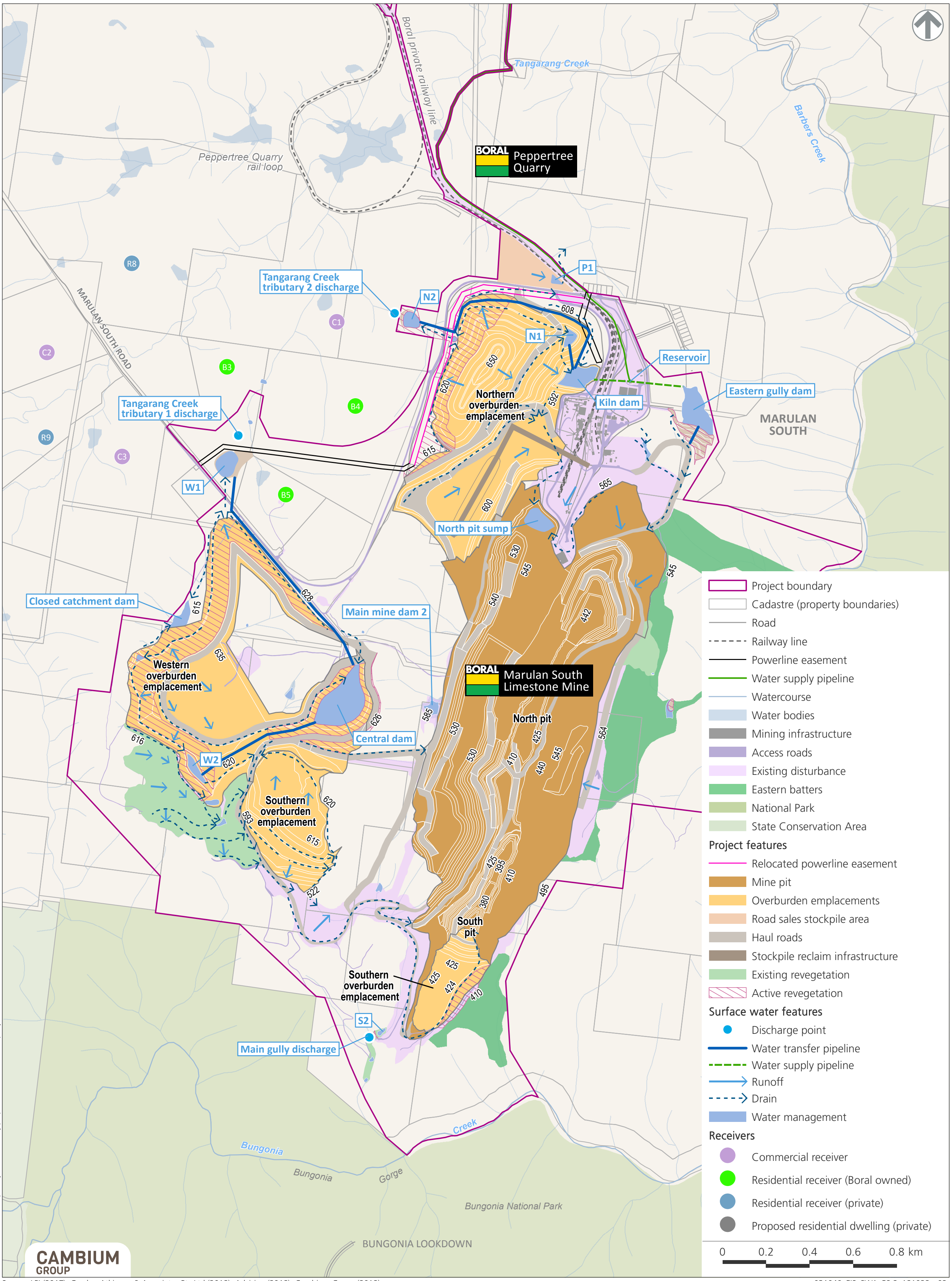


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

031040_EIS_SWA_F6-1_181022_v02

Figure 6.2
Indicative mine layout - Stage 1

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

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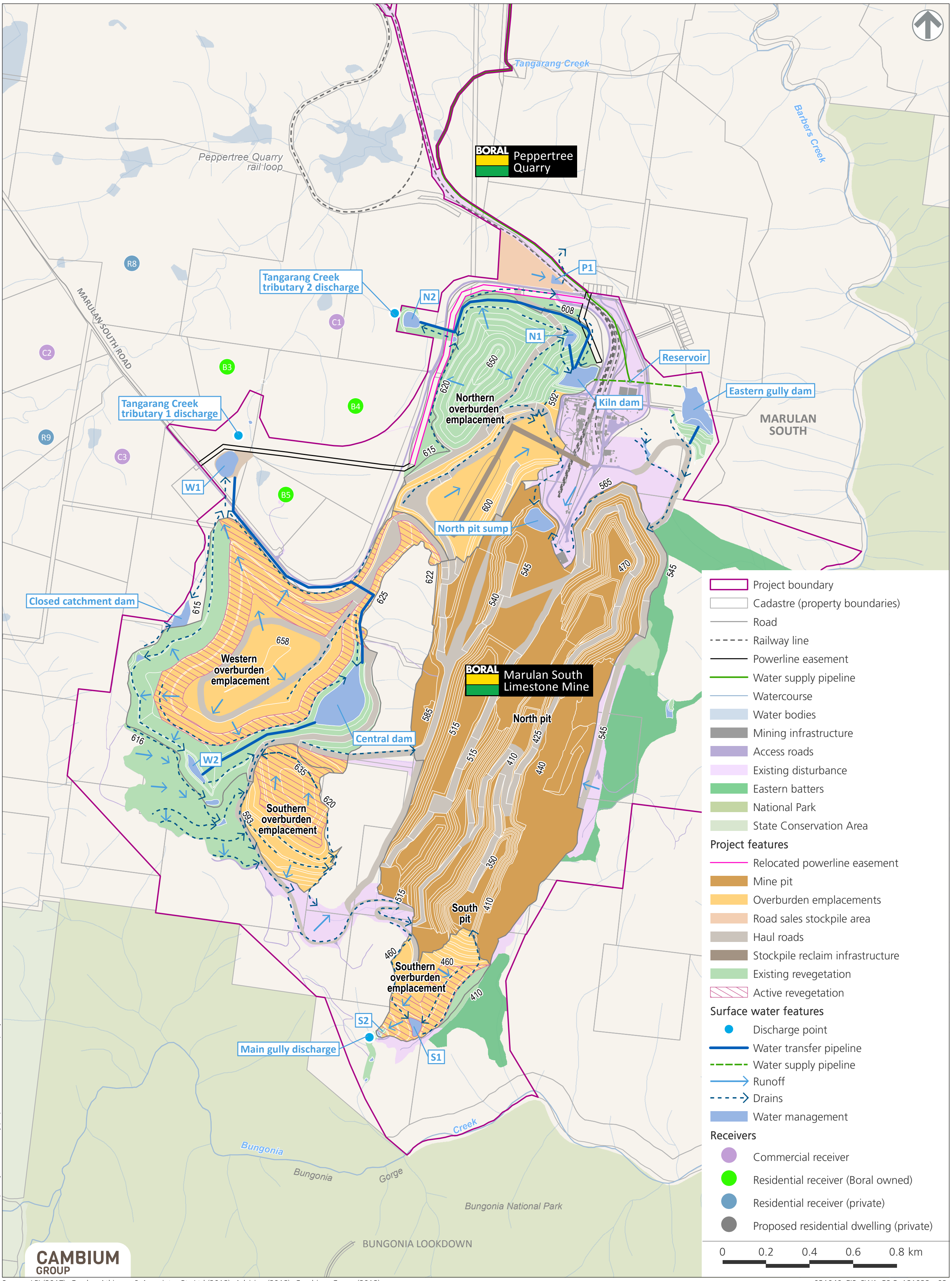
Figure 6.3
Indicative mine layout - Stage 2

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

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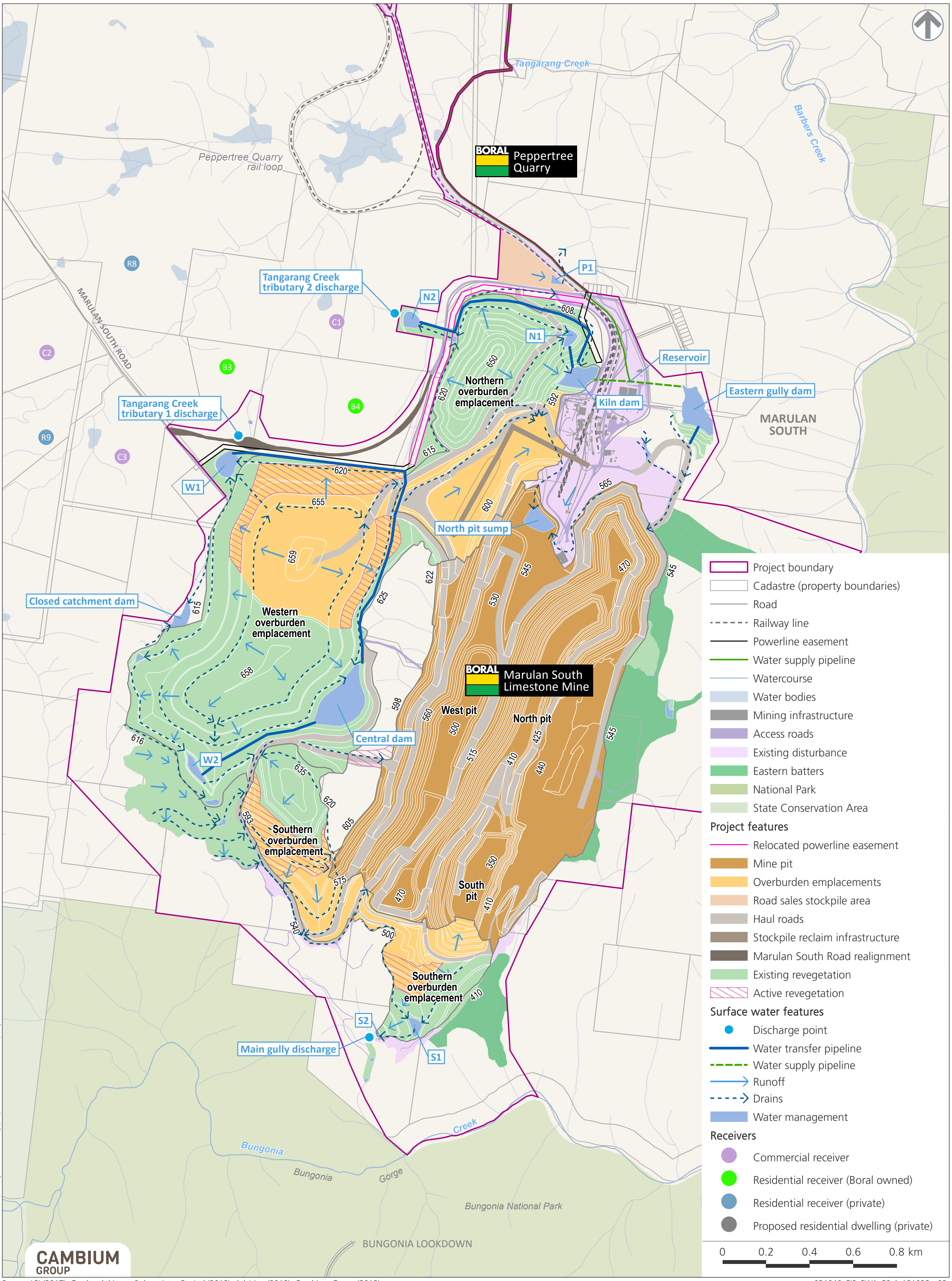
Figure 6.4
Indicative mine layout - Stage 3

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT

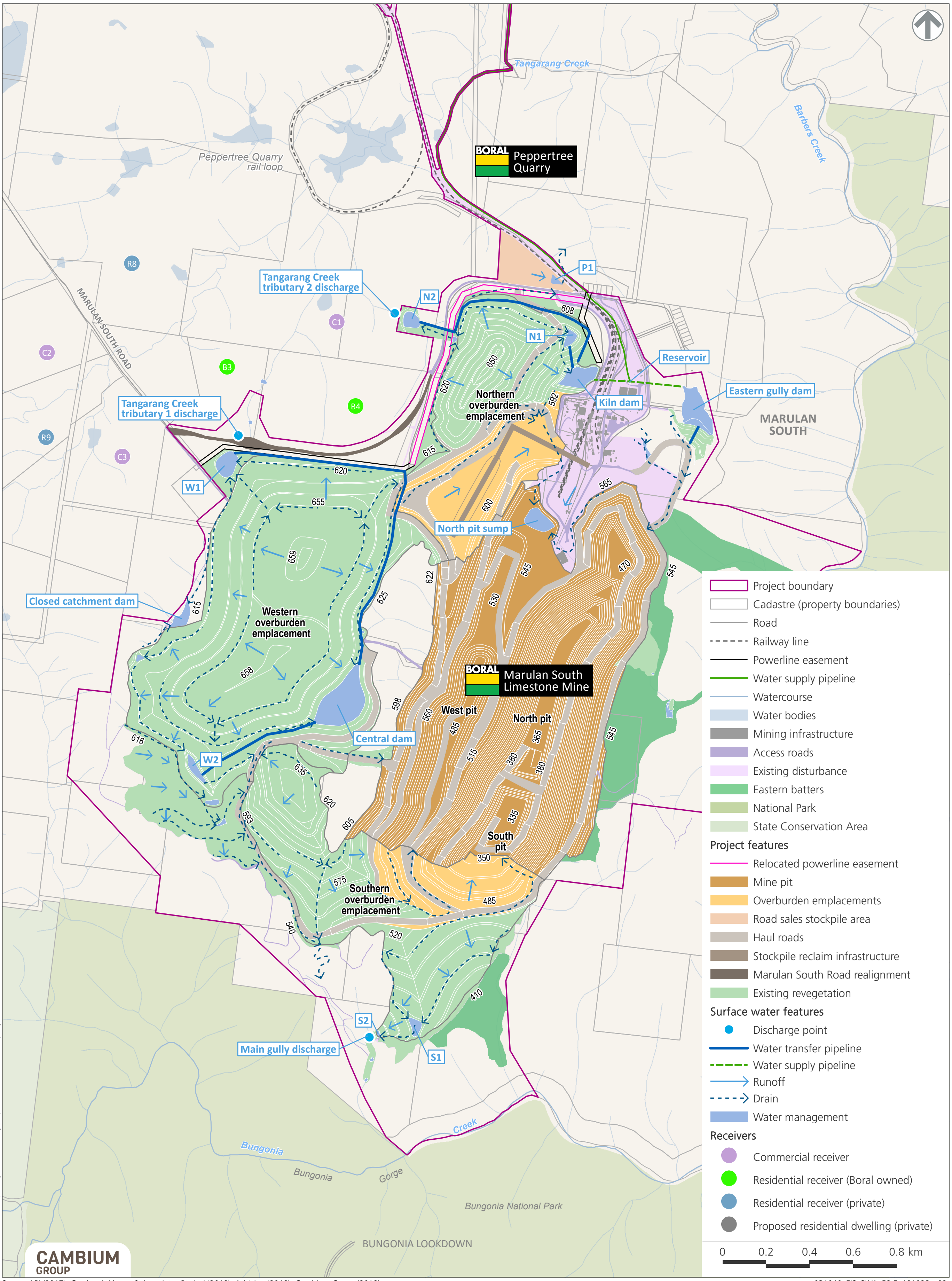


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

031040_EIS_SWA_F6-4_181023_v02

Figure 6.5
Indicative mine layout - Stage 4

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



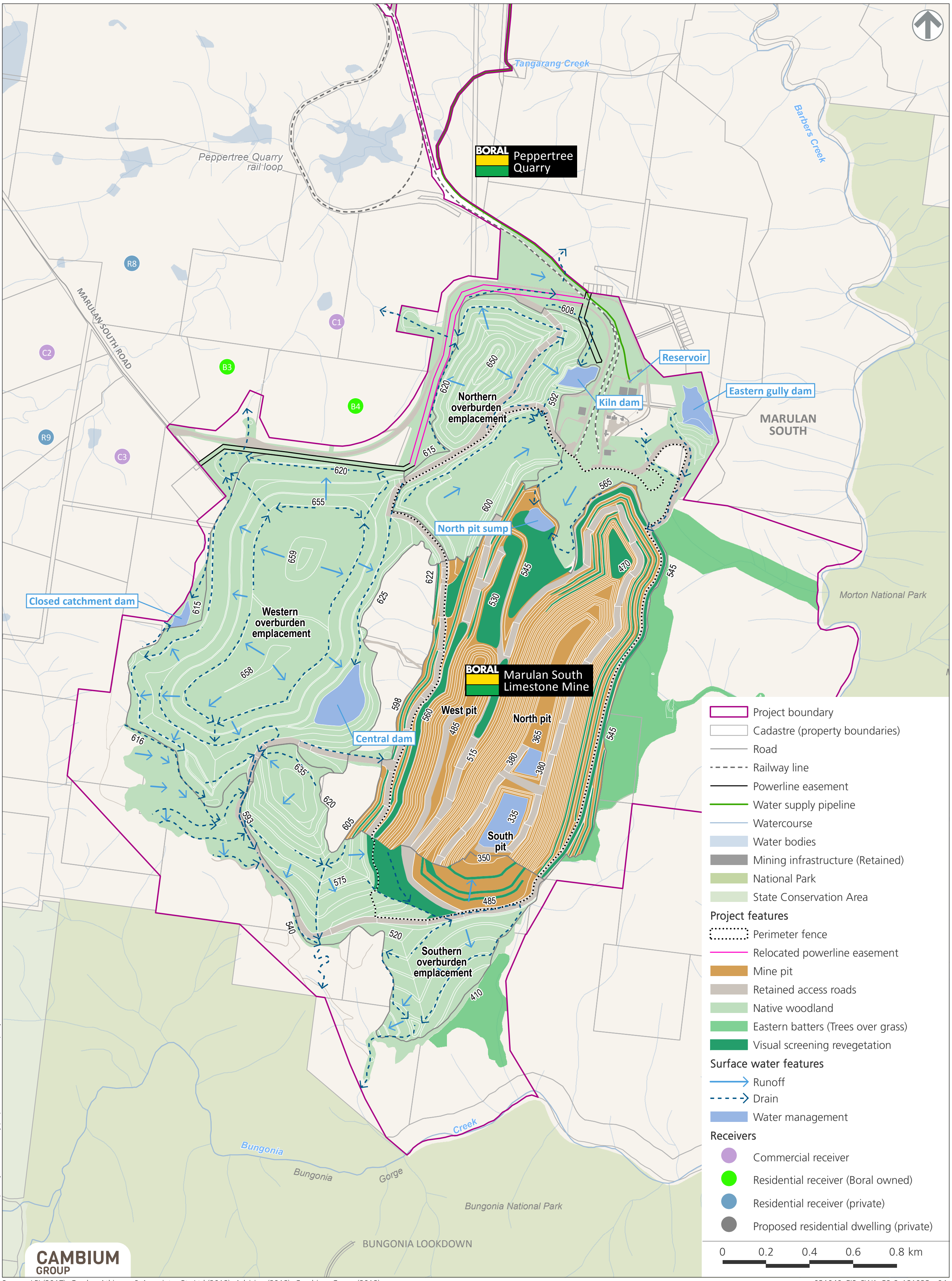
CAMBIUM GROUP

Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

031040_EIS_SWA_F6-5_181023_v02

Figure 6.6
Final landform

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

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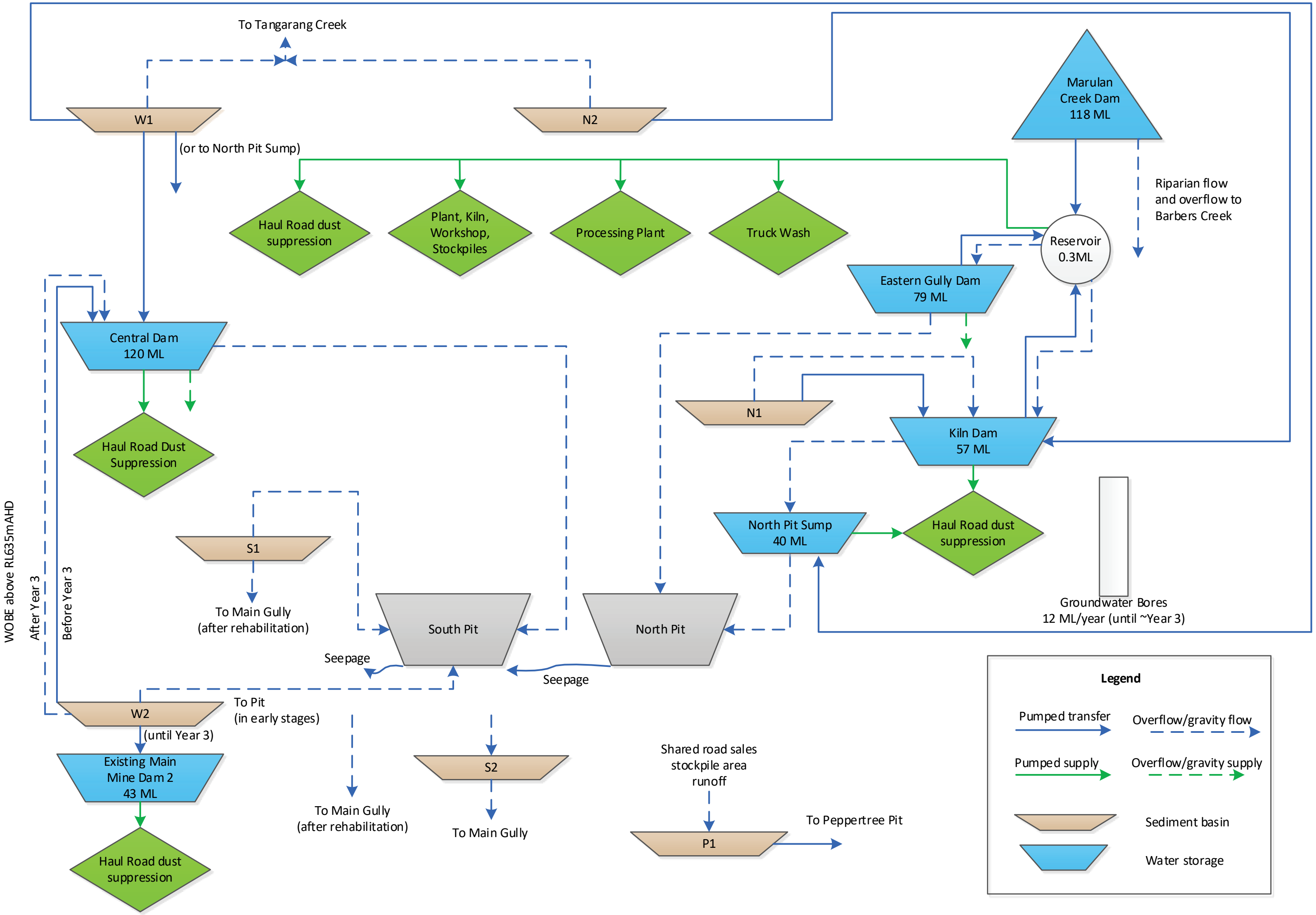


Figure 6.7: Water Management System Schematic

6.2.4 Water Supply

Currently the site relies on fresh water supply from Tallong Weir of approximately 76 ML/year primarily for 'processing' and, 'other' uses listed in Table 6.6 to supplement the on-site supply for dust suppression purposes from on-site runoff and groundwater bore supply (12 ML/year).

The proposed water management system is designed to maximise the re-use of water transferred from the sediment basins with supplementary supply obtained from the proposed Marulan Creek Dam instead of Tallong Weir.

6.2.4.1 Catchment Areas and Surface Runoff

The surface types within the site that would generate surface runoff that would be captured in the water management system are shown graphically on Figure 6.8 and comprise:

- natural/undisturbed
- completed rehabilitation
- active rehabilitation
- bare spoil/emplacement
- mine pit
- haul roads and hardstand.

The development of the various areas of the mine over the mine life is shown graphically on Figure 6.8. Schedules of annual overburden and limestone production have been prepared by Boral together with the layout of the overburden emplacements corresponding to Stages 1, 2, 3 and 4. Figure 6.8 outlines the indicative composition of the catchment areas which would be discharged to the pit, sediment basins or to the environment during the mine life. The water balance model accounts for year to year changes in the various classes of land surface as set out in Figure 6.8 and the associated changes in runoff characteristics.

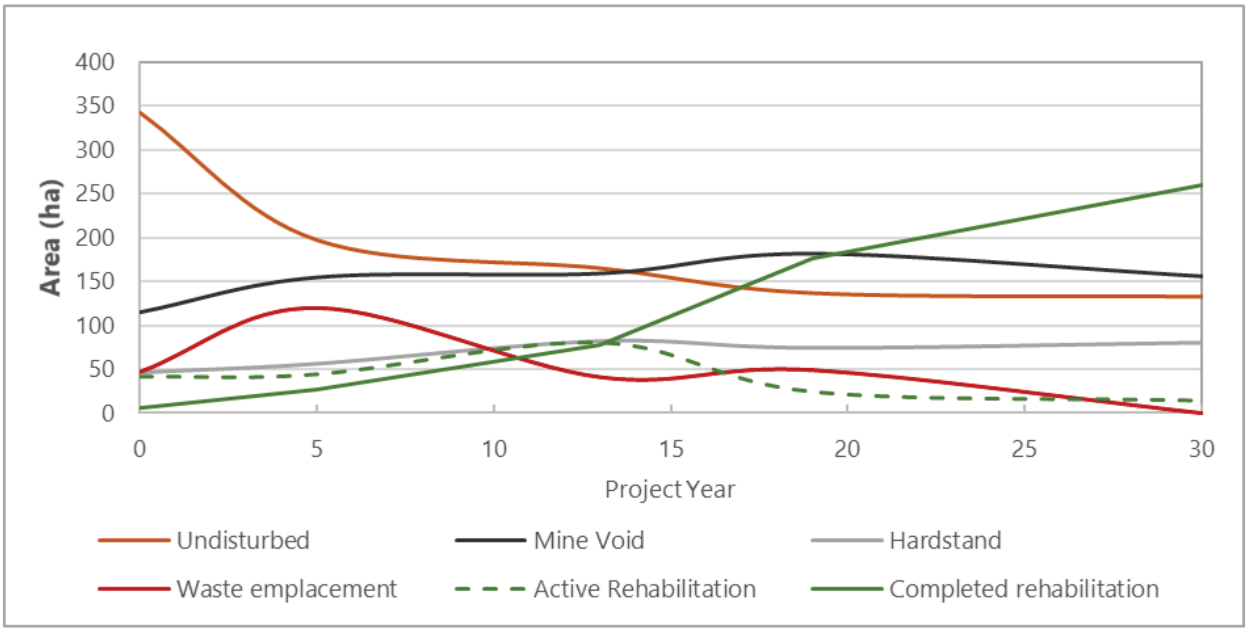


Figure 6.8: Mine development

The AWBM model (described in Annexure D) was used to estimate daily runoff depths from the various land surfaces for input to the water balance model. Further details are provided in Annexure B.

6.2.4.2 Groundwater Inflow

Information on predicted groundwater inflow to the mine workings has been obtained from the *Marulan Groundwater Technical Study*, prepared by AGE (2018). Table 6.3 lists the annual loss from the groundwater model to the mine pit.

Table 6.3: Groundwater Inflows

Mine Year	Groundwater Loss (ML/year)	Mine Year	Groundwater Loss (ML/year)
1	8.78	16	14.00
2	8.87	17	14.06
3	8.99	18	14.31
4	9.16	19	14.62
5	9.27	20	16.44
6	10.27	21	16.96
7	10.78	22	17.47
8	11.26	23	18.02
9	11.70	24	18.58
10	12.20	25	19.07
11	12.68	26	19.78
12	13.15	27	20.42
13	13.52	28	21.13
14	13.80	29	21.76
15	13.89	30	22.91

Source: AGE, 2018

Groundwater inflow is predicted to occur as seepage on the face and base at the northern end of the mine pit. Most seepage inflow will be lost by evaporation from the walls and floor of the pit.

Whenever the pit does not contain water (as a result of runoff from the pit, surrounding catchment or overflows from the water storage and sediment basins), the water balance model assumes that all groundwater inflow would be lost by evaporation. Whenever runoff leads to water being held temporarily in the pit, the model assumes that the groundwater inflows will contribute to the water held in the pit.

6.2.4.3 Seepage Loss from Mine Pits

Because there is a significant gradient on the groundwater table from north to south, the *Marulan Groundwater Technical Study* concludes that any runoff draining to the pit will continue to drain from the southern end of the pit. The pit flooding events that occurred in 2013 and 2015 (see Annexure E) have been analysed by AGE to estimate the following seepage characteristics for the existing mine pits:

- North Pit bulk permeability = 0.5 m/day
- South Pit bulk permeability = 1.25 m/day.

For water balance modelling purposes, the relationships between head and water seepage rate depicted in Figure 6.9 have been adopted based on data provided by AGE.

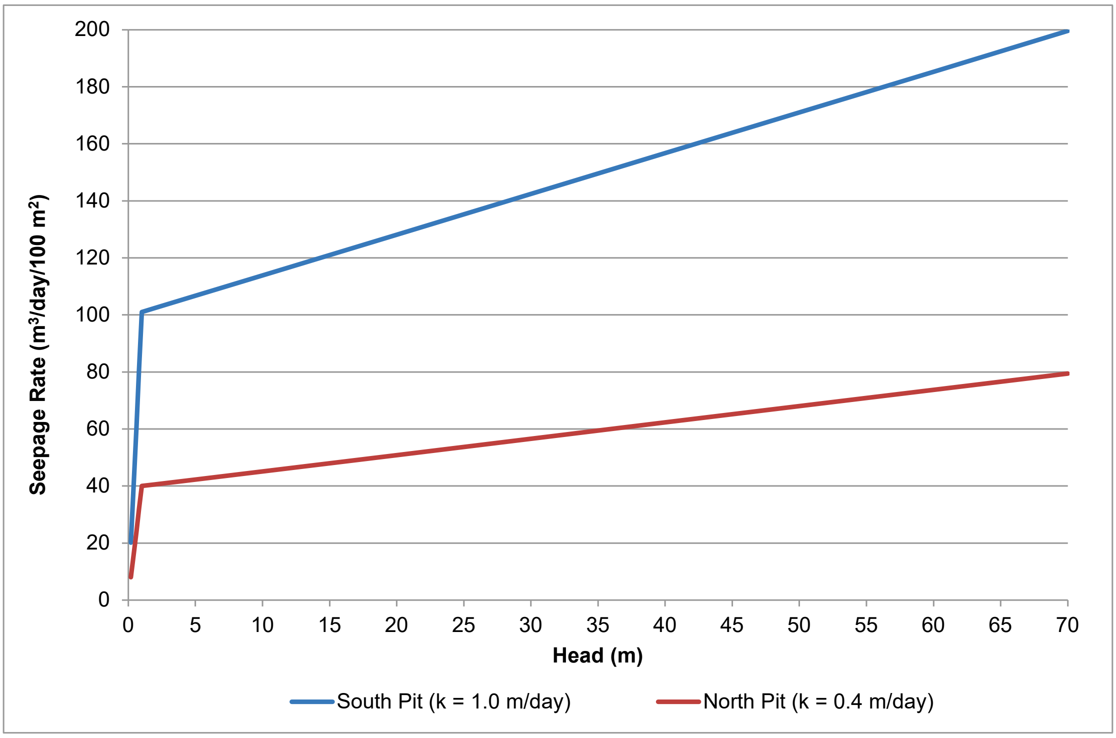


Figure 6.9: Assumed relationship between water depth (head) and seepage rate from the North and South Pits

To account for covering of the pit floor in the South Pit or the possible disruption of the limestone fracture system as a result of mining, the 'effective' seepage area has been conservatively assumed to be 10% of the floor area of the North Pit and 20% of the floor area of the South Pit. This conservative assumption is intended to demonstrate that there would still be sufficient capacity to drain water through pit floor seepage even if the permeability is severely impacted by mining.

Assessment of changes in seepage as a result of overburden emplacement in the southern Pit was completed by PSM in 20018 (Annexure F). The study concluded that, while there was a potential reduction in seepage capacity through the Southern Pit due to placement of overburden may occur, it was unlikely due to the increase in seepage capacity in the North Pit and large seepage capacity in the South Pit.

6.2.4.4 Supplementary Supply

The need for supplementary supply arises because:

- the existing two groundwater bores would most likely run dry in Stage 1 of the Project, if not before, due to the north advancing mine pit

- 'clean' water from Tallong Weir is currently required for the processes identified in Table 6.6, noting that the reliability of the existing supply from Tallong Weir is questionable in the long term
- the significantly increased area of out of pit emplacements involve longer haul roads and therefore require more water for dust suppression.

At present, the Marulan South Limestone Mine obtains licenced supplementary water supply via a pipeline from Tallong Weir. As part of the Project, it is proposed to construct a new dam on Marulan Creek. Licenced supplementary supply would be provided from this source.

For modelling purposes, the proposed capacity of the Marulan Creek dam (118 ML) was based on an assessment of the requirement for supplementary supply, the reliability of supply from different capacity dams, potential measures to reduce water demand and the availability of other potential sources of supply as set out in Section 7.6.

The water balance model separately accounts for all components of the water balance of Marulan Creek Dam including catchment runoff, evaporation and seepage loss, riparian release, supplementary supply to the mine and overflow via the spillway. Releases from Marulan Creek Dam in the water balance model were based on the riparian release rules in the water access licence for the Tangarang Creek Dam, which are provided in Section 8.3 and summarised in Table 6.4.

Table 6.4: Marulan Creek Dam Riparian Release Rules

Upstream Inflow	Downstream Riparian Release
<1 ML/d	= Inflow
1 - 10 ML/d	1 ML/d
>10 ML/d	10% of inflow

6.2.5 Mine Water Storages

The proposed water management system would involve the retention of existing mine water storages, upgrading certain dams to increase their storage capacity and the construction of additional storages, as set out in Table 6.5. Accordingly, the historical practice of directing surface water runoff to the South Pit void (for rapid percolation and filtration) would decrease over time.

Table 6.5: Existing and Proposed Mine Water Storages

Dam	Status	Water Storage Capacity (ML)	Top Water Surface Area (ha)	Comment
Kiln Dam	Existing	25	1.2	Current storage 27 ML, to be upgraded to 57 ML
Main Plant Dam 2	Existing	11	0.2	To be subsumed by Northern Emplacement
Mine Water Dam 1	Existing	12	0.2	To be subsumed by Western Emplacement
Mine Water Dam 2	Existing	43	1.4	To be replaced by Central Dam after Year 3
Central Dam	Proposed	120	2.4	New mine water storage
Eastern Gully Dam	Proposed	79	2.0	New mine water storage
North Pit Sump	Proposed	40	1.1	New mine water storage

6.2.6 Water Demand

6.2.6.1 Processing and other mine uses

Table 6.6 summarises the estimated water demand for mine processing and other mine purposes.

Table 6.6: Estimated Water Demand

Water Use	Demand (ML/year)	Clean Supply (ML/year)	Runoff Supply (ML/year)
Processing			
Hydration and steam loss	20	20	
Kiln cooling	2	2	
Limestone processing	48		48
Sub-total	**70**	**22**	**48**
Other			
Amenities	6	6	
Truck wash	2		2
Maintenance workshops	2		2
Sub-total	**10**	**6**	**4**
TOTAL	**80**	**28**	**52**

Source: Boral

6.2.6.2 Dust Suppression

Water use for dust suppression has been assessed based on changing lengths of haul roads as the mine develops and accounts for day to day rainfall and evaporation. The modelling of water requirements for dust suppression takes account of the water application requirements for "Level 2" control of dust, as specified by the US EPA. "Level 2" dust suppression assumes an application of 2 L/m^2/hour to maintain a moisture content of 3.5% on the working surface. For a notional 10 hour day when water loss could occur because of incident solar radiation and wind, this equates to a 20 mm depth of water application. For modelling purposes, the depth of water application was assumed to be a function of the difference between pan evaporation and incident rainfall, with a maximum of 20 mm/day.

The mine staging plans show a network of haul roads that would provide access around the mine site. The total length of haul roads at the mine is currently 16 km. However, on any particular day, only a few specific haul routes would be active and, therefore, require water for dust suppression. For water balance modelling purposes, haul road data has been interpolated from the mine plans on an annual basis and summarised in Table 6.7. An area of 2 ha of hardstand was assumed to also require dust suppression to account for stockpiles and roads around the processing facility.

Table 6.7: Haul Road distances requiring dust suppression

Year (Stage)	Average Active Haul Road Distance (km)
0 (Stage 1)	7.1
5 (Stage 1)	6.5
13 (Stage 2)	8.3
19 (Stage 3)	6.8
30 (Stage 4)	5

The Air Quality Assessment for the project was prepared by Todoroski Air Sciences. Todoroski Air Sciences (pers com, 2016 and 2018) also undertook an independent assessment of the water requirements to achieve dust control efficiency of at least 80% based on the data inventory in the Air Quality Assessment (specific segment road length, utilisation rate, truck movement numbers, etc) together with average hourly evaporation for each month of the year. The analysis showed that to achieve a control efficiency of around 85% each month, the site would require an average application of approximately 90 ML of water per annum to the haul roads. This is consistent with the findings of the water balance analysis.

6.2.7 Overburden Emplacement Drainage Management

As shown in Figure 1.5 the Project would involve expansion of the North Pit to create a single pit, the construction of overburden emplacements to the north, west and south of the mine pit and back-filling a portion of the existing South Pit. A key requirement for the future management of water at the Project is the control of runoff from the out-of-pit overburden emplacements and the provision of appropriate sediment controls. The proposed overburden drainage system has been designed to convey runoff from the overburden emplacements in a controlled manner and direct the flow to suitable locations for the construction of sediment basins.

The development of the mine would occur in four stages as illustrated in Figure 6.2 to Figure 6.5, which also show the concept drainage scheme for the overburden emplacement areas for each stage of the Project. The figures also show the proposed discharge locations from sediment basins W1, N2 and S2 into Tangarang Creek and Main Gully. The drainage scheme for the final landform is shown on Figure 6.6.

Table 6.8 summarises the historical and concept design post-mining catchment areas for the three points where discharge to the surrounding environment is proposed.

Table 6.8: Overburden Emplacements - Historical and Future Catchment Areas Draining Off Site

Discharge Location	Historic Catchment Area (ha)	Future Catchment Area (ha)
Main Gully (Tributary of Bungonia Creek)	232	186 (136 rehabilitated overburden + 50 natural)
Tangarang Creek upstream of Tangarang Dam	614	664 (93 rehabilitated overburden + 571 natural)

The data in Table 6.8 indicates that the total catchment area draining to Tangarang Creek upstream of the Peppertree Quarry is expected to increase by 50 ha or about 8% of the existing catchment area. The potential impact of this increase in catchment area on flow in the tributary creeks and the operation of the Peppertree Quarry Tangarang Creek Dam is discussed in Section 9.4.

The concepts and assumptions which underlie the overburden emplacements drainage management are provided below.

6.2.7.1 Contour Banks and Channels

A series of contour banks and channels would be used to reduce the slope length of the overburden emplacement batters and to minimise erosion as shown on Figure 6.2 to Figure 6.5. These contour banks and channels would be progressively constructed within the benches of the emplacements. Where possible, the grade of the contour drains shown on Figure 6.2 to Figure 6.5 will be limited to approximately 1%. The actual constructed grade would be identified during the detailed design phase.

6.2.7.2 Rock Lined Chutes

Where 1% grade contour drains cannot fully capture runoff from the emplacement areas, rock lined chutes would be progressively constructed to deliver runoff to the discharge points. During detailed design it may be possible to develop shorter alignments in order to reduce visibility from Bungonia lookout. A consequence of this would be that runoff would need to be conveyed along the contours to the relevant outlet point.

6.2.7.3 Overburden Rehabilitation

Rehabilitation of the overburden emplacement areas would occur progressively. When an area is fully rehabilitated, it is considered that the associated surface runoff from these areas would be ‘clean’, and could be discharged to the environment without further treatment.

6.2.7.4 Drainage from the Western Emplacement

The Western Emplacement is designed to have two large, slightly domed plateau areas on the top draining to both central and perimeter drainage lines as shown in Figure 6.2 to Figure 6.5. An important feature of the concept drainage arrangements for these plateau areas is for a small ridge (~1 m high) to be constructed around the perimeter of the plateau areas to prevent uncontrolled runoff down the batters. The area inside the perimeter ridges would be gradually sloped towards either the central drainage line or rock chute discharge points to permit free drainage. At the point where the drainage line on the plateau reaches the steeper batter slopes, a flow control structure (weir or pipe) would regulate the discharge onto the rock chute that would convey water down the batter. A temporary shallow pond would be formed behind the flow control.

6.2.7.5 ‘Closed’ Catchment to the West of the Western Emplacement

The existing development of the Western Emplacement occurred across a pre-existing drainage line that drained in a southerly direction towards the South Pit (Figure 6.1). The existing catchment upstream of the blocked drainage line has an area of about 40 ha of ‘natural’ land and about 2 ha of overburden. Runoff from this catchment has formed a pond of about 0.7 ha in area where the original drainage line abuts the emplacement. The latest aerial photography indicates that the pond is well established and does not show signs that the water area has varied significantly over time.

Once mining is complete, the catchment draining to the pond is expected to comprise about 17 ha of ‘natural’ land and 7 ha of the batter of the emplacement that is not capable of being drained to the sediment basins to the north or south. Runoff from the final catchment is expected to be about 60% of current (after accounting for increased runoff from the batters) and the pond is likely to reduce in area. However, a semi-permanent water body is expected to persist and provide an opportunity for a small wetland/pond ecosystem to develop.

6.2.8 Sediment Basin Design and Operation

A series of sediment basins are proposed at key locations as shown on Figure 6.2 to Figure 6.5 (designated N1, N2, W1, W2, S1, S2 and P1). These basins would be sized and operated in accordance with the requirements set out in *Managing Urban Stormwater: Soils and Construction* (Landcom 2004).

Specifically, the basins would be operated so as to restore the required 'air space' (settlement zone) within five days of the end of a rainfall event. Water taken from the sediment basins to meet this requirement would be transferred to the water storage dams as shown on Figure 6.2 to Figure 6.5. These storage dams would act as the source of water for site operations including dust suppression and limestone processing.

The indicative water holding capacity of the sediment basins has been determined in accordance with Table 6.1 of *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (DECC, 2008) using the criteria for 'fine' or 'dispersive' sediments. The dams have been sized to capture the runoff from a 95th percentile 5 day storm (52.8 mm) according to the criteria for discharge to a 'sensitive' environment. Indicative sizing of these dams is provided in Table 6.9.

Table 6.9: Indicative Sediment Basin Sizes

Location	Designation	Catchment Area (ha)	Settlement Zone (ML)	Sediment Zone (ML)	Required Volume (ML)
Northern Emplacement (east)	N1	15	5.8	2.9	8.7
Northern Emplacement (west)	N2	16	4.8	2.4	7.2
Western Emplacement (north)	W1	25.5	7.2	3.6	10.8
Western Emplacement (south)	W2	13	5.0	2.5	7.5
Southern Emplacement	S1	25	3.8	1.9	5.7
Southern Emplacement	S2	13	2.7	1.4	4.1
Shared road sales stockpile area	P1	13	5.6	2.8	8.4

The overburden emplacements would be progressively enlarged over time and shaped and rehabilitated on those sections that have been completed. The overburden or waste rock in the emplacements is expected to eventually break down into a fine soil that is assumed to have runoff characteristics equivalent to 'Soil Hydrologic Group D' (as defined in Table F2 of *Managing Urban Stormwater: Soils & Construction,* Landcom 2004) (volumetric runoff coefficient of 0.74).

A small sediment basin (P1) would be provided to treat runoff from the Road Sales Stockpile Area located adjacent to the access road on the northern side of the site. This site would contain stockpiles of crushed limestone and road base products (from Peppertree Quarry). The sediment basin would be designed in accordance with the criteria for 'coarse' sediments as set out in *Managing Urban Stormwater: Soils & Construction* (Landcom 2004).

Proposed erosion and sediment control measures associated with the re-alignment of a section of Marulan South Road are discussed in Section 10.4 while Section 10.3 outlines the proposed environmental management measures that would be employed for construction of the proposed Marulan Creek Dam.

7 Simulated Performance of Water Management System

7.1 Overview

The performance of the water management system over the life of the mine has been assessed using a daily water balance model. Details of the modelling are provided in Annexure B. The water balance model accounts for runoff from the overburden areas and all inflows to and losses from storages. The model includes the progressive changes in the mine as well as taking account of climate conditions (rainfall and evaporation) which govern the runoff from the overburden emplacements and the requirement for water for haul road dust suppression.

The water balance model has been set up to reflect the water management system depicted in Figure 6.7 and to represent the daily inflows and outflows from each of the separate elements of the water management system as the mine evolves.

The water balance model has been configured to assess the effect of climate on the performance of the water management system. The water balance model has been set up to permit an assessment of the risk of water shortfall or discharge at any stage of the mine life. This is achieved by modelling the progressive development of the mine over 30 years combined with 98 climate scenarios representing all the different sequences of 30 years of rainfall represented in the historic climate record.

7.2 Key Modelling Assumptions and Limitations

For water balance assessment purposes, only sources contributing to, or taking water from, the following water storages are considered in the analysis:

- Mine Pit
- Sediment Basins W1, W2, N1, N2 and S1
- Kiln Dam
- Mine Water Dam 2 / Central Dam
- Eastern Gully Dam
- North pit sump
- Marulan Creek Dam.

Key assumptions and limitations associated with the water balance modelling are as follows:

1. The historic climate data for Marulan (George St) (Table 4.1 and Table 4.5) provides an adequate sample of possible climate scenarios during 30 years of mining.
2. The areas of overburden emplacements draining to the various sediment basins and the changes in surface conditions (bare spoil through to fully rehabilitated) as represented in Figure 6.8 provide an appropriate indication of how the mine would evolve.
3. The runoff characteristics of the different land surfaces are appropriately represented by the parameters used in the AWBM runoff model derived from local and published data. Because it is recognised that this aspect of the modelling has the greatest uncertainty, the sensitivity of the model results to under or overestimate runoff characteristics has been assessed (see Section 7.10).

4. Water requirements for limestone processing and other mine purposes are based on similar water use for the existing operation as presented in Table 7.6. The other major water use would be for dust suppression. The modelling of water use for dust suppression assumes that sufficient water would be available to maintain a moist, but not muddy, surface on operating haul roads.
5. All water demands would preferably be met from within the water management system, supplemented with a licensed supply from the proposed Marulan Creek Dam, which would be built during the first 2 to 3 years of the Project.
6. Water retained within each of the sediment basins would be pumped out within five days of the end of a storm to one of the mine water storage dams for subsequent re-use on site.
7. Groundwater seepage into the pit would be lost to evaporation.
8. Excess runoff draining to the mine pit from surrounding catchments, or overflow from sediment basins and water storage dams, would seep into the underlying limestone at rates based on historic observations of flooding in the pits.
9. Data for input to the water balance model is provided in Section 4.1 and Section 6.2.

7.3 Operating Rules

The water balance model is based on the following operating rules:

- water would be taken from the mine water dams as necessary for operational purposes
- supply to the mine water management system from Marulan Creek Dam is assumed to occur at a rate of 0.5 ML/day when the storage in Kiln Dam is less than 47 ML or Eastern Gully dam is less than 70 ML
- All sediment basins would be sized and operated in accordance with the requirements for Type ‘F’ or ‘D’ sediment basins. Within five days of the end of a storm, any water in the sediment basins (up to the design capture volume) would be transferred via a combination of pipeline and drains, pump and gravity fed out of the basins
- Sediment Basin W1 water would be transferred to Central Dam or North pit sump. Any overflow would drain to Tangarang Creek
- Sediment Basin W2 water would be transferred to Main Mine Dam 2 until Central Dam has been commissioned. Until Stage 2 (about Year 11), all runoff from the southern section of the Western Emplacement is assumed to drain to the Mine Pit via the haul road (as occurs at present). Thereafter, overflow from W2 would be directed into a pipeline or channel that would drain to the western tributary of Main Gully which drains to the existing flow and water quality monitoring station in Main Gully. By that time, the area of the Western Overburden Emplacement draining to W2 would be complete and rehabilitated
- Sediment Basin S1 water would be drained by gravity into the South Pit. Any overflow would also drain to the South Pit. Once the Southern Emplacement has been rehabilitated overflows will be directed off site into Main Gully
- water in Sediment Basin N1 would be transferred to Kiln Dam and overflow to North Pit Sump
- water in Sediment Basin N2 would be transferred to Kiln Dam and overflow to Tangarang Creek
- runoff from the catchment areas of the Eastern Gully Dam and the existing Main Mine Dam 2 would drain directly into these dams and, in common with the other water storage dams, water would be taken for local operations (e.g. dust suppression) or transferred to one of the other water storage dams to make best use of the available storage capacity in all the dams. Any overflow from these dams would drain to the Pit

- In the event that the mine storage dams are filled to capacity, any overflow would drain to the Pit.

7.4 Internal Consistency in the Water Balance Model

The internal consistency of the water balance model was compared against three criteria:

1. check that individual total water inputs (e.g. groundwater, rainfall) and outputs (water use for operational purposes) correspond with the source data
2. check the overall water balance for individual storages over the life of the mine to ensure that water is not gained or lost
3. check the overall site water balance for the life of the mine to ensure that water is not gained or lost.

Table 7.1 provides details of the water balance results and verification undertaken for the mine water sources, demand, supply and losses over both the 30 year life of the mine and the average annual results. The data in Table 7.1 is based on the median, dry and wet 30 year historic climate sequences. The data shows that, for all elements of the water balance model, the sum of the water inputs equals the sum of the water outputs. This indicates that the water balance model is internally consistent and that water is not gained or lost.

Table 7.1: Overall Water Balance Check over the Life of the Mine

Demand/Supply Location	Dry 1905-1935 ML	Dry 1905-1935 ML/year	Median 1986-2016 ML	Median 1986-2016 ML/year	Wet 1952-1982 ML	Wet 1952-1982 ML/year
Source						
Rainfall	789	26	1,033	34	1,317	44
Runoff	19,118	637	21,883	729	29,855	995
Marulan Creek Dam	3,363	112	2,947	98	2,678	89
Bore/Tallong Dam	212	7	199	7	247	8
Groundwater inflow	416	14	416	14	416	14
Total	**23,898**	**797**	**26,478**	**883**	**34,513**	**1,150**
Demand						
Dust suppression	3,736	125	3,437	115	3,824	127
Plant demands	2,400	80	2,400	80	2,400	80
Total	**6,136**	**205**	**5,837**	**195**	**6,224**	**207**
Supply						
Reservoir	2,368	79	2,397	80	2,400	80
Kiln Dam	1,372	46	1,023	34	771	26
Central Dam	1,621	54	1,747	58	2,075	69
North Pit Sump	633	21	649	22	881	29
Total	**5,994**	**200**	**5,816**	**194**	**6,127**	**204**
Shortfall (dust suppression)	142	5	21	1	97	3
Losses						
Evaporation – Dams	1,306	44	1,378	46	1,745	58
Evaporation – Groundwater	416	14	416	14	416	14
Sediment basin overflow	176	6	207	7	391	13
Diversion from rehabilitation	83	3	57	2	322	11
Seepage	15,824	527	18,489	616	24,826	827
Total	**17,445**	**582**	**20,100**	**670**	**27,651**	**922**
Change in storage	**93**		**109**		**-31**	
Balance	**0**		**0**		**0**	

7.5 Water Balance Model Results

The water balance model was used to assess water sources, use, losses and change in water storage through the mine life under 98 climate sequences. It should be noted that the results in Table 7.1 only provide a snapshot of the performance of the water management system for three climatic scenarios. A more comprehensive understanding of the performance of the system can be gained from the graphical presentation of the results of the modelling over the mine life. The results provided below are in the form of probability plots showing the likelihood of occurrence of the result over the mine life.

It should be noted that, in the probability plot figures below, the coloured band represents a probability range of occurrence for the result or metric for all of the 98 modelled climate sequences over the 30 year mine life. For example, in Figure 7.1, the coloured band represents the range of annual runoff volumes from the 10th percentile result to the 90th percentile result. The median result is shown as a black line. It should be noted that the plots show the statistical probability of the results and do not correlate to a specific climate sequence, i.e. the black line in Figure 7.1 is the median result for all climate sequences, not the result corresponding to the median climate scenario. Detailed results tables are included in Annexure B.

7.5.1 Water Sources

The main water source for the Project is runoff collected on the mine site in sediment basins and the mine water dams. Runoff during the mine life is approximately 850 ML/year (average), with a range of 279 to 1,685 ML year. Annual median, 10th and 90th percentile runoff over the life of the mine is shown in Figure 7.1.

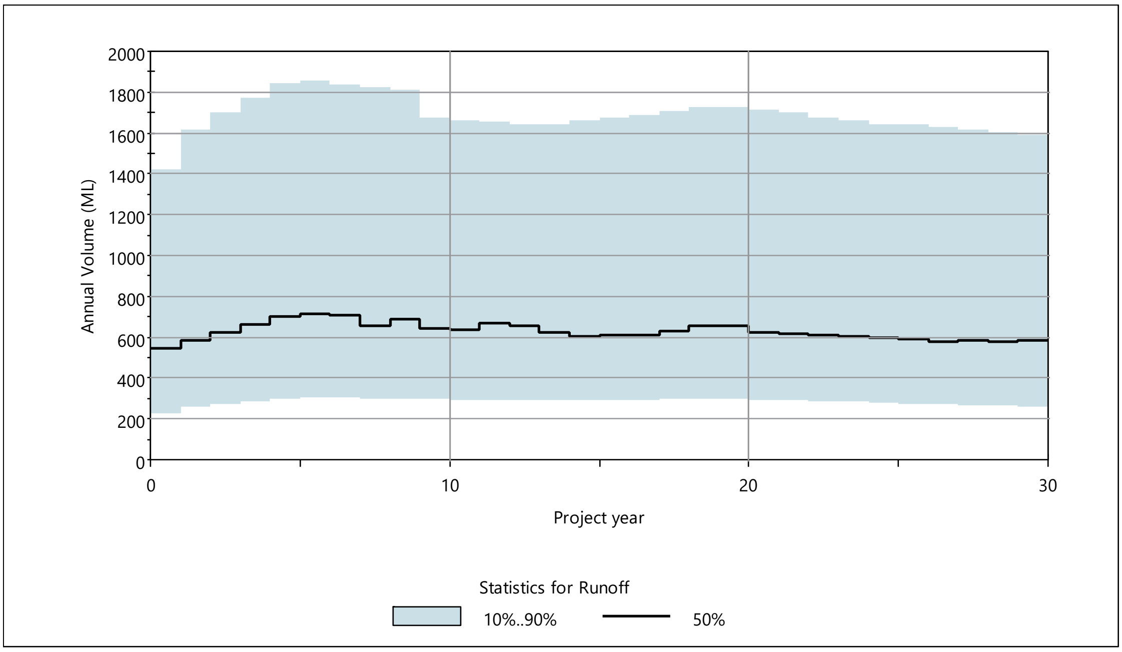


Figure 7.1: Annual Runoff Probability Ranges

A component of the rainfall and runoff collected in sediment dams and onsite mine water dams will be utilised in the site water supply. Over the mine life annual supply from captured rainfall and runoff is approximately 94 ML/year, with a range of 82 to 109 ML/year.

Extraction from the Marulan Creek Dam (Figure 7.2) and Tallong Dam plus the groundwater bore (Figure 7.3) provide additional supply when site runoff is not adequate to supply the site demands. Extraction from these sources is limited by licence conditions.

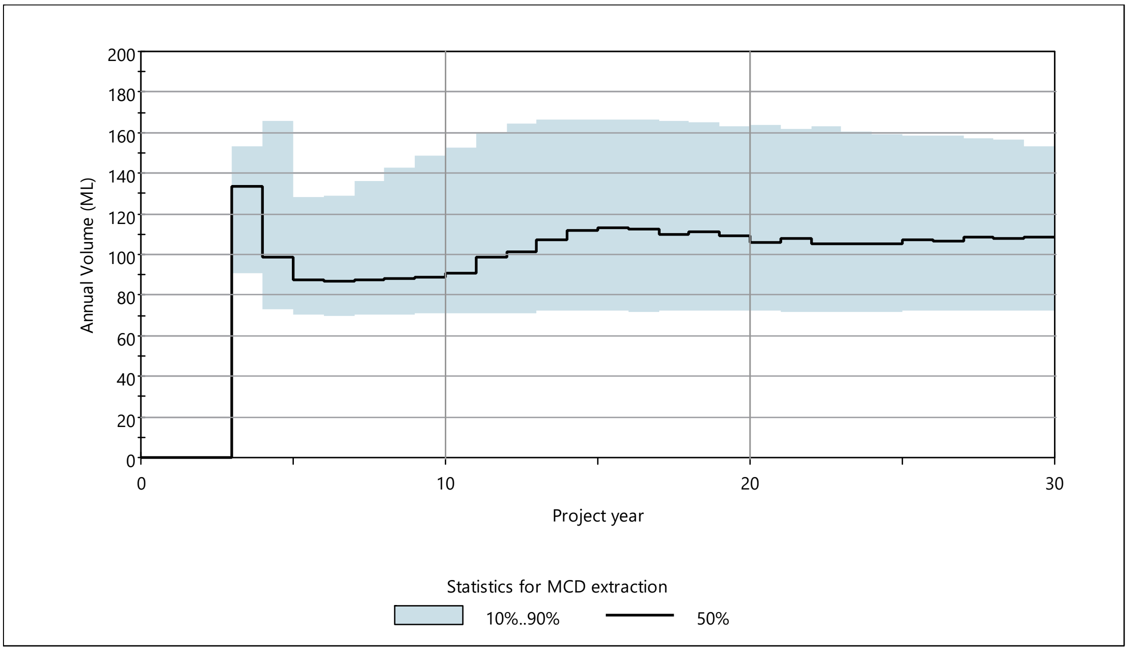


Figure 7.2: Annual Extraction Probability Ranges for Marulan Creek Dam

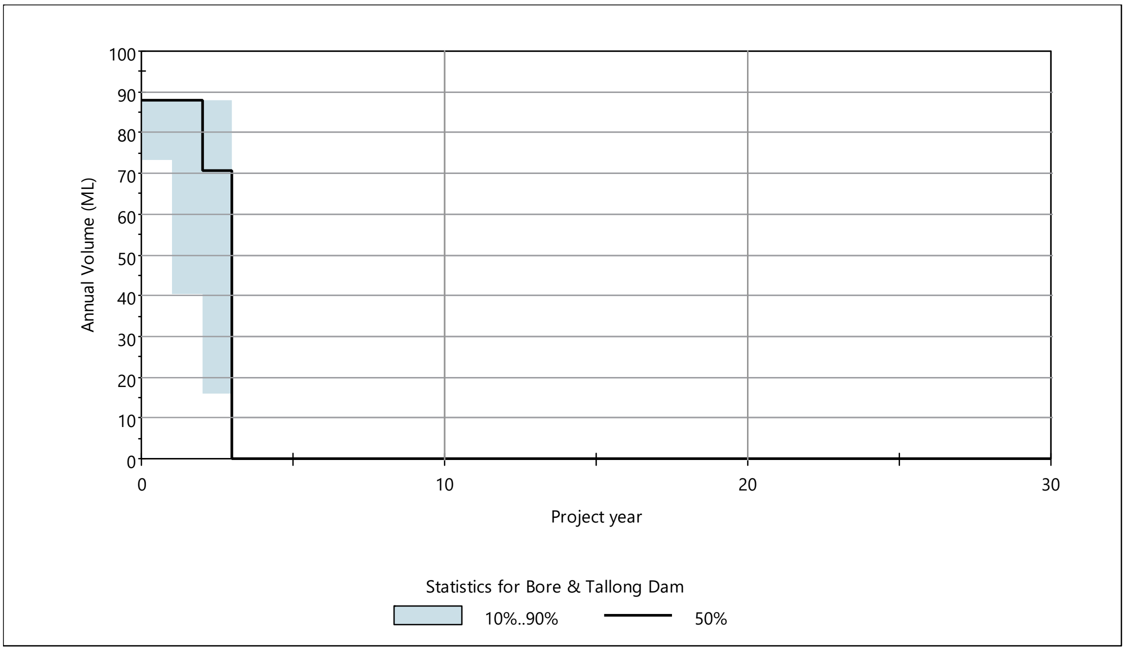


Figure 7.3: Annual Extraction Probability Ranges for the Groundwater Bore and Tallong Dam

Groundwater inflow to the open cut mine pit (Table 6.3) has been included in the water balance, but it does not provide any significant supply as almost all of this inflow would evaporate.

7.5.2 Water Usage

Table 7.1 shows that dust suppression comprises approximately 60% of the total site demand. The demand for water for dust suppression varies through the Project life as shown in Figure 7.4, with variability in the demand related to climatic conditions, i.e. greater demand during dry periods and less during wet. Dust suppression over the mine life is on average 121 ML/year, with a range of 115 to 126 ML/year. Processing demand (Section 6.2.6.1) is constant and is not influenced by climatic conditions.

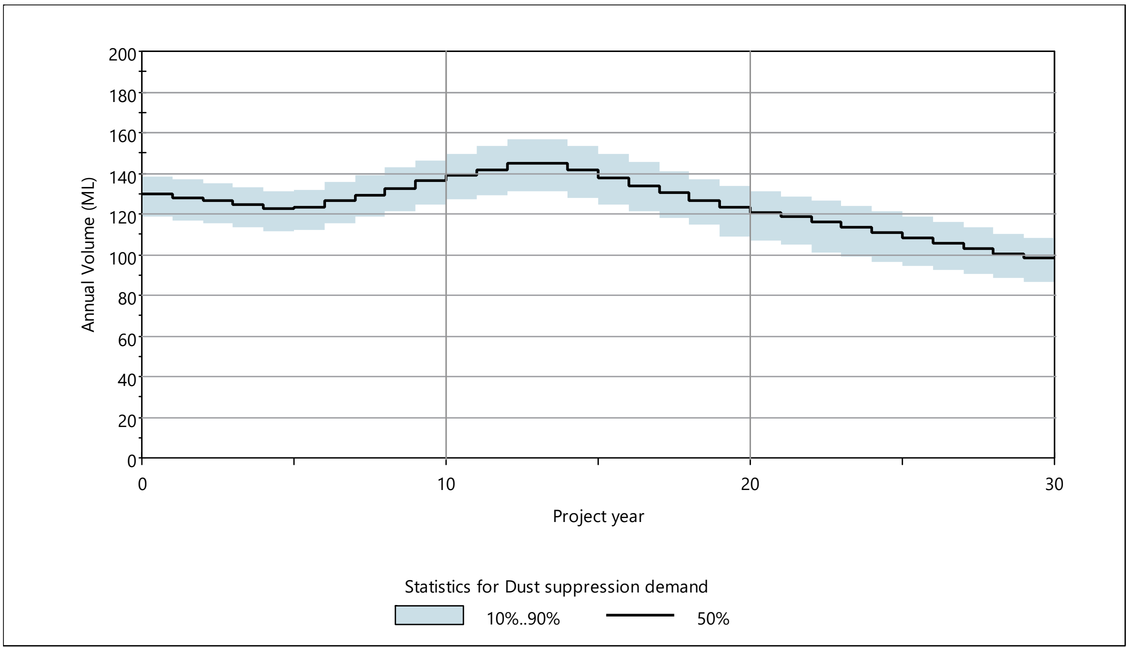


Figure 7.4: Probability of Dust Suppression Requirements

7.5.3 Water Losses

Water is lost from the water management system in the form of seepage from the mine pit, evaporation from the site water storages and overflow (in excess of the design capacity) from the sediment basins. Figure 7.5 to Figure 7.7 show the probability of the volumes of losses from the mine water system over the mine life. The main water loss from the site water system is through seepage to groundwater via the pit (Figure 7.5).

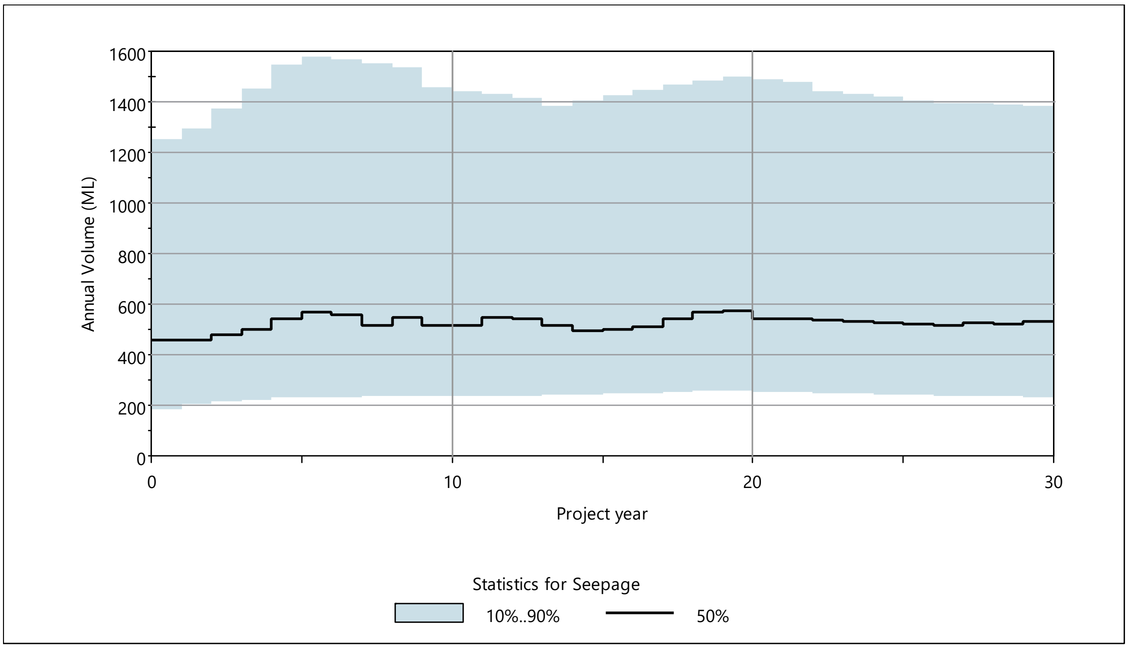


Figure 7.5: Annual Seepage Loss Probability

The variation of evaporation over time from water stored in the sediment basins and water storages is shown on Figure 7.6. Evaporation increases until all of the basins and storages have been constructed and then becomes fairly stable at around Year 14. There is variability in the amount of evaporation each year as a result of the climatic conditions and some uncertainty in the amount of water in storage.

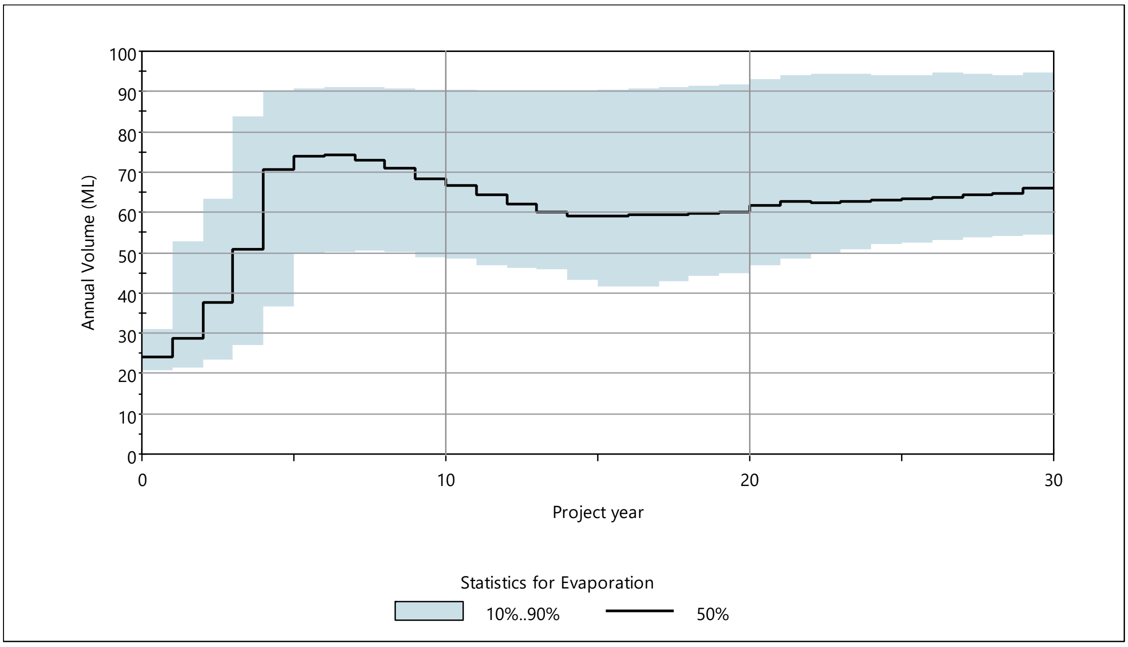


Figure 7.6: Annual Evaporation Loss Probability

Overflow from the system occurs when rainfall exceeds the design capacity of the sediment basins. Sediment basin overflow during the mine life is on average 9 ML/year, with a range of 3 to 19 ML year. Annual median, 10th and 90th percentile overflow volume is shown in Figure 7.7.

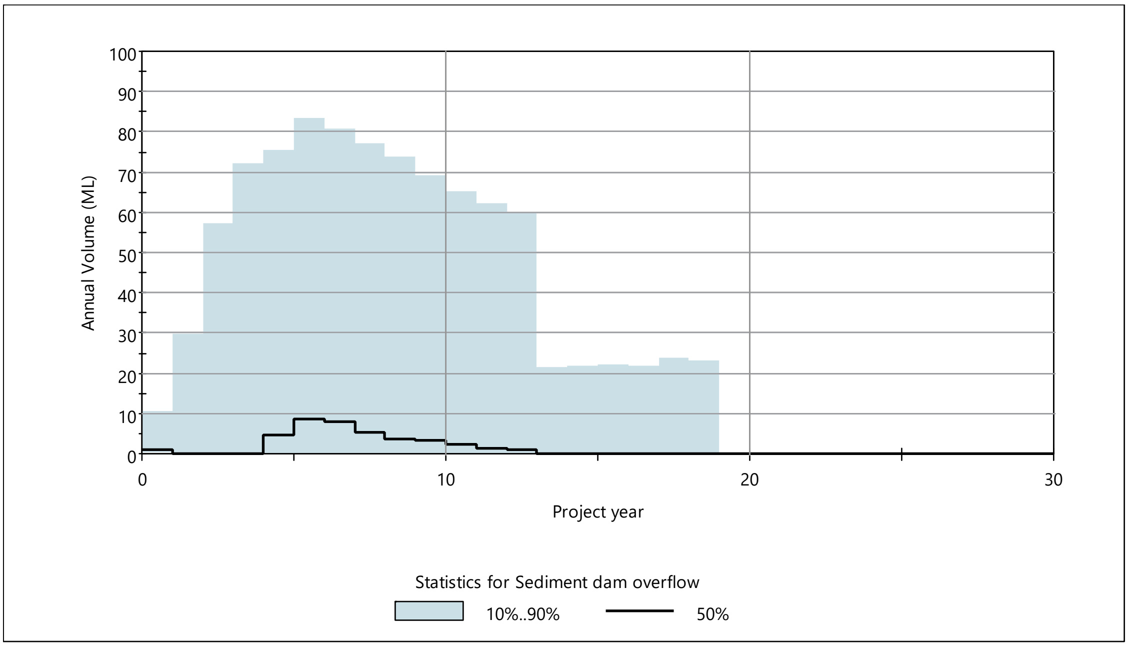


Figure 7.7: Annual Sediment Basin Overflow Probability

7.5.4 Mine Water Storages

The onsite mine water dams will be used to receive water from Marulan Creek Dam and balance the supply of water from runoff and demand for processing and dust suppression. Figure 7.8 to Figure 7.11 show the variability in volume of water storage and extraction throughout the mine life for water stored in the Project water storages.

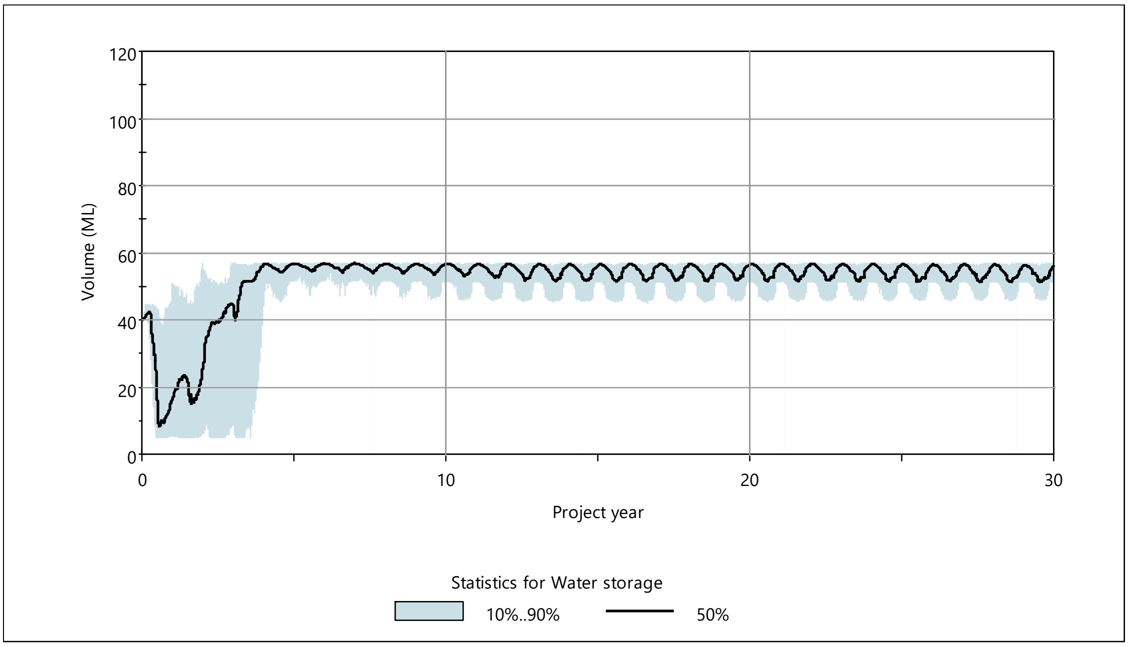


Figure 7.8: Kiln Dam

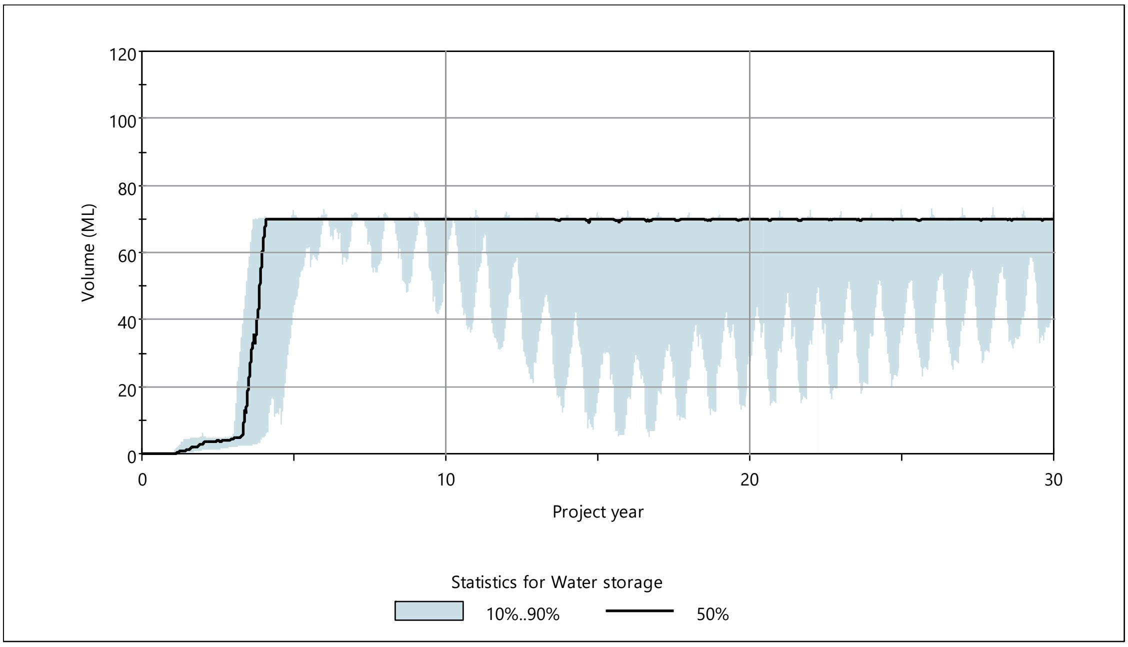


Figure 7.9: Eastern Gully Dam

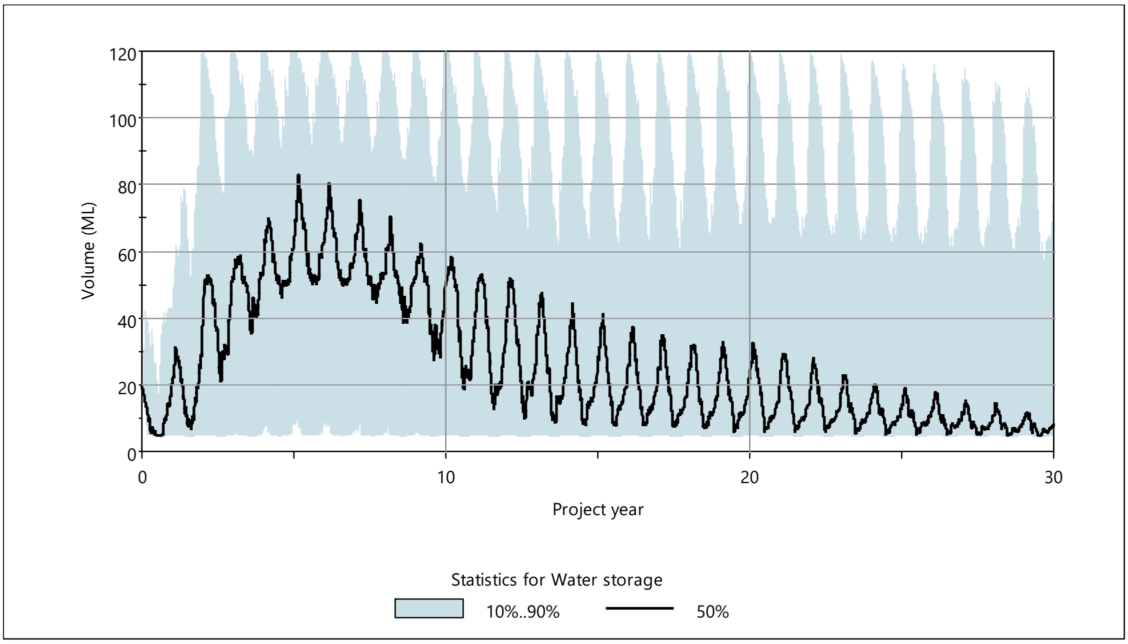


Figure 7.10: Central Dam

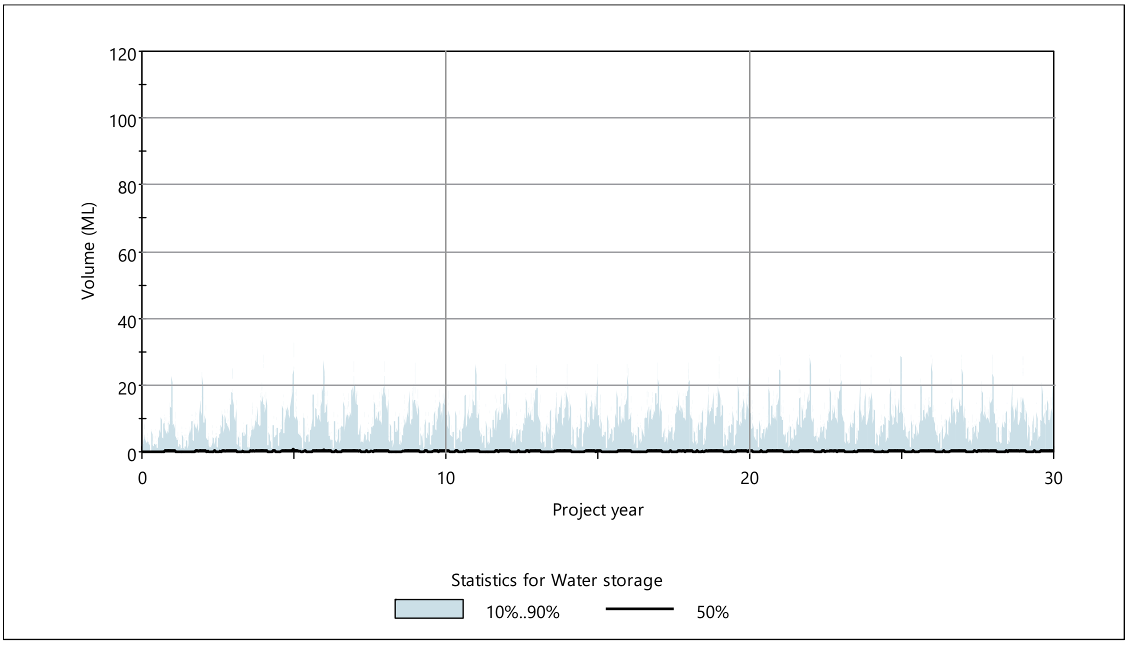


Figure 7.11: North Pit Sump

7.6 Marulan Creek Dam

Figure 7.12 shows that the water volume in the proposed Marulan Creek Dam would be maintained close to full capacity for most of the time, with occasional periods when the water level would be drawn down significantly as a result of the constant riparian release (refer Section 6.2.4.4) and the transfer of water to the mine water management system.

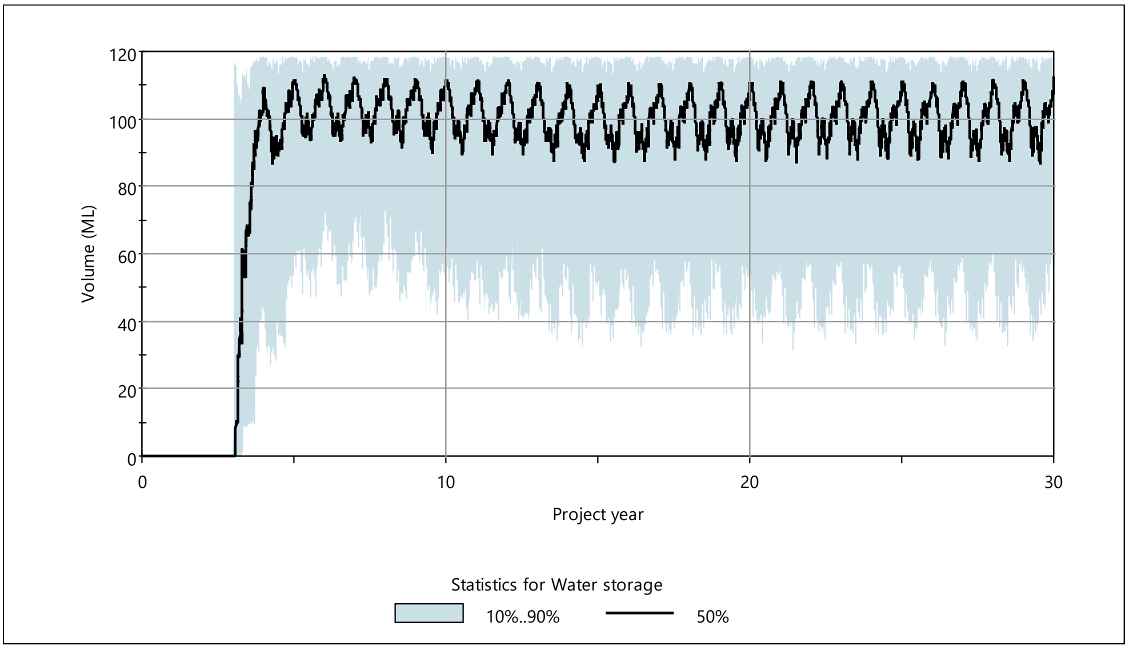


Figure 7.12: Marulan Creek Dam

Table 7.2 summarises the probability of annual extraction volume requirements for external supply from the Marulan Creek Dam at various years in the mine life, as well as the average over the life of the mine.

Table 7.2: Probability of required extraction volumes from Marulan Creek Dam

Year	Volume (ML/year)				
	Average	10th Percentile	Median	90th Percentile	Maximum
1	0	0	0	0	0
5	110	73	99	166	183
13	111	70	101	166	183
19	114	72	111	166	183
Life of mine	98	84	100	109	113

The results set out in Table 7.2 indicate that the average supplementary water supply from Marulan Creek Dam over the life of the mine would be of the order of 98 ML/year with a range of 84 to 109 ML/year. The maximum demand would be 183 ML/year. Without Marulan Creek Dam, there would be significant shortfall in meeting the demands for all purposes which would severely restrict operation of the mine.

7.7 Water supply reliability

Water supply reliability represents the total life of mine supply (for processing and dust suppression) divided by the demands. Average water supply reliability for the 98 simulations is over 95%, with the shortfall probability shown in Figure 7.13.

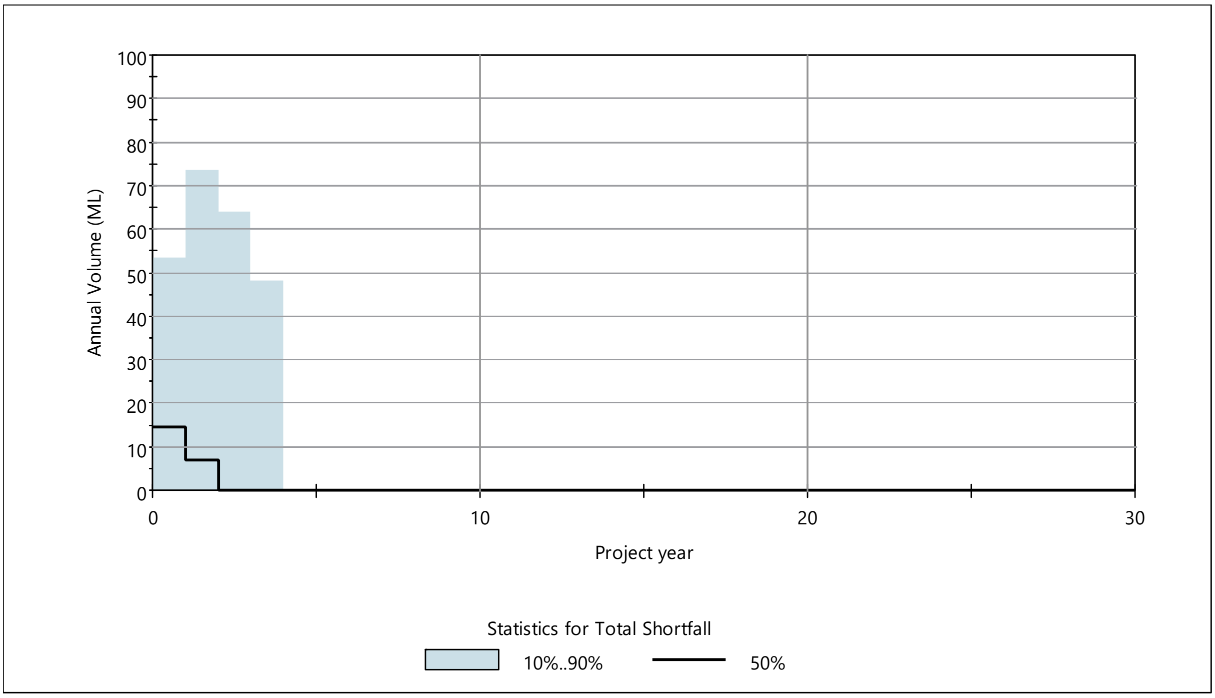


Figure 7.13: Annual Shortfall Probability

Table 7.3 summarises the probability of annual extraction volume requirements for external supply from the Marulan Creek Dam at various years in the mine life, as well as the average over the life of the mine.

Table 7.3: Water shortfall probability

Year	Volume (ML/year)			
	Average	10th Percentile	Median	90th Percentile
1	21	0	15	55
5	3	0	0	0
13	3	0	0	0
19	3	0	0	0
Life of mine	5	0	4	9

The residual shortfall could be covered by purchase of water entitlements from within the Barbers Creek Water Source (total entitlements 1,176 ML/year). Supply to meet peak demand in dry years could be obtained by temporary transfer from other licenced supplies within the Barbers Creek Water Source. Under extended drought conditions, the available supply could also be extended by the use of chemical dust suppressants. The impacts of the use of chemical dust suppressants on the annual external water demand were assessed in the water balance model. For modelling purposes, it was assumed that demand for water for dust suppression would be reduced by 50% when monthly rainfall was less than the 25th percentile, and this would continue until monthly rainfall was greater than the 50th percentile. The model demonstrated that use of chemical dust suppressants could reduce the total external water demand by approximately 40% in some years (average reduction 19% over the life of mine), as water for dust suppression accounts for approximately 60% of the total water demand for the Project.

7.8 Performance of Sediment Basins

Overflow probability from the sediment basins is shown graphically on Figure 7.7. Table 7.4 summarises the performance of the sediment basins over the 30 year life of the mine for median, wet and dry climate sequences. Approximately 18 – 26% of the runoff into the dams would overflow following rainfall events that exceed the design capacity of the sediment basins, depending on the climate sequence.

The frequency of overflow from the sediment basins is predicted to be low. Under the median climate sequence the site would expect 46 days of overflow from the sediment basins over the 30 year life of the Project (an average 1.6 days per year). This frequency is less than the expected frequency (one to two overflow events per year) quoted in Table 6.2 of *Managing Urban Stormwater: Soils & Construction– Volume 2E: Mines and Quarries* (DECC, 2008).

Table 7.4: Sediment basins performance over 30 year life of mine

	Units	10th Percentile Dry 1905-1935	Median 1986-2016	90th percentile wet 1952-1982
Runoff	ML	836	811	1361
Rain	ML	89	105	169
Evaporation	ML	154	147	227
Transfer to mine water dams	ML	486	495	588
Diversion	ML	117	58	322
Overflow	ML	167	207	391
	% inflow	18%	23%	26%
	Days	60	49	87
	Days/year	2.0	1.6	2.9
Change in storage	ML	1	9	2

7.9 Flooding in the Mine Pit during Operations

The water balance model assumes that runoff from the pit itself as well as overflows from the water storage dams and Sediment Basins S1 and W2 would drain to a sump at the base of the mine pit. The sump is assumed to be approximately 5 m deep (below the lowest level of mining) to collect any runoff that reaches the base of the mine. Modelling indicates that during operations on average 583 ML/year will report as surface water flow into the mine void. This includes local runoff from within the pit catchment, direct rainfall and overflow from sediment basins and mine water storage dams.

Figure 7.14 shows the modelled water level in the pit is less than 0.5 m for most of the time, with heavy rainfall causing the pit sump to fill. Extreme rainfall can be expected to cause some flooding of the pit floor, with modelling indicating a maximum water depth of 12.9 m (7.9 m above the pit floor). Due to the high seepage capacity of the pit floor, any water that floods the pit floor is expected to drain away quickly. Importantly, modelling does not show any situations that would lead to long term accumulation of water in the pit.

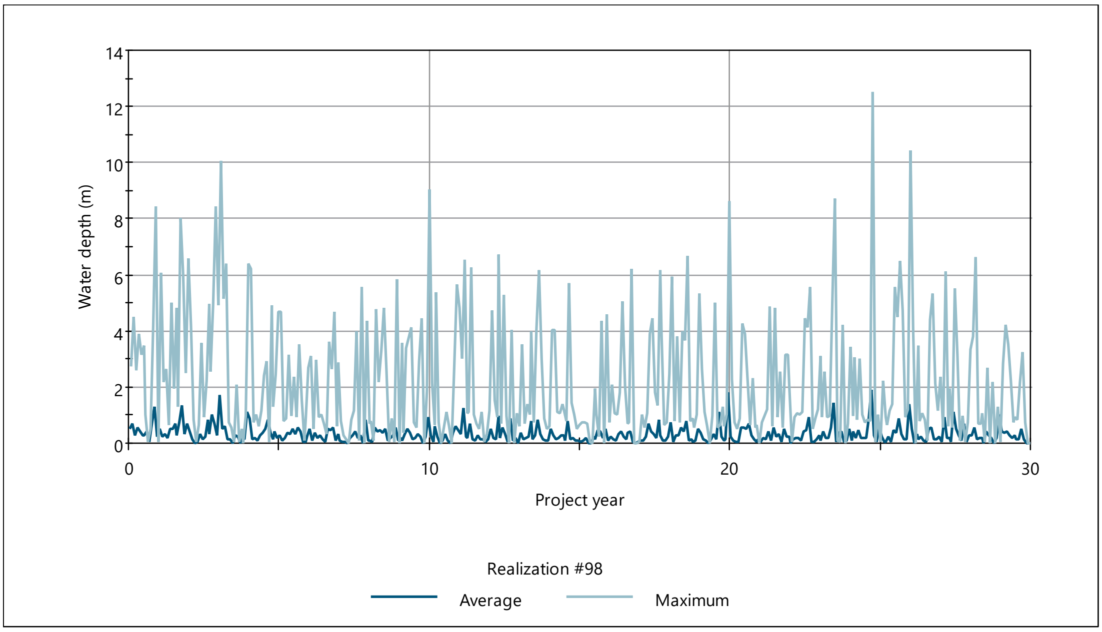


Figure 7.14: Monthly average and maximum water levels in the pit

7.10 Sensitivity Analysis

As shown in Table 4.6, the predicted effects of climate change on median annual rainfall vary from -3% to -1% (with a range of -11% to +7%) in the near term (2030) and -2% to -3% (with a range of -20% to +16%) in the longer term (2090). To account for uncertainties in future climate and runoff the sensitivity analysis has examined the effect of altering the runoff from all land surface types by applying runoff multipliers of 0.8 and 1.2. Table 7.5 identifies the percentage change in the average and maximum supply of water from Marulan Creek Dam and overflows from the sediment basins resulting from the analysis of variation in runoff due to climate change effects.

Table 7.5: Sensitivity of water management system performance to changes in runoff and climate change

Scenario	Climate sequence start year	Runoff Factor	Change in average supply from MCD	Change in max annual supply from MCD	Change in average overflow from sediment basins draining off site	Average Overflow from sediment basins Draining Off Site (days/year)
Median -20%	1986	0.8	-6.5%	0%	-33%	1.3
Median +20%	1986	1.2	+9%	0%	+30%	2.0
Wet -20%	1952	0.8	-3%	0%	-35%	2.4
Wet +20%	1952	1.2	+5%	0%	+33%	3.2
Dry -20%	1905	0.8	-5%	0%	-36%	1.3
Dry +20%	1905	1.2	+6%	0%	+38%	2.2

The noteworthy aspects of the results in Table 7.5 are:

- a change in runoff of ±20% leads to a range in changes in the average supply from the Marulan Creek Dam of -6.5% to +9% for all climatic conditions
- a change in runoff of ±20% leads to an average increase in overflow from the sediment basins by about ±35% for median climate conditions. However, the number of days per year of overflow is still within the expected range as set out in Table 6.2 of *Managing Urban Stormwater: Soils & Construction – Volume 4: Mines and Quarries* (DECC, 2008).

Modelling was also undertaken to assess the sensitivity of the water levels in the mine pit during mining. The analysis showed that increasing runoff by a factor of 1.2 would result in a small increase in the maximum water level from 12.9 to 16 m in the open cut mine pit but generally the water levels remain similar, with no long-term accumulation of water in the pit.

7.11 Operational Water Balance Modelling Conclusions

The water balance analysis presented in Section 7 and Annexure B demonstrates that the proposed mine water management system has sufficient capacity and flexibility to accommodate a wide range of climate conditions whilst:

- providing security of supply for mine operations
- controlling discharge from sediment basins in accordance with the relevant guidelines for discharge to 'sensitive' receiving environments
- containing mine-affected water on-site, with no uncontrolled off-site release from the mine water dams.

Noteworthy aspects of the water management system performance are:

- the proposed water supply system has a high level of reliability over the mine life (greater than 95%), shortfall varies from 0 and 9 ML/year, with an average of 5ML/year
- over the mine life the annual rainfall and runoff captured on the site provides a supply of between 82 and 109 ML/year, with an average of 94 ML/year
- to satisfy the site water demands, water is required from external sources. Over the mine life the average annual volume of supply from the proposed Marulan Creek Dam varies from 84 to 109 ML/year, with a median of 100 ML/year. Peak annual demand is 183 ML/year, which is limited by the pumping rate (0.5 ML/day) from Marulan Creek Dam
- overflow from the sediment basins to Tangarang Creek or Main Gully also varies with climate sequence with a range of 3 to 19 ML/year, and an average of 9 ML/year
- under the median climate sequence frequency of overflow from the sediment basins to Tangarang Creek or Main Gully averages 1.6 days per year, which indicates that the sizing and operation of the sediment basins is consistent with the requirements of Table 6.2 in *Managing Urban Stormwater: Soils & Construction, Volume 2E – Mines and Quarries* (DECC, 2008)
- the volume of water required for dust suppression shows little variation between different climate sequences with a range of 115 ML/year to 126 ML/year, with an average of 121 ML/year.

The water balance analysis shows that a peak demand of about 183 ML/year would be required to supplement runoff from within the Project. This supply would be provided by the proposed Marulan Creek Dam. Boral currently holds a water access licence for 76 ML/year from Tallong Weir. Boral would seek to acquire sufficient licenced water entitlements from within the Barbers Creek Management zone (total surface water entitlements 1,176 ML/year) to account for water extraction from the proposed Marulan Creek Dam.

Water usage for dust suppression on haul roads and around the limestone processing facilities could be reduced to 50% of normal usage by the use of chemical dust suppressants. This would reduce the overall site demand by at least 30% or about 65 ML/year. Therefore, the mine has a range of options to ensure that it does not run the risk of running out of water during an extreme dry year or sequence of years.

7.12 Post Closure Mine Water Management

A separate water balance model has been prepared to assess the water balance of the water management system as a whole and the remnant void in particular (refer Annexure B). The post-closure water balance analysis assumes that:

- all sediment and water storage dams that drain to the mine pit would remain but would only be subject to evaporation and seepage losses, with no water extracted for operational purposes
- all sediment and water storage dams that drain to Main Gully would either be rehabilitated or form part of the post closure land use. If retained, any runoff overflow from these dams or basins would drain off-site
- all sediment and water storage dams that drain to Tangarang Creek would be retained as detention storages to regulate discharge and to minimise any impact resulting from increased peak flow rates
- outflows from the system would comprise:
  - runoff from the rehabilitated emplacements draining to Sediment Basins W1 and N2 and then to Tangarang Creek
  - runoff from the rehabilitated emplacements draining to the original locations of Sediment Basins W2 and S2 and then to Main Gully
  - overflow from all other dams in the water management system to the remnant mine void
  - seepage loss from the base of the mine void
  - riparian flow and overflow from the Marulan Creek Dam to Marulan Creek
- the components of the water balance in the remnant mine void would comprise:
  - runoff from the pit itself
  - runoff from the section of the Southern Emplacement that drains direct to the mine void (38 ha)
  - runoff from areas surrounding the pit that do not drain to a water storage or sediment basin (32 ha)
  - groundwater inflow of approximately 9 ML/year (additional information provided by AGE to the *Groundwater Technical Study* [AGE, 2018])
  - seepage from the overburden of the section of the Southern Emplacement overlying the footprint of the South Pit (15 ha)
  - overflows from various dams draining to the pit
  - seepage loss is assumed to occur from the surface area of the ponded water.

The post-closure water balance assessment also included an assessment of the post closure flow regime compared to the pre-mining regime. This analysis (see Annexure B) takes into account the changes in the catchment area as well as the anticipated increase in runoff from rehabilitated overburden emplacements compared to pre-mining natural conditions.

7.12.1 Post Closure Flooding in the Mine Pit

The model results show that on average 466 ML/year of runoff would report to the mine void. The mine void would have minor quantities of water in the base and would, on rare occasions, hold water up to 13 m deep as a result of rainfall runoff in the pit, overflow from the remaining mine water dams and direct rainfall. However, all water entering the pit would be lost by seepage and the water levels would not lead to any risk of overflow from the void.

Table 7.6 lists the percentage contribution of various sources of water that comprise the water held in the mine pit and shows that runoff from the pit itself and the immediate surrounds (including the Mine Infrastructure Area) constitute 98.7% of the average inflow. Accordingly, redirecting overflow from water storages or sediment basins would not significantly affect flood depth in the pit.

Table 7.6: Contributions to Water in the Mine Pit

Source of Water	Percentage Contribution
Runoff from the pit and uncontrolled catchments	98.7%
Direct rainfall onto the water surface	1.0%
Overflow from Mine Water Dams	0.3%

Modelling was also undertaken to assess the sensitivity of the water levels in the mine pit following completion of mining. The analysis showed that increasing runoff by a factor of 1.2 would result in a small increase in the maximum water level in the open cut mine pit from 13 m to 15.5 m but generally the water levels remain similar, with no long-term accumulation of water in the pit.

7.12.2 Main Gully

The pre-mining catchment of Main Gully contained about 232 ha of natural catchment. The long-term average annual flow is about 122 ML/year. For post-mining conditions, the catchment will be restored to an area comparable to pre-mining conditions (see Table 6.8) and will include about 136 ha of rehabilitated land. The post-mining average annual flow in Main Gully (102 ML/year) is predicted to be comparable to pre-mining conditions (122 ML/year).

7.12.3 Tangarang Creek

In the case of Tangarang Creek, there is an increase in the catchment area of 50 ha or about 8% of the existing catchment draining to the water supply dam for Peppertree Quarry. The change in the catchment runoff characteristics of the areas of overburden emplacement are predicted to lead to an increase of about 9% in the average annual flow into the dam, but have negligible impact on the daily flow regime, as shown in Figure 7.15. The sediment basins at the point of discharge to the tributaries of Tangarang Creek would be retained and would be configured to act as detention basins to ensure that peak flows from the basins are not significantly increased compared to existing conditions.

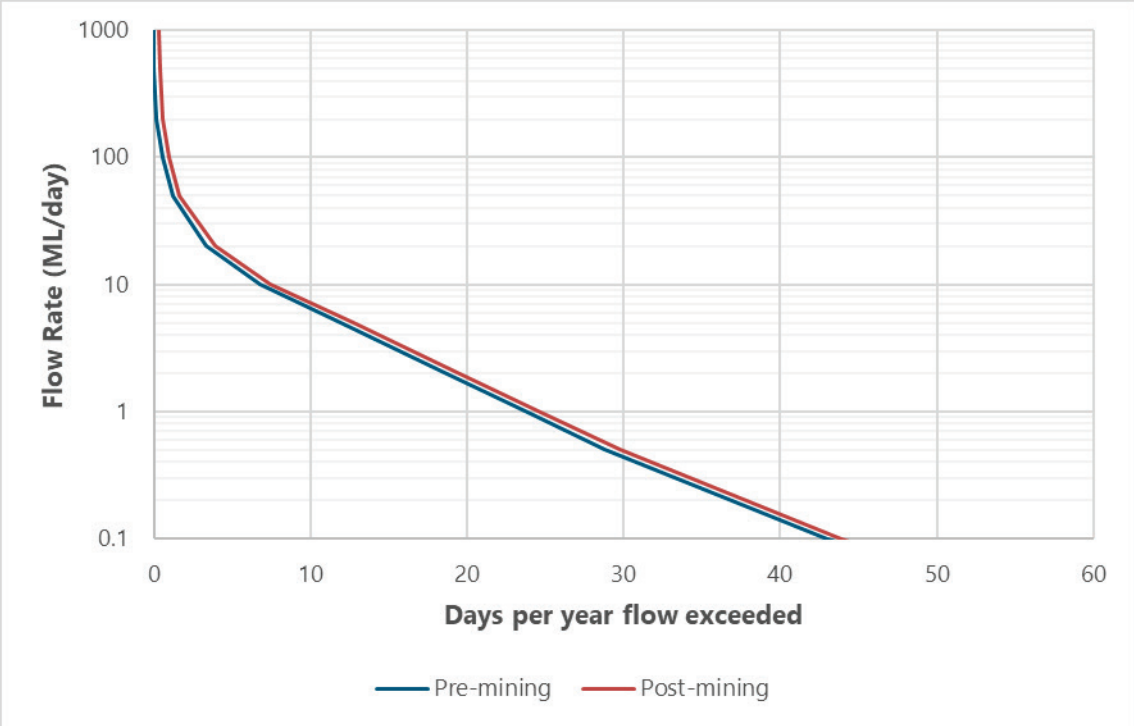


Figure 7.15: Pre- and Post-Mining Flow Regime in Tangarang Creek

8 Marulan Creek Dam

8.1 Concept Design

As shown by the analysis in Section 7.6, operation of the limestone mine and processing facilities requires additional water to supplement the supply available by collection and re-use of runoff from the overburden emplacements. For the Project Boral wishes to establish its own supplementary supply by constructing a dam on Marulan Creek as shown on Figure 8.1.

It is proposed to adopt a homogeneous earth fill dam with a crest level at 600 m AHD, full storage level at 597 m AHD, full storage capacity of 118 ML and embankment batter slopes at 2.5H:1V. The width of the spillway has been designed for the estimated 1% AEP design peak flow for the Marulan Creek Dam catchment (120 m^3/s) (PSM, 2016).

The existing Peppertree Quarry dam on Tangarang Creek maintains environmental flows to prevent any potential impacts upon downstream ecology. Boral has committed to environmental flow releases equivalent to 10% of average daily flows, in addition to spills during flood events from the Peppertree Quarry dam (ERM, 2006). The Marulan Creek Dam has been designed to comply with similar requirements for environmental flows. The adopted riparian release rules from Marulan Creek Dam for purposes of the water balance model are provided in Table 6.4.

8.2 Hydrologic and Hydraulic Assessment

There are no stream gauges on Marulan Creek which would allow direct analysis of the existing flow regime and to assess the impact of the dam on the existing flow regime. The nearest gauges, other than the Shoalhaven River which has very different flow characteristics, are located on Bungonia Creek and Kialla Creek. Details of these gauges which are provided in Table 8.1 show that the catchment areas are significantly larger (164 km^2 and 96 km^2 respectively) than Marulan Creek (about 20 km^2) and have relatively short periods of record (21 and 26 years respectively).

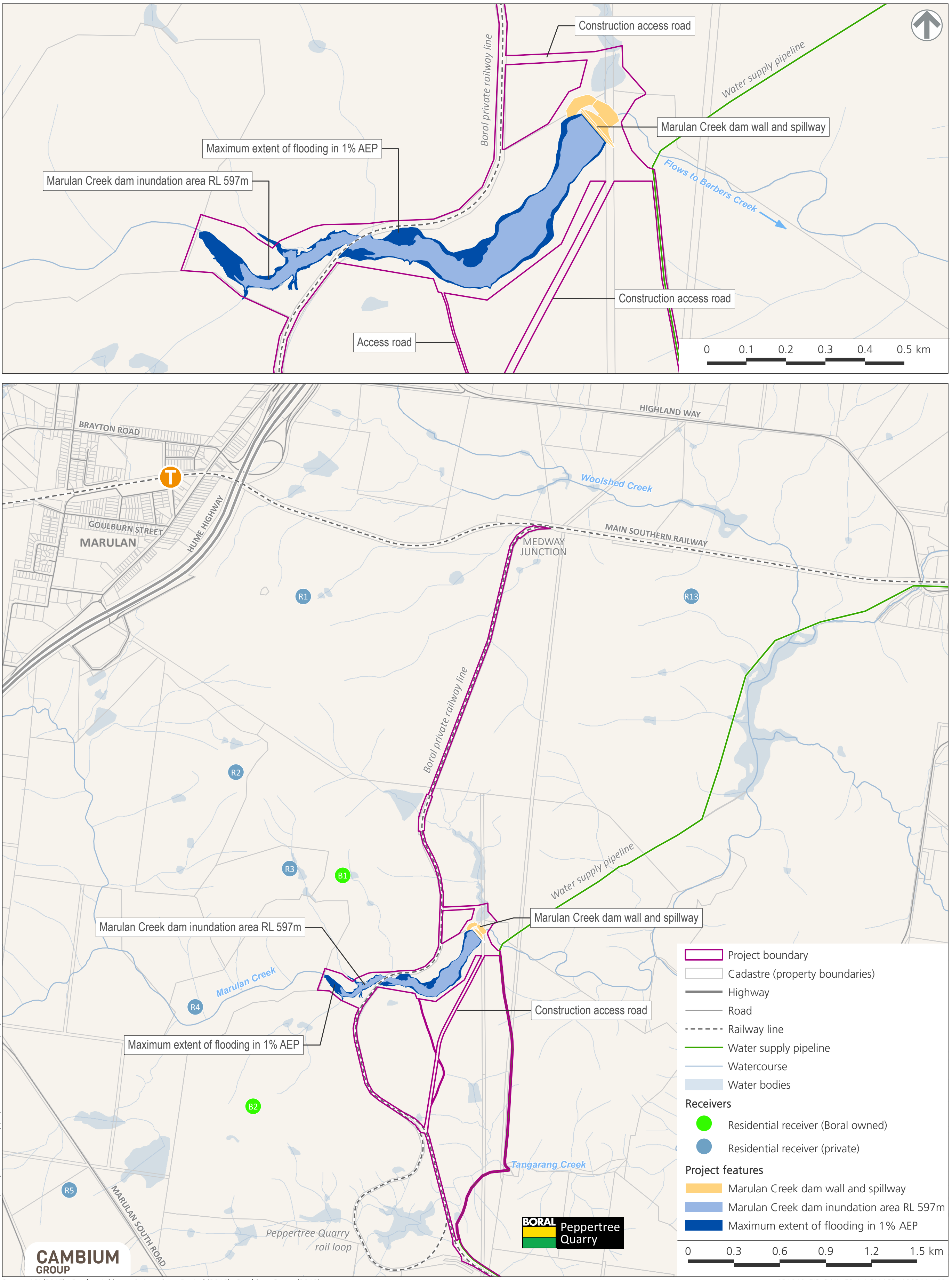
In order to assess the long-term flow regime in Marulan Creek, and the potential impact of the proposed Marulan Creek Dam, daily flow has been modelled using runoff parameters derived from the flow records listed in Table 8.1 together with the climate record described in Annexure D. The Australian Water Balance Model (AWBM) has been adopted for modelling. Details of the model calibration process and generation of a daily flow sequence for input to the water balance model is described in detail in Annexure D.

Table 8.1: Stream Gauges Used for Estimating Flows in Marulan Creek

Gauging Station Name	Bungonia Creek at Bungonia	Kialla Creek at Pomeroy
Gauging Station Number	215014	212040
Catchment Area (km^2)	164	96
Start Record	1981	1979
Complete Years of Record	21	26
Location Relative to Project Area	12 km south	43 km north-west

Figure 8.1
Location and general layout of Marulan Creek dam

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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Modelled flow has been included in the site water balance analysis discussed in Section 7 and accounts for:

- supplementary water supply for the operation of the Project
- riparian releases to maintain downstream flow (in accordance with the release rules in Table 6.4).

Flow duration curves produced by the water balance model for natural and regulated flow (as a result of the proposed dam) in Marulan Creek are shown on Figure 8.2. The modelled natural flow exhibits flow characteristics expected for an ephemeral creek such as Marulan Creek. The regulated flow duration curve shows steady flow of about 0.3 ML/day which represents a riparian release outflow from the dam in compliance with the anticipated water licence conditions. As shown in Table 7.2, average annual volume of supply from the proposed Marulan Creek Dam varies from 84 to 109 ML/year, with a median of 100 ML/year. Maximum annual supply from the dam is 183ML/year throughout the mine life.

The average annual flow downstream of the dam is expected to reduce from 1,023 ML/year under existing conditions to 829 ML/year during mine operation.

8.3 Water Licencing

Assuming that the water access licence for an entitlement of 76 ML/year from Tallong Weir (WAL25207) and 10ML/year from Barbers Creek (WAL25373) can be transferred to Marulan Creek Dam (both are located within the Barbers Creek Management Zone – see Section 3.2.5.1), Boral will seek to purchase an additional entitlement of 97 ML/year from within the available pool of access licences (1,176 ML/year) within the management zone (see Table 3.2). In the event that the water access licence for water from Tallong Weir cannot be transferred, Boral would seek to purchase 173 ML/year of water entitlement from within the available pool of access licences within the management zone.

It is anticipated that the water access licence for the Marulan Creek Dam would include similar provisions to those in the water access licence for the Tangarang Creek Dam relating to two aspects of the operation of the dam (Table 6.4), and which have been taken into account in the water balance model:

Riparian Release

12. *When the inflow of Tangarang Creek to the dam is greater than 10 megalitres per day (116.0 litres per second), downstream releases to Tangarang Creek are required to be equal to 10 percent of the inflow.*

13 *When the inflow of Tangarang Creek to the dam is less than 10 megalitres per day (116.0 litres per second) and greater than or equal to 1.0 megalitres per day, downstream releases to Tangarang Creek shall be no less than 1.0 megalitres per day.*

14 *When the inflow of Tangarang Creek to the dam is less 1.0 megalitres per day, downstream releases to Tangarang Creek must be equivalent to the inflow at the time.*

Water Access

15 (A) *Subject to any access or flow condition contained in the licence, the holder may in any one year commencing 1 July divert up to the licenced volume of 145 megalitres of water for mine use.*

(B) *Notwithstanding paragraph (A) the holder may divert up to twice the licenced volume in one year provided diversions do not exceed three times the licenced volume in any three year period.*

In order to achieve the requirement for downstream flow, it is likely that the design of the Marulan Creek Dam would include a seepage zone to provide a flow of 0.3 ML/ day equivalent to 10% of the average daily flow.

A works approval from DPI Water will also be required for the construction of the Marulan Creek Dam.

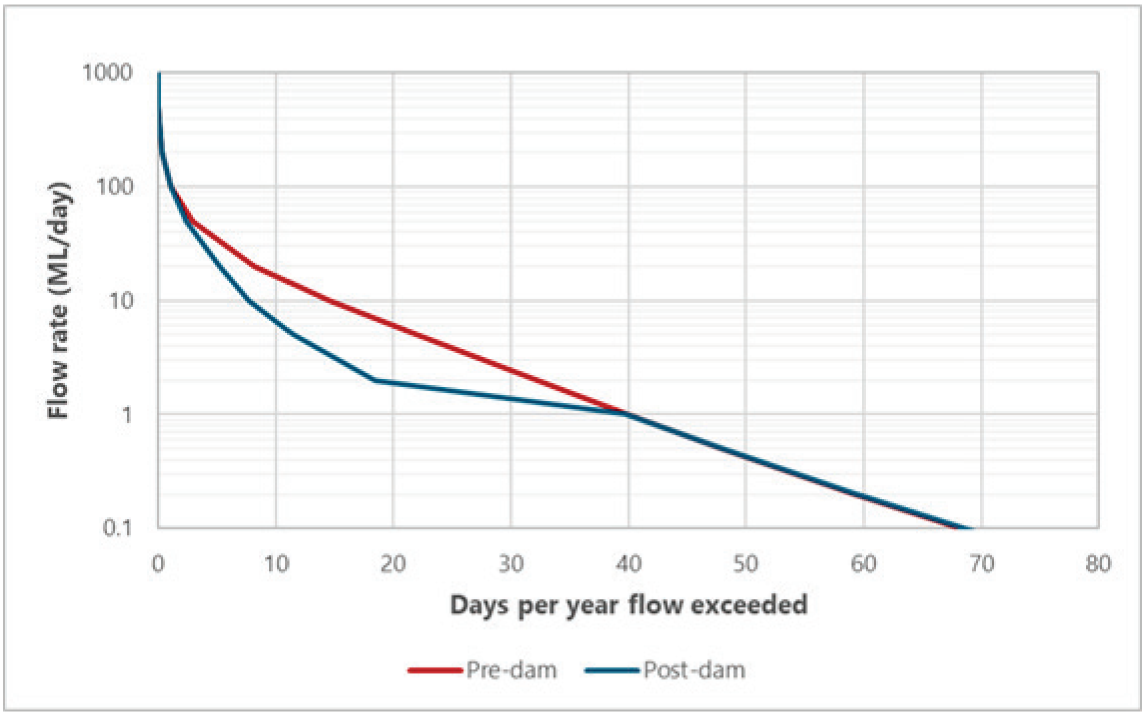

Figure 8.2: Marulan Creek Flow Duration Curves for a 30 Year Climate Period

8.4 Construction Environmental Management

The following construction issues would be considered during detailed design and the preparation of a construction environmental management plan for the Marulan Creek Dam:

- temporary diversion – provision for a temporary diversion or bypass would need to be set in place prior and during construction of the dam and spillway. A solution may comprise a temporary embankment upstream, and the provision and maintenance of a low flow channel around the construction site
- rock excavation in spillway – some rock excavation as well as dealing with large buried fresh grandiorite boulders may be required as part of the spillway excavation
- a site specific erosion and sediment control plan would be prepared before construction. Erosion and sediment works would be in accordance with *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004).

8.5 Flooding

The proposed full storage level in the dam is 597 m AHD which would have a water area of 5.9 ha within Boral owned land. The extent of flooding in the Marulan Creek Dam will be controlled by the spillway geometry (PSM, 2016).

The concept design for the dam (PSM, 2016) included an assessment of flood levels for the 1% AEP flood in the vicinity of the existing railway bridge over Marulan Creek, approximately 1 km upstream of the proposed Marulan Creek Dam. The model predicted that, under the existing conditions, flows greater than the 1% AEP flood would pass below the bridge without inundating the rail. For the scenario with the Marulan Creek Dam in place, the modelling indicated that there would be a 0.5 m increase in water level upstream of the bridge compared to existing conditions, however the bridge would not be subject to inundation for events up to the 1% AEP flood event.

PSM recommended that any impact of inundation of the embankment could be addressed in detailed design. Detailed design will also ensure that the extent of flooding remains within Boral owned land, through adjustments to the spillway design. The likely maximum extent of flooding during the 1% AEP flood is shown in Figure 8.1.

9 Surface Water Impacts

9.1 Summary of Key Impact Assessment Criteria

This section documents the key water quantity and quality impact assessment criteria adopted for this Surface Water Assessment based on the relevant statutory requirements and guidelines set out in Section 3 and in the Project SEARs. A summary of the key criteria and the cross-reference to where it is identified is provided in Table 9.1 and Table 9.2 below. Annexure A provides a listing of the SEARs and the sections of this Surface Water Assessment where each requirement is addressed.

9.1.1 Water Supply and Licencing Criteria

Table 9.1: Water Supply and Licencing Criteria

Criteria	Criteria Met?	Section where addressed
Barbers Creek and Bungonia Creek Management Zones of the *Greater Metropolitan Region Unregulated Area Water Sharing Plan* (refer Section 3.2.5.1)		
▪ the requirement for licencing of any proposed water 'take' from the source	Yes	Section 9.3
▪ potential impact on any downstream water users	Yes	Section 9.3
The exemption under Schedule 1(3) of the *Water Management (General) Regulation 2011* to the requirements of the harvestable rights orders made under Section 54 of the WMA (refer Section 3.1.1.1)	Yes	Section 9.3

9.1.2 Water Quality Criteria

As outlined in Section 3.2.3, the *Southern Rivers Catchment Action Plan* (Southern Rivers Catchment Management Authority, 2013) recommends that the water quality criteria for physical and chemical ecological stressors specified in the *Australia and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) should be adopted as water quality objectives throughout the Shoalhaven catchment. The specific criteria set out in the Guidelines (Table 3.3.2) are default criteria and to be used in the absence of relevant local data in order to 'trigger' further investigation.

As the area around the mine drains to the Shoalhaven River, which is part of the Sydney Water Supply catchment, criteria for drinking water quality are also relevant considerations. The *Annual Water Quality Monitoring Report 2013-14* (Sydney Catchment Authority) lists a range of water quality benchmarks for catchment streams that have also been taken into account in assessing appropriate water quality trigger values for Bungonia Creek and Barbers Creek.

The benchmarks nominated by WaterNSW (formerly Sydney Catchment Authority) in catchment streams are the ANZECC guideline ranges for upland rivers and are included in Table 11.3.

Table 9.2: Water Quality Criteria

Criteria	Criteria Met?	Section where addressed
The existing water quality in potentially affected watercourses in relation to:		
▪ Requirements of *ANZECC water quality guidelines* (refer Section 3.2.2)	Yes	Section 11.2.1
▪ The recommendations of the Healthy Rivers Commission to use the water quality criteria published in the prevailing water quality guidelines (refer Section 3.2.3):	Yes	Sections 9 and 11.2
The relevant provisions of the *Southern Rivers Catchment Action Plan as set out in the Southern Rivers CAP 2023 Paper – Water* (refer Section 3.2.4)		
▪ healthy and diverse native aquatic fauna	Yes	Section 9.5
▪ water quality supports community uses and values suitable for human consumption that meet ANZECC guidelines 100% of the time	Yes	Section 9.5
Neutral or Beneficial Effect on Water Quality Assessment Guideline as set out in the NorBE Assessment Checklist (refer Table 3.3 in Section 3.2.6)	Yes	Table 3.3 Section 9.5.3
The relevant provisions of *Managing Urban Stormwater: Soils and Construction – Volumes 1, 2D and 2E* (refer Section 3.2.6)	Yes	Sections 6.2.3, 6.2.8, 7.5, 7.7, 9.5.1 and 10
The relevant provisions of *State Environment Planning Policy (Sydney Drinking Water Catchment) 2011* (refer Section 3.1.4)	Yes	Section 9.5.3

9.1.3 Other Considerations

Other matters considered in assessing the potential impacts and mitigation measures relating to the Project are:

Impact on flows in creeks

- change to flow regime in the creeks draining from the mine area
- change in Marulan Creek stream geomorphology
- change to the flow regime downstream of Marulan Creek Dam.

Impact on water quality

- discharge from the Blow Hole
- construction and operation of the Marulan Creek Dam
- construction of a diversion of Marulan South Road.

Flood impacts:

- potential flooding in tributaries of Tangarang Creek as a result of catchment area changes
- backwater flooding upstream of Marulan Creek Dam.

9.2 Water Supply

Section 6 describes the existing and proposed water management facilities including the enlargement of one dam, construction of three new mine water storages (Table 6.5), the Marulan Creek Dam (Sections 6.2.4.4, 7.6 and 8), and progressive construction of seven sediment basins (Table 6.9) as overburden emplacement progresses.

Water demands for site operations have been assessed from existing uses for limestone processing (which will continue at a similar rate as previously) and analysis of water demands for dust suppression based on climatic data (and benchmarked against EPA dust suppression requirements). Water collected in the sediment basins would be transferred to the water storage dams for subsequent use as the primary source of water for site operations. Supplementary supply will be provided by Marulan Creek Dam (118 ML capacity) once it is constructed. Sections 7.6 and 8 provides more information on the need for Marulan Creek Dam to replace Tallong Dam.

A detailed water balance analysis has been prepared which accounts for progressive change in the layout of overburden areas over time combined with all climate sequences from the historic record. The modelling has been undertaken to test the resilience of the water management system to both wet and dry conditions. Details of the water balance analysis are set out in Section 7 and described in further detail in Annexure B. Table 9.3 provides a summary of the main supply and demand components of the overall average annual water balance.

Table 9.3: Average Annual Site Water Balance over the Life of the Mine

Water Demand		Water Supply	
Water Use	**Median Annual (ML)**	**Water Source**	**Average Annual (ML)**
Plant demands	80	Runoff	848
Dust suppression	126	Rainfall	36
Shortfall	-5	Groundwater	14
		Marulan Creek Dam	98
		Bore/Tallong Weir	7
		Evaporation	-64
		Sediment basin overflow	-9
		Diversion	-7
		Seepage	-714
		Adjustment for change in storage	-8
Total	**201**	**Total**	**201**

The data shows that the site would be about 50% self-sufficient for supply from runoff transferred from sediment basins, with the balance provided from off-site sources. Boral proposes to purchase surface water entitlements to cover the supply from the proposed Marulan Creek Dam. Section 7.6 provides more information on the need for Marulan Creek Dam to replace Tallong Dam while Section 8.3 addresses issues relating to water licencing.

While the water balance analysis indicates that the supplementary supply from Marulan Creek Dam would be around 100 ML/year, the actual requirement would vary from year to year. The modelling indicates that, in extreme conditions, the demand for supplementary supply could be 183 ML in a single year. This volume results from the limit imposed by the daily pumping rate from Marulan Creek Dam (0.5 ML/day).

Under extended drought conditions and when there is shortage of water in the on-site water storage dams, the water usage for dust suppression on haul roads and around the limestone processing facilities could be reduced to 50% of normal usage by the use of chemical dust suppressants. This would reduce the overall site demand in some years by 30% or about 65 ML. Therefore, the mine has an option to ensure that it does not run the risk of running out of water during an extreme dry year or sequence of years.

9.3 Water Licensing

9.3.1 Water Access Licensing

The proposed Marulan Creek Dam would be located within the Barbers Creek management zone which is located within the surface water management zone of the Greater Metropolitan Region Unregulated Area Water Sharing Plan. The total surface water entitlement within this zone is 1,176 ML/year. Boral proposes to acquire sufficient water access licences from within the Barbers Creek Management Zone to cover the proposed supplementary supply for the operation of the Project. It is not anticipated that there will be any difficulty in obtaining the required licences from the market.

As there are no downstream users, licenced extraction of water from Marulan Creek Dam would not have any impact on other users.

9.3.2 Harvestable Rights

The maximum harvestable right dam capacity (MHRDC) for a landholding is calculated by multiplying the area of the land holding by a location specific multiplier value, available from the online calculator on the WaterNSW website. The landholding owned by Boral attributable to the Project for purposes of harvestable rights is 481 ha. Accordingly, the MHRDC for the Project is approximately 36 ML.

Table 9.4 lists the existing clean water storage dams located within the Boral landholding attributable to the Project which would be included in the Project's MHRDC. Clean water storages within the Boral landholding consist of farm dams located upstream of mining activities (2009-2015 MOP Surface Water Assessment). The existing capacity of clean water storage dams (as opposed to sediment/pollution control dams) is approximately 6.8 ML, which is less than the harvestable right of 36 ML. Accordingly, clean water dams totalling an additional 29.2 ML could be constructed on first or second order streams (not including excluded works) without a licence.

Table 9.4: Identified Clean Water Storage Dams within the Boral Project Landholding

Clean Water Dam	Volume (ML)	Location
Minor Mine Dam 1	4.0	Located upstream of mine operations north east of the WOE
Minor Mine Dam 2	0.5	Located north east of Main Gully overburden emplacement
Minor Mine Dam 3	0.4	Located in far west of site west of WOE
Minor Farm Dam 1	0.3	Located north of CML16 upstream of WOE
Minor Farm Dam 2	1.0	Located immediately upstream of the WOE
Northern clean water diversion dam	0.6	Clean water diversion around Main Plant 2 dam
TOTAL	**6.8**	

As discussed in Section 3.1.1.1, "*dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a Government agency or Local*

Government Council to prevent contamination of a water source" are exempt from the MHRDC under the WMA.

Consultation with DPI Water has confirmed that the sediment basins and water storage dams proposed as part of the Project, including structures that collect runoff from haul roads, limestone stockpiles and infrastructure areas, as well as sediment basins constructed to control runoff from emplacements, would be required for purposes of pollution control and would therefore be exempt from the Project's MHRDC, provided they are located on first or second order streams.

Table 6.5 lists the identified water storage dams and Table 6.9 lists the proposed sediment basins located within the Project.

Marulan Creek Dam would be licensed under the WMA.

9.4 Impact on Flow in Creeks

9.4.1 Creeks Draining from the Mine Area

Pre-development catchments and creeks are shown on Figure 4.4. The Project would lead to the following changes in the catchment areas and flows draining off site (summarised in Table 9.5):

- The catchment draining to a small north-eastern tributary of Tangarang Creek (Figure 4.4 Tributary A2) within the Barbers Creek Management Zone would be increased by the construction of the Northern Overburden Emplacement. The site of the proposed Sediment Basin N2 currently has a small farm dam located to the west of Marulan South Road. The existing farm dam has a natural catchment area of about 12.5 ha including a 900 m section of Marulan South Road. Downstream of the existing farm dam, the tributary creek drains in a north-westerly direction passing to the north of the agricultural lime manufacturing facility. The tributary has a total catchment area of about 40 ha at the point where it joins a larger tributary before draining under the existing rail loop. At present the proposed footprint of the Northern Overburden Emplacement on the eastern side of Marulan South Road drains towards the North Pit. As the emplacement is built and progressively expanded, the area draining towards the tributary of Tangarang Creek would increase by a maximum of 33 ha. During mining, only occasional overflows from Sediment Basin N2 would drain to the tributary of Tangarang Creek. In order to minimise the potential for downstream flooding, the overflow outlet from the sediment basin would be by means of a pipe outlet designed to ensure that the 10th percentile annual exceedance probability flow at the culvert under the rail loop did not increase by more than 10%.
- The catchment draining to the eastern tributary of Tangarang Creek within the Barbers Creek Management Zone (Figure 4.4 Tributary A1) would be increased as a result of the construction of the northern section of the Western Overburden Emplacement. The eastern tributary has a total catchment of 99 ha at the point where it drains through a culvert under the rail loop. As the emplacement is progressively expanded, the area draining towards the tributary of Tangarang Creek would increase by a maximum of 17 ha, of which 50 ha would be occupied by the Western Overburden Emplacement. During mining, only occasional overflows from the Sediment Basin W1would drain to the tributary of Tangarang Creek. In order to minimise the potential for downstream flooding, the overflow outlet from the sediment basin would be by means of a pipe outlet designed to ensure that the 10th percentile annual exceedance probability flow at the culvert under the rail loop did not increase by more than 10%.
- The combined catchment of Tangarang Creek upstream of The Peppertree Quarry Water Supply Dam (Figure 4.4 Catchment A) increases from 614 to 664 ha during mining.

- The existing Western Overburden Emplacement and adjoining areas (some of which have already been rehabilitated) drain to the South Pit via the existing haul road (Figure 4.4 Tributary B1). By the middle of Stage 2, a total area of about 47 ha including the southern section of the Western Overburden Emplacement would likely be diverted back into a tributary of Main Gully within the Bungonia Creek Management Zone, replicating the historic catchment area draining to this Management Zone.
- The pit void will expand to the east, however the is no change in the catchment areas draining to Bungonia Creek (Figure 4.4 Tributary B2) as this area currently drains into the pit void.
- Likewise, the pit void expands to the east into a tributary of Barbers Creek (Figure 4.4 Tributary C1) progressively during the project, however there is no change in the catchment area as this area currently drains to the pit void.

Table 9.5: Changes in Catchment Areas Draining Off Site

Catchment	Receiving Water	WSP Management Zone	Historic catchment area (ha)	Existing catchment area (ha)	Future catchment area (ha)	Overflow Control
Northern Overburden Emplacement (north-west corner)	Tangarang Creek (north-eastern tributary)	Barbers Creek	40	40	73 (26 ha overburden emplacement)	Sediment Basin N2 with controlled discharge
Western Overburden Emplacement (northern section)	Tangarang Creek (eastern tributary)	Barbers Creek	99	99	116 (49 ha overburden emplacement)	Sediment Basin W1 with controlled discharge
Tangarang Creek upstream of Tangarang Creek Dam	Tangarang Creek Dam	Barbers Creek	614	614	664 (75 ha overburden emplacement)	See above
Western Overburden Emplacement and adjoining areas	Main Gully	Bungonia Creek	232	38	186 (93 ha overburden emplacement)	Sediment Basin S2
Tributaries of Barber Creek	Barbers Creek	Barbers Creek	296	98	98 (65 ha overburden emplacement)	Revegetated Overburden Emplacement (Eastern Batters)
Tributaries of Bungonia Creek	Bungonia Creek	Bungonia Creek	128	45	45	Revegetated Overburden Emplacement (Eastern Batters)

As reported in Section 7.12.2, post-mining the flow regime in Main Gully is predicted to be comparable to pre-mining conditions, and to be improved significantly from current conditions in which a large proportion of the catchment drains to the South Pit.

The water balance modelling has included an analysis of the flow regime in Tangarang Creek for pre-mining and post-mining catchment areas and conditions (refer Section 7.12.3). An increase of 50 ha in the catchment area draining to Tangarang Creek and a change in catchment characteristics are predicted to lead to a small overall increase in average annual flow of about 9% with similar flow duration characteristics. Given this, the changes in flow regime are not expected to have a significant adverse impact on Tangarang Creek or the tributaries that receive runoff from the overburden emplacements.

9.4.2 Marulan Creek Riparian Flow

With regards to riparian flows, the conditions of the Water Licence issued by the former NOW (now DoI Water) under Section 12 of the *Water Act 1912* for the Peppertree Quarry dam on Tangarang Creek are listed in Section 8.3.

The design of the Peppertree Quarry's Tangarang Dam includes a seepage layer that provides seepage flow that is dependent on the water level in the dam. Monitoring has demonstrated that the seepage flow exceeds the licence requirement.

It is anticipated that a water licence for the proposed Marulan Creek Dam would include similar requirements. The water balance modelling of Marulan Creek Dam includes a daily riparian release in accordance with the release rules provided in Table 6.4.

9.4.2.1 Creek geomorphology

Construction works for the Marulan Creek Dam embankment and spillway will impact local creek geomorphology as described in Section 8.4. During construction a diversion channel will divert flows around the works area, such that the impacts will be restricted to the immediate construction area of approximately 200 m of the current creek channel. The conceptual spillway channel includes drop structures/rip rap at the downstream end to tie into the natural creek level (PSM, 2016).

Following commissioning of the dam, up to 5.9 ha of open grazing land will be inundated by the dam including 1,200 m of the current Marulan Creek channel. The flow regime upstream of the dam full storage level is not anticipated to change (above 597 m AHD), with no impact on stream geomorphology.

Downstream of the dam embankment, riparian releases from the dam will maintain a similar flow regime when the dam water level is below the full storage level, as shown in Figure 8.2. When the dam is full, flow in the creek will pass through the dam spillway such that downstream flow is the same as that upstream. With the maintenance of a similar flow regime in Marulan Creek, creek geomorphology downstream of the dam is not expected to be impacted.

9.5 Water Quality

There would be two sources of water release from the mine:

- occasional overflow from sediment basins in the event of rainfall in excess of the design requirements
- "clean" runoff from rehabilitated overburden emplacement areas following completion of mining.

Seepage from the mine pit is not included as a water release from the mine pit.

The standard of treatment proposed would provide water that is better than or comparable to the water quality in the receiving environment. Therefore, no adverse water quality impacts are expected on Tangarang Creek, Main Gully or Bungonia Creek or the Barbers Creek, Bungonia Creek and Shoalhaven River Management Zones. No impacts are anticipated on downstream users, including the turkey farm operations (DPI Agriculture requirement) or on aquatic fauna. The water quality discharged from the mine is not anticipated to impact detrimentally on the existing water quality currently available for community uses and values.

Refer Section 11.2 below for further information on water quality trigger values for future water quality monitoring of watercourses adjacent to the mine.

9.5.1 Sediment Basins

As discussed in Section 7.7, Table 6.2 of *Managing Urban Stormwater Soils and Construction, Volume 2E: Mines and Quarries* (DECC 2008), provides an indicative average overflow frequency of 1 to 2 days per year for sediment basins designed to capture runoff from a 95th percentile rainfall event using the criteria for retention of 'fine' or 'dispersive' sediments for watercourses that discharge to 'sensitive' environments.

The model results in Table 7.4 show that on average there would be 1.6 days per year on which the sediment basins would overflow. This frequency of overflow indicates that the sediment basins will achieve a reduction in sediment discharge that is consistent with the requirements for discharge to 'sensitive' environments.

Compliance with the requirements for sediment basins that discharge to 'sensitive' environments is also consistent with the requirements for neutral or beneficial effects as set out in Table 3.3.

9.5.2 Geochemistry

As discussed in Section 1.2.8, dissolved metal/metalloid concentrations in initial surface runoff and seepage from most overburden or waste rock materials at the waste rock or overburden emplacements are unlikely to impact on the quality of the mine surface water resources. Most trace metal/metalloids in overburden or waste rock are sparingly soluble in slightly alkaline contact water and are unlikely to impact on the quality of mine surface water.

9.5.3 SEPP 58 (Sydney Drinking Water) 2011 Considerations

As discussed in Section 3.1.4, SEPP 58 (Sydney Drinking Water) 2011 aims to provide for healthy water catchments, delivering high quality water while permitting development. The proposed sediment basins would be designed and managed in accordance with the requirements for long term sites that discharge to 'sensitive' environments. This level of runoff retention and treatment is consistent with the principles of the NorBE objectives and meets the requirements of the NorBE checklist, which is provided in Table 3.3.

9.5.4 Seepage from the South Pit

The continued mine operations are expected to reduce sediment loads in the pit as a result of the proposed sediment basin network. Infilling of the South Pit will increase the distance between the pit and any discharge points in Bungonia Creek, also decreasing the potential for the carriage of sediment to receiving waters. Infilling of the South Pit may also slow the rate of seepage from the pit, allowing the pit to act as a large sedimentation basin and providing additional treatment of sediment from the mine prior to release via seepage (PSM, 2018).

9.5.5 Marulan South Road Diversion Construction

An existing section of Marulan South Road (approximately 1,950 m) would be realigned with a new section of about 1,220 m. Construction of the new section of road would take approximately four months. During construction, standard erosion control works for road construction would be implemented (as set out in Appendix D of *Managing Urban Stormwater: Soils and Construction, Volume 2 D, Main Road Construction* (DECC, 2008)). No impacts on local water quality are anticipated during the construction of the road.

9.5.6 Marulan Creek Dam

During construction of the Marulan Creek Dam embankment and spillway, standard erosion and sediment control works would be implemented as described in Section 8.4. No impacts on local water quality are anticipated during the construction phase.

Once commissioned, Marulan Creek Dam will operate in a similar manner to the Tangarang Creek Dam at the adjacent Peppertree Quarry, where catchment inflow is stored in the dam with water extracted for operational requirements and daily riparian releases (Section 8.3). Since the commissioning of the Tangarang Creek Dam, monitoring has shown seasonal variation in water quality parameters upstream and downstream of the dam. Riparian releases from the dam have provided water quality and flow that are unlikely to be adversely impacting ecology of downstream systems or potential users in terms of stock watering or irrigation purposes (Boral, 2017).

Thermal stratification can occur in large dams with water levels greater than 10 m. Thermal stratification is where warmer oxygen rich waters form a layer above colder, lower oxygen water. In south-eastern Australia, the release of unseasonably cold water from the deeper layer of thermally stratified dams (known as cold water pollution) poses threats to aquatic ecology (Preece, 2004). At the full storage level, the maximum water depth is approximately 6 m. Cold water pollution from riparian releases is not anticipated.

In a similar manner, water quality in the Marulan Creek Dam is anticipated to be similar to the baseline water quality in Marulan Creek as described in Section 5.2. The dam riparian release arrangement will be determined during detailed design, detailing the dam offtake points and how releases are made at different dam levels. Riparian release water quality will be similar to the baseline conditions, with seasonal variation in water quality parameters depending on catchment conditions and rainfall. No impacts on downstream water quality are anticipated as a result of the operation of the dam.

9.6 Cumulative Impacts

The following sections set out matters relating to potential cumulative impacts associated with other resource extraction facilities in the vicinity of the Marulan South Limestone Mine.

9.6.1 Peppertree Quarry

Peppertree Quarry is a Boral Resources (NSW) Pty Ltd granodiorite quarry located directly north of Marulan South Limestone Mine. Barbers Creek is the primary receiving watercourse for any discharge of runoff from the Peppertree Quarry site. The water management approach for Peppertree Quarry is detailed in the Peppertree Water Management Plan. Key elements of Peppertree Quarry's water management are summarised below:

- 'clean water' runoff from undisturbed areas is diverted around operational areas, wherever practical, to the main water storage dam on Tangarang Creek.
- 'dirty water' from areas of disturbed ground on the northern and western side of the development is directed into sediment basins that have been designed and are operated in accordance with the design requirements set out in the Conditions of Approval.

- 'dirty water' from the quarry pit and areas draining into the pit, which comprise the large majority of the site, is pumped via a settlement dam which discharges to the main water storage dam on Tangarang Creek.

The quarry has no licenced discharge points for water (EPL 13088).

The quarry operates within the guidelines for NorBE and water quality monitoring undertaken for this Project has shown no impact on water quality in Barbers Creek.

The Project may potentially result in slightly increased flows to Tangarang Creek and Peppertree Quarry. This is not expected to result in any negative impacts.

9.6.2 Lynwood Quarry

Lynwood Quarry is a hard rock quarry currently being operated by Holcim (Australia) Pty Ltd to the north west of Marulan South Limestone Mine and Peppertree quarry. The EIS for the quarry was prepared by Umwelt (2005).

Approximately 160 ha of the Lynwood Quarry project area, including the access road to the quarry and the associated interchange located at the Hume Highway, lies within the Marulan Creek catchment (Umwelt, 2005). According to the EIS, it is predicted that a slight increase in flood level immediately downstream of the project area of up to 6 mm during the 20 year ARI storm event would occur in Marulan Creek.

The EIS concluded that the Lynwood Quarry is not expected to have any noticeable impact on flow and water quality in Marulan Creek.

9.6.3 Cumulative Impact Assessment

Based on the information provided in Sections 9.6.1 and 9.6.2, the Project would have negligible impacts on surface water quality and flow in the vicinity of the Project. The predicted impacts would be managed in accordance with the measures identified in Section 10 and monitored in accordance with the protocols in Section 11. Therefore, the Project would make only a negligible contribution to any cumulative surface water impacts associated with other projects in the local area.

9.7 Post-Mining Residual Impacts

At the completion of mining, the following actions would be undertaken to ensure there are minimal residual impacts from the mining operation:

- the emplacement areas would be rehabilitated/ re-vegetated in accordance with the *Soils, Land Resources and Rehabilitation Assessment* (LAMAC, 2018)
- the sediment basins draining to Tangarang Creek tributaries would be retained to act as detention basins to control peak flows
- the sediment basins draining to Main Gully would be re-profiled and revegetated to assist in restoring the natural flow regime
- other sediment basins and water storage dams would either be left in place as water features for stock watering or irrigation purposes, or be removed and the area rehabilitated, dependant on the adopted final land use of the site
- hardstand areas and haul roads not required for site access would be rehabilitated so as to allow runoff to the natural drainage systems

- environmental flow releases resulting from a seepage system within the structure of the dam as well as spills during flood events would continue from Marulan Creek. As there would be no water extracted for operation of the limestone mine, spills from the dam would increase compared to the spills during mine operation.

Once these actions are completed it is expected that there would be negligible residual impacts on surface water flow or water quality in any of the receiving waters.

9.7.1 Final Void

Based on the characterisation of seepage from the base of the pit set out in the *Groundwater Technical Study* (AGE 2018), the water balance analysis for the final void shows that all water draining to the pit, including runoff from the pit itself, (466 ML/year on average) would seep through the base of the pit. Following periods of heavy rainfall the water level in the pit could be as much as 13 m above the base of the pit, but would never reach a level where overflow to the surface drainage system could occur (140 m above the floor of the pit). Assessment of changes in seepage as a result of overburden emplacement in the Southern Pit was completed by PSM in 20018 (Annexure F). The study concluded that, while there was a potential reduction in seepage capacity through the Southern Pit due to placement of overburden, it was unlikely due to the increase in seepage capacity in the North Pit and large seepage capacity in the South Pit.

As discussed in Section 9.5.4 above, infilling of the South Pit will increase the distance between the pit and any discharge points in Bungonia Creek, decreasing the potential for the carriage of sediment to receiving waters. Infilling of the South Pit may also slow the rate of seepage from the pit, allowing the pit to act as a large sedimentation basin and providing additional treatment of sediment from the mine prior to release via seepage (PSM, 2018).

In relation to the final landform, it is anticipated that post-mining water levels in the pit will reach a long-term equilibrium such that the pit will not keep filling indefinitely. The high level of regional evaporation relative to annual rainfall and the high permeability of the limestone forming the pit floor and walls also support this expectation.

As part of the post-mining water management system, the final void would operate as a large sedimentation basin / treatment system. The final mine pit floor configuration includes two large sediment retention basins, a northern basin at about 365/355 m AHD and southern basin at about 350/335 m AHD (refer to Figure 6.6). These basins will provide an estimated storage capacity of 70 ML and 400 ML respectively. The first basin would be sized to provide initial settlement of sediment. An outlet structure or spillway in this pre-treatment basin would release flows into the second basin through which treated flows would discharge to receiving waters as seepage, as currently occurs in the mine pit.

The TARPS and adaptive management measures that will be put in place will ensure that the design permeability rate is maintained to ensure overflow from the void post-mining is avoided.

9.7.2 Flooding

The proposed full storage level in the dam is 597 m AHD which would have a water area of 5.9 ha within Boral owned land. The extent of flooding in the Marulan Creek Dam will be controlled by the spillway geometry. Detailed design will ensure that the extent of flooding remains within Boral owned land, through adjustments to the spillway design. The maximum extent of flooding during the 1% AEP flood is shown in Figure 8.1.

As discussed in Section 8.5, the Marulan Creek Dam is predicted to result in a 0.5 m increase in water level upstream of the existing railway bridge compared to existing conditions, however the bridge would not be subject to inundation for events up to the 1% AEP flood event.

10 Mitigation and Management Measures

10.1 Avoidance Measures

Mitigation of potential surface water impacts would be addressed primarily through the design and operation of the water management system for the Project. The key feature of the proposed system is that all runoff from overburden emplacements would be directed into sediment basins that would be designed and operated in accordance with the requirements of *Managing Urban Stormwater: Soils and Construction*.

An outline of the proposed water management system for the Project is provided in Section 6.2. The system has been designed in accordance with the objectives and design criteria provided in Section 6.2.1 to avoid or minimise impacts to water quality and quantity by the Project.

As described in Section 0, the water management system would segregate runoff of different quality and treat and/or dispose of it appropriately. Although limited opportunity exists due to topographical constraints 'clean' surface runoff would be diverted around disturbed areas and released from site wherever possible, while 'dirty' runoff would be directed to sediment basins and the mine void.

Only runoff from storms in excess of the specified design storm would discharge, in some instances, to Tangarang Creek or Main Gully. In other instances, discharge from the sediment basins would drain to the mine pit. Further details are provided in the sections below.

The implementation of these key elements of the Project is expected to minimise the potential for water quality or flow impacts due to the Project.

10.2 Site Water Management and Pollution Control

Although the water consumption requirements of the Project and the water balance of the system would fluctuate with climatic conditions and the development of the mine, the water management system has been designed to be adaptable. The water balance modelling demonstrates that the proposed mine water management system has sufficient capacity and flexibility to accommodate a wide range of climate conditions while:

- providing security of supply for mine operations
- controlling discharge from sediment basins in accordance with the requirements of *Managing Urban Stormwater: Soils and Construction*.

The water balance analysis in Section 7 indicates that the water management will be capable of operating in a manner in which all water that needs to be transferred from the sediment basins within five days of the end of a storm can generally be accommodated in the mine water storage dams. The only off site discharges would be from sediment basins W1, N2 and S2 in the case of:

- wet weather discharges in the event of a storm rainfall in excess of the design rainfall and after all possible transfers of water to the mine water dams has occurred
- controlled discharges within five days of the end of a storm rainfall event in order to restore capacity in the dams before the next rainfall event. This would only occur on the rare occasions when there is insufficient capacity in the mine water dams to receive water from the sediment basins.

A variation to EPL944 will be required to specify conditions for water quality monitoring and discharge to water from Sediment Basins W1, N2 and S2.

The indicative water holding capacities of the sediment basins have been determined, and will be operated, in accordance with the requirements for projects with disturbance longer than three years, as set out in Table 6.1 of *Managing Urban Stormwater: Soils and Construction: Volume 2E Mines and Quarries* (DECC, 2008) using the criteria for 'fine' or 'dispersive' sediments. With the exception of Sediment Basin P1, the basins have been sized to capture the runoff from a 95th percentile five day storm.

A small Sediment Basin P1 would be provided to treat runoff from the Shared Road Sales Stockpile Area located adjacent to the access road on the northern side of the site. This site would contain stockpiles of crushed limestone from the mine and granodiorite products from Peppertree Quarry. The sediment basin would be designed in accordance with the criteria for 'coarse' sediments as set out in *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004). Sediment Basin P1 has been designed to capture the runoff from a 90th percentile five day storm as it is limited by space constraints and discharges internally to the Peppertree Quarry pit.

Runoff collected in all of the sediment basins (with the exception of S2) would be pumped to one of the mine water storage dams for reuse in limestone processing or dust suppression.

The overburden emplacements would be progressively enlarged over time and shaped and rehabilitated on those sections that had been completed in accordance with the *Soils, Land Resources and Rehabilitation Assessment* (LAMAC, 2018). The overburden or waste rock in the emplacements is expected to eventually break down into a fine soil that is assumed to have runoff characteristics equivalent to 'Soil Hydrologic Group D' as defined in Table F2 of *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004) with a volumetric runoff coefficient of 0.74.

Containment of spills and leaks of liquids will be in accordance with the technical guidelines section 'Bunding and Spill Management' of the Authorised Officers Manual (EPA, 1995) (http://www.epa.nsw.gov.au/mao/bundingspill.htm). Containment will be designed for no-discharge.

Following Project Approval a detailed site Surface Water Management Plan (SWMP) would be prepared setting out the specific details and the operational rules of the water management system (refer Section 10.7 below).

10.3 Marulan Creek Dam

For the construction phase of the Marulan Creek Dam, a site specific Construction Environmental Management Plan would be prepared including an Erosion and Sediment Control Plan that complies with the requirements of *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004) (Section 8.4). In addition to the standard erosion and sediment control techniques, particular attention would be given to the temporary diversion of the creek during construction. Monitoring required during construction of the dam is identified in Section 11.2.

Operation of the Marulan Creek Dam will be included in the Surface Water Management Plan (refer Section 10.7).

10.4 Road Diversion

An existing section of Marulan South Road (about 1,950 m) would be realigned with a new section of about 1,220 m. Construction of the new section of road would take about 4 months. During construction, standard erosion control works for road construction would be implemented (as set out in Appendix D of *Managing Urban Stormwater: Soils and Construction, Volume 2 D, Main Road Construction*, DECC, 2008).

10.5 Sewage Treatment

The existing sewage treatment system is described in Section 6.1.4. Following Project Approval, sewage would continue to be managed using the existing system as no significant increase in load (based on staff numbers) is expected.

10.6 Water Conveyance Structures

All hydraulic conveyance structures such as contour banks, drainage swales, drop structures, rock chutes and spillways would be designed to remain stable in the event of a 1% AEP storm in accordance with the requirements set out in Table 6.1 of *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (DECC, 2008).

10.7 Surface Water Management Plan

As part of the detailed operational environmental management plans to be prepared following Project Approval, a site SWMP would be prepared that reflects the detailed design of the mine and its water management system. The operating rules for the water management system would be further developed at that time and would be reviewed as part of the periodic review of the SWMP to reflect operating experience.

The SWMP will include the management and mitigation measures identified in this report and address the requirements of the SEARs including the following:

- operational procedures to manage environmental impacts
- monitoring procedures
- training programs
- community consultation
- complaint mechanisms including site contacts
- strategies to use monitoring information to improve performance
- strategies to achieve acceptable environmental impacts and to respond in the event of any exceedences.

Operation of the Marulan Creek Dam will also be included in the SWMP. The SWMP will be prepared in accordance with the relevant guidelines.

10.8 Erosion and Sediment Control

The site erosion and sediment control system would be managed through erosion and sediment control plans that would be progressively developed over the life of the Project. The plans would be updated periodically to meet the particular changes to the Project over the mine life. The effectiveness of the plans would also be assessed through monitoring and by a formal auditing process.

Erosional stability would be a key requirement of site rehabilitation and closure works design. The operational erosion and sediment control works would be retained and maintained during the rehabilitation and revegetation establishment phase. Following the establishment of self-sustaining, stable final landforms, key elements of the operational sediment control structures would either be left as passive water control storages (if practicable) or would be reshaped or removed if they could not be left without an ongoing maintenance requirement. Rehabilitation of disturbed areas will be carried out in accordance with the recommendations in the *Soils, Land Resources and Rehabilitation Assessment* (LAMAC, 2018).

The erosion and sediment control plans will be prepared in accordance with the requirements of the SEARS and the relevant guidelines.

10.9 Adaptive Management

A Trigger Action Response Plan (TARP) will be included in the SWMP to allow adaptive management if/where required. The TARP will identify appropriate triggers, actions and responses and will be based on the following principles:

- it will be adequately resourced both in terms of personnel and equipment
- it will focus on prevention and control through early detection
- it will set triggers based on a detailed knowledge of what is normal
- it will be regularly reviewed and revised
- any mandated actions will be carried out promptly.

Relevant surface water quality triggers for inclusion in the TARP are identified in Table 9.2.

The TARP will be an important aspect of the management of the final void.

11 Proposed Monitoring, Licencing and Reporting Procedures

This section provides a description of the measures that would be implemented to monitor and report on the surface water aspects of the Project.

11.1 Climate Monitoring

Continuous climate data monitoring would continue to be carried out at the Limestone Mine and Peppertree Quarry Weather Stations. The parameters monitored are listed in Table 11.1.

Table 11.1: Climate Monitoring Parameters

Peppertree Quarry Station	Limestone Mine Station
Rainfall [mm]	Rainfall [mm]
Temperature (Max and Min) [^{o}C]	Temperature (Max, Min, Average) [^{o}C]
Humidity (Max and Min) [%]	Humidity (Max and Min) [%]
Wind Speed [m/s]	Wind Speed (Max gust, Average) [km/h]
Time of Max Wind Gust	Time of Max Wind Gust
Evapotranspiration [mm]	Average Wind Direction [degrees]
Solar radiation [MJm^{2}]	

From a surface water management perspective, the key factors to be monitored are rainfall and evaporation. The parameters in Table 11.1 would be used to calculate evaporation using the Penman-Monteith equation, which is considered more representative of evapotranspiration conditions than the traditional Class A evaporation pan, and can be adapted to estimate open water evaporation.

11.2 Surface Water Quality Monitoring

11.2.1 Site Surface Water Quality Monitoring and Discharge

Runoff would be discharged from the site at the locations identified in Table 11.2 and shown on Figure 6.2 to Figure 6.5. Table 11.2 also identifies the proposed monitoring to be undertaken for any controlled discharge from the site.

Water quality monitoring during discharge would be by means of a grab sample which would be analysed for:

- Oil and grease
- pH
- Total Suspended Solids
- Turbidity

Monitoring will be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC, 2004).

Table 11.2: Site Discharge Locations

Receiving Water	Discharge Structure	Type of discharge	Proposed Monitoring
Main Gully	Sediment Basin S2 and automatic water sampling facility	Discharge to water	Daily samples collected during any discharge offsite, expect where rainfall exceeds the design criteria
North-eastern tributary of Tangarang Creek	Sediment Basin N2	Discharge to water	Daily samples collected during any discharge offsite, except where rainfall exceeds the design criteria
Eastern tributary of Tangarang Creek	Sediment Basin W1	Discharge to water	Daily samples collected during any discharge offsite, except where rainfall exceeds the design criteria

11.2.2 Ambient Surface Water Quality Monitoring

The existing surface water quality monitoring program is described in Section 5 and further detail is provided in Annexure C. Ambient surface water quality monitoring should continue to be undertaken at the following existing sites:

- Marulan Up — Marulan Creek upstream of proposed dam
- Marulan Dn — Marulan Creek downstream of proposed dam
- Main Gully Sample Point — Downhill of B68 Main Gully Spring (Blow Hole)
- Tangarang Up (U1) — Tangarang Creek upstream of Tangarang
- Tangarang Down (T1) — Tangarang Creek downstream of Peppertree quarry
- Barbers Up — Barbers Creek upstream of mine
- Barbers Dn — Barbers Creek downstream of mine
- Bungonia Up — Bungonia Creek upstream of mine
- Bungonia Dn — Bungonia Creek downstream of mine
- SR1 — Shoalhaven River site 1
- SR2 — Shoalhaven River site 2
- SR3 — Shoalhaven River site 3

The locations of these sites are identified in Table 5.5 and shown on Figure 5.3 and the parameters to be monitored identified in Table 5.3. Routine monitoring at the sites in Marulan Creek, Barbers Creek, Bungonia Creek and the Shoalhaven River will continue on a quarterly basis during operation of the mine (refer details in Table 5.5). Cessation of monitoring in Barbers Creek and the Shoalhaven River may be considered once the Northern and Western Overburden Emplacements and all externally draining sections of the Southern Overburden emplacement is completed and rehabilitation has been established. However, ongoing quarterly monitoring would be continued in Main Gully (in accordance with Table 11.2) and Bungonia Creek.

Once Project Approval is granted, the procedures for monitoring and management action as set out in Section 10 would be implemented. Water quality monitoring results would be assessed on receipt of test results and reported annually in the Annual Environmental Monitoring Report. All water quality monitoring would be undertaken in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutant in NSW* (DEC, 2004).

Regular monitoring of water quality in Marulan Creek would be undertaken for the duration of construction of the Marulan Creek Dam. The frequency of the monitoring would be identified in the SWMP.

11.2.3 Water Quality Trigger Values

The recommendations of a number of relevant guidelines have been considered in the identification of appropriate site specific water quality trigger values for Bungonia Creek and Barbers Creek.

As the area around the mine drains to the Shoalhaven River, which is part of the Sydney Water Supply catchment, criteria for drinking water quality are also relevant considerations. The *Annual Water Quality Monitoring Report 2013-14* (Sydney Catchment Authority) lists a range of water quality benchmarks for catchment streams that have also been taken into account in assessing appropriate water quality trigger values for Bungonia Creek and Barbers Creek. The benchmarks nominated by WaterNSW (formerly Sydney Catchment Authority) in catchment streams are provided in Table 11.3.

As outlined in Section 3.2.3, the *The Healthy Rivers Commission's (HRC) Independent Inquiry into the Shoalhaven River System* (HRC, 1999) recommends that the water quality criteria for primary and secondary contact recreation specified in the ANZECC Guideline be adopted as water quality objectives throughout the Shoalhaven catchment. The physical and chemical parameters relevant to this Surface Water Assessment are identified in Table 5.2.2 of the Guidelines and include:

- pH: 5.0 – 9.0
- temperature: 15 – 35°C

In addition, the HRC recommends the following water quality objectives for nutrients:

- Total Phosphorus: 40 – 60 µg/L
- Total Nitrogen: 500 µg/L.

The ANZECC Guideline default ecosystem protection trigger values for physical and chemical stressors for South-east Australia for slightly disturbed ecosystems in upland rivers are provided in Table 11.3. These trigger values are more stringent that than those for primary and secondary contact recreation.

The ANZECC Guidelines specify that two years of monthly sampling (24 samples) is sufficient to provide an indication of the local ecosystem variability and to provide a basis for derivation of 'trigger' values appropriate to conditions in a particular creek system. For physical and chemical stressors for slightly or moderately disturbed ecosystems, such as that surrounding the Marulan South Limestone Mine, the Guidelines recommend the use of the 20^{th} and 80^{th} percentile values of data as the basis for revised 'trigger' values.

The results of the Project water quality monitoring in the Shoalhaven River are shown in Table 5.6. At the time of preparation of this Surface Water Assessment, 25 - 31 samples (depending on location) have been obtained for the watercourses which could potentially be impacted by the Project. The 20^{th} and 80^{th} percentile values of this data have been identified and used as the basis for the proposed trigger values to assess any potential mining-induced impacts on water quality in Barbers Creek and Bungonia Creek in Table 11.3. As part of the preparation of a Surface Water Management Plan following Project Approval, these trigger values would be reviewed to account for any further water quality monitoring and, if justified, updated.

Table 11.3: Proposed Water Quality 'Trigger' Values for Bungonia Creek and Barbers Creek

Parameter	ANZECC Default Trigger for Ecosystem Protection[1]	WaterNSW Benchmarks for Catchment Streams[2]	Proposed 'Trigger Values'
pH	6.5 – 8.0	6.5 – 8.0	6.5 – 8.5
EC (µS/cm)	350	NA	1,600
Total nitrogen (mg/L)	0.25	0.25	4.0
Total phosphorus (mg/L)	0.02	0.02	0.03
Turbidity (NTU)	25	25	25
Total suspended solids (mg/L)	N/A	N/A	50

[1] *Default trigger values for physical and chemical stressors for South-east Australia for slightly disturbed ecosystems in upland rivers*

[2] *Table 4.4 in Annual Water Quality Monitoring Report - Sydney Catchment Area 2014-15 (WaterNSW),*

Barbers Creek and Bungonia Creek are fifth order creeks with very large catchment areas. Sediment, nitrogen and phosphorus due to agricultural land use in the catchments upstream of the mine are likely to significantly influence water quality in these creeks. The site specific trigger values proposed in Table 11.3 reflect the water quality upstream of any possible influence from the mine, as it based on monitoring of these local conditions.

The values will be triggered by results of monitoring upstream and downstream of the mine on Barbers and Bungonia creeks and used as follows and included in the TARP discussed in Section 10.9:

- If, during quarterly ambient surface water quality monitoring the upper bounds for pH, EC, TSP or turbidity are exceeded downstream of the mine but not exceeded upstream of the mine, it will trigger further monitoring on a monthly basis for two more months at the sampling point where the exceedance was measured.
- If one or more of the same parameters are exceeded in the three consecutive months of monitoring downstream of the mine but not exceeded during this period upstream of the mine, it will trigger assessment of potential sources in the mine.
- If the assessment finds the change in water quality may be caused by the mine, the source will be identified and operations will be reviewed and revised to address the impact.
- Following the revision of operations, monthly monitoring will continue to be undertaken at the sampling point where the exceedance was measured, until none of the parameters trigger values are exceeded. Thereafter monitoring at that sampling point will revert to quarterly monitoring.

This further assessment would include investigation of the potential pathways for water quality impacts within the Marulan South Limestone Mine area to identify whether the change in water quality is attributable to mining activities, and the nature of activity that has caused the change. Any assessment would take account of ongoing monitoring of water quality at the auto-sampler site in Main Gully downstream of Sediment Basin S2.

11.3 Water Balance Monitoring

The water balance assessment documented in Section 7 and Annexure B of this report is based on the best available science in relation to runoff characteristics of the various types of mine surfaces within a mine. It is considered adequate and fit for the purposes of this Surface Water Assessment.

Sufficient records would be kept allowing regular review of the site water balance in order to assess whether any changes are required to the capacity of the various elements of the water management system or to the mode of operation. Water levels in the water storage dams listed in Table 6.5 would be recorded at least monthly, with flowmeters installed on transfer pipelines that record both flow rate and total flow with readings taken at least monthly. Similarly, major water uses such as lime processing and dust suppression would be equipped with flowmeters that record total volume and flow rate with readings taken at least monthly.

Data from the water balance monitoring would also provide input into the TARP/adaptive management measures (refer Section 10.9).

A review of the water balance model and future projections of the risk of excess or shortfall of water would be carried out periodically. It is recommended that the water balance model is reviewed at least every 3 years, prior to any modification in the mine staging or as the result of a water related incident at the site.

11.4 Visual Inspections

Visual inspections/monitoring of all temporary and permanent surface water management structures would be undertaken regularly to identify any risks of failure in walls, or effects of erosion etc.

11.5 Monitoring of Water Level in Final Void

As discussed in Section 9.7.1, it is anticipated that post-mining water levels in the pit will reach a long-term equilibrium such that the pit will not keep filling indefinitely. The high level of regional evaporation relative to annual rainfall and the high permeability of the limestone forming the pit floor and walls also support this expectation. As the lowest lip of the pit is approximately 140 m above the base of the pit and a maximum water level of 13 m in the final void is predicted, overflow from the void is not anticipated to be an issue.

Monitoring of the water level of the final void will be undertaken to confirm seepage rate and adaptive measures undertaken if increased water levels under heavy rainfall conditions becomes an issue.

11.6 Licensing and Approvals

If the Project is approved, Boral would apply for a variation to the existing Environmental Protection Licence (EPL No. 944) to specify conditions for water quality monitoring and discharge from Sediment Basins W1, N2 and S2.

Subject to Project Approval, Boral would either seek to transfer its existing entitlement for water from Tallong Weir and/or acquire any additional water licences from the Barbers Creek management zone to cover the maximum supplementary supply from Marulan Creek Dam (total 183 ML/year).

Under the *2011 Greater Metropolitan Region Groundwater Sources* WSP, groundwater extraction requires an authorisation under a water access licence or some form of exemption. The mine currently has two bores with a total entitlement of 12 ML/year. These bores would most likely run dry early in Stage 1 of the Project, if not before, due to the north advancing mine pit.

There is no process in place to consider return flows/groundwater recharge. Therefore, all groundwater take (incidental or otherwise) needs to be accounted for by obtaining a groundwater entitlements sufficient to account for the peak take prior to that extraction occurring. In order to address this requirement Boral obtained additional groundwater entitlement (WAL41976) of 838ML in September 2017.

As discussed in Section 3.1.1.1, dams located on a first or second order stream solely for the capture, containment and recirculation of mine affected water consistent with best management practice to prevent the contamination of a water source are “excluded works” and do not need to be licensed under the WMA. Therefore, it is expected that the sediment basins and mine water storage dams proposed for the Project (as identified in Table 7.4) would not require licensing.

As outlined in Section 9.3.2, other dams totalling 29.2 ML could be constructed on first or second order streams without the requirement for a licence under harvestable rights.

A works approval to construct and operate the Marulan Creek Dam would be obtained from DPI(Water). Works supply approvals and controlled activity approvals under the WMA are not required for State Significant Development.

12 Conclusions

This Surface Water Assessment:

- addresses all the relevant requirements of the Secretary's Environmental Assessment Requirements (SEARs) (see Section 2 and Annexure A)
- identifies legislation, policy and guidelines relevant to the Project (see Section 3)
- documents the existing catchment conditions and water quality in the creeks and rivers adjacent to the Project area (Sections 1, 4 and 5 and Annexures C and D)
- describes the proposed site water management system for the Project, including water supply and demand requirements (Sections 6 and 7) and the provision of a dam on Marulan Creek to provide a supplementary supply (Section 8)
- assesses the potential impacts of any changes in the flow and water quality resulting from the proposed Project, and the proposed mitigation actions and management measures to minimise any residual impacts (Sections 9 and 10 and Annexure C and D)
- identifies appropriate monitoring to verify the predicted impacts of the Project and initiate any additional mitigation measures required (Section 11).

The proposed mine water management system would capture runoff from all disturbance areas in sediment basins that would be designed and operated in accordance with *Managing Urban Stormwater: Soils and Construction*. Water retained in the sediment basins would be transferred to a series of onsite water storage dams for reuse in limestone processing and dust suppression.

A daily water balance model has been used to assess the performance of the water management system in terms of the reliability of supply, overflow to the mine pit and offsite discharge. The water balance analysis demonstrates that the proposed water management system for the Project is extremely robust and is capable of providing security of supply for mine operations while ensuring that controlled overflow from the sediment basins would be in accordance with *Managing Urban Stormwater: Soils and Construction*.

The robustness of the water management system has been demonstrated through the assessment of the performance of the system under a range of climate scenarios and through testing the effects of under- or over-estimating surface runoff. The sensitivity analysis indicates that the water management system is capable of meeting site water demands and controlling overflows from the sediment basins under a range of assumed runoff scenarios.

The model shows that a maximum supplementary supply of about 183 ML/year would be required from the proposed Marulan Creek Dam. With this supplementary supply, the water balance modelling demonstrates that the proposed mine water management system has sufficient capacity and flexibility to accommodate a wide range of climate conditions while providing security of supply for mine operations and controlling discharge from sediment basins in accordance with *Managing Urban Stormwater: Soils and Construction*.

The results of the water balance modelling also show that, during mine operations, overflow from water storage dams, runoff from land surrounding the pit and runoff from the pit itself would be about 580 ML/year. Some of this water would evaporate, but the majority would be lost by seepage and contribute to the groundwater system.

Any water storage dams and sediment basins no longer required for final land use requirements would be decommissioned and rehabilitated. Rehabilitation and revegetation of the emplacements, upper "inner" facing slopes of the Southern Overburden Emplacement and upper mine benches and infrastructure areas would be undertaken in accordance with the *Soils, Land Resources and Rehabilitation Assessment* (LAMAC, 2018) to minimise erosion and sedimentation. Runoff from the Western Overburden Emplacement and western section of the Southern Overburden Emplacement would be allowed to drain off site via Main Gully. Drainage from Sediment Basin S1 would also be directed to Main Gully via the S2 Sediment Basins.

Post-mining water levels in the pit are anticipated to reach a long-term equilibrium such that the pit would not keep filling indefinitely due to the high level of regional evaporation relative to annual rainfall and the high permeability of the limestone forming the pit floor. Post-mining water management and treatment would be achieved by using the pit as a large sedimentation basin / treatment system.

13 References

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Annexure A Secretary's Environmental Assessment Requirements (SEARs)

Annexure A – Marulan South Limestone Mine Continued Operations: Secretary's Environmental Assessment Requirements

Requirement	Reference
Secretary's Environmental Assessment Requirements	
General Requirements	
The EIS must include:	
• A full description of the development, including:	
– a water management strategy, having regard to the EPA's, NSW Office of Water's and Water NSW's requirements	Sections 6.2, 7 and 8
• a list of any approvals that must be obtained before the development may commence	Sections 3, 9.3 and 11.6
• an assessment of the likely impacts of the development on the environment, focusing on the specific issues identified below, including:	Section 9
– a description of the existing environment likely to be affected by the development, using sufficient baseline data;	Sections 1 and 4
– an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant laws, environmental planning instruments, guidelines, policies, plans and industry codes of practice;	Sections 3 and 9
– a description of the measures that would be implemented to mitigate and/or offset the potential impacts of the development, and an assessment of:	Section 10
○ whether these measures are consistent with industry best practice, and represent the full range of reasonable and feasible mitigation measures that could be implemented;	
○ the likely effectiveness of these measures; and	
○ whether contingency plans would be necessary to manage any residual risks;	
– a description of the measures that would be implemented to monitor and report on the environmental performance of the development if it is approved	Section 11
Specific Requirements - Water	
The EIS must address the following specific issues:	To the extent relevant to surface water:
• an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, NSW Office of Water's and Water NSW's requirements and the *NSW Aquifer Interference Policy*;	Sections 3 and 9
• an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users;	Sections 7 and 9
• a 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;	Sections 6 and 7, and Annexure B
• 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;	Sections 3 and 7
• 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; and	Sections 3 and 7
• a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;	Sections 6.2, 7, 8, 10 and 11

Requirement	Reference
Agency' Correspondence	
NSW Department of Primary Industries (DPI)- Agriculture NSW	
The EIS should assess the impacts of the limestone mine on the existing turkey farms and in particular address the following:	
• The quantity and quality of surface water as a result of sedimentation and pollution and the impacts on the turkey farm operations will need to be assessed, particularly as soils are sodic and dispersive in nature. It should be noted that water for turkey farm operations is required to be of a high standard to achieve commercial outputs, address animal welfare issues and disease control. Water is for instance required to be treated to drinking water standards	Sections 7 and 9
The guideline "Agriculture Issues for Extractive Industry Development" provides further information on the issues and information to be included in an EIS for extractive industries and can be accessed at: http://www.dpi.nsw.gov.au/content/agriculture/resources/lup/development-assessment/extractive-industries	Noted
Water Resources Check that the environmental assessment:	
• Identifies water resources and drainage patterns in the locality, including water quality and flows. This should include assessment of the significance of affected catchments for irrigation or other agriculture use.	Sections 1, 4 and 5, and Annexure C
• Calculates site water balances and then models any changes to ground and surface water flows as result of surface drainage diversions and groundwater depressurisation. This should include the predicted time for groundwater systems to restabilise and any other impacts on water users.	Section 7 and Annexure B
• Documents any likely changes to surface and ground water quality in relation to surrounding agricultural land uses. This should identify any changes in acidity, salinity and turbidity, proposed erosion control and mitigation measures, and the predicted time duration over which such changes occur.	Sections 7 and 9
NSW Department of Primary Industries (DPI)- Water	
It is recommended that the EIS be required to include (refer to **Attachment A** of the DPI Water letter for further detail):	
• Details of water proposed to be taken (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.	Section 6
• Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project).	Sections 6.2, 7.6, 10.3 and 12.6
• The identification of an adequate and secure water supply for the life of the project. Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased.	Sections 8, 9 and 9.2
• A detailed and consolidated site water balance.	Section 7 and Annexure B
• A detailed assessment against the NSW Aquifer Interference Policy (2012) using the NSW Office of Water's assessment framework.	Refer Groundwater Assessment
• Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	Section 9
• Full technical details and data of all surface and groundwater modelling, and an independent peer review.	Sections 6 and 7
• Proposed surface and groundwater monitoring activities and methodologies.	Section 11
• Proposed management and disposal of produced or incidental water.	Sections 6 and 7, and Annexure B
• Details surrounding the final landform of the site, including final void management (where relevant) and rehabilitation measures.	Sections 6, 7.11, 9.7 and 11.5
• Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	Section 9.6
• Consideration of relevant policies and guidelines.	Section 3

Requirement	Reference
• A statement of where each element of the SEARs is addressed in the EIS (i.e. in the form of a table).	This Annexure A
Attachment A requirements The EIS is required to:	
• Demonstrate how the proposal is consistent with the relevant rules of the Water Sharing Plan including rules for access licences, distance restrictions for water supply works and rules for the management of local impacts in respect of surface water and groundwater sources, ecosystem protection (including groundwater dependent ecosystems), water quality and surface-groundwater connectivity.	Sections 3, 4.6 and 9.3
• Provide a description of any site water use (amount of water to be taken from each water source) and management including all sediment dams, clear water diversion structures with detail on the location, design specifications and storage capacities for all the existing and proposed water management structures.	Sections 6.2, 7, 8 and 9, and Annexure D
• Provide an analysis of the proposed water supply arrangements against the rules for access licences and other applicable requirements of any relevant WSP, including: o Sufficient market depth to acquire the necessary entitlements for each water source. o Ability to carry out a "dealing" to transfer the water to relevant location under the rules of the WSP. o Daily and long-term access rules. o Account management and carryover provisions.	Sections 3, 4.6 and 9.3
• Provide a detailed and consolidated site water balance.	Section 7 and Annexure B
The EIS should take into account the following policies (as applicable): • NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012) • NSW State Rivers and Estuary Policy (1993) • NSW Water Extraction Monitoring Policy (2007)	Section 3
Marulan Creek Dam	
A dam on Marulan Creek could be considered however substantial and appropriate justification as suggested by undertaking an options analysis is considered absolutely appropriate and essential.	Section 8 and Annexure D
The exemptions under Section 89J however do not apply to volumetric licensing and so all predicted water use (take) must be accounted for by having adequate entitlement and appropriate licensing.	Sections 3 and 11.6
Licensing Considerations The EIS is required to provide:	
• Identification of water requirements for the life of the project in terms of both volume and timing (including predictions of potential ongoing groundwater take following the cessation of operations at the site - such as evaporative loss from open voids or inflows).	Sections 6.2 and 7, and Annexure B
• Details of the water supply source(s) for the proposal including any proposed surface water and groundwater extraction from each water source as defined in the relevant Water Sharing Plan/s and all water supply works to take water.	Sections 6.2 and 7, and Annexure B
• Explanation of how the required water entitlements will be obtained (i.e. through a new or existing licence/s, trading on the water market, controlled allocations etc).	Sections 3, 6.2, 7, 8, 9 and 11.6
• Information on the purpose, location, construction and expected annual extraction volumes including details on all existing and proposed water supply works which take	Sections 6.2, 7, 8 and 9, and Annexure B

Requirement	Reference
surface water, (pumps, dams, diversions, etc).	
• Details on all bores and excavations for the purpose of investigation, extraction, dewatering, testing and monitoring. All predicted groundwater take must be accounted for through adequate licensing. • Details on existing dams/storages (including the date of construction, location, purpose, size and capacity) and any proposal to change the purpose of existing dams/storages. • Details on the location, purpose, size and capacity of any new proposed dams/storages. • Applicability of any exemptions under the Water Management (General) Regulation 2011 to the project. • Water allocation account management rules, total daily extraction limits and rules governing environmental protection and access licence dealings also need to be considered.·	Sections 6.2, 7, 8 and 9, and Annexure B Sections 6 and 9.3 Sections 6.2, 7 and 9 Section 3.1 and 9.3 Section 3.2.5
Surface Water Assessment The predictive assessment of the impact of the proposed project on surface water sources should include the following: • Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project. • Identification of all surface water sources as described by the relevant water sharing plan. • Detailed description of dependent ecosystems and existing surface water users within the area, including basic landholder rights to water and adjacent/downstream licensed water users.	Section 4 Section 3 Section 9.3
• Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources. • Assessment of predicted impacts on the following: ○ flow of surface water, sediment movement, channel stability, and hydraulic regime, ○ water quality, ○ flood regime, ○ dependent ecosystems, ○ existing surface water users, and ○ planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans.	Sections 6.2 and 7 Section 9
Landform rehabilitation (including final void management) The Environmental Impact Statement report should include: • Justification of the proposed final landform with regard to its impact on local and regional surface and groundwater systems; • A detailed description of how the site would be progressively rehabilitated and integrated into the surrounding landscape; • Outline of proposed construction and restoration of topography and surface drainage features if affected by the project; • Detailed modelling of potential groundwater volume, flow and quality impacts of the presence of an inundated final void (where relevant) on identified receptors specifically considering those environmental systems that are likely to be groundwater dependent; • An outline of the measures to be put in place to ensure that sufficient resources are available to implement the proposed rehabilitation; and	Section 7.11, 9.7 and 11.5 Section 7.2 Section 7.2, 7.11, 9.7 and 11.5 Section 7.11 and 9.7

Requirement	Reference
• The measures that would be established for the long-term protection of local and regional aquifer systems and for the ongoing management of the site following the cessation of the project.	Section 11.5
Sustainable Water Supply • The water supply requirements and potential water available should be identified in the EIS to enable the Office of Water to assess the viability of the water supply required.	Section 6.2, 7, 8, 9 and 10
NSW Resources and Energy	
Description of Existing Environment, Identification of Impacts and Constraints All areas affected by the proposal should be shown in the context of the natural and built environments. This should be in sufficient detail to enable an understanding of the scale of impacts and gauge the effectiveness of proposed control measures.	Sections 1 and 6
The EIS should state the interaction between the proposed mining activities and the existing environment and so include a comprehensive description of the following activities and their impacts: • surface and groundwater usage and management;	Sections 1 and 4 – 10
The following are the key issues to be addressed in the EIS that are likely to have a bearing on rehabilitation and mine closure: • where a void is proposed to remain as part of the final landform, the assessment is to provide details in regards to the following: 3) Outcomes of the surface and groundwater assessments in relation to the likely final water level in the void. This should include an assessment of the potential for fill and spill along with measures required be implemented to minimise associated impacts to the environment and downstream water users.	Sections 6.2, 7.11, 9.7 and 11.5 Sections 6.2, 7.12, 9.7 and 11.5
Open Cut Mining The EIS must assess surface water flow and flooding regimes and how these will be impacted and mitigated by the project both during and after mining has ceased. This is to include an evaluation of potential impacts from the final void on both surfaces and groundwater quality and flow regimes. Justification must be supported by the information provided by the proponent, including but not limited to: • General and relevant site condition including depths of cover, geological, hydrogeological, hydrological, geotechnical, topographic, and climatic conditions;	To the extent relevant to surface water: Sections 6.2, 7, 8, 9 and 11.5, and Annexure D Sections 1, 4 and 6
EPA	
Summary and General Comments: In summary, the EPA's key information requirements for the proposal include an adequate assessment of: • …Water quality	Sections 5 and 9.5, and Annexure C
In carrying out the assessment, the proponent should refer to the relevant guidelines as listed in Attachment B EPA letter and any relevant industry codes of practice and best practice management guidelines. • The EIS must include a comprehensive description of the production processes, all discharges and emissions to the environment, an assessment of likely environmental impacts, and a comprehensive description of any proposed control measures. • The environmental sensitivity of the site and surrounds should be discussed. Details are required on the location of the proposed development, including the affected environment, to place the proposal in its local and regional environmental context including surrounding land uses, land use zonings and potential sensitive receptors.	Section 3 Sections 6.2, 7, 8, 9, 10 and 11 Sections 1, 4, and 6, and Annexures C and D

Requirement	Reference
• The EIS should describe mitigation and management options that will be used to prevent, control, abate or mitigate identified environmental impacts associated with the project and to reduce risks to human health and prevent the degradation of the environment. This should include an assessment of the effectiveness and reliability of the measures and any residual impacts after these measures are implemented	Sections 10 and 11
• The EIS should address the specific requirements outlined below and assess impacts in accordance with the relevant guidelines mentioned. A full list of guidelines is at Attachment B (of the DPE letter).	Section 3
B. The Proposal **1. Objectives of the Proposal** The objectives of the proposal should be clearly stated and refer to: a) the size and type of the operation, the nature of the processes and the products, by-products and wastes produced b) a life cycle approach to the production, use or disposal of products c) the anticipated level of performance in meeting required environmental standards and cleaner production principles d) the staging and timing of the proposal and any plans for future expansion e) the proposal's relationship to any other industry or facility.	Sections 1.6, 3, and 9
2. Description of the Proposal ***General:*** • Outline the production process including: a) the environmental "mass balance" for the process - quantify in-flow and out-flow of materials, any points of discharge to the environment and their respective destinations (sewer, stormwater, etc.)	Sections 6.2, 7, 10.1, 10.2 and 11.2
• Outline cleaner production actions, including: e) water management system including all potential sources of water pollution, proposals for re-use, treatment etc., emission levels of any wastewater discharged, discharge points, summary of options explored to avoid a discharge, reduce its frequency or reduce its impacts, and rationale for selection of option to discharge.	Sections 6.2, 7, 9 and 10
Water: • Provide details of the project that are essential for predicting and assessing impacts to waters including:	
a) the quantity and physio-chemical properties of all the potential water pollutants and the risks they pose to the environment and human health, including the risks they pose to Water Quality Objectives in the ambient waters(as defined on www.environment.nsw.giv.au\ieo, using technical criteria derived from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC 2000)	Sections 3.2, 4.8, 5.1.2 and 9.5, and Annexure C
b) the management of discharges with potential for water impacts	Sections 7.7, 10 and 11.2
c) Drainage works and associated infrastructure; land-forming and excavations; working capacity of structures; and water resource requirements of the proposal.	Sections 6.2, 7 and 9
• Outline site layout, demonstrating efforts to avoid proximity to water resources (especially for activities with significant potential impacts e.g. effluent ponds) and showing potential areas of modification of contours, drainage etc.	Section 6.2
• Outline how total water cycle considerations are to be addressed showing total water balances for the development (with the objective of minimising demands and impacts on water resources). Include water requirements (quantity, quality and sources(s)) and proposed storm and wastewater disposal, including types, volumes, proposed treatment and management methods and re-use options.	Sections 6.2 and 7, and Annexure B

Requirement	Reference
3. Rehabilitation • Outline considerations of site maintenance, and proposed plans for the final condition of the site (ensuring its suitability for future uses).	Section 6.2, 9.7 and 11.5
4. Consideration of alternatives and justification for the proposal • Consider the environmental consequences of adopting alternatives for waste and water management.	Section 9
C. The Location **1. General:** • Provide an overview of the affected environment to place the proposal in its local and regional environmental context including:	
a) meteorological data (e.g. rainfall, temperature and evaporation, wind speed and direction)	Sections 1.2, 4.1 and 4.1.3
b) topography (landform element, slope type, gradient and length)	Sections 1.2
c) surrounding land uses (potential synergies and conflicts)	Sections 1.2
d) geomorphology (rates of landform change and current erosion and deposition processes)	
e) soil types and properties (including erodibility; engineering and structural properties; dispersibility; permeability; presence of acid sulfate soils and potential acid sulfate soils)	Section 1.2.7
f) ecological information (water system habitat, vegetation, fauna).	Section 5 and Annexure C (water quality)
• Provide and analyse site representative data on meteorological parameters such as rainfall, evaporation and cloud cover	Sections 4.1 and 4.2
4. Water: • Describe the catchment including proximity of the development to any waterways and provide an assessment of their sensitivity / significance from a public health, ecological and /or economic perspective. The Water Quality and River Flow objectives on the website: www.environment.nsw.gov.au/ieo should be used to identify the agreed environmental values and human uses for any affected waterways. This will help with the description of the local and regional area.	Sections 1, 3 and 4
D. Identification and prioritisation of issues/scoping of impact assessment • Provide an overview of the methodology used to identify and prioritise issues. The methodology should take into account:	
a) relevant NSW government guidelines	Section 3
b) industry guidelines	Section 3
c) EISs for similar projects	Section 9.6
d) relevant research and reference material	Sections 3 and 13
e) relevant preliminary studies or reports for the proposal	N/A
f) consultation with stakeholders	Refer EIS
• Provide a summary of the outcomes of the process including: a) all issues identified including local, regional and global impacts (e.g increased/decreased greenhouse emissions) b) key issues which will require a full analysis (including comprehensive baseline assessment) c) issues not needing full analysis though they may be addressed in the mitigation strategy d) justification for the level of analysis proposed (the capacity of the proposal to give rise to high concentrations of pollution compared with the ambient environment or environmental outcomes is an important factor in setting the level of assessment)	The SWA has been prepared to address issues relating to surface water.

Requirement	Reference
E. The Environmental issues **1. General:** • The potential impacts identified in the scoping study need to be assessed to determine their significance, particularly in terms of achieving environmental outcomes, and minimising environmental pollution • Identify gaps in information and data relevant to significant impacts of the proposal and any actions proposed to fill those information gaps so as to enable development of appropriate management and mitigation measures. This is in accordance with ESD requirements. *Note: The level of detail should match the level of importance of the issue in decision making which is dependent on the environmental risk.*	The SWA has been prepared to address issues relating to surface water. The SWA has been prepared to address issues relating to surface water. Ongoing monitoring described in Section 11.
Describe Baseline Conditions: • Provide a description of existing environmental conditions for any potential impacts.	Sections 1 and 4, and Annexures B and C
Assess Impacts: • For any potential impacts relevant for the assessment of the proposal provide a detailed analysis of the impacts of the proposal on the environment including the cumulative impact of the proposal on the receiving environment especially where there are sensitive receivers. • Describe the methodology used and assumptions made in undertaking this analysis (including any modelling or monitoring undertaken) and indicate the level of confidence in the predicted outcomes and the resilience of the environment to cope with the predicted impacts. • The analysis should also make linkages between different areas of assessment where necessary to enable a full assessment of environmental impacts eg assessment of impacts on air quality will often need to draw on the analysis of traffic, health, social, soil and/or ecological systems impacts; etc. • The assessment needs to consider impacts at all phases of the project cycle including: exploration (if relevant or significant), construction, routine operation, start-up operations, upset operations and decommissioning if relevant. • The level of assessment should be commensurate with the risk to the environment.	Section 9 Sections 6.2, 7 and 8, and Annexures B and D Sections 6.2, 7 and 8, and Annexures B and D Sections 6.2, 7, 8 and 9, and Annexure B Sections 6.2, 7, 8 and 9, and Annexure B
Describe Management and Mitigation Measures: • Describe any mitigation measures and management options proposed to prevent, control, abate or mitigate identified environmental impacts associated with the proposal and to reduce risks to human health and prevent the degradation of the environment. This should include an assessment of the effectiveness and reliability of the measures and any residual impacts after these measures are implemented. • Proponents are expected to implement a 'reasonable level of performance' to minimise environmental impacts. The proponent must indicate how the proposal meets reasonable levels of performance. For example, reference technology based criteria if available, or identify good practice for this type of activity or development. A 'reasonable level of performance' involves adopting and implementing technology and management practices to achieve certain pollutant emissions levels in economically viable operations. Technology-based criteria evolve gradually over time as technologies and practices change. • Use environmental impacts as key criteria in selecting between alternative sites, designs and technologies, and to avoid options having the highest environmental impacts. • Outline any proposed approach (such as an Environmental Management Plan) that will demonstrate how commitments made in the EIS will be implemented. Areas that should be described include: a) operational procedures to manage environmental impacts b) monitoring procedures c) training programs d) community consultation e) complaint mechanisms including site contacts	Sections 9, 10 and 11 Sections 9, 10 and 11 Sections 6.2, 7, 8, 9 and 10 Sections 10 and 11

Requirement	Reference
f) strategies to use monitoring information to improve performance g) strategies to achieve acceptable environmental impacts and to respond in event of exceedences.	
4. Water ***Describe Baseline Conditions***	To the extent relevant to surface water:
• Describe existing surface and groundwater quality – an assessment needs to be undertaken for any water resource likely to be affected by the proposal and for all conditions (e.g. a wet weather sampling program is needed if runoff events may cause impacts). *Note: Methods of sampling and analysis need to conform with an accepted standard (e.g. Approved Methods for the sampling and Analysis of Water Pollutants in NSW (DEC 2004) or be approved and analyses undertaken by accredited laboratories).*	Section 5 and Annexure C. Groundwater related issues are addressed in the Groundwater Assessment appended to the EIS
• Provide site drainage details and surface runoff yield.	Sections 6.2 and 7, Annexure B
• State the ambient Water Quality and River Flow Objectives for the receiving waters. These refer to the community's agreed environmental values and human uses endorsed by the Government as goals for the ambient waters. These environmental values are published on the website: www.environment.nsw.gov.au/ieo. The EIS should state the environmental values listed for the catchment and waterway type relevant to your proposal.	Sections 3 and 5, Annexure C
• State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC 2000 *Guidelines for Fresh and Marine Water Quality*.	Sections 3 and 6, Annexure C
• State any locally specific objectives, criteria or targets, which have been endorsed by the government e.g. the Healthy Rivers Commission Inquiries.	Section 3
• Where site specific studies are proposed to revise the trigger values supporting the ambient Water Quality and River Flow Objectives, and the results are to be used for regulatory purposes (e.g. to assess whether a licensed discharge impacts on water quality objectives), then prior agreement from the EPA on the approach and study design must be obtained.	Sections 5 and 9.5, Annexure C
• Describe the state of the receiving waters and relate this to the relevant Water Quality and River Flow Objectives (i.e. are Water Quality and River Flow Objectives being achieved?). Proponents are generally only expected to source available data and information. However, proponents of large or high risk developments may be required to collect some ambient water quality/river flow/groundwater data to enable a suitable level of impact assessment. Issues to include in the description of the receiving waters could include: a) lake or estuary flushing characteristics; b) specific human uses (e.g. exact location of drinking water offtake); c) historic river flow data where available for catchment. d) a description of the condition of the local catchment e.g. erosion levels, soils, vegetation cover, etc	Sections 1 and 5, and Annexure C
Assess impacts	
• No proposal should breach clause 120 of the *Protection of the Environment Operations Act 1997* (i.e. pollution of waters is prohibited unless undertaken in accordance with relevant regulations).	Sections 3, 10.2 and 11.6
• Identify and estimate the quantity of all pollutants that may be introduced into the water cycle by source and discharge point including residual discharges after mitigation measures are implemented.	Sections 7, 9 and 10.2
• Include a rationale, along with relevant calculations, supporting the prediction of discharges.	Sections 6.2, 7 and 8, and Annexure B
• Describe the effects and significance of any pollutant loads on the receiving environment. This should include impacts of residual discharges through modelling, monitoring or both, depending on the scale of the proposal. Determine changes to hydrology (including drainage patterns, surface runoff yield, flow regimes, wetland hydrologic regimes and groundwater).	Section 7, 9, 10 and 11

Requirement	Reference
• Describe water quality impacts resulting from changes to hydrologic flow regimes (such as nutrient enrichment or turbidity resulting from changes in frequency and magnitude of stream flow).	Sections 9.4 and 9.5
• Identify potential impacts associated with geomorphological activities with potential to increase surface water and sediment runoff or to reduce surface runoff and sediment transport. Also consider possible impacts such as bed lowering, bank lowering, instream siltation, floodplain erosion and floodplain siltation.	
• Containment of spills and leaks shall be in accordance with the technical guidelines section 'Bunding and Spill Management' of the Authorised Officers Manual (EPA, 1995) (http://www.epa.nsw.gov.au/mao/bundingspill.htm) and the most recent versions of the Australian Standards referred to in the Guidelines. Containment should be designed for no-discharge.	Section 10.2
• The significance of the impacts listed above should be predicted. When doing this it is important to predict the ambient water quality and river flow outcomes associated with the proposal and to demonstrate whether these are acceptable in terms of achieving protection of the Water Quality and River Flow Objectives. In particular the following questions should be answered:	Baseline conditions Sections 1, 4 and 5, and Annexure C and D. Impacts: Section 9 Water Quality and River Flow Objectives: Section 3
a) will the proposal protect Water Quality and River Flow Objectives where they are currently achieved in the ambient waters? and	Sections 7, 8, 9 and 10
b) will the proposal contribute towards the achievement of Water Quality and River Flow Objectives over time, where they are not currently achieved in the ambient waters?	Sections 7, 8, 9 and 10
• Where a licensed discharge is proposed, provide rationale as to why it cannot be avoided through application of a reasonable level of performance, using available technology, management practice and industry guidelines.	Section 6
• Where a licensed discharge is proposed, provide the rationale as to why it represents the best environmental outcome and what measures can be taken to reduce its environmental impact.	Section 6
• Reference should be made to the relevant guidelines e.g. *Managing Urban Stormwater: Soils and Construction* (DECC, 2008), *Guidelines for Fresh and Marine Water Quality* ANZECC 2000).	Sections 1, 3, 4, 5, 6, 9 and 11, and Annexure C
Describe management and mitigation measures	Section 10
• Outline stormwater management to control pollutants at the source and contain them within the site. Also describe measures for maintaining and monitoring any stormwater controls.	Sections 6.2, 7, 9 and 10
• Outline erosion and sediment control measures directed at minimising disturbance of land, minimising water flow through the site and filtering, trapping or detaining sediment. Also include measures to maintain and monitor controls as well as rehabilitation strategies.	Sections 3, 6, 8, 9, 10.8 and 11
• Describe wastewater treatment measures that are appropriate to the type and volume of wastewater and are based on a hierarchy of avoiding generation of wastewater; capturing all contaminated water (including stormwater) on the site; reusing/recycling wastewater; and treating any unavoidable discharge from the site to meet specified water quality requirements.	Sections 6.1.1 and 6.1.4
• Outline pollution control measures relating to storage of materials, possibility of accidental spills (e.g. preparation of contingency plans), appropriate disposal methods, and generation of leachate.	Section 10.2
• Describe hydrological impact mitigation measures including:	
a) Site selection (avoiding sites prone to flooding and waterlogging, actively eroding or affected by deposition)	Sections 6.2 and 7
b) Minimising runoff	Sections 6.2 and 7

Requirement	Reference
c) Minimising reductions or modifications to flow regimes	Section 9.4
• Describe geomorphological impact mitigation measures including:	
a) site selection	Section 6.2
b) erosion and sediment controls	Sections 3, 6, 8, 9 and 10.8
c) minimising instream works	N/A
d) treating existing accelerated erosion and deposition	Sections 3, 6, 8, 9 and 10.8
e) monitoring program.	Section 11
• Any proposed monitoring should be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC2004).	Section 11.2
7. Cumulative Impacts	
• Identify the extent that the receiving environment is already stressed by existing development and background levels of emissions to which this proposal will contribute.	Sections 1, 4 and 5, and Annexure C
• Assess the impact of the proposal against the long term air, noise and water quality objectives for the area or region.	Section 9.4, 9.5 and 9.6
• Identify infrastructure requirements flowing from the proposal (e.g water and sewerage services, transport infrastructure upgrades).	Section 6.2, 7
• Assess likely impacts from such additional infrastructure and measures reasonably available to the proponent to contain such requirements or mitigate their impacts (e.g travel demand management strategies).	Section 9.6
F. List of Approvals and Licences	
• Identify all approvals and licences required under environmental protection legislation including details of all scheduled activities, types of ancillary activities and types of discharges (to air, land, water).	Sections 3.2.5, 6.1.5, 6.2, 7.10, 8.3, 9.3, 9.4 and 11.6
G. Compilation of Mitigation Measures	
• Outline how the proposal and its environmental protection measures would be implemented and managed in an integrated manner so as to demonstrate that the proposal is capable of complying with statutory obligations under EPA licences or approvals (e.g outline of an environmental management plan).	Sections 10 and 11
• The mitigation strategy should include the environmental management and cleaner production principles which would be followed when planning, designing, establishing and operating the proposal. It should include two sections, one setting out the program for managing the proposal and the other outlining the monitoring program with a feedback loop to the management program.	Sections 10 and 11
Water NSW	
The proximity of the site to Bungonia Creek and Shoalhaven Rover and any impacts on water quality and quantity from the proposed project are of concern to Water NSW. The EIS will need to demonstrate that the proposed measures to capture and treat water impacted by the proposal will have no impact on water quality within the Shoalhaven River. To address the above issues Water NSW recommends the following be included in the Secretary's requirements:	
• As agreed with via correspondence from Department of Planning and Infrastructure (Ref qb 174202 dated 5 August 2011) the following be included as a standard Secretary's Requirement in the Drinking Water Catchment:	
"The EIS must assess potential risks to surface and groundwater quality during construction and operation, demonstrating clear consideration of the principle of achieving a neutral or beneficial effect on water quality in the drinking water catchment, consistent with the State Environment Planning Policy (Sydney Drinking Water Catchment) 2011. The EIS must include a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation".	Sections 3.2.6 and 9.5.3
• A detailed description of those aspects of the project which have the potential to impact on the quality and quantity of surface and ground waters at and adjacent to the project. This should include:	To the extent relative to surface water:

Requirement	Reference
○ The location, management and storage of all hazardous materials; ○ The location of road crossings, unsealed roads and their proximity to watercourses; ○ The location of and description of all water quality management measures; ○ The location of and description of all water monitoring points (surface and ground waters).	No change to existing facilities Section 6.2 Sections 6.2 and 7 Sections 5, 9.5 and 11.2
• The surface water and groundwater assessment should also address the following matters: ○ Pre-development and post development run off volumes and pollutant loads from the site; ○ Details of the measures to manage wastewaters associated with processing quarry materials, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied; ○ details of how impacts associated with the diversion, storage or relocation of any watercourses will be managed and mitigated ○ Details of how potential connections between waters within the quarry area will be separated from groundwater and external surface water; ○ Assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including implications from keeping the quarry void; ○ Details of the structural stability and integrity of all stormwater management measures including the structural stability and integrity of dams over the life of the project; ○ Details of the ongoing maintenance and monitoring of stormwater management measures including dams on the site; ○ Details of the proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor and, if necessary, mitigate impacts on surface water and groundwater resources.	To the extent relative to surface water: Sections 5 and 9.4, and Annexure C Sections 3.2.6, 6.2, 7, 9.5.3, 10 and 11 Sections 6.2, 7 and 9.4 Section 1.2.6 and 6.2 Section 9 Sections 10 and 11 Sections 10 and 11 Section 10.9 and 11
• Consider the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather.	Section 6.2, 7 and 7.8
• Consider the principles outlined in the 'Managing Urban Stormwater- Soils and Construction- 'Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008).	Sections 7, 8, 9, 10
• Provide details of measured and predicated quarry performance with respect to water quality management since its commencement including details of incidents.	Section 5 and Annexure C
• Provide concept plans/protocols/ procedures for the following: ○ Environmental Management Plan ○ Soil and Water Management Plan- including triggers, actions, responses ○ Procedures for managing spills ○ Details of the practices proposed to ensure materials transported to and from the site do not spill or otherwise cause soil or water pollution. ○ Post-quarrying rehabilitation plan.	Sections 10 and 11 to the extent that these issues relate to surface water.
Water NSW notes that there are a number of large quarries operating in the Marulan area. These quarries have the potential to have a cumulative impact. Water NSW recommends the Secretary's requirements specifically address cumulative impacts with respect to water quality and water quantity.	Section 9.6
OEH	
OEH recommends the EIS needs to appropriately address the following: **Water and Soils** 5. The EIS must map the following features relevant to water including:	

Requirement	Reference
a. Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment). d. Proposed intake and discharge locations.	Section 4 Sections 6.2 and 8
6. The EIS must describe background conditions for any water resource likely to be affected by the project including: a. Existing surface water; b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations; c. Water Quality Objectives (as endorsed by the NSW Government www.environment.nsw.gov.au/ieo/index.htm); d. Indicators and trigger values/criteria for the environmental values identified above in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	 Sections 1, 4 and 5 Section 4, 6.2 and 7 Sections 3 and 9 Section 5 and 11.2 and Annexure C
7. The EIS must assess the impacts of the project on water quality, including: a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how Water Quality Objectives are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include assessment of mitigating effects of proposed stormwater and wastewater management during and after construction; b. Identification of proposed monitoring of water quality.	To the extent that these issues relate to surface water: Sections 7, 9 and 10 Section 11.2
8. The EIS must assess the impact of the proposed project on hydrology, including: a. Water balance including quantity, quality and source; b. Effects to downstream rivers, water and floodplain areas; c. Effects to downstream water-dependant fauna and flora; d. Impacts to natural processes and functions within rivers, wetlands and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches); e. Changes to environmental water availability, both regulated/licenses and unregulated/rules-based sources of such water; f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options; g. Identification of proposed monitoring of hydrological attributes.	 Sections 6.2 and 7, and Annexure B Section 9 Aquatic ecology issues are addressed in the *Aquatic Ecology Assessment* (Niche, 2018) Aquatic ecology issues are addressed in the *Aquatic Ecology Assessment* (Niche, 2018) Section 9 Section 10 Section 11
Flooding 9. The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a. Flood prone land; b. Flood planning area, the area below the flood planning level; c. Hydraulic categorisation (floodways and flood storage areas).	 Section 9.7.2
10. The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including minimum of the 1in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.	Section 9.7.2

Requirement	Reference
11. Modelling in the EIS must consider and document: a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood; b. Impacts of the proposed project on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories; c. Relevant provisions of the NSW Floodplain Development Manual 2005.	Section 9.7.2
12. The EIS must assess the impacts on the projection flood behaviour, including: a. Whether there will be detrimental increases in the potential flood affection of other properties, assets and infrastructure; b. Consistency with Council floodplain risk management plans; c. Compatibility with the flood hazard of the land; d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land; e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site; f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; g. Any impacts the proposed project may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council; h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council; i. Emergency management, evacuation and access, and contingency measures for the proposed project considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES; j. Any impacts the proposed project may have on the social and economic costs to the community as consequence of flooding.	Section 9.7.2

Annexure B Water Balance Analysis

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1 Introduction

This annexure provides an assessment of the performance of the water management system for the proposed Marulan South Limestone Mine Continued Operations Project (the Project) over the Operational Phase in terms of:

- security of water supply for operational purposes
- predicted frequency and volume of off-site water release from the Project.

A water balance model that runs on a daily time step for the period of operation of the mine has been developed for the assessment. For the Operational Phase, the model reflects the progressive changes in the mine overburden emplacements and groundwater inflows that would occur over the 30 year mine life.

A range of climate scenarios based on a 30 year sequence extracted from the historical rainfall data and other associated time series data was used in the model. A selected range of scenarios has been assessed to demonstrate the performance of the water management system under average and extreme (both wet and dry) climatic sequences.

A version of the water balance model has been developed to simulate the long term behaviour of the water management system following completion of mining.

The various elements of the mine water management system have been sized so as to store and transport all mine water and to ensure that only treated mine water would be released from the site.

Figures 6.2 to 6.5 of the main *Surface Water Assessment* report show the four stages of the development of the mine and the Western, Northern and Southern Overburden Emplacements. The current mine layout has overburden emplacements on the eastern side of the Mine Pit (which will not be developed further) and the Western Emplacement. The existing Western Emplacement (about 38 ha), other areas to the west of the Mine Pit (about 180 ha) and the existing Infrastructure Area (about 12 ha) all drain to the existing Mine Pit (about 100 ha). Any surface runoff that flows to the existing Mine Pit drains rapidly through the base of the pit and has negligible impact on limestone production.

Figure 1.1 is a schematic diagram showing the conceptual water management system for the Operational Phase, some elements of which would be constructed soon after project commencement with the remainder progressively constructed as needed during the progressive development of the mine as described in Section 3 below.

The staging shown in Figures 6.2 to 6.5 of the main *Surface Water Assessment* report which form the basis of the water management system shown in Figure 1.1 are conceptual, based on projected mine production and overburden schedules. The water management system depicted in Figure 1.1 would be progressively constructed and modified to meet the actual mine development.

Early in Stage 1, Sediment Dams N1, N2, P1 and W2 would be constructed along with the proposed Central Dam, Eastern Gully Dam, Kiln Dam (enlargement of existing dam), Marulan Creek Dam and North Pit sump for water storage (capacity details provided in Section 2.3.1). Although some of these facilities would overflow to the pit in high rainfall events, the frequency of discharge to the mine pit would be significantly reduced compared to existing conditions.

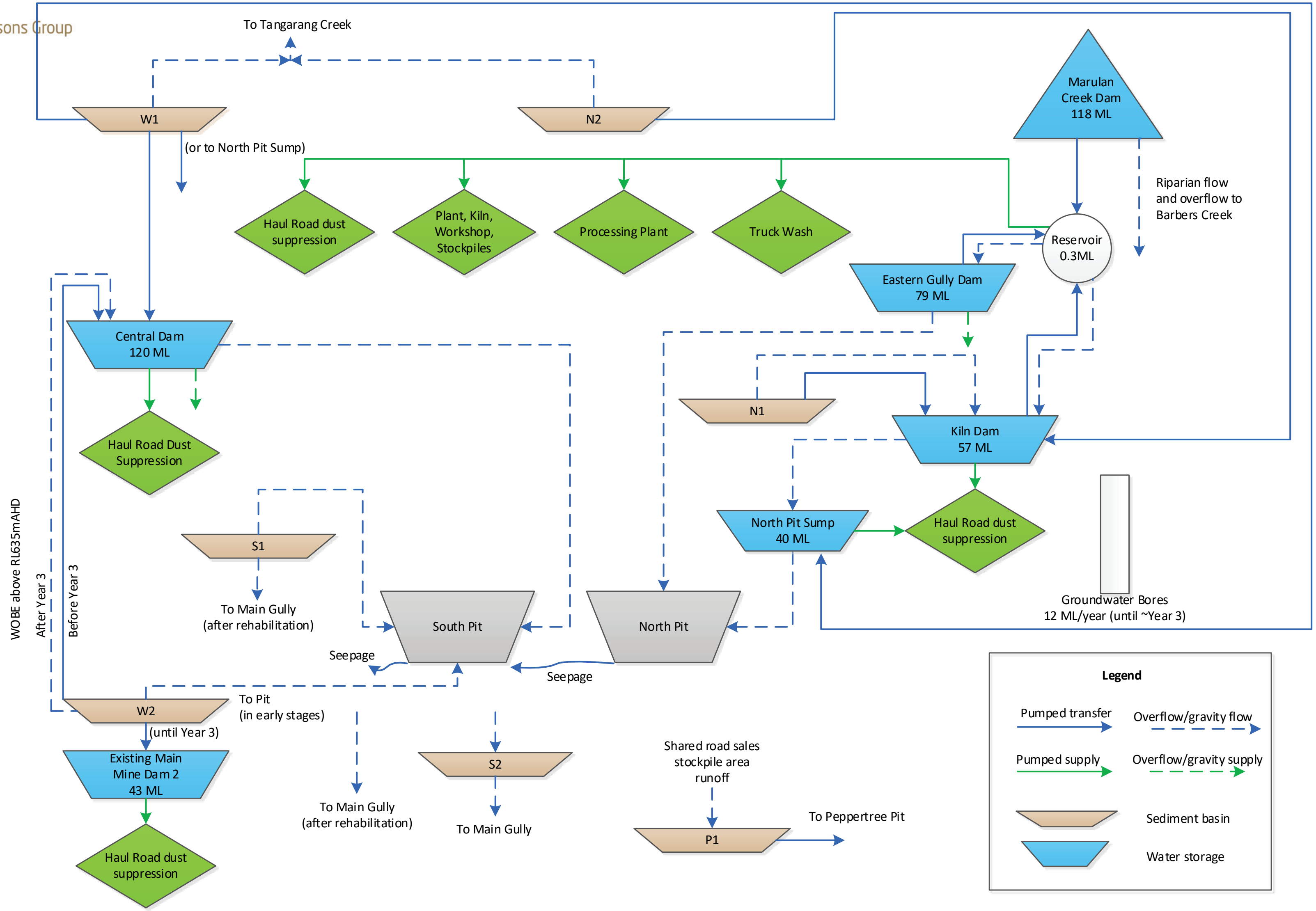


Figure 1.1: Water Management System Schematic Diagram

Mine Catchment Areas

The water balance model assumes that surface drainage from catchments likely to generate runoff with significant sediment loads would report to sediment dams that would be constructed and operated in accordance with the requirements set out in *Managing Urban Stormwater: Soil and Construction, Volume 2E – Mines and Quarries* (DECC, 2008). Runoff from storms less than the specified design storm (55.5 mm of rainfall over 5 days) would be transferred to the mine water management system and then be used for dust suppression or limestone processing. Any overflow from the sediment dams as a result of storm rainfall in excess of the design requirements would discharge to the mine pit, to Main Gully or to Tangarang Creek which drains to the Peppertree Quarry Dam.

Sediment Dams and Water Storages

Section 2.3 provides further details of the sources contributing to, or taking water from, the following sediment dams and water storages which are considered in the water balance analysis:

- Sediment Dams N1, N2, S1, W1 and W2
- the existing Mine Water Dam 2 (43 ML)
- the existing Kiln Dam (enlarged from 25 ML to 57 ML)
- the proposed Eastern Gully Dam (79 ML), Central Dam (120 ML) and North Pit sump (40 ML)
- the proposed Marulan Creek Dam (118 ML).

Water Sources

The main source of water for mine operations would be:

- site runoff
- existing groundwater bores (functional until subsumed by mining - about 3 years)
- supplementary supply from Tallong Weir and the proposed Marulan Creek Dam.

Surface runoff contributing to water management system has been estimated on the basis of the AWBM rainfall:runoff model described in greater detail in Section 2.2.4.1.

Water Demands and Losses

The water demands and losses that are included in the water balance model include:

- water demands for limestone processing (provided by Boral)
- water demands for dust suppression (calculated in the water balance model as a function of rainfall, evaporation and haul road length)
- evaporation losses from all water surfaces
- overflows from sediment dams (when rainfall exceeds the design storm)
- overflows from water storage dams to the mine pit.

2 Modelling Data

The water balance model utilises the following data which are described in detail in the subsequent sections:

Daily time series data:

- rainfall
- evaporation
- flow in Marulan Creek.

Mine operation data (30 years):

- progressive development of overburden emplacement areas
- daily water used for limestone processing and general mine operations
- groundwater inflow to the mine pit
- water requirements for dust suppression.

Site characterisation:

- catchment areas and runoff characteristics
- volume: area characteristics of water storages
- groundwater inflow and seepage losses in the mine pits.

2.1 Time Series Data

For purposes of water balance modelling and in line with common practice in relation to water management, a 'water year' starting in July has been adopted. Thus, reference to data starting in 1892 refers to data commencing in July 1892

2.1.1 Rainfall

The daily rainfall records for Marulan, George St (Station 070063) were obtained from the Scientific Information for Landowners (SILO) climate database. SILO is an online database of historic daily climate records for Australia, developed by the Bureau of Meteorology (BoM) and the Queensland Government, launched in 1997. The SILO database is currently hosted by the Qld Science Delivery Division of the Department of Science, Information Technology and Innovation (DSITI) and contains Australian climate data from 1889 to present. Datasets are constructed from climate data collected by the BoM with interpolation where there are data gaps as follows:

- 'Patched Point' Datasets are observed data with missing or suspect values 'patched' with interpolated data
- 'Data Drill' datasets access grids of data interpolated from point observations by the BoM. The data in the Data Drill are all synthetic.

The patched data record for Marulan (George St) for the period 1 July 1889 – 30 June 2017 was obtained from SILO for the analysis for the site water balance assessment. The record comprised 77% historic station data. Missing data in this record was infilled with interpolated daily observations.

Table 2.1 contains the monthly and annual rainfall statistics for the patched data record for Marulan (George St) which was used in the water balance analysis.

Table 2.1: Monthly Rainfall Statistics for Marulan (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	70	70	70	50	52	51	48	45	46	58	59	63	696
Minimum	1	0	0	0	0	0	0	0	0	1	0	0	288
10th %ile	14	7	10	8	7	9	9	10	15	16	8	13	473
Median	62	52	49	39	30	42	33	33	38	47	50	53	663
90th%ile	145	160	140	114	116	131	98	101	91	115	121	128	960
Maximum	222	273	330	233	406	382	319	224	166	263	248	220	1469

The statistics show that average annual rainfall in the vicinity of the Project is around 696 mm. Peak precipitation occurs in the summer months, with lower rainfall in winter. In wet (90th percentile) years the annual rainfall can be up to 960 mm while in a dry (10th percentile) year it can be as low as 473 mm.

Figure 2.1 shows the cumulative departure of rainfall from the long term average. The figure shows that the area has experienced extended drought periods (graph sloping downwards to the right), particularly an extended drought in 1900 – 1948. Although it contained some drier years, the period 1948 – 1978 was predominantly wetter than the long term average. The dry, median and wet 30 year rainfall sequences adopted for the water balance modelling are also shown on Figure 2.1.

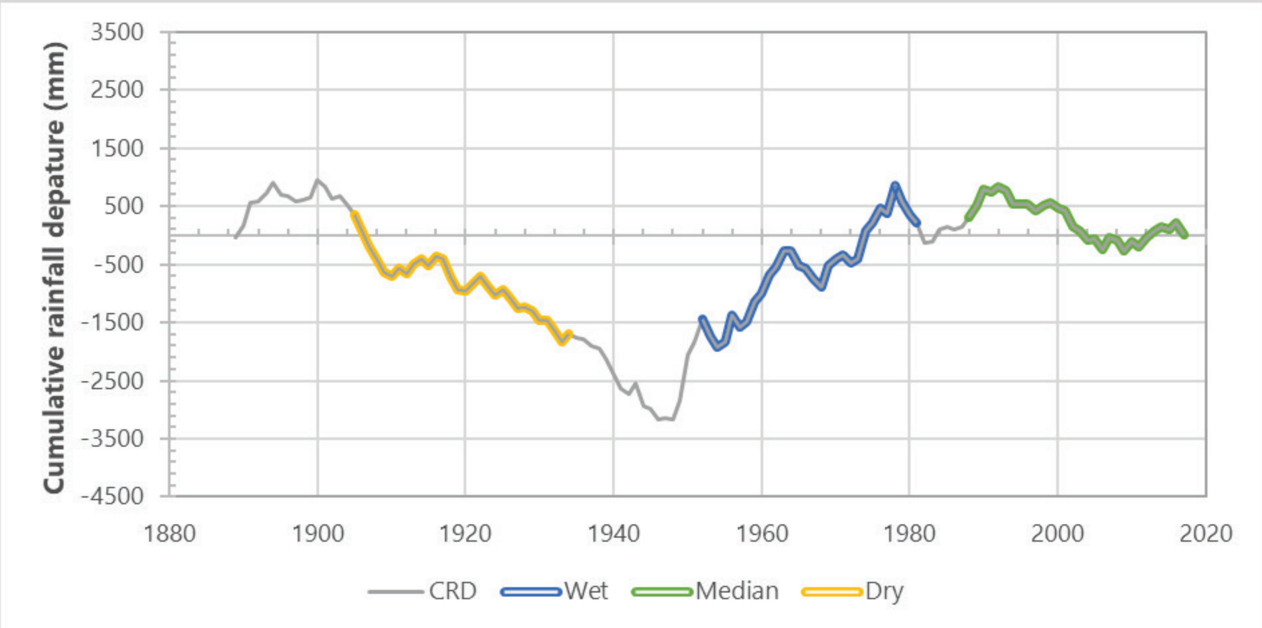


Figure 2.1: Residual Rainfall (1889 – 2017)

Table 2.2 summarises the variability of the historic rainfall record. The variation in the range for yearly rainfall sequences is less than for individual seasons because an extreme in one season is not necessarily followed by an extreme in other seasons in the same year. The annual variability reflects this averaging effect which is more pronounced in the 30 year sequence for the same reason.

Table 2.2: Historic Rainfall Variability

Season	Variation from Average		
	20% Probability	**10% Probability**	**Maximum**
Summer	-40% to +46%	-55% to +61%	-82% to +137%
Autumn	-38% to +68%	-52% to +119%	-94% to +248%
Winter	-45% to +52%	-60% to +98%	-80% to +235%
Spring	-34% to +38%	-51% to 64%	-80% to +145%
Year	-23% to +28%	-29% to 45%	-57% to +121%
30 year sequence	-8% to +8%	-10% to +10%	-13% to +20%

2.1.2 Evaporation

SILO patched pan evaporation data for Marulan George St (Station No. 70063) for the period 1 July 1889 to 30 June 2017 was obtained for use in the site water balance assessment, to represent evaporation from water storages and day to day variation of dust suppression water requirements. The data comprised long term average monthly data from 1889 to the end of 1968 and daily data from 1969 to current. Statistics for the patched pan evaporation data for Marulan (1969 – 2017) are provided in Table 2.4.

Table 2.3: Monthly Evaporation Statistics for Marulan (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	185	142	122	79	53	37	43	66	93	126	148	185	1278
Minimum	137	95	86	48	39	24	29	48	62	86	100	121	1017
10th %ile	146	111	97	61	43	28	34	52	76	98	116	143	1088
Median	189	143	121	78	51	36	43	64	91	122	146	174	1257
90th %ile	223	175	151	96	66	47	54	82	112	159	179	236	1478
Maximum	267	215	178	120	78	51	71	98	165	186	261	296	1752

Table 2.4 compares the median monthly historic pan evaporation at Goulburn TAFE (BOM Station 070263) and the patched pan evaporation data for Marulan. Table 2.4 also includes mean monthly pan coefficients for Canberra Airport which is the nearest station with high quality Class-A pan evaporation data (McMahon et al, 2013). These pan factors have been used to convert the daily pan evaporation data to estimates of open water evaporation from water storages.

Table 2.4: Mean Monthly Evaporation Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Marulan (SILO)	185	142	122	79	53	37	43	66	93	126	148	185
Goulburn (BOM)	195	145	124	75	50	33	37	60	84	121	150	186
Pan Factor	0.785	0.791	0.770	0.801	0.802	0.849	0.881	0.879	0.873	0.883	0.852	0.811

2.1.3 Adopted Climate Sequences

Because the water balance model keeps track of all runoff, water transfers and volumes in various storages on a day to day basis for a 30 year climate sequence over life of the Project, a large quantity of data is generated even for a single scenario. For purposes of demonstrating the long-term performance of the system under dry, median and wet conditions, the climate sequences listed in Table 2.5 were adopted for detailed analysis. The dry, wet and median 30 year rainfall sequences adopted for the water balance analysis are also shown on Figure 2.1.

Table 2.5: Climate Sequences Adopted for Analysis

Statistic	Climate Sequence Adopted
10th percentile (dry)	1905-1935
50th percentile (median)	1986-2016
90th percentile (wet)	1952-1982

2.1.4 Climate Change

The NSW and ACT Regional Climate Modelling (NARCliM) Project (a multi-agency research partnership between the NSW and ACT governments and the University of NSW) prepared high spatial resolution climate projections for NSW and the ACT in 2014. The *South-East and Tablelands Region Climate Change Snapshot* (OEH, 2014) provides the climate change projections for the near future (2030) and far future (2070+). Projections for the annual average rainfall range from a decrease (drying) to an increase by 2030 and also span both drying and wetting scenarios by 2070.

In 2015, Commonwealth Scientific & Industrial Research Organisation (CSIRO) issued *Climate Change in Australia Projections for Australia's Natural Resource Management (NRM) Regions*. These reports present projections of future climate for various natural resource management regions which are grouped into 'clusters' and 'sub-clusters'. The Project is located in the East Coast cluster and East Coast South sub-cluster (CSIRO, 2015 *Climate Change in Australia Projections – Cluster Report- East Coast*). The projections are based on current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and aerosol emissions.

The Global Climate Model (GCM) simulations presented in the report represent the full range of emission scenarios, as defined by the Representative Concentration Pathways (RCPs) used by the International Panel on Climate Change. Projects for three RCP scenarios are provided:

- RCP2.6 – representing a low emission scenario
- RCP4.5 - representing a pathway consistent with intermediate emissions, which stabilise the carbon dioxide concentration at about 540 parts per million (ppm) by the end of the 21st century
- RCP8.5 - representing a high-emission scenario, for which the carbon dioxide concentration reaches about 940 ppm by the end of the 21st century.

Projections are given for two 20-year time periods: the near future 2020–2039 (referred to as 2030) and 2080–2099 (referred to as 2090). The spread of model results are presented as the range between the 10th and 90th percentile in the model output. For each time period, the model spread can be attributed to three sources of uncertainty: the range of future emissions, the climate response of the models and natural variability.

The key predictions for the East Coast likely to impact on the water balance are:

- average, maximum and minimum temperatures are projected to continue to increase with very high confidence
- the temperature reached on the hottest days, the frequency of hot days and the duration of warm spells are projected to increase with very high confidence
- average winter rainfall is projected to decrease with medium confidence and a range of changes are projected in other seasons
- increased intensity of extreme rainfall events is projected with high confidence
- there is high confidence in little change in relative humidity for the near future and medium confidence in a decrease for late in the century
- projections for potential evapotranspiration indicate increases with high confidence in all seasons by late in the 21st century.

Further details are provided below.

2.1.4.1 Temperature

Past Temperature Trends
Surface air temperatures in the cluster have been increasing since national records began in 1910, especially since 1960. The mean temperature increased by around 0.8°C between 1910 and 2013.

Projections
Continued substantial warming for mean, maximum and minimum temperatures are projected with very high confidence.

For the near future (2030), the mean warming is around 0.4 to 1.3 °C above the climate of 1986–2005. For late in the century (2090) it is 1.3 to 2.5 °C for an intermediate scenario (RCP4.5) and 2.7 to 4.7 °C for a high emission scenario (RCP8.5).

A substantial increase in the temperature reached on the hottest days, the frequency of hot days and the duration of warm spells is projected with very high confidence. Correspondingly, a substantial decrease in the frequency of frost risk days is projected by 2090 with high confidence.

2.1.4.2 Rainfall

Past Rainfall Trends
The East Coast experienced prolonged periods of extensive drying in the early 20th century, but annual rainfall shows no long-term trend throughout the 20th century.

Rainfall Projections
Table 2.6 below summarises the CSIRO's seasonal rainfall projections for the near future and far future for the three RCP scenarios. The table provides the 10th and 90th percentile predictions as well as the median (50th percentile).

There is high confidence that natural climate variability will remain the major driver of rainfall changes in the next few decades in this cluster with 20-year mean changes of -15 to +10 % annually, and -30 to +20 % seasonally, relative to the climate of 1986–2005.

Under RCP4.5 and RCP8.5, by 2090 a decrease in winter rainfall is projected with medium confidence. A range of changes are projected in the other seasons, with a tendency for increase in summer, but uncertainty over driving processes. The magnitude of possible seasonal differences from the climate of 1986–2005 indicated by GCM results is around -25 to +20 % under RCP4.5 and -30 to +25 % under RCP8.5.

Impact assessment in this region should consider the risk of both a drier and wetter climate.

Extreme Rainfall and Drought
Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be reliably projected.

Time spent in drought is projected, with medium confidence, to increase over the course of the century.

2.1.4.3 Evaporation

Potential evapotranspiration is projected to increase in all seasons as warming progresses (high confidence) by the late 21st century. There is only medium confidence in the magnitude of these projections due to shortcomings in the simulation of observed historical changes.

Table 2.6 summarises the CSIRO's seasonal evapotranspiration projections for the near and far future for the three RCP scenarios.

Table 2.6: Seasonal Rainfall and Evapotranspiration Projections as a Result of Climate Change for the East Coast South

Season	Near Future (2030)						Far Future (2090)					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Rainfall (% change)												
Summer DJF	1	-13 to 18	1	-10 to 15	2	-13 to 14	-2	-22 to 10	0	-15 to 19	11	-12 to 27
Autumn MAM	-2	-16 to 8	-3	-22 to 15	-3	-13 to 14	-6	-23 to 12	-1	-22 to 18	-2	-28 to 20
Winter JJA	-2	-19 to 10	-5	-18 to 14	-8	-20 to 12	-3	-16 to 8	-8	-24 to 7	-17	-31 to 1
Spring SON	-3	-18 to 18	-1	-19 to 12	-3	-20 to 11	0	-19 to 10	-6	-23 to 9	-8	-30 to 14
Annual	-2	-9 to 7	-3	-10 to 6	-1	-11 to 6	-2	-16 to 8	-2	-16 to 9	-3	-20 to 16
Evapotranspiration (% change)												
Summer DJF	4.2	2.0 to 6.0	3.1	1.6 to 5.7	4.4	1.9 to 6.8	6.6	4.6 to 8.4	7.6	5.3 to 10.7	13.0	8.5 to 17.5
Autumn MAM	4.5	-0.4 to 8.8	3.6	0.5 to 7.4	5.2	2.3 to 9.4	6.3	3.9 to 9.8	9.1	6.1 to 13.2	19.3	12.8 to 24.0
Winter JJA	4.1	2.0 to 7.3	3.9	2.1 to 8	5.7	1.7 to 8.1	5.4	2.4 to 6.7	8.7	5.5 to 14.1	20.6	13.2 to 25.6
Spring SON	3.6	1.0 to 7.1	3	-0.3 to 4.1	3.0	1.0 to 6.2	3.8	1.4 to 7.1	7.2	2.6 to 8.2	11.4	7.4 to 15.4
Annual	3.9	2.7 to 5.9	3.4	2.3 to 4.4	4.2	2.3 to 6.0	5.9	4.2 to 6.8	7.8	5.3 to 9.5	14.3	10.1 to 18.1

Source: Climate Change in Australia Projections - Cluster Report – East Coast (CSIRO, 2015)

The climate change projections for both rainfall and evapotranspiration described above have been included in the water balance modelling in the following manner:

- The operational water balance over the mine life will be impacted by the 'near future' climate projections. As set out in Table 2.6, the range for possible changes in annual rainfall for all climate scenarios in the near future (2030) is from -11% to +7% with a median of -3% to -1%. Annual evapotranspiration is predicted to increase in the range of +2.3% to +6% with a median of +3.4% to +4.2%. (For modelling purposes it has been assumed that the percentage change quoted for evapotranspiration also applies to open water evaporation.) The uncertainties in rainfall and evapotranspiration projections are included in the sensitivity analysis set out in Section 4.8.
- The water balance analysis for the mine void (see Section 5.3) considers the long term (1,000 year) water level and salinity in the lake that will form in the base of the void following completion of the project after 2040. In order to account for possible long term future change in the climate, the water balance analysis assesses the impact of the 'far future' high range estimates for rainfall (-20% to +16%) and evapotranspiration (+4.2% to +18.1%) on the equilibrium water level (Table 2.6).

2.2 Mine Operation Data

2.2.1 Overburden Placement and Haul Roads

The mine plan involves:

- the continued expansion of the existing Western Emplacement
- the construction of the Northern and Southern Emplacements
- the progressive filling at the southern and western sides of the pit.

Schedules of annual overburden and limestone production have been prepared by Boral together with the layout of the overburden emplacements corresponding to Stages 1, 2, 3 and 4.

The mine staging plans show a network of haul roads that would provide access around the mine site. However, on any particular day, only a few specific routes would be active and, therefore, require water for dust suppression. For water balance modelling purposes, haul road data has been interpolated from the mine plans on an annual basis and summarised in Table 2.7. An area of 2 ha of hardstand area was assumed to also require dust suppression.

Table 2.7: Haul Road distances

Year	Average Haul Road Distance (km)
0	7.1
5	6.5
13	8.3
19	6.8
30	5

The development of the various areas of the mine over the mine life is shown graphically on Figure 2.2.

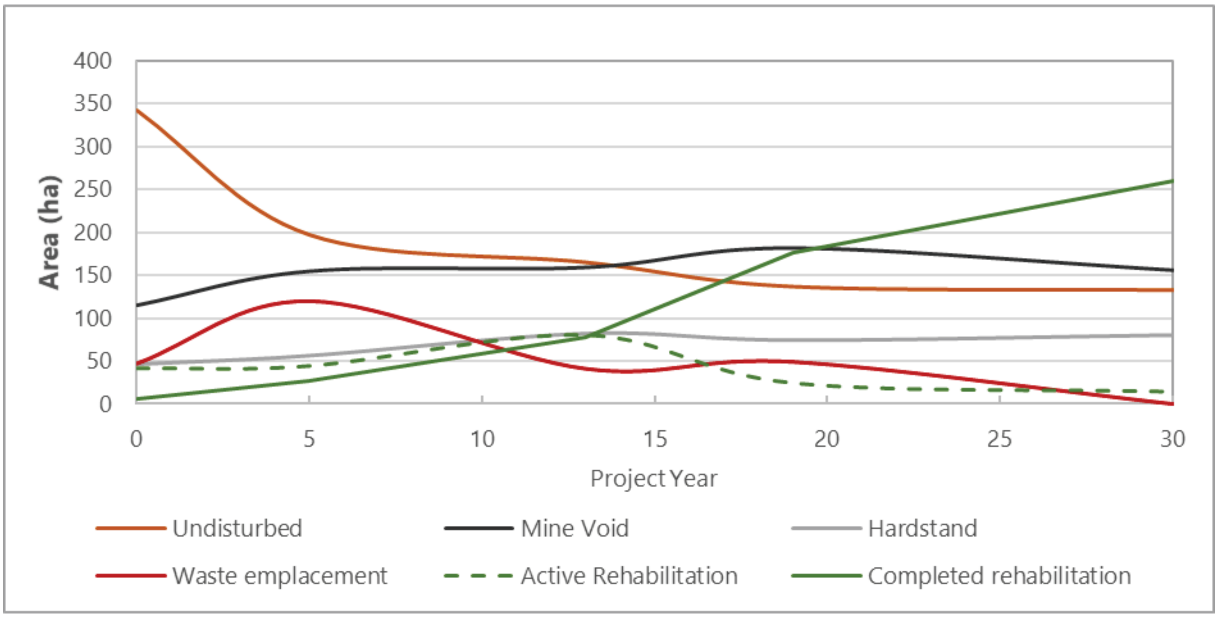


Figure 2.2: Mine development

2.2.2 Staging of Construction of Water Management Facilities

The following indicative staging of construction of water management facilities and management of any overflows is proposed:

Stage 1 (as shown in Figure 6.2 of the main *Surface Water Assessment* report) would involve:

- Construction of the new Marulan Creek, Central and Eastern Gully water storage dams, enlargement of the existing Kiln Dam, revegetation of all new dam walls
- Upgrade Tallong Weir to Marulan pipeline to allow connection of the Marulan Creek Dam to the Reservoir
- Pipeline connecting Eastern Gully Dam to Kiln Dam via the Reservoir
- Construction of the North Pit Sump towards the end of Stage 1 following north west mine development
- Construction of Sediment Basins N1 and N2 in preparation for emplacement of overburden in the Northern Overburden Emplacement
- Installation of pipelines to connect N1 and N2 to Kiln Dam, Eastern Gully Dam to Kiln Dam via the Reservoir, and W1 and W2 to Central Dam
- Completion of the Northern Overburden Emplacement including overburden emplacement to create southern stockpile/reclaim area. Commencement of rehabilitation of western section of Northern Overburden Emplacement
- Construction of Sediment Basin P1 to receive runoff from the new shared road sales stockpile area
- Completion of construction of Sediment Basin W1 to control runoff from the upper slopes of the Western Overburden Emplacement that progresses northwards toward Marulan South Road
- Completion of rehabilitation of the lower slopes of the Western Overburden Emplacement
- Progressive "in-pit" filling of the Southern Overburden Emplacement and commencement of western "out-of-pit" section. Progressive rehabilitation of the lower south-eastern slopes of the

Southern Overburden Emplacement.

Stage 2 (as shown in Figure 6.3 of the main Surface Water Assessment report) would involve:

- Complete rehabilitation of the Northern Overburden Emplacement (northern section) and complete construction of new stockpile/reclaim area infrastructure (southern section of Northern Overburden Emplacement) to allow northern mine pit development
- Progressive filling and rehabilitation of the southern section of the Western Overburden Emplacement
- Progressive filling of the Southern Overburden Emplacement above current South Pit rim. As the level of overburden rises above the level of the South Pit rim, Sediment Basin S1 would be constructed at approximately 440 m AHD. Water captured in this sediment basin would be used for revegetation purposes and dust suppression in the immediate area. Any overflow to be directed along the contour to limestone benches to drain to the base of the South Pit.
- A small area in the Southern Overburden Emplacement (0.8 ha) which would be at a lower elevation than Sediment Basin S1 would drain towards Main Gully where the existing sediment control facilities would be enlarged (to 1 ML) to form Sediment Basin S2 to treat any runoff from the emplacement and natural catchment before it discharges towards Bungonia Creek.
- Progressive rehabilitation of the lower southern and south-eastern slopes of the Southern Overburden Emplacement and upper slopes of the western "out-of-pit" section.

Stage 3 (as shown in Figure 6.4 of the main Surface Water Assessment report) would involve:

- Decommissioning of Sediment Basins N1 and N2 as actively managed sediment basins once rehabilitation of the Northern Overburden Emplacement (northern section) is well established, but would likely be retained for water storage and transfer as required for ongoing land management.
- Relocation of existing Marulan South Road to permit construction of the complete northern section of the Western Overburden Emplacement. Construction of new section of Marulan South Road including required erosion and sediment controls. Progressive rehabilitation of the lower slopes of the northern section of the Western Overburden Emplacement
- Rehabilitation of the batter slopes of the southern section of the Western Overburden Emplacement would be completed. If runoff water quality is appropriate, overflow from Sediment Basin W2 could be redirected directed by pipe or into a channel that discharged into the western tributary of Main Gully
- Mining progressing to west within the main pit, creating a smaller west pit. Runoff collected in the west pit will seep into groundwater, with any overflow reporting to the south pit
- Continued filling of the Southern Overburden Emplacement to join western "out-of-pit" section with the initial southern "in-pit" fill area. Rehabilitation of the upper batters of the western section and lower slopes of the southern and south-eastern sections of the Southern Overburden Emplacement.

Stage 4 (as shown in Figure 6.5 of the main Surface Water Assessment report) would involve:

- Completion of rehabilitation of the northern section of the Western Overburden Emplacement. Sediment Basins W1 and W2 to be decommissioned as actively managed sediment basins once rehabilitation was well established but would likely to be retained for water storage and transfer as required for ongoing land management.
- Completion of filling and rehabilitation of the outer slopes of the Southern Overburden Emplacement. Once rehabilitation has been well established, the drainage arrangements would be modified so that all runoff from the western section of the emplacement would be allowed to drain directly off site via Main Gully. Drainage from Sediment Basin S1 would also be directed to

Main Gully via the existing S2 series of sediment basins.

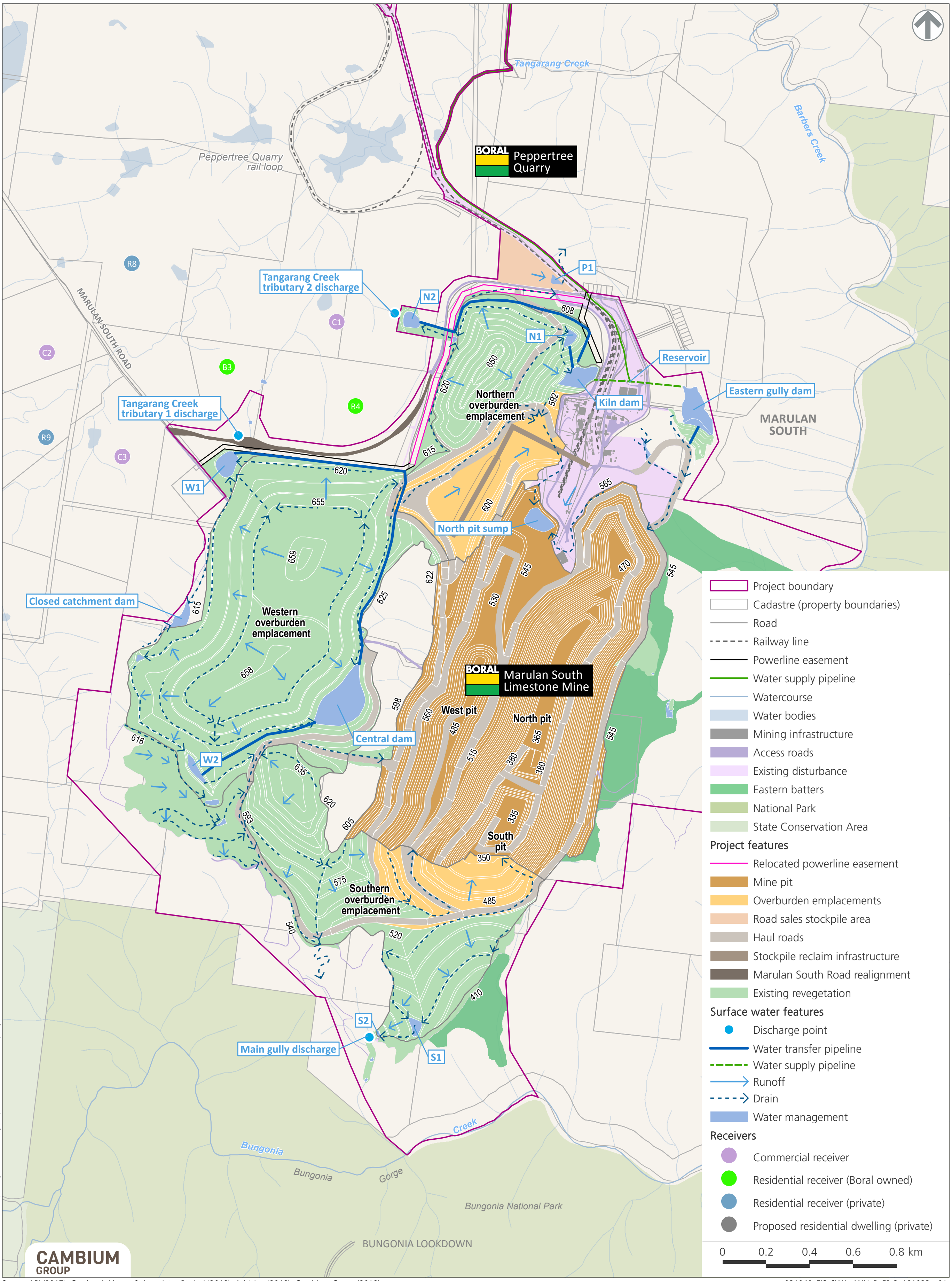
- Assuming limestone mining did not continue beyond the proposed 30 year mine plan period the final mine pit floor configuration includes two large sediment retention basins, a northern basin at about 365/355 m AHD and southern basin at about 350/335 m AHD. These basins will provide an estimated storage capacity of 70 ML and 400 ML respectively..

Conceptual Final Landform Design (as shown in Figure 6.6 of the main Surface Water Assessment report) represents the conceptual end of the 30 year mine life. The conceptual layout of the mine drainage facilities at this stage is shown in Figure 2.3 and would involve:

- Maintenance of established rehabilitation on all emplacements.
- Establishment of revegetation on available upper "inner" facing slopes of the Southern Overburden Emplacement to minimise erosion and sedimentation following final landform construction.
- Establishment of revegetation on select upper mine benches and infrastructure areas to minimise erosion and sedimentation.
- Completion of the modified drainage arrangements undertaken toward the end of Stage 4 including:
  - runoff from the Western Overburden Emplacement and western section of the Southern Overburden Emplacement would be allowed to drain directly off site via Main Gully
  - drainage from Sediment Basin S1 would also be directed to Main Gully via the existing S2 series of sediment basins
  - mine pit floor sediment basins and associated drainage works.
- Decommissioning of any water storage dams and sediment basins no longer required for final land use requirements.

Figure 2.3
Concept layout of drainage systems and dams

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT ANNEXURE B



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Advisian (2018), Cambium Group (2018).

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2.2.3 Operational Water Requirements

Water requirements during operations would be associated with:

- limestone processing
- dust suppression
- potable water.

Limestone Processing

Limestone processing and evaporation losses are estimated to be 70 ML/year, comprising:

- limestone hydration and steam loss 20 ML/year
- limestone processing and rail load-out 48 ML/year
- kiln cooling 2 ML/year.

Dust Suppression

The water requirements for dust suppression on haul road and hardstand areas are closely related to the daily weather (as hot windy days can be expected to generate dust). Thompson and Visser (2002) studied the water requirements for dust suppression on mine haul roads and demonstrated a robust relationship between water requirements for dust suppression and the potential evaporation on the day, while taking into account any incident rainfall. An algorithm based on the work of Thompson and Visser has been benchmarked against estimated mine water use at two mines in the Hunter Valley and has been adopted for the site water balance model. This element of the water balance model takes account of the area of active machinery movement, daily rainfall and daily evaporation.

The modelling of water requirements for dust suppression also takes account of the water application requirements for "Level 2" control of dust, as specified by the US EPA. "Level 2" dust suppression assumes an application of 2 L/m^2/hour to maintain a moisture content of 3.5% on the working surface. For a notional 10 hour (summer) day when water loss could occur because of incident solar radiation and wind, this equates to a 20 mm depth of water application. For modelling purposes, the depth of water application was assumed to be a function of the difference between pan evaporation and incident rainfall, haul road length and traffic rates. A maximum rate of 20 mm/day was adopted.

The Air Quality Assessment for the project was prepared by Todoroski Air Sciences. Todoroski Air Sciences (pers com, 2016 and 2018) also undertook an independent assessment of the water requirements to achieve dust control efficiency of at least 80% based on the data inventory in the Air Quality Assessment (specific segment road length, utilisation rate, truck movement numbers, etc) together with average hourly evaporation for each month of the year. The analysis showed that to achieve at control efficiency of around 85% each month, the site would require an average application of approximately 90 ML of water per annum to the haul roads. This is consistent with the findings of the water balance analysis.

Other Uses

Other water uses accounted for in the water balance analysis include:

- potable water use for amenities 6 ML/year
- truck wash-down 2 ML/year
- workshop and maintenance 2 ML/year.

2.2.4 Water Sources

The site water sources comprise:

- surface runoff from overburden and 'natural' land draining to the sediment dams and mine water storage dams
- groundwater bore supply (12 ML/year) until existing bores are subsumed by mining
- supplementary supply from Tallong Weir (76 ML/year) (current) and Marulan Creek Dam (proposed).

2.2.4.1 Catchment Areas and Surface Runoff

The surface types within the site that would generate surface runoff that would be captured in the water management system are listed in Table 2.8 and shown graphically on Figure 2.2.

The AWBM model (described in Annexure D) has been used to estimate daily runoff depths from the various land surfaces for input to the water balance model. Parameters representing the soil moisture storage characteristics of these areas were derived from:

- calibration against gauged runoff from creeks in the region (see Annexure D)
- the ACARP report (2001) for mine spoil and pits
- runoff characteristics for hardstand areas in MUSIC (V5, eWater, 2012).

The ACARP report (2001) quotes a range of moisture storage characteristics for similar surface types at different mines. Using the historic climate record for Marulan (1883 – 2014), the range of model AWBM parameters that give the minimum, maximum and average runoff for the different surface types were used to derive the range of expected runoff expressed as a percentage of rainfall as set out in Table 2.8.

In June/July 2013 and August 2015 there have been two significant rainfall events that have led to flooding in both mine pits. Observations of the volume held in the North Pit in August 2015, supplemented by anecdotal information from 2013 have been used to verify the AWBM runoff characteristics for the catchments draining to the North Pit (see Annexure E). This analysis indicated that the runoff from the 2013 and 2015 rainfall events is best characterised by the minimum values quoted in Table 2.8. These values have been adopted for water balance modelling purposes.

Table 2.8: Percentage Runoff for AWBM Parameters

Surface Type	Runoff % of Rainfall		
	Min	Ave	Max
Natural		7.6%	
Fully rehabilitated	8.0%	15.3%	18.9%
Partial rehabilitation	15.3%	18.9%	25.6%
Bare spoil	22.6%	26.6%	35.7%
Mine pit	38.5%	48.1%	55.7%
Pit surround		33.5%	
Haul roads and hardstand		33.5%	

2.2.4.2 Groundwater Inflow and Seepage Loss

Information on predicted groundwater inflow to the mine workings has been obtained from the *Marulan Groundwater Technical Study* (Appendix B to the EIS), prepared by AGE (2018). Table 2.9 lists the annual loss from the groundwater model towards the mine pit.

Table 2.9: Groundwater Inflow

Mine Year	Groundwater Loss (ML/year)	Mine Year	Groundwater Loss (ML/year)
1	8.78	16	14.00
2	8.87	17	14.06
3	8.99	18	14.31
4	9.16	19	14.62
5	9.27	20	16.44
6	10.27	21	16.96
7	10.78	22	17.47
8	11.26	23	18.02
9	11.70	24	18.58
10	12.20	25	19.07
11	12.68	26	19.78
12	13.15	27	20.42
13	13.52	28	21.13
14	13.80	29	21.76
15	13.89	30	22.91

Source: AGE, 2018

Groundwater inflow is predicted to occur as seepage on the face and base at the northern end of the mine pit and most seepage inflow will be lost by evaporation from the walls and floor of the pit.

While ever the pit does not contain water (as a result of runoff from the pit, surrounding catchment or overflows from the water storage and sediment dams as depicted in Figure 1.1), the water balance model assumes that all groundwater inflow would be lost by evaporation. Whenever runoff leads to water being held temporarily in the pit, the model assumes that the groundwater inflows will contribute to the water held in the pit.

Because there is a significant gradient on the groundwater table from north to south, the *Marulan Groundwater Technical Study* concludes that any runoff draining to the pit will continue to drain from the southern end of the pit. The pit flooding events that occurred in 2013 and 2015 (see Section 2.2.4.1) have been analysed to estimate the following seepage characteristics for the existing mine pits:

- North Pit bulk permeability = 0.5 m/day
- South Pit bulk permeability = 1.25 m/day.

For water balance modelling purposes, the relationships between head and water seepage rate depicted in Figure 2.4 have been adopted based on data provided by AGE.

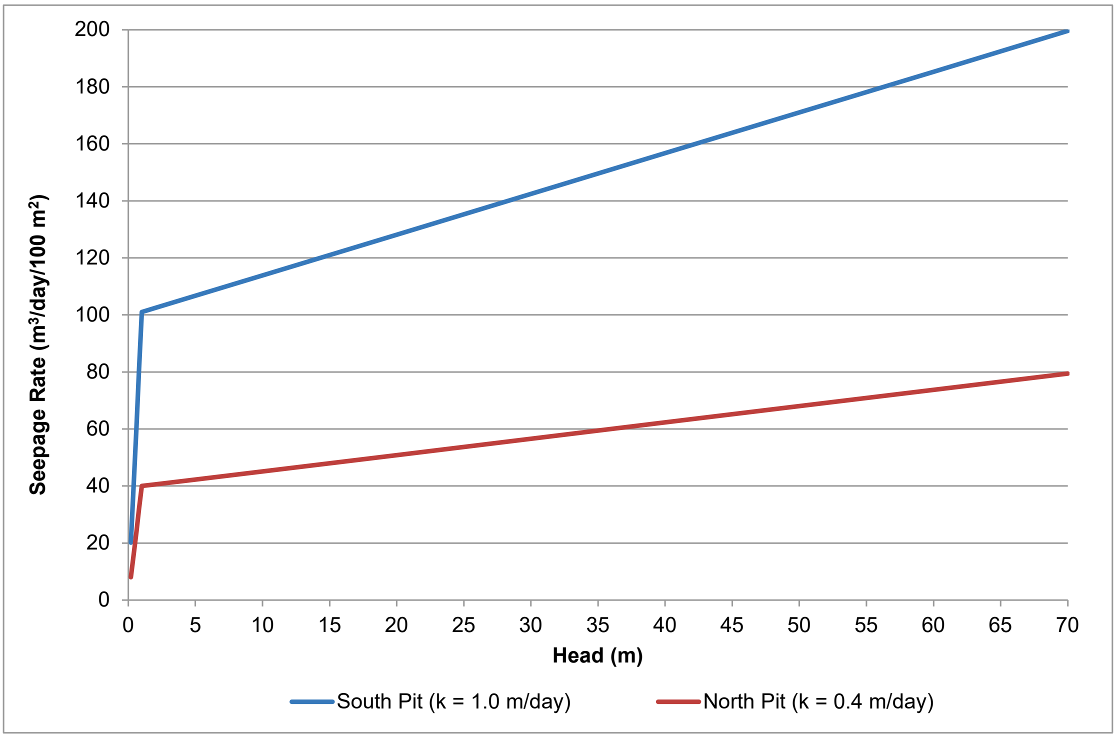

Figure 2.4: Assumed relationship between water depth (head) and seepage rate from the North and South Pits

2.2.4.3 Supplementary Supply

At present, the Marulan Limestone Mine obtains licenced supplementary water supply via a pipeline from Tallong Weir. As part of the Project, it is proposed to construct a 118 ML dam on Marulan Creek. Licenced supplementary supply averaging about 120 ML/year and up to a maximum of 183 ML/year (refer Figure 4.2) would be provided from this source.

For modelling purposes it has been assumed that supplementary supply from Marulan Creek Dam would be used to meet any shortfall in available supply for operational and dust suppression purposes.

2.3 Operational and Pollution Control Storages and Structures

2.3.1 Operational Storages

The existing and proposed operational storage dams are listed in Table 2.10. To account for rainfall and evaporation on the water surface on a day to day basis in the water balance model, a relationship between storage volume and water surface area has been derived from the geometry of each of the mine water storage dams).

Table 2.10: Operational Storages

Dam	Status	Water Storage Capacity (ML)	Top Water Surface Area (ha)	Comment
Kiln Dam	Existing	57	1.2	Current storage 27 ML, to be upgraded to 57 ML
'Blue Lagoon'	Existing	11	0.2	To be subsumed by Northern Emplacement
Mine Water Dam 1	Existing	12	0.2	To be subsumed by Western Emplacement
Mine Water Dam 2	Existing	43	1.4	To be replaced by Central Dam
Central Dam	Proposed	120	2.4	New storage
Eastern Gully Dam	Proposed	79	2.0	New storage
North Pit Sump	Proposed	40	1.1	New storage
Marulan Creek Dam	Proposed	118	5.9	New storage

2.3.2 Sediment Control Dams and Basins

As shown on Figure 1.1 and Figure 2.3, sediment control dams would be progressively constructed as required to control runoff from all out of pit emplacement areas. The indicative water holding capacity of these dams has been determined in accordance with Table 6.1 of *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (DECC, 2008) using the criteria for 'fine' or 'dispersive' sediments. The dams have been sized to capture the runoff from a 95th percentile 5 day storm (55.5 mm) according to the criteria for discharge to a 'sensitive' environment.

The overburden emplacements would be progressively enlarged, shaped and rehabilitated over time. The waste rock in the emplacements is expected to eventually break down into a fine soil that is assumed to have runoff characteristics equivalent to 'Soil Hydrologic Group D' (as defined in Table F2 of *Managing Urban Stormwater: Soils & Construction* (Landcom 2004).

A small sediment control basin (P1) will be provided to treat runoff from the Peppertree western noise bund and the Roadside Sales Stockpile Area located adjacent to the access road on the northern side of the site. This site would contain stockpiles of limestone and gravel (from Peppertree Quarry). The sediment control basin would be designed in accordance with the criteria for 'coarse' sediments as set out in *Managing Urban Stormwater: Soils & Construction* (Landcom 2004).

Table 2.11: Indicative Sediment Dam Sizes

Location	Designation	Catchment Area ha	Settlement Zone (ML)	Sediment Zone (ML)	Required Volume (ML)
Northern Emplacement (east)	N1	15	5.8	2.9	8.7
Northern Emplacement (west)	N2	16	4.8	2.4	7.2
Western Emplacement (north)	W1	25.5	7.2	3.6	10.8
Western Emplacement (south)	W2	13	5.0	2.5	7.5
Southern Emplacement	S1	25	3.8	1.9	5.7
Southern Emplacement	S2	13	2.7	1.4	4.1
Shared road sales stockpile	P1	13	5.6	2.8	8.4

2.3.3 Water Conveyance Structures

In accordance with the requirements set out in Table 6.1 of *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (DECC, 2008), all hydraulic conveyance structures would be designed to remain stable in the event of a 100 year ARI event.

3 Operational Water Management System

This section describes the operational water management system which has been developed to comply with accepted best practice principles for mine site water management and to satisfy the Project's specific objectives and design criteria. The results of the simulated performance of the water management system are set out in Section 4.

Section 5 provides a description of the post-mining water management system and its performance.

A schematic diagram of the proposed water management system for Stages 1 to 4 is provided in Figure 1.1 and the features of the interconnected water structures comprising the water management system are described below.

For water balance assessment purposes, only sources contributing to, or taking water from, the following water storages are considered in the analysis:

- Mine Pit
- Sediment Dams W1, W2, N1, N2 and S1
- Kiln Dam
- Central Dam
- Eastern Gully Dam
- North pit sump
- Marulan Creek Dam.

Supporting structures such as drains and diversions will be progressively constructed to direct runoff into the appropriate storages.

The mine water balance model includes the following operating rules for various storages:

- water would be taken from the mine water dams as necessary for operational purposes
- supply to the mine water management system from Marulan Creek Dam is assumed to occur at a rate of 0.5 ML/day when the storage in Kiln Dam is less than 47 ML or Eastern Gully dam is less than 70 ML
- All sediment basins would be sized and operated in accordance with the requirements for Type 'F' or 'D' sediment basins. Within five days of the end of a storm, any water in the sediment basins (up to the design capture volume) would be transferred via a combination of pipeline and drains, pump and gravity fed out of the basins
- Sediment Basin W1 water would be transferred to Central Dam or North pit sump. Any overflow would drain to Tangarang Creek
- Sediment Basin W2 water would be transferred to Main Mine Dam 2 until Central Dam has been commissioned. Until Stage 2 (about Year 11), all runoff from the southern section of the Western Emplacement is assumed to drain to the Mine Pit via the haul road (as occurs at present). Thereafter, overflow from W2 would be directed into a pipeline or channel that would drain to the western tributary of Main Gully which drains to the existing flow and water quality monitoring station in Main Gully. By that time, the area of the Western Overburden Emplacement draining to W2 would be complete and rehabilitated

- Sediment Basin S1 water would be drained by gravity into the South Pit. Any overflow would also drain to the South Pit. Once the Southern Emplacement has been rehabilitated overflows will be directed off site into Main Gully
- water in Sediment Basin N1 would be transferred to Kiln Dam and overflow to North Pit Sump
- water in Sediment Basin N2 would be transferred to Kiln Dam and overflow to Tangarang Creek
- runoff from the catchment areas of the Eastern Gully Dam and the existing Main Mine Dam 2 would drain directly into these dams and, in common with the other water storage dams, water would be taken for local operations (e.g. dust suppression) or transferred to one of the other water storage dams to make best use of the available storage capacity in all the dams. Any overflow from these dams would drain to the Pit
- In the event that the mine storage dams are filled to capacity, any overflow would drain to the Pit.

4 Water Balance Model Results

The water balance model has been set up to reflect the water management systems depicted in Figure 1.1 and to represent the daily inflows and outflows from each of the separate elements of the water management system described in Section 3.

The model has been set up in a manner that permits an assessment of the risk of shortfall or release of water at any stage of the mine life. This is achieved by modelling the progressive development of the mine combined with selected climate scenarios representing the range of sequences of rainfall in the historic climate record.

As outlined in Section 3, the model includes a range of operating rules that reflect the rate at which water can be transferred between storages and limits on the volume of water in a particular storage before water is pumped in or out.

4.1 Model Verification

Following the set-up of the water balance model as described in Section 3 and using the data set out in Section 2, the performance of the model was verified against three criteria:

1. Check that individual total water inputs (e.g. groundwater) and outputs (water use for operational purposes) correspond with the source data. In some instances, where data is generated by the model (e.g. rainfall and evaporation losses from storages) and direct comparison was not possible, a comparison between the model results to estimates prepared from first principles was made. The results were considered acceptable if there was reasonable correspondence between the model results and the estimates.
2. Check the overall water balance for individual storages over the life of the mine to ensure that water is not gained or lost.
3. Check the overall site water balance for the life of the mine.

Table 4.1 provides details of the water balance verification undertaken for the Sediment Dams, the Mine Pit, the Mine Water Dams and Marulan Creek Dam over the 30 year life of the mine. The data in Table 4.1 is based on the median, dry and wet 30 year rainfall sequences. The data shows that, for all elements of the water balance model, the sum of the water inputs equals the sum of the water outputs. This indicates that the water balance model is internally consistent and that water is not gained or lost.

Table 4.1: Overall Water Balance Check (ML) over the Life of the Mine

Demand/Supply Location	Dry 1905-1935	Median 1986-2016	Wet 1952-1982
Source			
Rainfall	759	1,033	1,317
Runoff	18,596	21,883	29,855
Marulan Creek Dam	3,608	2,947	2,678
Bore/Tallong Dam	266	199	247
Groundwater inflow	416	416	416
Total	**23,645**	**26,478**	**34,513**
Demand			
Dust suppression	3,736	3,437	3,824
Plant demands	2,400	2,400	2,400
Total	**6,136**	**5,837**	**6,224**
Supply			
Reservoir	2,368	2,397	2,400
Kiln Dam	1,372	1,023	771
Central Dam	1,621	1,747	2,075
North Pit Sump	633	649	881
Total	**5,994**	**5,816**	**6,127**
Shortfall			
Dust suppression	142	21	97
Losses			
Evaporation – Dams	1,306	1,378	1,745
Evaporation – Groundwater	416	416	416
Sediment Dam overflow	176	207	391
Diversion from rehabilitation	83	57	322
Seepage	15,824	18,489	24,826
Total	**17,445**	**20,100**	**27,651**
Change in storage	**93**	**109**	**-31**
Balance	**0**	**0**	**0**

4.2 Model approach

As described previously, the water balance model has been configured to assess the effect of climate on the performance of the water management system. The water balance model has been set up to permit an assessment of the risk of water shortfall or discharge at any stage of the mine life. This is achieved by modelling the progressive development of the mine over 30 years combined with 98 climate scenarios representing all the different sequences of 30 years of rainfall represented in the historic climate record.

The water balance model was used to assess water sources, use, losses and change in water storage through the mine life under 98 climate sequences. The results are provided below in the form of probability plots showing the likelihood of occurrence of the result over the mine life.

It should be noted that in the probability plot figures below, the coloured band represents a probability range of occurrence for the result or metric for all of the modelled climate sequences over the 30 year mine life. For example, in Figure 4.1, the coloured band represents the range of annual runoff volumes from the 10th percentile to the 90th percentile. The median result is shown as a black line. It should be noted that the plots show the statistical probability of the results and do not correlate to a specific climate sequence, ie. the black line in Figure 4.1 is the median result for all climate sequences, not the result corresponding the median climate scenario.

4.3 Model Results

4.3.1 Water Sources

The main water source for the Project is runoff collected on the mine site in sediment dams and the mine water dams, supplemented by supply from Marulan Creek Dam and the groundwater bores. The volume of generated from runoff over the life of the mine is shown in Figure 4.1.

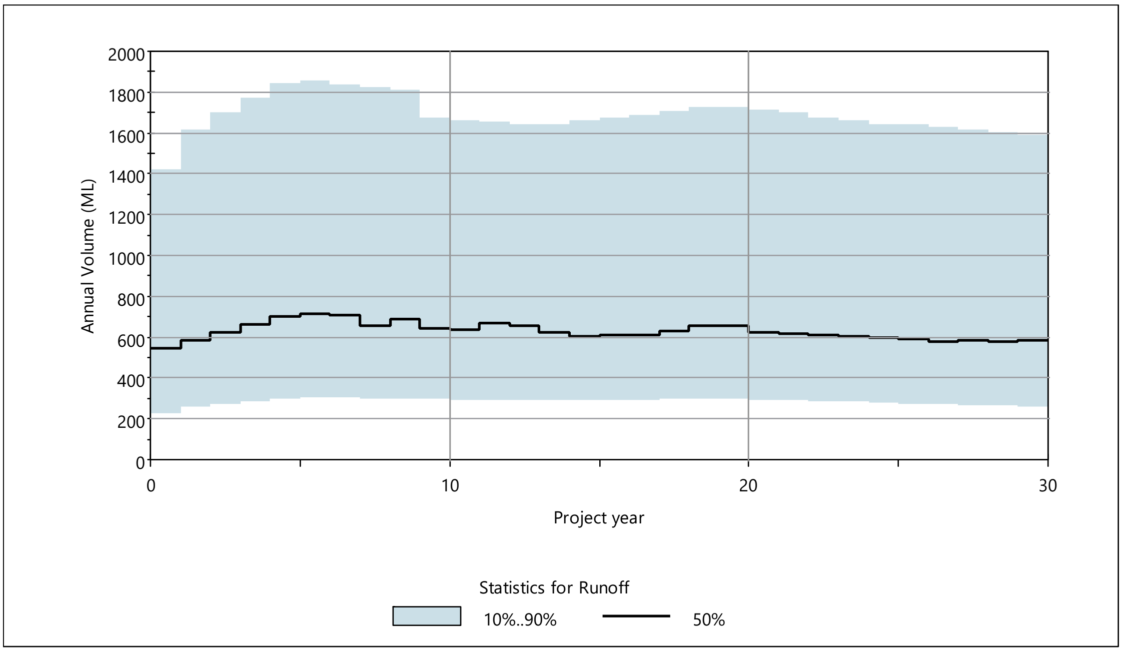

Figure 4.1: Annual Runoff Probability Ranges

Extraction from the Marulan Creek Dam and the groundwater bore would provide additional supply when site runoff is not adequate to supply the site demands, as shown in Figure 4.2 and Figure 4.3. Extraction from these sources is limited by licence conditions.

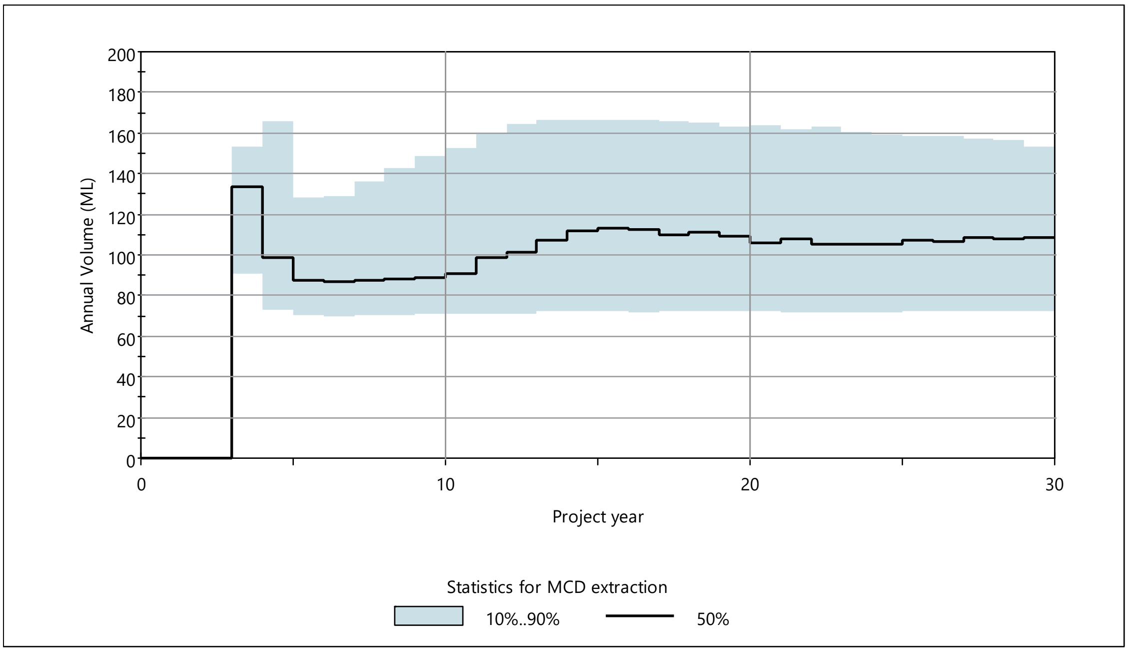

Figure 4.2: Annual Extraction Probability Ranges for Marulan Creek Dam

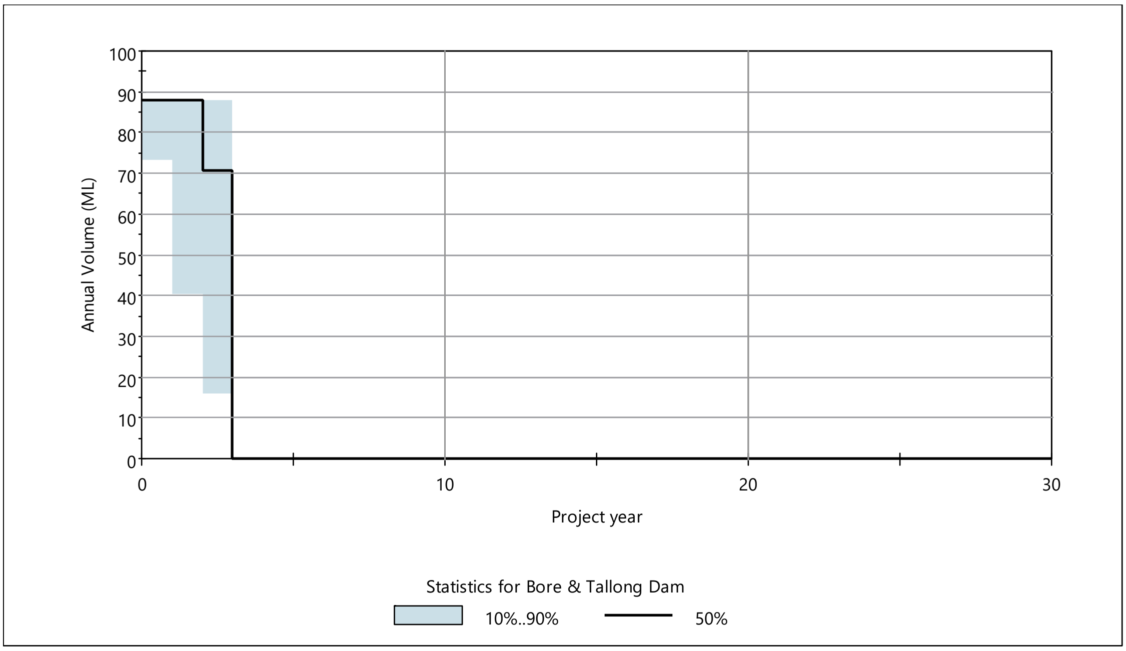

Figure 4.3: Annual Extraction Probability Ranges for the Groundwater Bore and Tallong Dam

Groundwater inflow to the open cut (Table 2.9) has been included in the water balance, but it does not provide any significant supply as almost all of this inflow would evaporate.

4.3.2 Water Usage

Dust suppression comprises approximately 60% of the total site demand. The demand for dust suppression varies through the Project life (Figure 4.4), with variability in the demand related to climatic conditions, ie. greater demand during dry periods and less during wet. Processing demand (Section 2.2.3) is not influenced by climatic conditions.

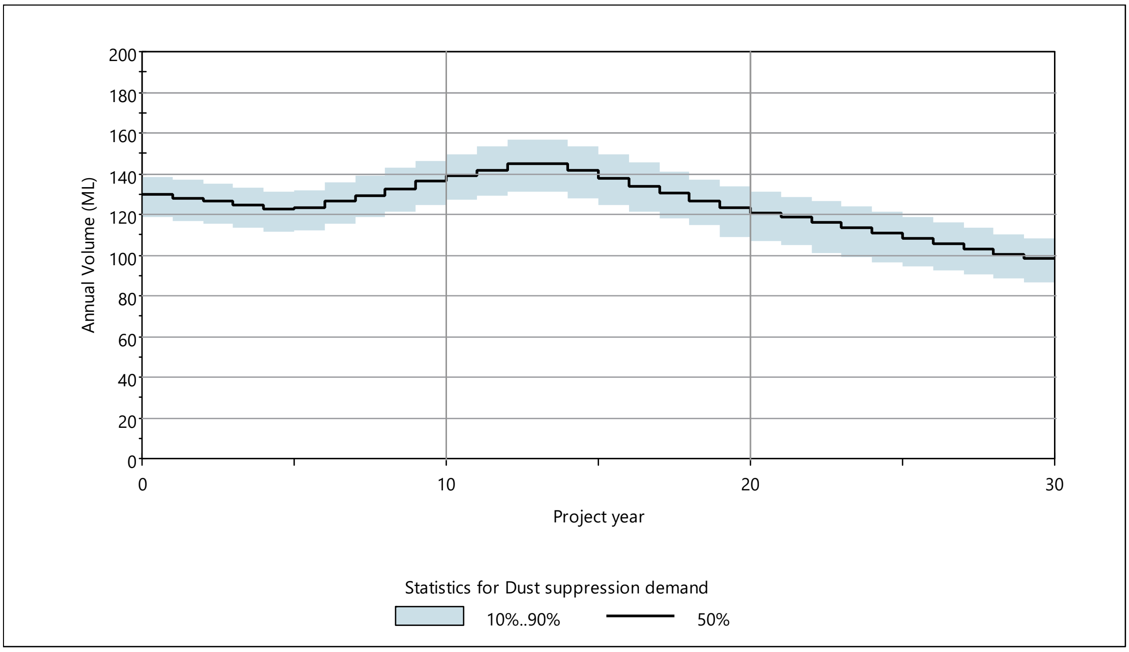

Figure 4.4: Probability of Dust Suppression Requirements

4.3.3 Water Losses

The main water loss from the site water system is through seepage to groundwater via the pit (Figure 4.5).

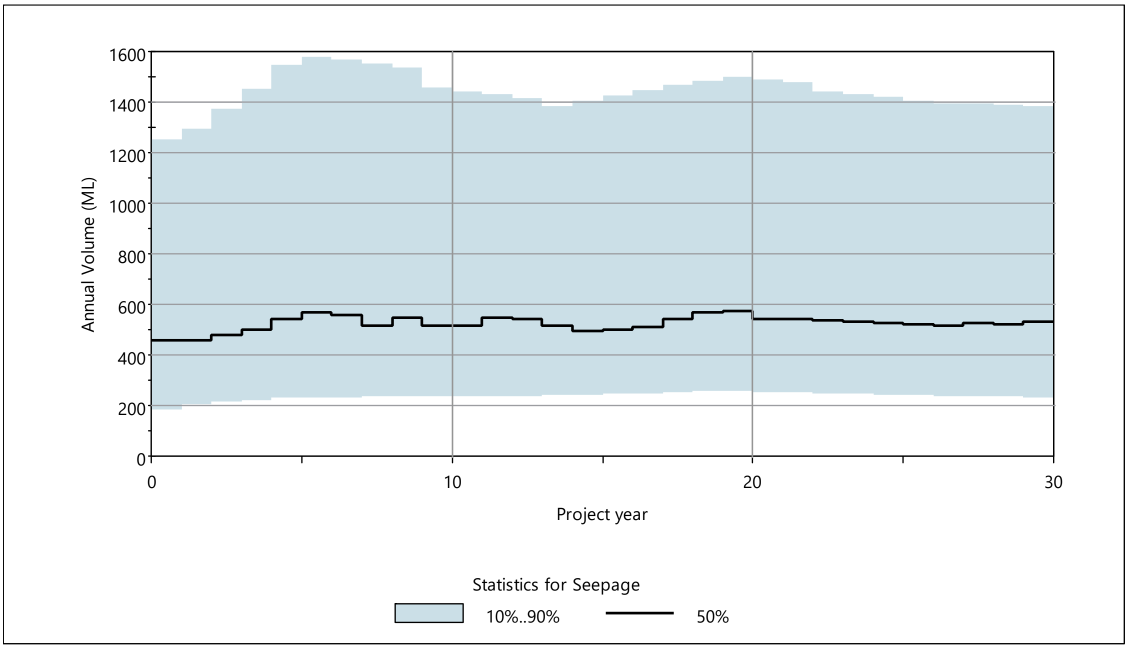

Figure 4.5: Annual Seepage Loss Probability

Other losses to the water system include evaporation from water stored in the site dams and storages. The variation of evaporation over time is shown on Figure 4.6. Evaporation increases until all of the storages have been constructed and then becomes fairly stable at around Year 14. There is variability in the amount of evaporation each year as a result of the climatic conditions and some uncertainty in the amount of water in storage.

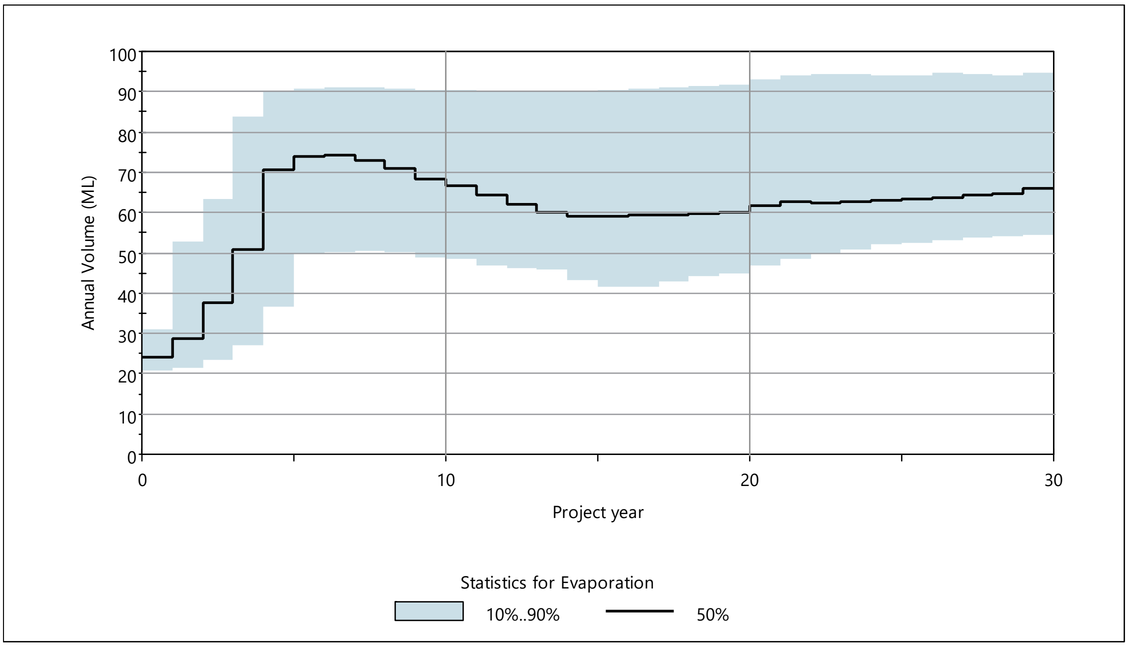

Figure 4.6: Annual Evaporation Loss Probability

Overflow from the system occurs when rainfall exceeds the design capacity of the sediment dams (Figure 4.7).

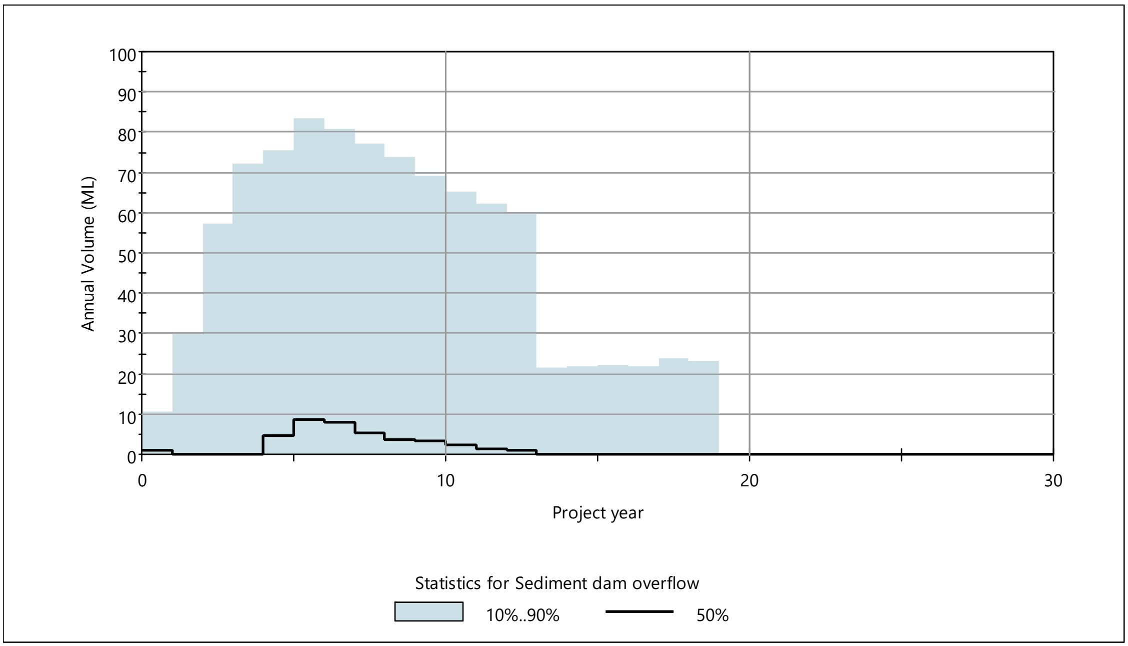

Figure 4.7: Annual Sediment Dam Overflow Probability

4.3.4 Water Storages

Onsite water storages would be used to balance the supply of water from runoff and demand for processing and dust suppression. For purposes of assessing the probability of having an excess or shortage of water, the water balance model has been run for the 98 climatic sequences.

Figure 4.8 to Figure 4.12 show the variability in storage and extraction throughout the mine life.

Figure 4.8 shows that the water volume in the proposed Marulan Creek Dam would be maintained close to full capacity for most of the time, with occasional periods when the water level would be drawn down significantly as a result of the constant riparian release of 0.3 ML/day (102 ML/year) and the transfer of water to the mine water management system.

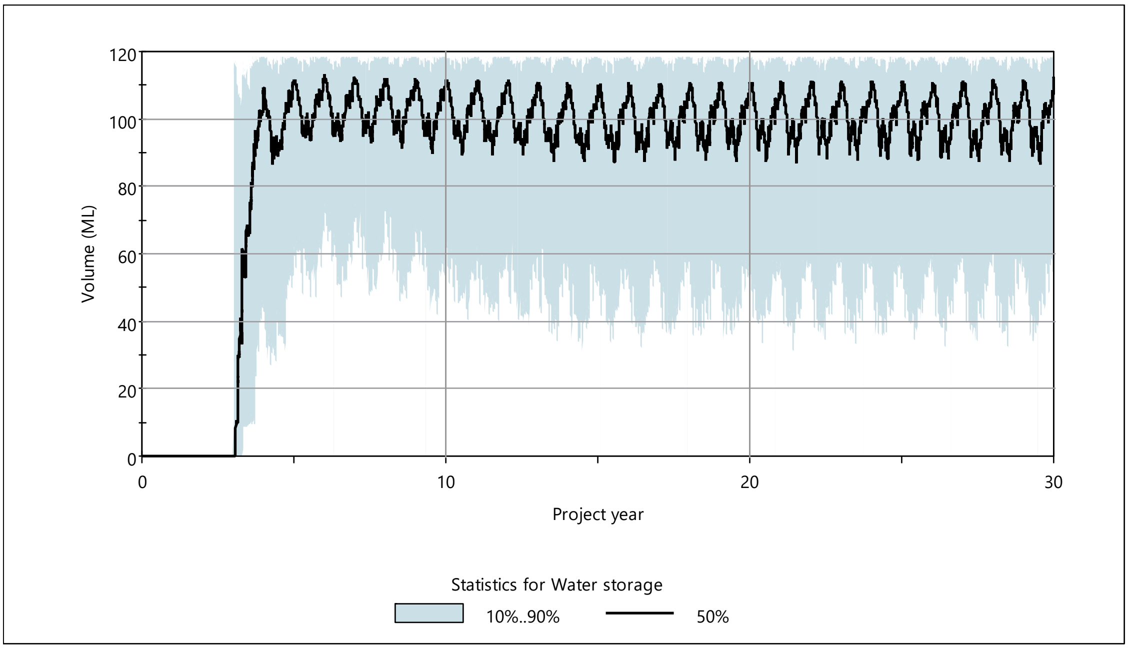

Figure 4.8: Marulan Creek Dam

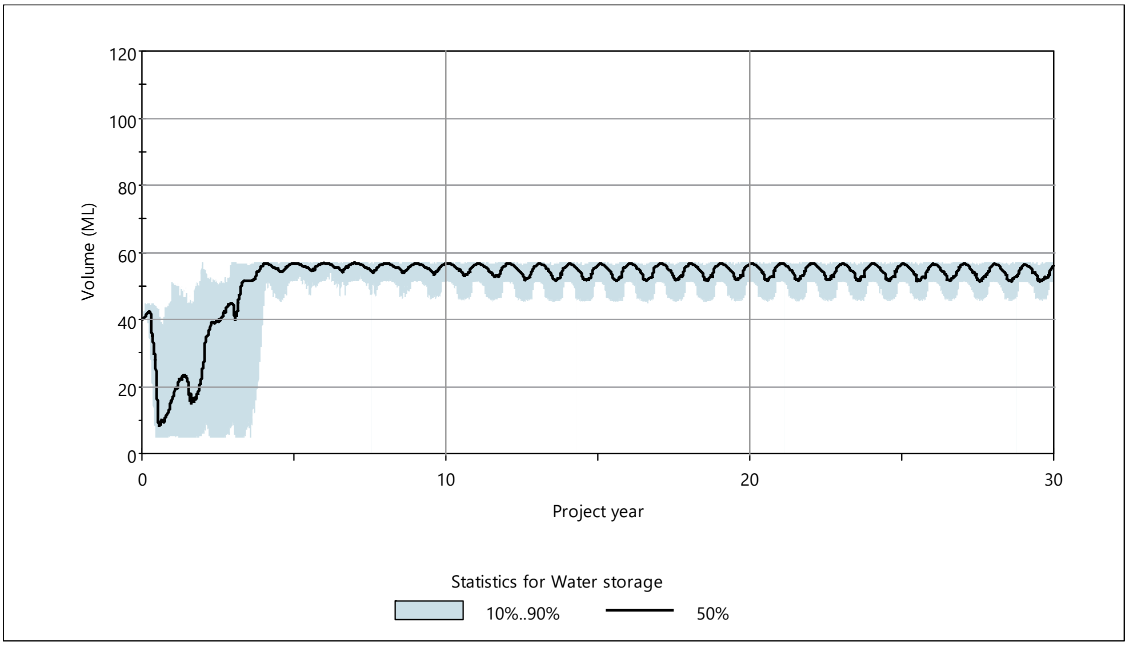

Figure 4.9: Kiln Dam

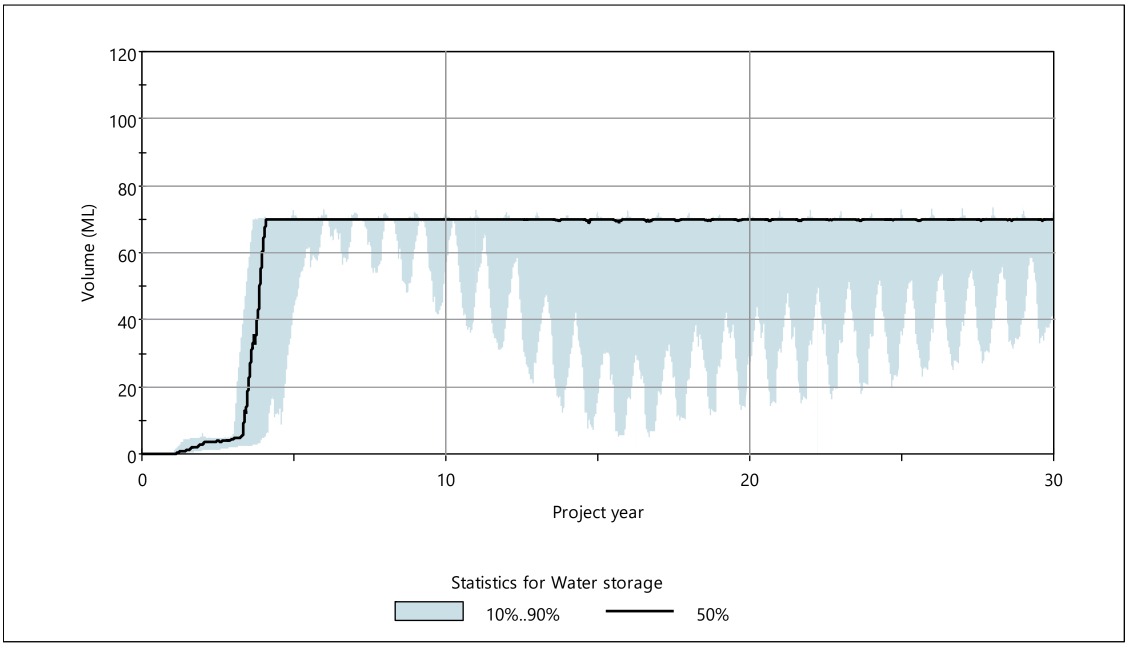

Figure 4.10: Eastern Gully Dam

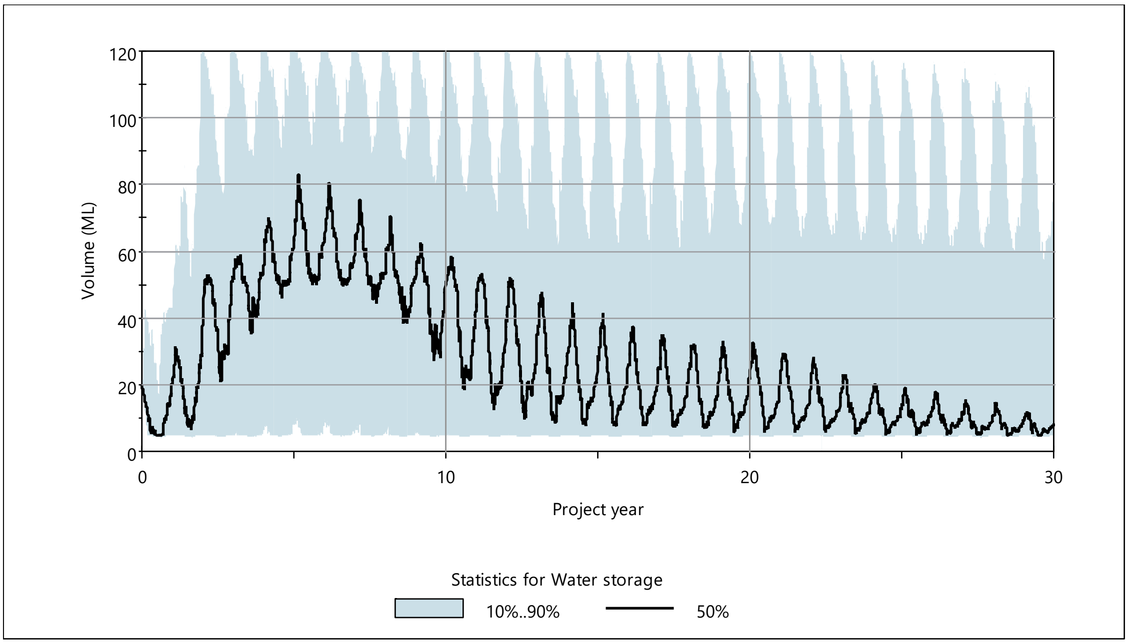

Figure 4.11: Central Dam

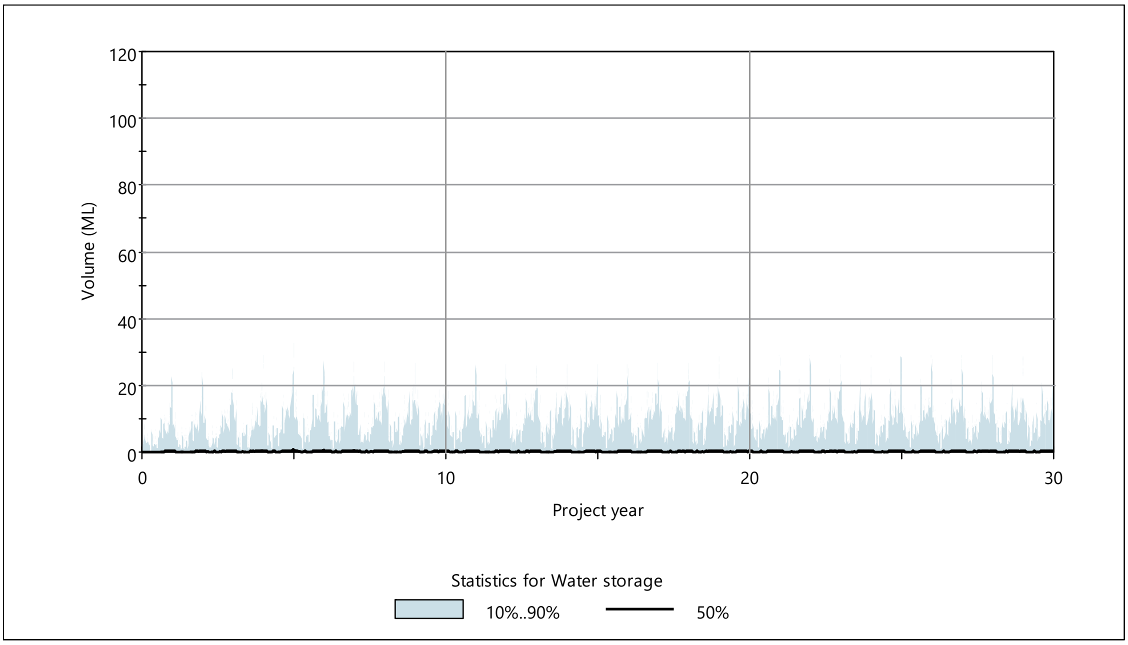

Figure 4.12: North Pit Sump

4.4 Flooding of the Mine Pit

The water balance model assumes that runoff from the pit itself as well as overflows from the water storage dams and Sediment Basins S1 and W2 would drain to a sump at the base of the mine pit. The sump is assumed to be approximately 5 m deep (below the lowest level of mining) to collect any runoff that reaches the base of the mine. As shown in Figure 4.13, the modelled water level in the pit is less than 0.5 m for most of the time, with occasional events when the water level can be expected to exceed 12.9 m (7.9 m above the pit floor) and lead to some disruption of mining for a short period while water drains away.

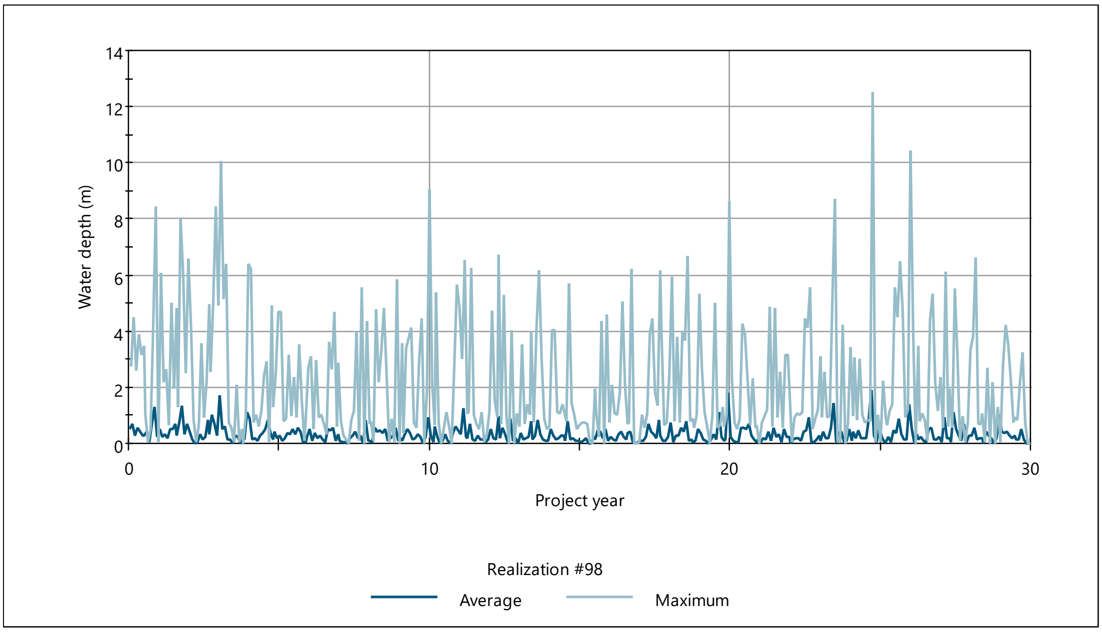

Figure 4.13: Monthly average and maximum water levels in the pit

Table 4.2 lists the percentage contribution of various sources of water that comprise the water held in the mine pit and shows that runoff from the pit itself and the immediate surrounds constitute 87% of the total volume. Accordingly, redirecting overflow from water storages or sediment dams will not significantly affect flood depth in the pit.

Table 4.2: Contributions to Water in the Mine Pit

Source of Water	Average Volume (ML/year)	Percentage Contribution
Runoff from the pit and uncontrolled catchments	509	87.3%
Overflow from Mine Water Dams	66	11.3%
Seepage and overflow from Sediment Dam S1	7	1.2%
Direct rainfall onto the water surface	1	0.2%

4.5 Requirement for additional external water supply

Table 4.3 summarises the probability of annual volume requirements for external supply from the Marulan Creek Dam at various years in the mine life, as well as the average over the life of the mine.

Table 4.3: Probability of required extraction volumes from Marulan Creek Dam

Year	Volume (ML/year)			
	10th Percentile	Median	90th Percentile	Maximum
1	0	0	0	0
5	73	99	166	183
13	70	101	166	183
19	72	111	166	183
Life of mine	84	100	109	

4.6 Water Supply Reliability

Water supply reliability represents the total life of mine supply (for processing and dust suppression) divided by the demands. Average water supply reliability for the 98 simulations is over 95%, with the shortfall probability shown in Figure 4.14

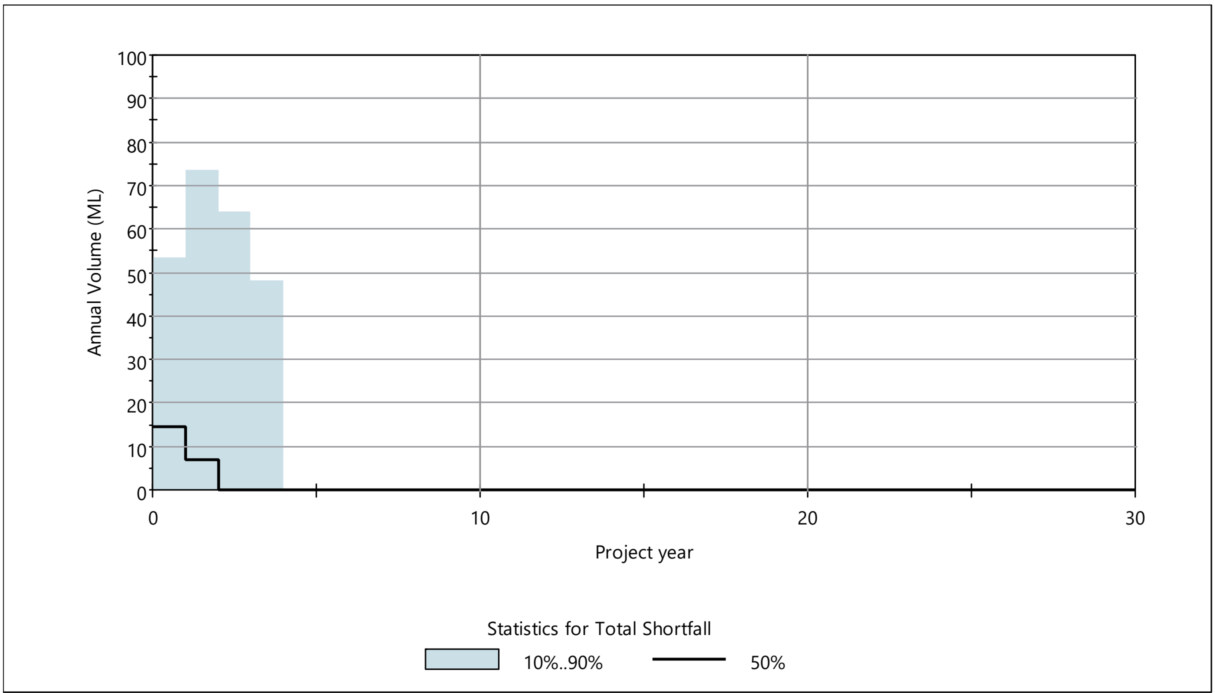

Figure 4.14: Annual shortfall probability

Table 4.4: Probability of shortfall volumes

Year	Volume (ML/year)			
	Average	10th Percentile	Median	90th Percentile
1	21	0	15	55
5	3	0	0	0
13	3	0	0	0
19	3	0	0	0
Life of mine	5	0	4	9

The impacts of the use of chemical dust suppressants on the annual external water demand were assessed in the water balance model. For modelling purposes, it was assumed that demand for water for dust suppression would be reduced by 50% when monthly rainfall was less than the 25th percentile, and this would continue until monthly rainfall was greater than the 50th percentile. The model demonstrated that use of chemical dust suppressants could reduce the total external water demand by approximately 40% in some years (average reduction 19% over the life of mine), as water for dust suppression accounts for approximately 60% of the total water demand for the Project. The increased supply reliability is shown in Figure 4.16 compared to the base case reliability in Figure 4.15

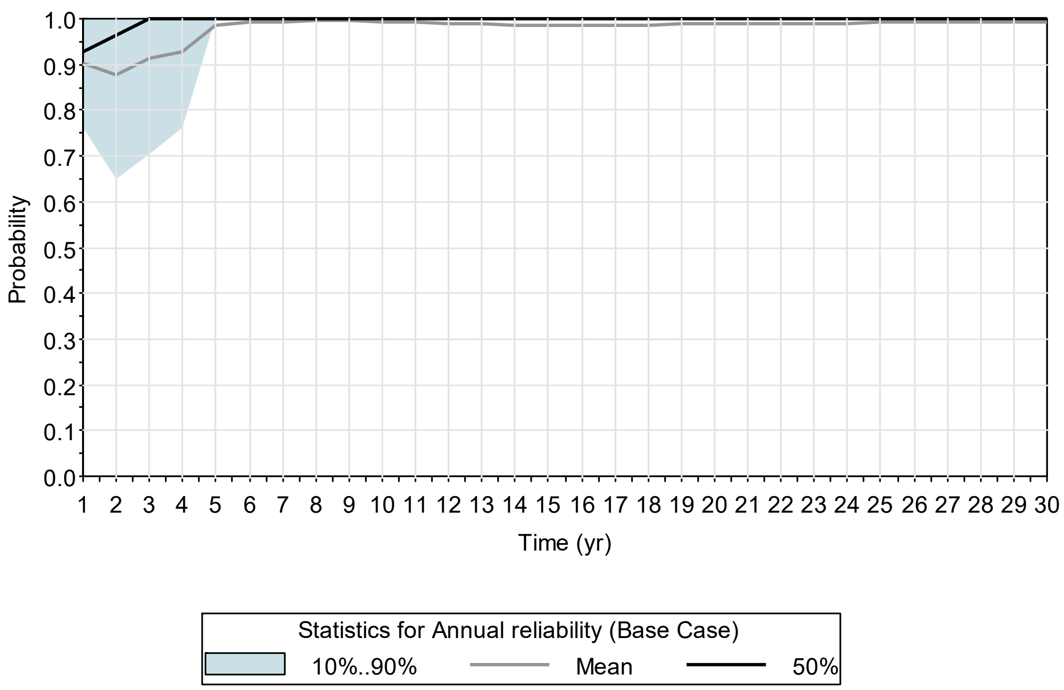

Figure 4.15: Supply reliability (base case)

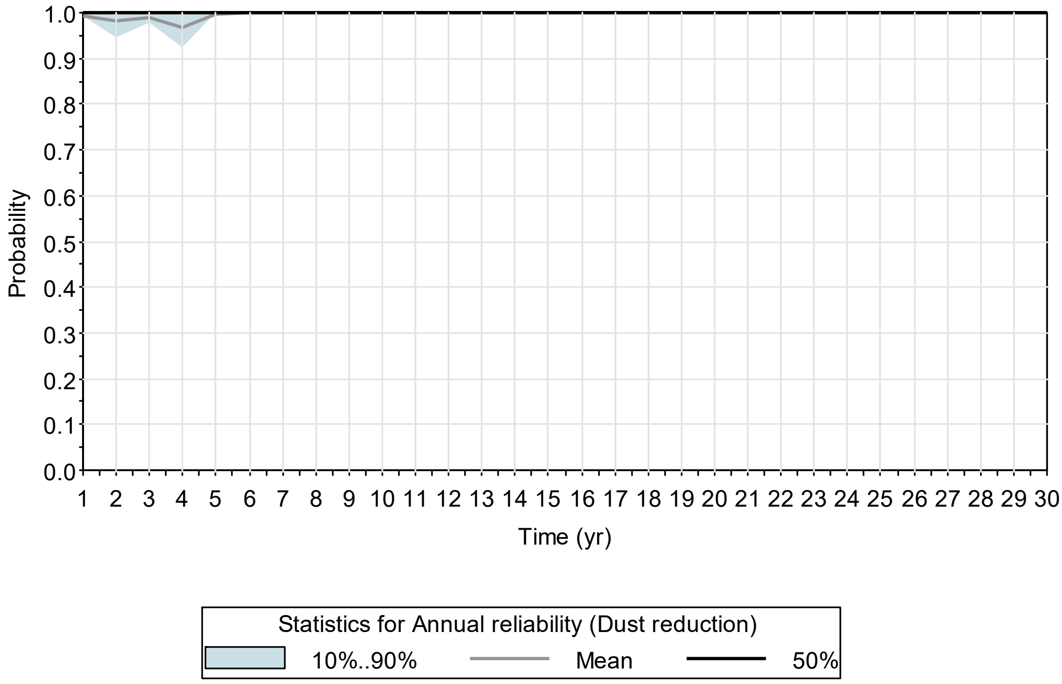

Figure 4.16: Supply reliability with chemical dust suppression

4.7 Sediment dam performance

Table 4.5 summarises the performance of the sediment dams over the 30 year life of the mine for median, wet and dry climate sequences. Approximately 18 – 26% of the runoff would overflow following rainfall events that exceed the design capacity of the sediment dams, depending on the climate sequence.

The frequency of overflow from the sediment dams is predicted to be low. Under the median climate sequence the site would expect 46 days of overflow from the sediment dams over the 30 year life of the Project (an average 1.6 days per year). This frequency is less than the expected frequency (two to four overflow events per year) quoted in Table 6.2 of *Managing Urban Stormwater: Soils & Construction– Volume 2E: Mines and Quarries* (DECC, 2008).

Table 4.5: Sediment dam performance over life of mine

	Units	Dry 1905-1935	Median 1986-2016	Wet 1952-1982
Runoff	ML	836	811	1361
Rain	ML	89	105	169
Evaporation	ML	154	147	227
Transfer to mine water dams	ML	486	495	588
Diversion	ML	117	58	322
Overflow	ML % inflow Days Days/year	167 18% 60 2.0	207 23% 49 1.6	391 26% 87 2.9
Change in storage	ML	2.0	1.6	2.9

4.8 Sensitivity Analysis

The sensitivity of the performance of the mine water management system to changes in surface runoff has been assessed by applying a multiplier to the modelled runoff. As shown in Table 2.8, the range of published runoff parameters generally produces runoff in the range of ±20% of the average.

In addition, Table 2.6 shows that the predicted effects of climate change on median annual rainfall vary from -3% to -1% (with a range of -11% to +7%) in the near term (2030) and -2% to -3% (with a range of -20% to +16%) in the longer term (2070).

To account for uncertainties in future climate and runoff the sensitivity analysis has examined the effect of altering the runoff from all land surface types by applying runoff multipliers of 0.8 and 1.2. Table 4.6 identifies the percentage change in the average and maximum supply of water from Marulan Creek Dam and overflows from the sediment basins resulting from the sensitivity analysis of runoff and climate change effects.

Table 4.6: Sensitivity of water management system performance to changes in runoff and climate change

Scenario	Climate sequence start year	Runoff Factor	Change in average supply fromMCD	Change in max annual supply from MCD	Change in average overflow from sediment dams draining off site	Average Overflow from Sediment Dams Draining Off Site (days/year)
Median -20%	1986	0.8	-6.5%	0%	-33%	1.3
Median +20%	1986	1.2	+9%	0%	+30%	2.0
Wet -20%	1952	0.8	-3%	0%	-35%	2.4
Wet +20%	1952	1.2	+5%	0%	+33%	3.2
Dry -20%	1905	0.8	-5%	0%	-36%	1.3
Dry +20%	1905	1.2	+6%	0%	+38%	2.2

The noteworthy aspects of the results in Table 4.6 are:

- a change in runoff of ±20% leads to a range in changes in the supply from the Marulan Creek Dam by ±10% for all climatic conditions
- a change in runoff of ±20% leads to an average increase in overflow from the Sediment Dams by about ±35% for median climate conditions. However, the number of days per year of overflow is still within the expected range as set out in Table 6.2 of *Managing Urban Stormwater: Soils & Construction – Volume 4: Mines and Quarries* (DECC, 2008).

4.9 Overall Performance of the Water Management System

Noteworthy aspects of the water management system performance are:

- the proposed water supply system has a high level of reliability over the mine life (greater than 95%), shortfall varies from 0 and 9 ML/year, with an average of 5ML/year
- over the mine life the annual rainfall and runoff captured on the site provides a supply of between 82 and 109 ML/year, with an average of 94 ML/year
- to satisfy the site water demands, water is required from external sources. Over the mine life the average annual volume of supply from the proposed Marulan Creek Dam varies from 84 to 109 ML/year, with a median of 100 ML/year. Peak annual demand is 183 ML/year, which is limited by the pumping rate (0.5 ML/day) from Marulan Creek Dam
- overflow from the sediment basins to Tangarang Creek or Main Gully also varies with climate sequence with a range of 3 to 19 ML/year, and an average of 9 ML/year
- under the median climate sequence frequency of overflow from the sediment basins to Tangarang Creek or Main Gully averages 1.6 days per year, which indicates that the sizing and operation of the sediment basins is consistent with the requirements of Table 6.2 in *Managing Urban Stormwater: Soils & Construction, Volume 2E – Mines and Quarries* (DECC, 2008)
- the volume of water required for dust suppression shows little variation between different climate sequences with a range of 115 ML/year to 126 ML/year, with an average of 121 ML/year.
- The water balance modelling demonstrates that the proposed mine water management system has sufficient capacity and flexibility to accommodate a wide range of climate scenarios while:
- providing security of supply for mine operations
- containing mine-affected water on-site, with no uncontrolled off-site release from the mine water dams.

5 Post Mining Water Management

5.1 System Configuration

Following completion of mining and rehabilitation of the emplacements, the configuration of the water management system would be as shown in Figure 5.1.

The system depicted in Figure 5.1, and the associated post-mining water balance analysis assumes that:

- all water storage dams that drain to the mine pit (Eastern Gully Dam, Central Dam and Northern Pit Sump) would remain but are only subject to evaporation and seepage loss, with no water extracted for operational purposes
- all sediment and water storage dams that drain to Main Gully or Tangarang Creek would be removed and rehabilitated (shown in dotted outline in Figure 5.1). All runoff from the relevant catchments would drain off-site
- Outflows from the system would comprise:
  - runoff from the rehabilitated emplacements draining to the original locations of Sediment Dams W1, N1 and N2 and then to Tangarang Creek
  - runoff from the rehabilitated emplacements draining to the original locations of Sediment Dams W2 and S1 and then to Main Gully
  - overflow from all other dams in the water management system to the North Pit;
  - seepage loss from the base of the pit
  - riparian flow and overflow from the Marulan Creek Dam to Marulan Creek.
- The components of the water balance in the remnant void are shown in Figure 5.2 and would comprise:
  - runoff from the pit itself
  - runoff from the section of the Northern Emplacement that drains direct to the North Pit (38 ha)
  - runoff from areas surrounding the pit that do not drain to a water storage or sediment dam (32 ha)
  - groundwater inflow provided by AGE (Figure 5.4)
  - seepage from the overburden of the section of the Southern Emplacement overlying the footprint of the South Pit (15 ha)
  - overflows from various dams shown in Figure 5.1
  - seepage is assumed to occur based on the surface area of the ponded water.
  - The adopted depth: area: volume characteristics of the remnant void are based on the geometry of the final void and are shown in Figure 5.3.

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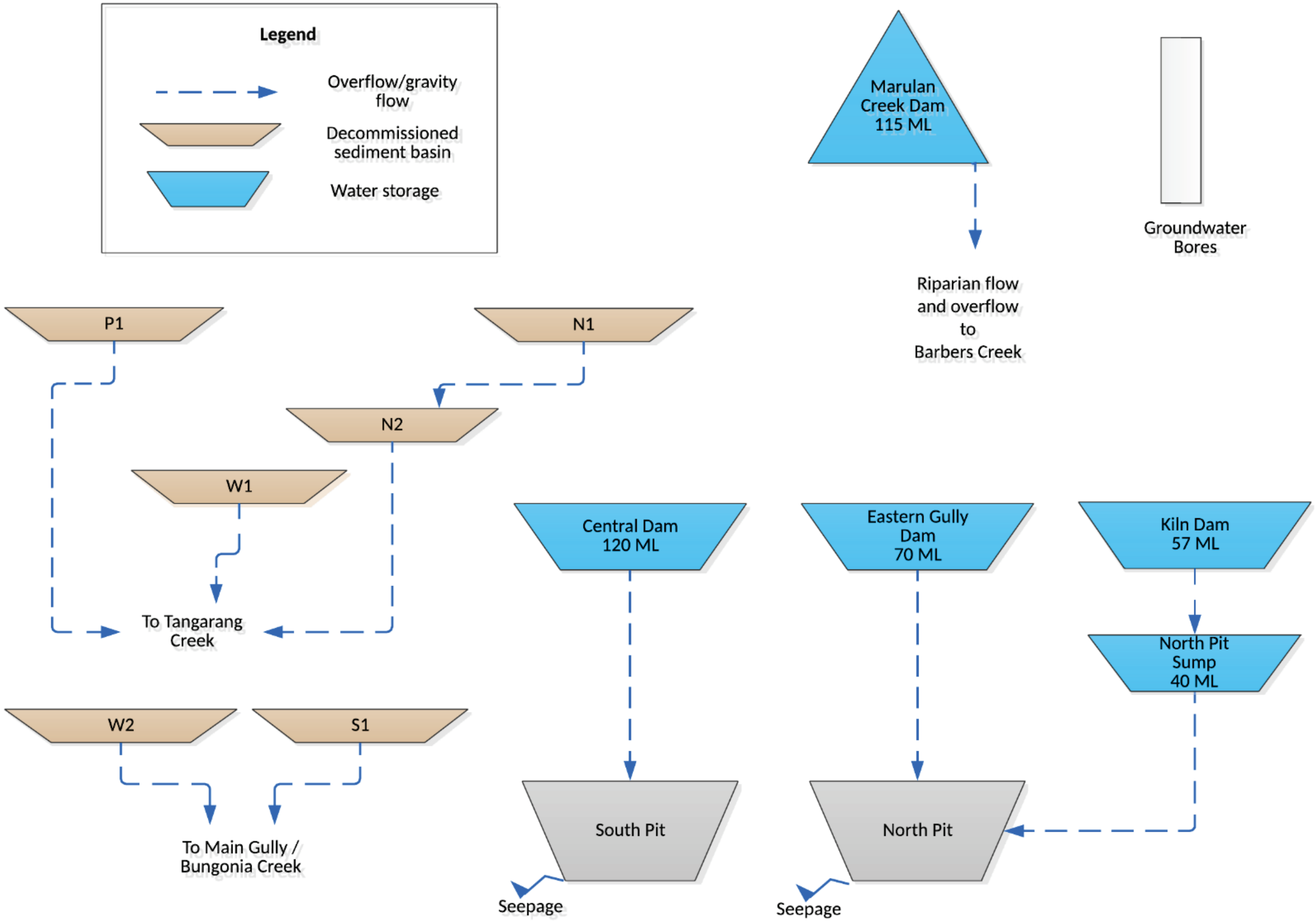

Figure 5.1: Post-Mining Water Management Schematic

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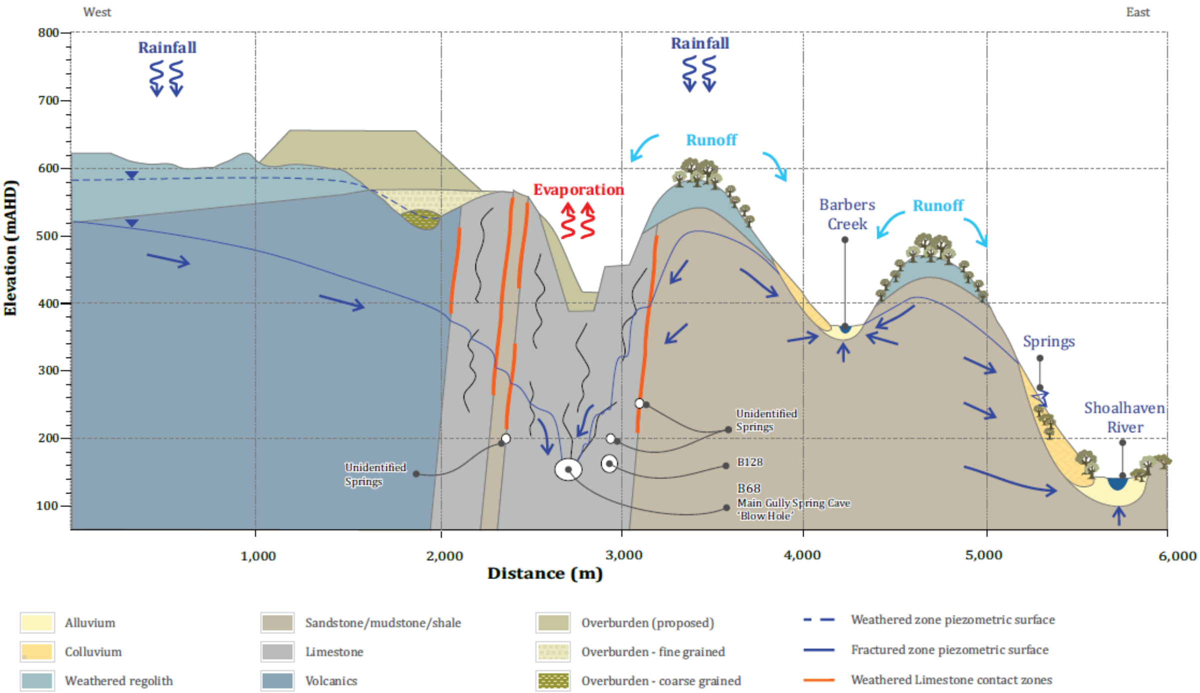


Figure 5.2: Conceptual Model - Post-Mining Water Balance in the Remnant Void

Source: AGE (2018)

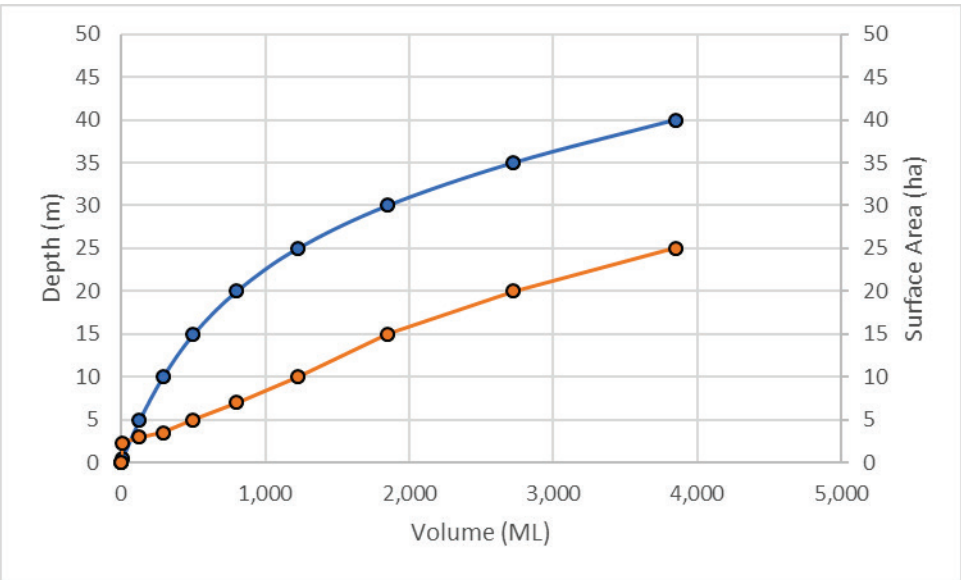


Figure 5.3: Depth: Area: Volume Characteristics for the Remnant Void

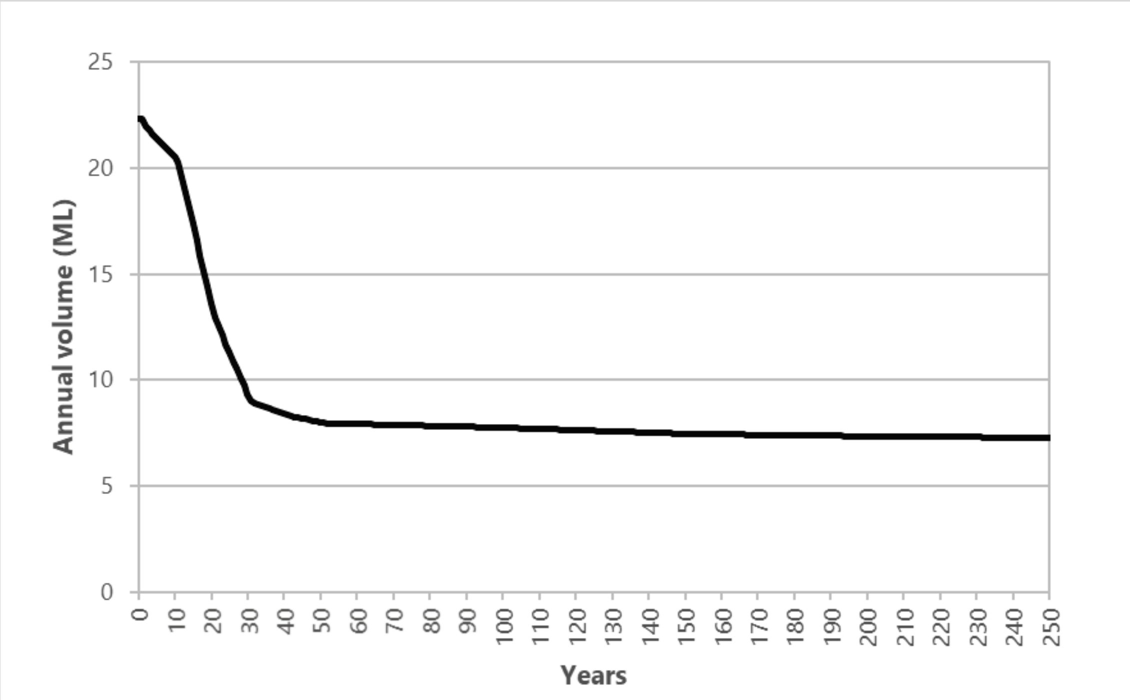


Figure 5.4: Groundwater inflow to the Remnant Void

5.2 Model Data and Assumptions

Modelling of the post-mining water management system assumes:

- the climate change projections range from a small rainfall decrease in the near future to a small increase in the far future. Accordingly, the 128 year historic climate sequence is assumed to be representative of the potential range of future rainfall.
- runoff characteristics of different land surfaces would remain the same as those adopted for the operational water balance modelling (as set out in Section 2.2.4.1).

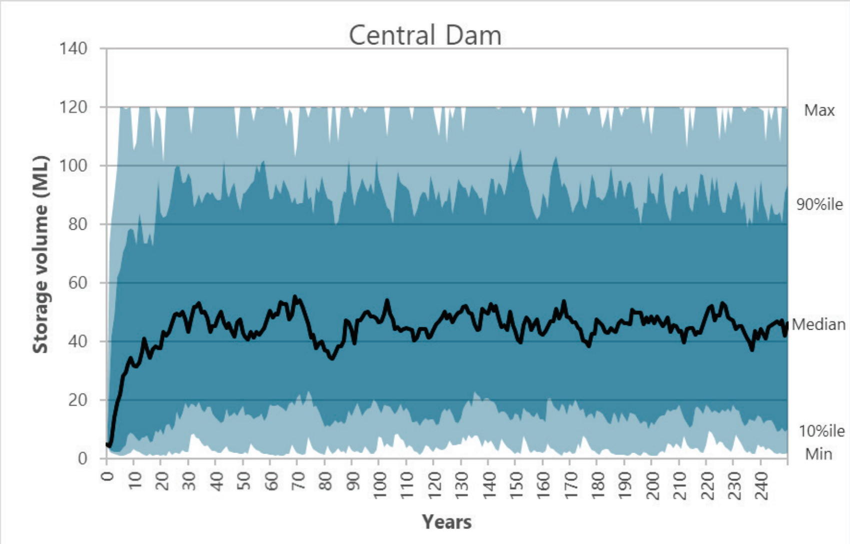
For purposes of this analysis, a synthetic monthly climate and runoff sequence was generated by calculating the monthly totals for the rainfall, evaporation and runoff. To create a synthetic 250 year record, years were then selected at random from the historical record.

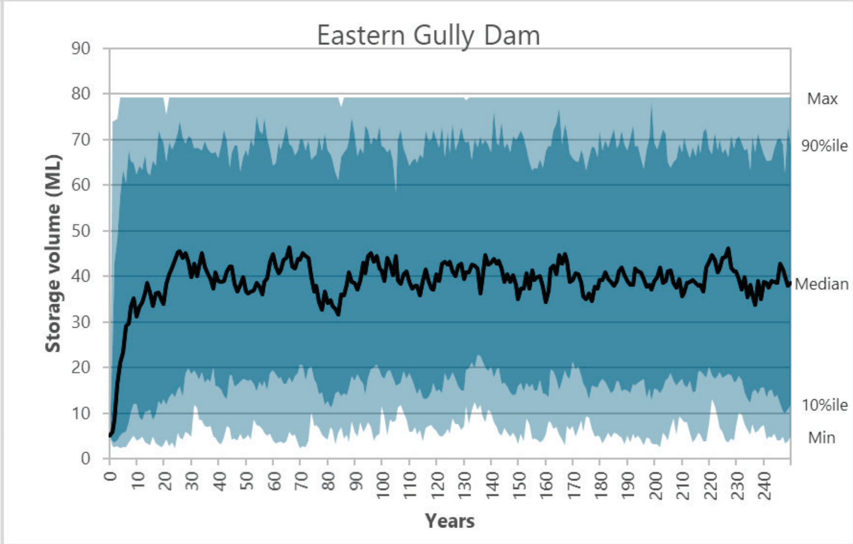
5.3 Post-Mining Water Balance Model Results

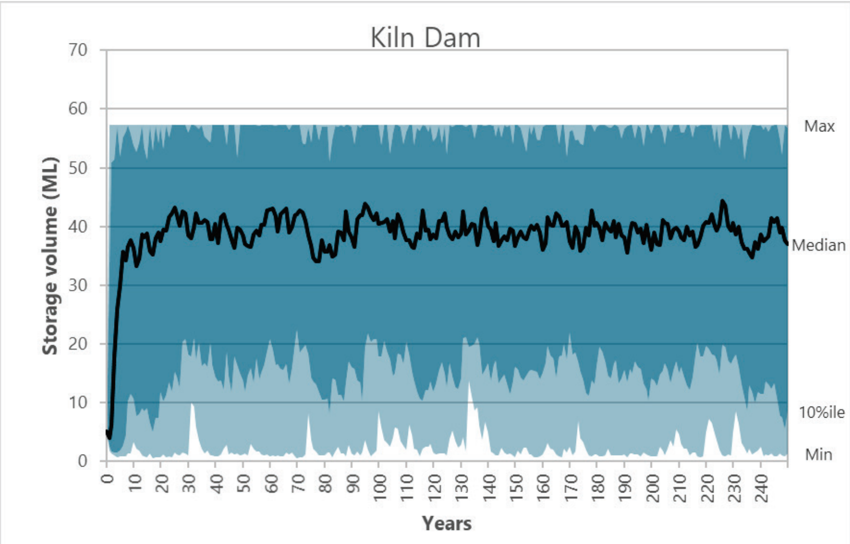
Figure 5.5 shows the performance of the mine water management system over a period of 250 years following completion of mining. The figure shows the following features:

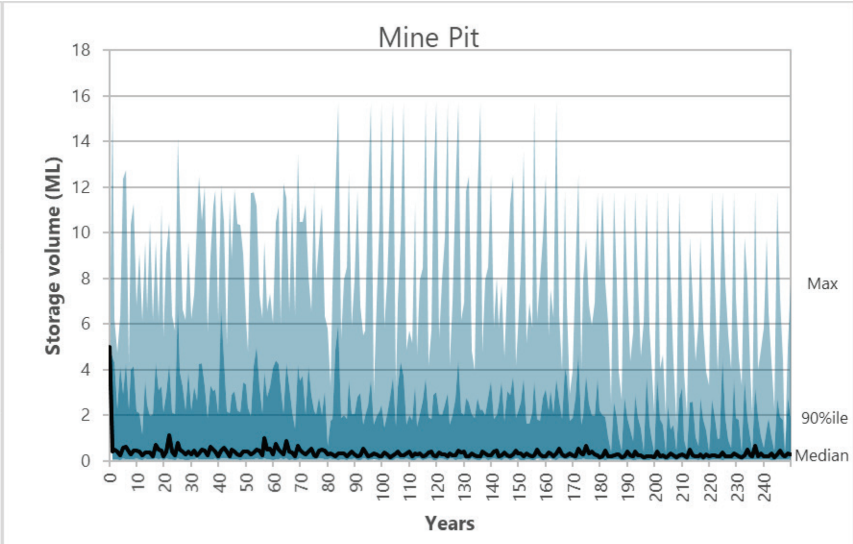
- the volume in the mine water dams would be much more variable on account of the fact that the dams would largely rely on runoff only and no transfer from sediment dams and/or external sources
- the mine pit would generally have minor quantities of water in the base as a result of rainfall onto the pit and, on rare occasions, have water level up to 13 m deep as a result of local rainfall and runoff and overflow from the remaining sediment dams and water storage dams
- the majority of water entering the pit would be lost by seepage.

The model results show that, on average, about 466 ML of runoff would report to the pit, of which about 99% would be attributable to runoff from within the pit itself.


Central Dam
Storage volume (ML)
0
20
40
60
80
100
120
140
Years
Max
90%ile
Median
10%ile
Min


Eastern Gully Dam
Storage volume (ML)
0
10
20
30
40
50
60
70
80
90
Years
Max
90%ile
Median
10%ile
Min


Kiln Dam
Storage volume (ML)
0
10
20
30
40
50
60
70
Years
Max
Median
10%ile
Min


Mine Pit
Storage volume (ML)
0
2
4
6
8
10
12
14
16
18
Years
Max
90%ile
Median

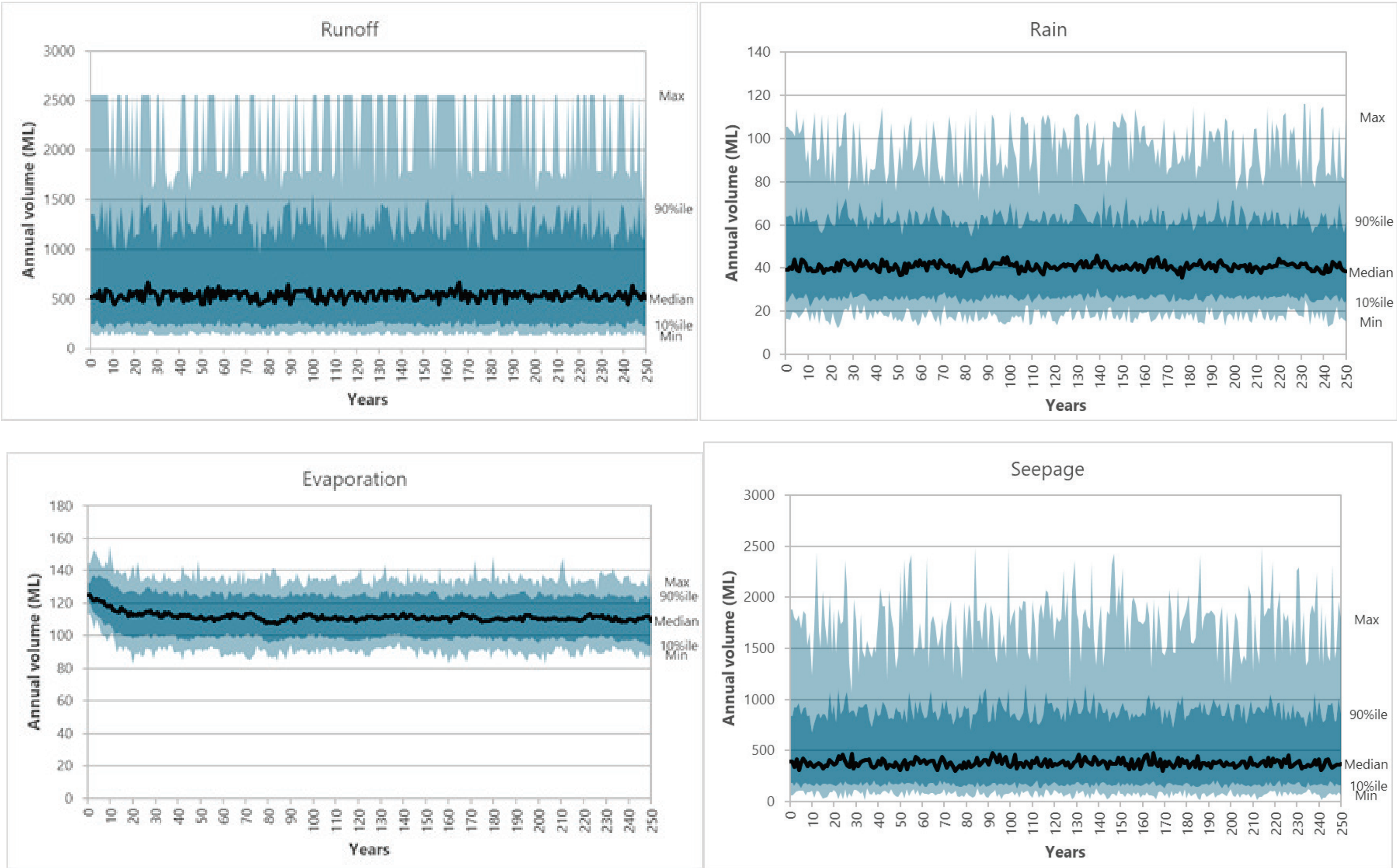


Figure 5.5: Variation in Dam and Pit Storage Volumes Post Mining

5.3.1 Post closure runoff sensitivity results

Analysis was undertaken to determine the impact of runoff assumptions to the maximum water level in the pit sump. The sensitivity analysis included assessment of changing runoff by ±20% for the 100 synthetic climate sequences. Key results from the sensitivity analysis are show in Figure 5.6 to Figure 5.9, with the resulting impact on the maximum water levels in the base of the pit following mine closure (Figure 5.10). With a 20% increase in rainfall the maximum water level is modelled to increase from 13 m to approximately 15.5m.

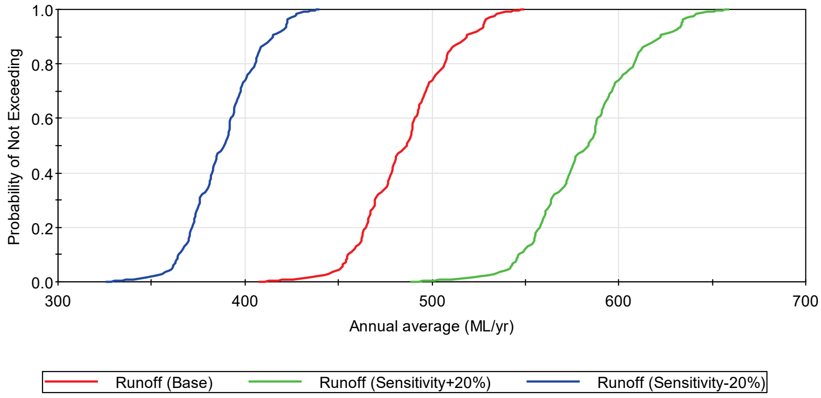


Figure 5.6: Post Closure annual average runoff sensitivity

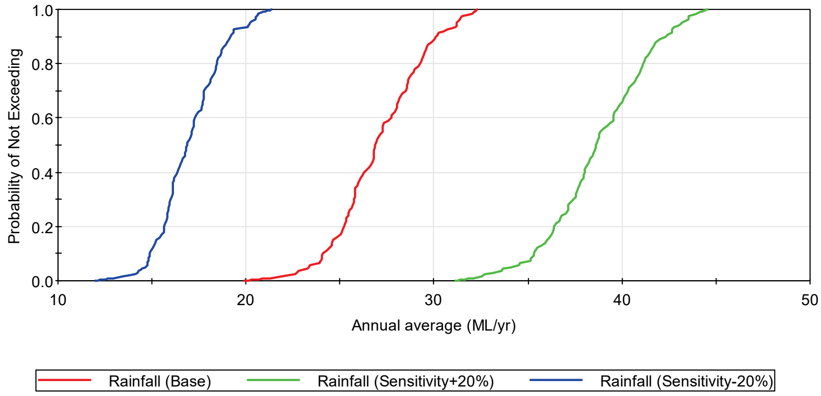


Figure 5.7: Post Closure annual average rainfall sensitivity

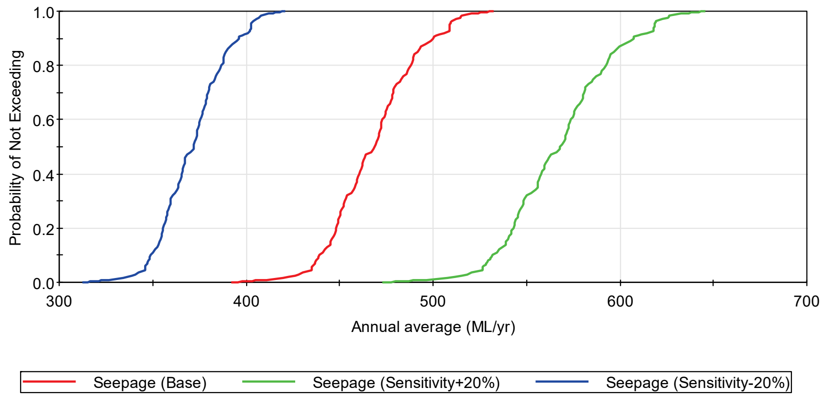


Figure 5.8: Post Closure annual average seepage sensitivity

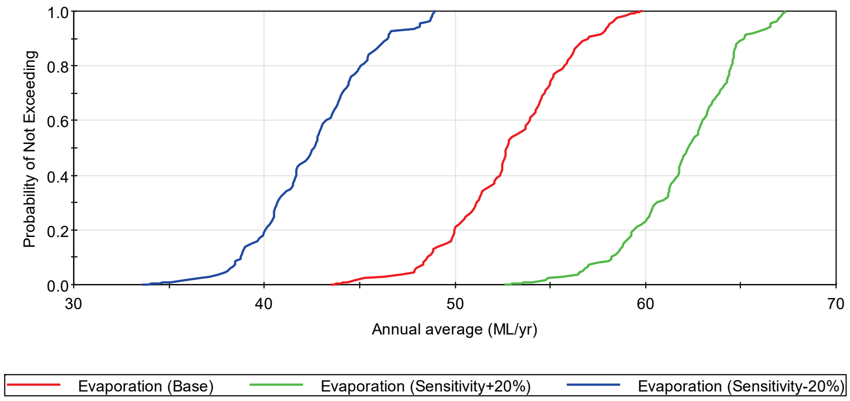


Figure 5.9: Post Closure annual average evaporation sensitivity

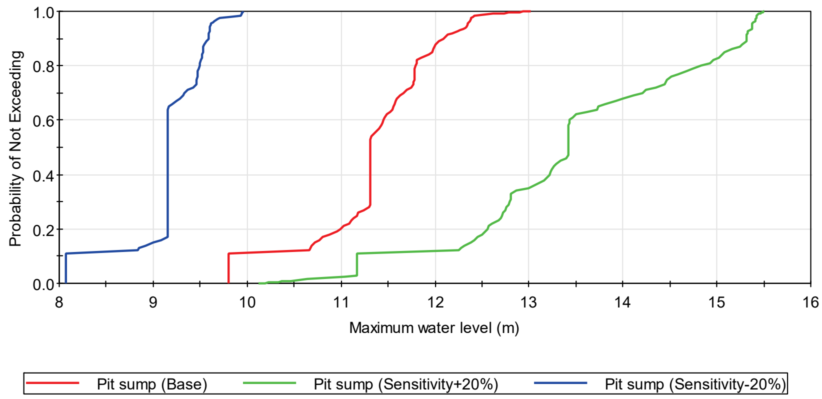


Figure 5.10: Post Closure pit sump maximum water level sensitivity

5.3.2 Flow Regime

Figure 5.11 and Figure 5.12 show the modelled flow duration graphs of flow to tributaries of Tangarang Creek and Main Gully for pre- and post-mining contributing catchments. This analysis takes account of the changes in the catchment area as well as the anticipated increase in runoff from rehabilitated overburden emplacements compared to pre-mining natural conditions. Both graphs show that the flow regime in these tributaries was highly ephemeral prior to mining and would remain so after mining ceases.

As a result of mining, the Tangarang Creek tributaries within the project area would increase the catchment area draining to the Peppertree Dam from 614 ha to 664 ha. As a result of this increase in catchment area and change in catchment properties has minimal impact on the flows, with average flow expected to increase by 9% (29 ML/year). Flow durations are very similar between the pre and post mining conditions.

As a result of mining, the catchment area of the Main Gully tributaries within the project area would decrease slightly from 232 ha to 186 ha. The change in catchment properties results in 17% decrease in average flow, with a decrease in the duration of lower flow events as shown in Figure 5.12.

These changes in flow regime are not expected to have any adverse impact on Tangarang Creek or Main Gully. In the case of Tangarang Creek, the flow regime following mining is expected to restore flow to conditions comparable to pre-mining compared to the current regime.

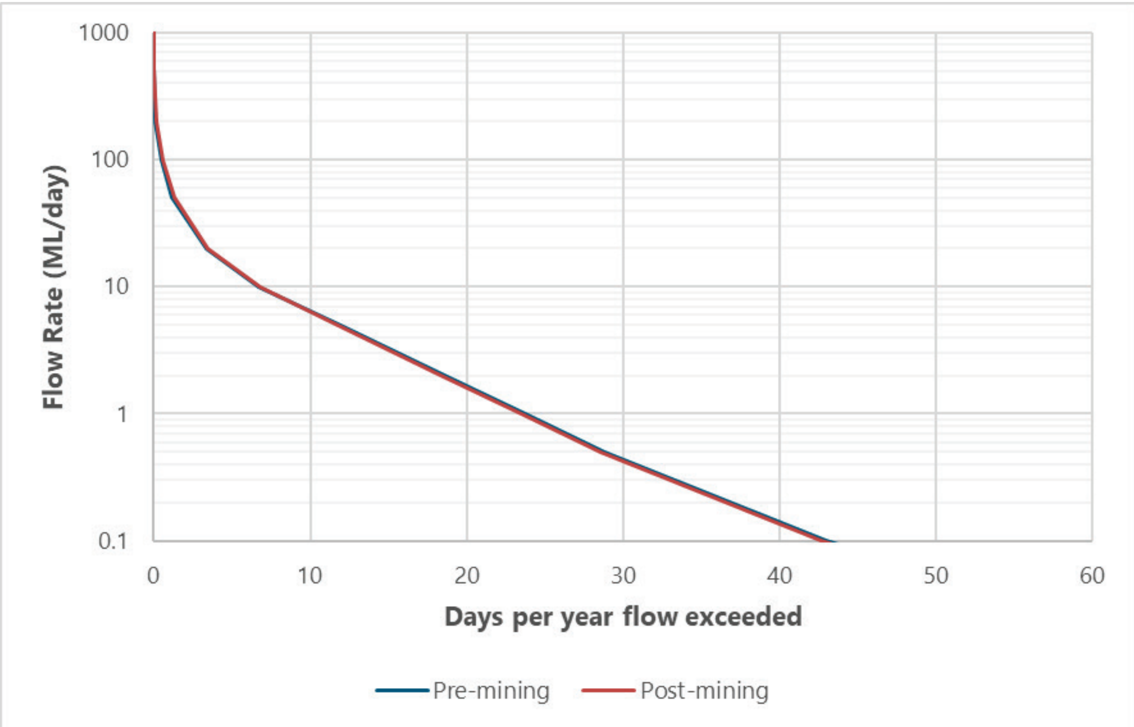


Figure 5.11: Pre and Post Mining Flow Duration for Tributaries Draining to Tangarang Creek

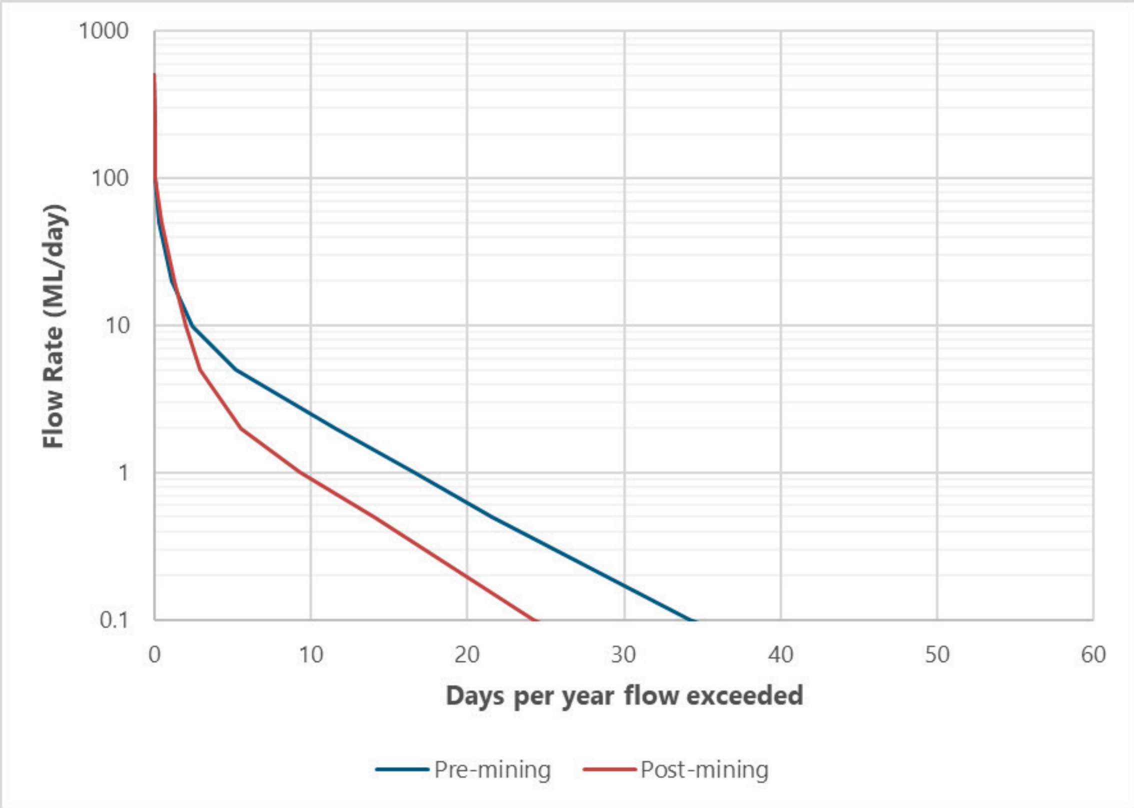


Figure 5.12: Pre and Post Mining Flow Duration for Tributaries Draining to Main Gully

6 Conclusions

The water balance analysis presented in this report demonstrates that the proposed water management system for the Project is robust and capable of providing security of supply for mine operations while ensuring that controlled overflow from the sediment basins would be in line with the guideline for the frequency of discharge into 'sensitive' receiving environments.

The robustness of the water management system has been demonstrated through the assessment of the performance of the system under a range of climate scenarios and through testing the effects of under- or over-estimating surface runoff.

The sensitivity analysis indicates that the water management system is capable of meeting site water demands and controlling overflows from the sediment dams under a range of assumed runoff.

The impact of current predictions of potential climate change effects on rainfall in the vicinity of Marulan has been assessed using the water balance model. The performance of the mine water management system to changes in surface runoff has been assessed by applying a multiplier to the modelled runoff.

The water balance modelling demonstrates that the proposed mine water management system has sufficient capacity and flexibility to accommodate a wide range of climate conditions while:

- providing security of supply for mine operations
- controlling discharge from sediment dams in accordance with the relevant guidelines for discharge to 'sensitive' receiving environments.

The water balance analysis for post mining conditions demonstrates that there is no risk of the water level in the pit reaching a level at which overflow to the environment could occur.

For post-mining conditions, the catchment area of the Main Gully tributaries within the project area would increase slightly (by 2 ha) resulting in a slight increase in average flow, however there a decrease in the duration of lower flow events is predicted. In the case of Tangarang Creek, an increase in the catchment area (by 34 ha) and change in catchment characteristics are predicted to increase flows by 4% (5 ML/year). Flow durations are very similar between the pre and post mining conditions. These changes in flow regime are not expected to have any adverse impact on Tangarang Creek or Main Gully.

7 References

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Annexure C Surface Water Quality

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Tables

Attachments

Attachment 1 Creek Surface Water Quality Data

1 Introduction

This annexure provides an assessment of surface water quality information in the vicinity of the Marulan South Limestone Mine. Water quality data is provided for:

- the mine site
- creeks in the vicinity of the mine
- the region.

2 Monitoring Approach

2.1 Mine Site Surface Water Monitoring

Marulan South Limestone Mine monitors site water quality at two locations, shown on Figure 2.1:

- Main Gully Auto-sampler
- Main Gully Sample Point.

The existing Marulan South Limestone Mine has one surface water discharge point that is monitored, being the Main Gully auto-sampler. The Main Gully sample point samples groundwater that daylights at the Blowhole, and therefore provides an indication of the groundwater quality contribution to surface waters in the vicinity of the mine. Flows from Main Gully discharge into Bungonia Creek.

Baseline surface water quality monitoring has been undertaken since February 2008 at these locations to understand the likely quality of runoff to be collected from haul roads and emplacement areas, and therefore the treatment requirements prior to site discharge.

The February 2009 variation to EPL944 required monitoring of water quality at three sampling locations within the mine site:

- EPL Monitoring Point 13 – North Pit Bore
- EPL Monitoring Point 13 – South Pit Bottom Level
- EPL Monitoring Point 14 – Main Gully Sample Point.

Water quality monitoring undertaken for EPL Monitoring Point 13 – North Pit Bore is considered to be groundwater monitoring and as such is not discussed in this Surface Water Assessment.

A subsequent variation to EPL944 (June 2012) removed the licence requirement for monitoring at EPL Monitoring Points 14 and 14, as the historical data collected from these points does not appear to indicate any connectivity between the activities undertaken at the premises and the previously observed instances of sediment laden water in Bungonia Creek. However, Boral has voluntarily continued to undertake monitoring at these locations and at the Main Gully Auto Sampler point beyond EPL requirements. The mine site surface water monitoring locations are summarised in Table 2.1, shown in Figure 2.1 and described below.

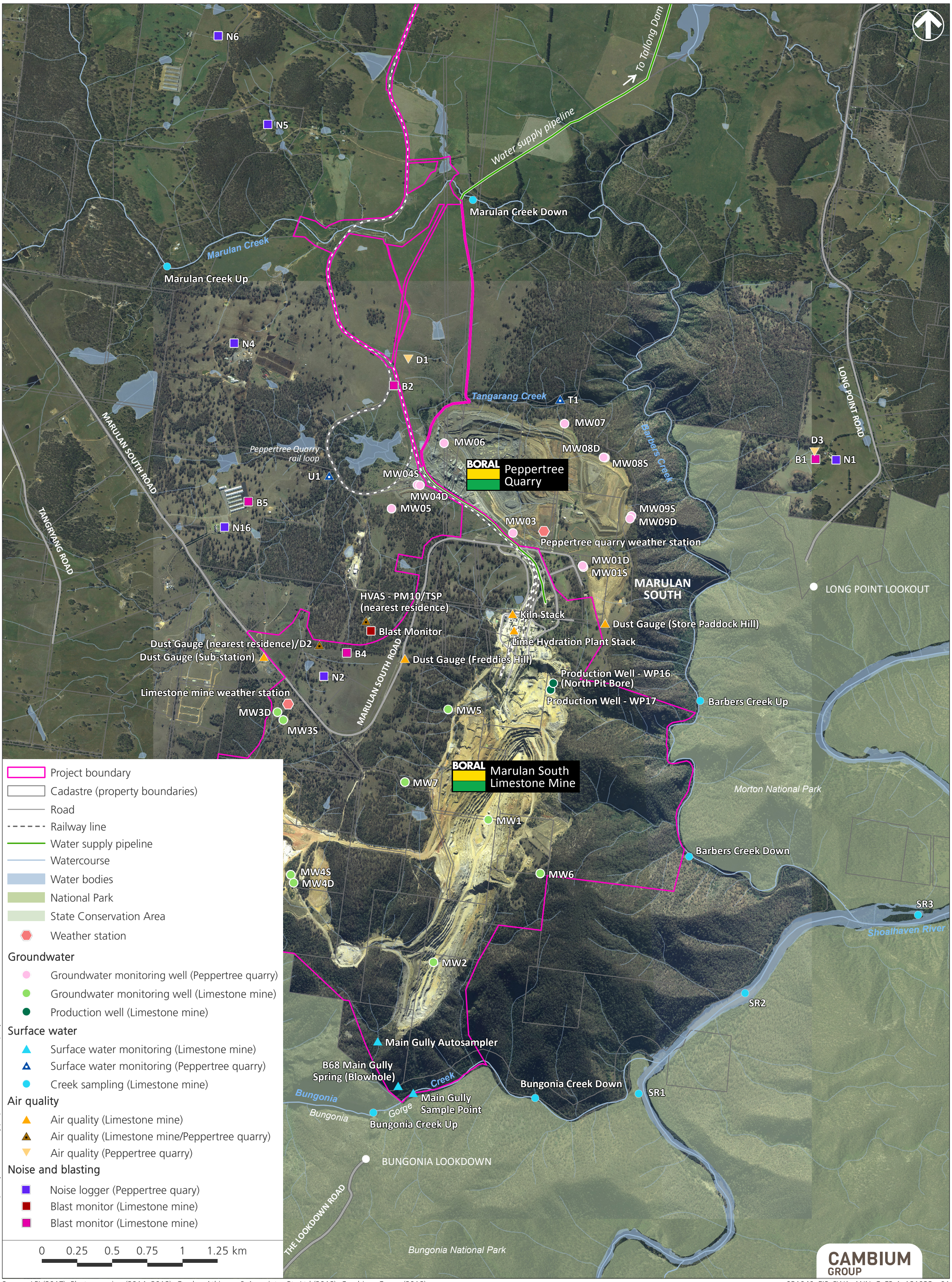
Table 2.1: Routine Mine Site Water Quality Monitoring Sites and Locations

Site	Description	Easting (mMGA)	Northing (mMGA)	Site specified in EPL 944	Monitoring Period	Frequency
South Pit Bottom Level	Lowest point of South Pit (previously EPL monitoring point 14)	227763	6146492	February 2009 – December 2011	Oct 2008 – Jun 2012	Approximately monthly
Main Gully Sample Point	Downhill of "Blow Hole" (previously EPL monitoring point 15)	227578	6145625	February 2009 – December 2011	Mar 2008 – Jun 2012 Nov 2014 – 2017 2017 →	Approximately monthly Monthly/Quarterly Quarterly
Main Gully Auto Sampler	Auto sampler	227324	6145992	N/A	Feb 2008 →	When water velocity sufficient to trigger auto-sampler

South Pit Bottom Level – this monitoring location (historically known as EPL Monitoring Point 14) was the lowest point in the south pit where runoff from within the mine is currently collected. Surface water collected in the base of the south pit seeps through the base and is filtered as it reaches the groundwater system. This surface water runoff is uncontrolled and untreated, but the South Pit Bottom Level acts as a sediment collection area. Samples from this location were collected between 2008 and 2012. However, the sampling at this location is not considered to be representative of runoff from the landscape and therefore this data has not been included in the analysis of baseline surface water quality in watercourses draining from the site or external to the site. The data collected at the South Pit is not considered further in this assessment.

Figure 2.1
Existing environmental monitoring locations

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
SURFACE WATER ASSESSMENT ANNEXURE C



Source: LPI (2017), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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Main Gully Sample Point – this monitoring location (historically known as EPL Monitoring Point 14) is located downhill from a natural feature known as the “Blow Hole”. The Blow Hole is a groundwater seep or spring (also known as B68 Main Gully Spring) and is located at an elevation that is below the base of the South Pit. It is possible that water seeping from the Blow Hole is representative of groundwater that includes seepage through the base of the South Pit. Due to the very steep terrain, access to the Blow Hole is not practical, and therefore, sampling is carried out at the Main Gully Sample Point in Main Gully, a tributary of Bungonia Creek. Sampling at this location was undertaken approximately monthly from March 2008 to June 2012 and then both monthly quarterly from November 2014 to 2017. Since 2017, sampling has been carried out quarterly.

Main Gully Auto Sampler – surface water at this location currently comprises runoff from a small area of the hall roads (about 5 ha) and surrounding vegetated areas. The water sampled this location would be typical of runoff from the haul roads and the overburden emplacement areas within the site. Surface water runoff pools in the lower of three sediment basins (Figure 2.2) from where a sample is taken by the Main Gully Auto Sampler (Figure 2.3). Sampling is undertaken when water velocity is sufficient to trigger the Auto Sampler.

Figure 2.2: Main Gully Auto Sampler collection point

Figure 2.3: Main Gully Auto Sampler

Prior to November 2014, the sampling regime (i.e. analytes and frequency) changed a number of times due to changes in EPL licensing requirements, as described above. Since November 2014, sampling for the analytes listed in Table 2.2 has been undertaken at the Main Gully Sample Point. The full suite of analytes monitored prior to November 2014 is not listed here.

Table 2.2: Analytes Monitored at Main Gully

pH	Sodium Adsorption Ratio	Electrical Conductivity
Total Dissolved Solids	Suspended Solids (from May 2015)	Total Hardness as CaCO3
Bromide	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3
Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulphate as SO4
Chloride	Calcium	Magnesium
Sodium	Potassium	Aluminium (dissolved & total)
Arsenic (dissolved & total)	Beryllium (dissolved & total)	Barium (dissolved & total)
Cadmium (dissolved & total)	Chromium (dissolved & total)	Cobalt (dissolved & total)
Copper (dissolved & total)	Lead (dissolved & total)	Manganese (dissolved & total)
Molybdenum (dissolved & total)	Nickel (dissolved & total)	Selenium (dissolved & total)
Strontium (dissolved & total)	Vanadium (dissolved & total)	Zinc (dissolved & total)
Boron (dissolved & total)	Iron (Dissolved and Total)	Mercury (Dissolved and Total)
Silicon as SiO2	Fluoride	Nitrite + Nitrate as N
Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P
Total Anions	Total Cations	Ionic Balance
Total Organic Carbon	Dissolved Oxygen	Biochemical Oxygen Demand

Other Supplementary/Opportunistic Sampling Locations – Additional and opportunistic sampling and analysis was also undertaken in 2009 (GSSE, 2009) including:

- two sites that receive runoff from relatively undisturbed catchments (Main Mine Dam 2 and a farm dam upstream of the Western Emplacement)
- two sites that receive runoff from overburden emplacement areas (Main Mine Dam 1 – previously located within the Western Emplacement; and the lower SE Sediment Dam on Main Gully).

Water quality data from this opportunistic sampling is summarised in Table 2.3. Based on this sampling GSSE concluded:

> *Review of the data collected shows that suspended sediment loads in all storages were well below typically recognised trigger levels for industry best practice (50 mg/L), indicating that coarse sediment loads (>1.2 micron) to these dams is satisfactory. No pollution from plant and machinery was detected in the sampled dams (no oil and grease detected). The pH levels varied from slightly alkaline to moderately alkaline as a reflection of the limestone geology of the area.*

Table 2.3: Water Quality in Storages in 2009

Parameter	Main Mine Dam 2	Farm Dam	Main Mine Dam 1	SE Sediment Dam
pH	8.08	7.41	7.55	7.74
Suspended Solids (mg/L)		10	8	8
Oil & Grease (mg/L)		<5	<5	<5

2.2 Creek Surface Water Monitoring

Baseline surface water monitoring in the creeks in the vicinity of the South Marulan Mine is undertaken at the sites identified in Table 2.4 and shown on Figure 2.1. Table 2.4 also provides the date monitoring commenced and the frequency of monitoring. Table 2.2 identifies the analytes and parameters that are monitored.

Table 2.4: Routine Creek Water Quality Monitoring Sites and Locations

Site	Description	Easting	Northing	Commencement of Monitoring	Monitoring Frequency
SR1	Shoalhaven River site 1	229183	6145620	July 2014	Monthly until 2017, quarterly since 2017
SR2	Shoalhaven River site 2	229940	6146335	July 2014	Monthly until 2017, quarterly since 2017
SR3	Shoalhaven River site 3	231172	6146891	July 2014	Monthly until 2017, quarterly since 2017
Bungonia Up	Bungonia Creek upstream of mine	227294	6145485	July 2014	Monthly until 2017, quarterly since 2017
Bungonia Dn	Bungonia Creek downstream of mine	228445	6145589	July 2014	Monthly until 2017, quarterly since 2017
Barbers Up	Barbers Creek upstream of mine	229518	6148416	September 2014	Monthly until 2017, quarterly since 2017
Barbers Dn	Barbers Creek downstream of mine	229542	6147306	September 2014	Monthly until 2017, quarterly since 2017
Marulan Up	Marulan Creek upstream of proposed dam	225825	6151504	November 2014	Monthly until 2017, quarterly since 2017
Marulan Dn	Marulan Creek downstream of proposed dam	228002	6151977	November 2014	Monthly until 2017, quarterly since 2017

Site	Description	Easting	Northing	Commencement of Monitoring	Monitoring Frequency
T1	Tangarang Creek downstream of Peppertree quarry (Peppertree Quarry monitoring site)	228730	6150550	February 2012	Quarterly during a flow event
WD1	Tangarang Creek Dam (Peppertree Quarry monitoring site)	227380	6150210	September 2012	Quarterly
U1	Tangarang Creek upstream of Tangarang Dam (Peppertree Quarry monitoring site)	226950	6149970	February 2012	Quarterly during a flow event

The sampling sites on Bungonia Creek and Barbers Creek were chosen to represent surface waters both upstream and downstream of the mine to provide a statistically representative baseline data set and identify any existing mining induced impacts.

Monitoring locations on Marulan Creek were identified to gather baseline data for the proposed Marulan Creek Dam and Marulan Creek is a tributary of Barbers Creek. Water quality monitoring at Tangarang Creek has also been undertaken for Peppertree Quarry since February 2012 and is included in this assessment as Tangarang Creek is a tributary of Barbers Creek.

The monitoring sites on the Shoalhaven River were chosen to represent the incremental catchment inflows from Barbers Creek and Bungonia Creek that include the Project area. Collection of water quality data at these locations is for the purpose of developing a baseline data set. Also, as the Shoalhaven River is the main conveyance supplying Tallowa Dam, this dataset will also be used to demonstrate the variability of water quality from the contributing catchments (Barbers and Bungonia) and the corresponding potential impact on water quality in the Shoalhaven River. This dataset is important in demonstrating the effectiveness of the mine water management system to achieve a Neutral or Beneficial Effect (NorBE).

2.3 Regional Surface Water Quality

As part of their Water Monitoring Program for the Sydney catchment area, WaterNSW (formerly Sydney Catchment Authority) monitors surface water quality in the Shoalhaven catchment, which is reported on an annual basis. Monitoring site E847 on the Shoalhaven River at Fossickers Flat (shown on Figure 2.4) is located approximately 15 km south-east (downstream) of Marulan South Limestone Mine and is the monitoring site closest to the mine site.

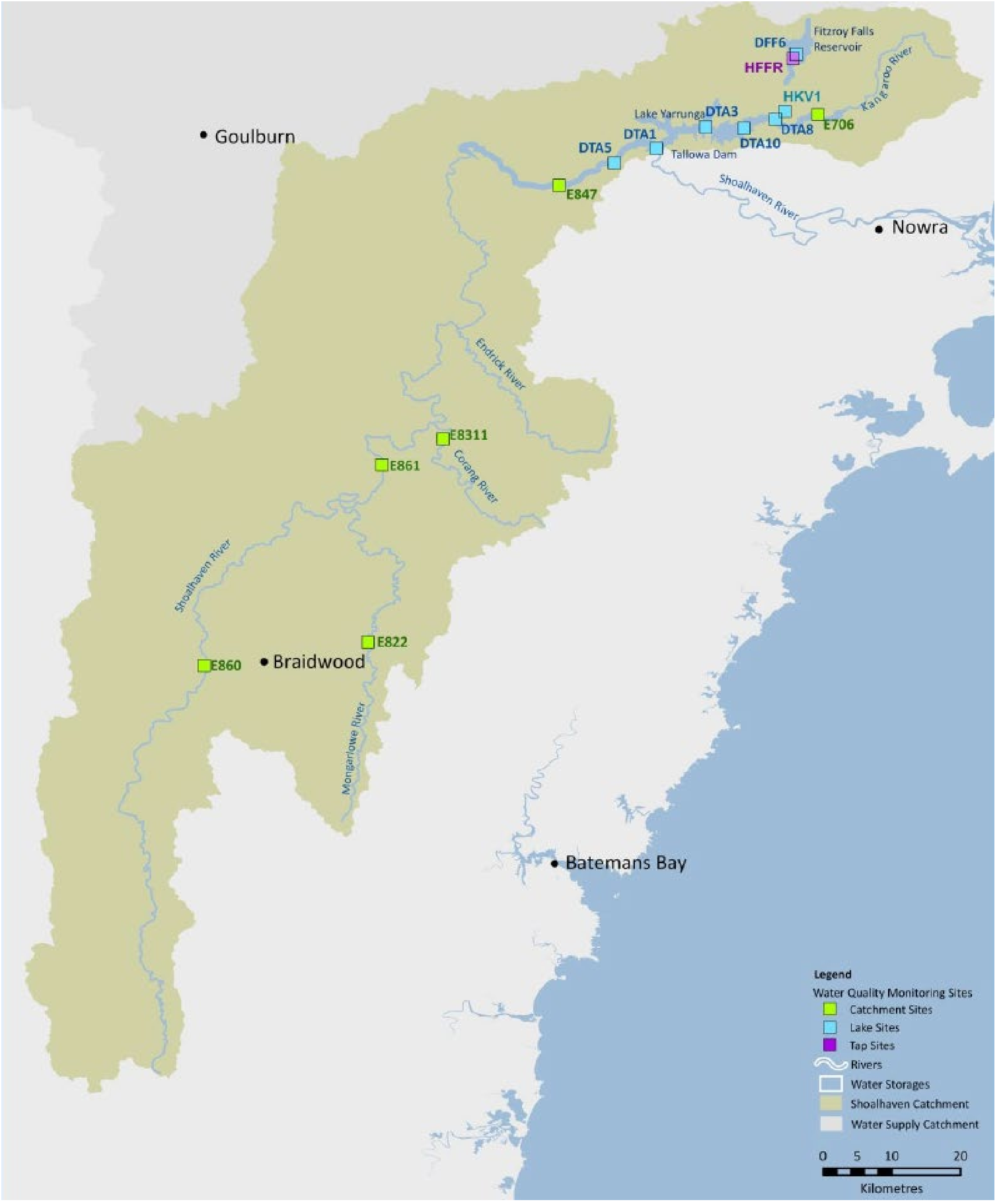

Figure 2.4: WaterNSW Sampling Sites in the Shoalhaven System

3 Water Quality Monitoring Data and Assessment

3.1 Site Water Quality

Table 3.1 provides a statistical summary of key analytes and parameters measured. Water quality results for pH, electrical conductivity (EC) and suspended solids (SS) water quality results are summarised in Figure 3.1 to Figure 3.3.

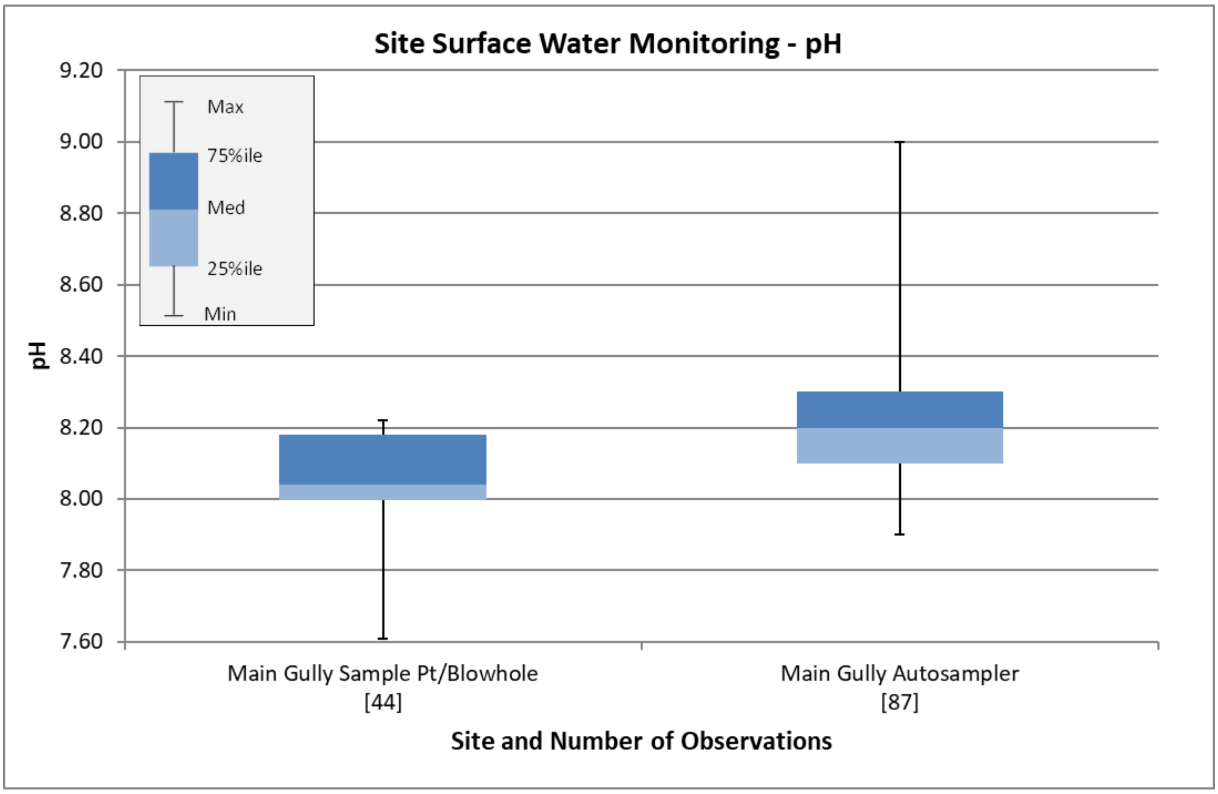

Figure 3.1: Site Surface Water Quality Monitoring Results – pH

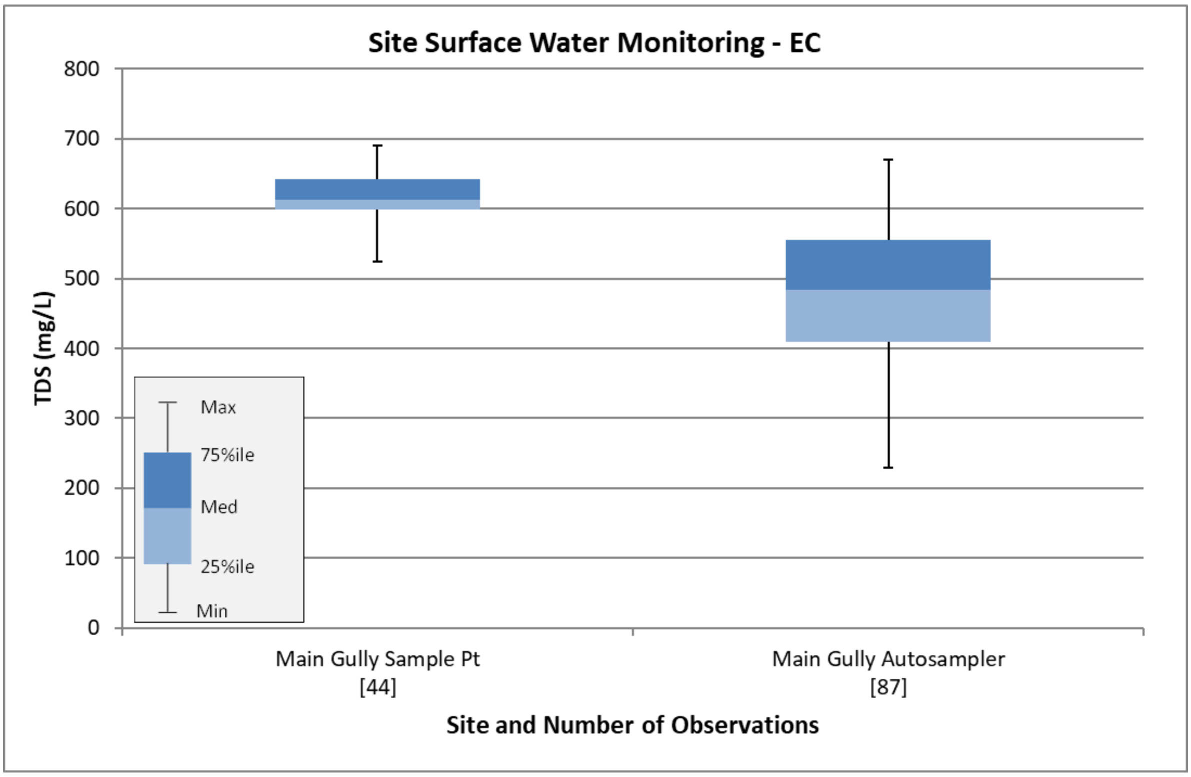

Figure 3.2: Site Surface Water Quality Monitoring Results – EC

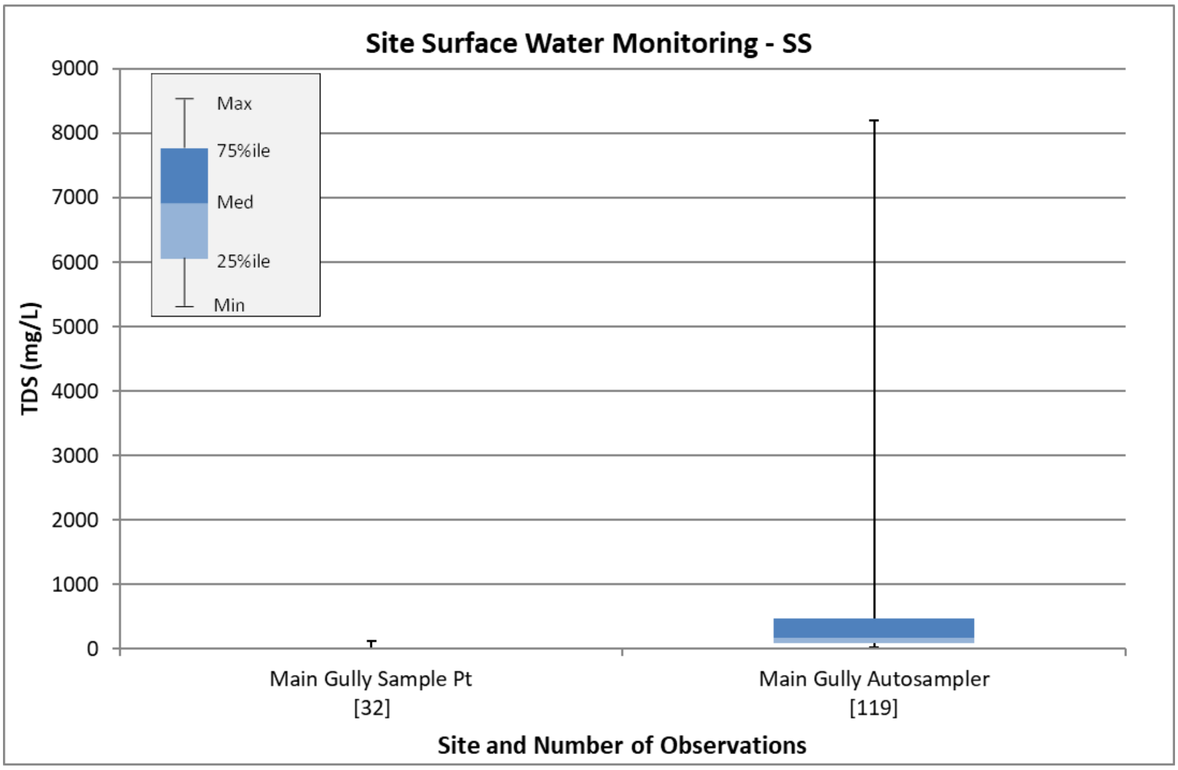

Figure 3.3: Site Surface Water Quality Monitoring Results – Suspended Solids

Table 3.1: Site Surface Water Quality Data

Analyte	Unit	Statistic	Main Gully sample point	Main Gully Autosampler
pH	pH value	Count	21	87
		20%ile	8.0	8.1
		Median	8.1	8.2
		80%ile	8.2	8.3
Electrical Conductivity @ 25°C	µS/cm	Count	21	87
		20%ile	590	400
		Median	610	484
		80%ile	630	570
Total Dissolved Solids	mg/L	Count	21	33
		20%ile	356	313
		Median	369	350
		80%ile	390	400
Suspended Solids	mg/L	Count	15	119
		20%ile	1.8	78
		Median	8.1	166
		80%ile	9.2	620
Aluminium (Dissolved)	mg/L	Count	8	25
		20%ile	<0.01	0.003
		Median	<0.01	0.008
		80%ile	<0.01	0.011
Manganese (Dissolved)	mg/L	Count	5	25
		20%ile	<0.001	0.001
		Median	<0.001	0.002
		80%ile	<0.001	0.002
Iron (Dissolved)	mg/L	Count	9	25
		20%ile	<0.05	0.03
		Median	<0.05	0.04
		80%ile	<0.05	0.05
Aluminium (Total)	mg/L	Count	21	24
		20%ile	0.005	0.88
		Median	0.011	1.80
		80%ile	0.074	4.12
Manganese (Total)	mg/L	Count	16	24
		20%ile	0.000	0.032
		Median	0.001	0.062
		80%ile	0.004	0.062
Iron (Total)	mg/L	Count	18	24
		20%ile	<0.05	1.12
		Median	<0.05	2.25
		80%ile	<0.05	5.72

** results under the minimum value able to be recorded were analysed as half that value e.g. Iron values under 0.05 were detailed as equal to 0.025*

Key aspects of the Main Gully Sample Point water quality monitoring results are:

- **pH** is slightly alkaline, with the 2-th – 80th percentile pH values ranging between 8.02 and 8.2, with a median value of 8.1. This range is consistent with the observed pH range in Bungonia Creek
- **salinity** (as indicated by EC) 20th – 80th percentile values ranging between 590 and 630 µS/cm, with a median value of 610 µS/cm. This range is consistent with the observed salinity range within Bungonia Creek (447 – 682 µS/cm)
- **suspended solids** 20th – 80th percentile concentrations range between 1.8 and 9.2 mg/L, with a median value of 8.1 mg/L. This is consistent with the observed suspended solid concentrations within Bungonia Creek (<5 mg/L).

Key aspects of the Main Gully Auto Sampler water quality monitoring results are:

- **pH** is slightly alkaline, with 20th – 80th percentile values pH values ranging between 8.1 and 8.3, with a median value of 8.2. This median value is consistent with the observed pH in Bungonia Creek
- **salinity** (as indicated by EC) 20th – 80th percentile values range between 400 and 570 µS/cm, with a median value of 484 µS/cm. The median EC value is less than the median observed salinity in Bungonia Creek
- **suspended solids** 20th – 80th percentile concentrations range between 78 and 620 mg/L, with a median value of 166 mg/L. This is much higher than the results observed in Bungonia Creek (median value of <5 mg/L).

The data collected at the site monitoring locations indicate that under existing conditions, the surface water and groundwater discharges are resulting in a water quality discharge that is consistent with the existing water quality of the receiving waters (Bungonia Creek). The exception is suspended solids measured at the Auto Sampler, which is much higher than the sample point and the downstream values in Bungonia Creek.

The data collected at the Main Gully Auto Sampler also indicates that the level of treatment of runoff from haul roads and emplacement areas within the site in the three sediment basis upstream of the Auto Sampler are generally sufficient to meet the water quality objectives for the Shoalhaven River catchment being that a neutral or beneficial effect will result, however additional treatment for suspended solids may be required.

3.2 Local Creek Water Quality

Attachment 1 provides a statistical summary of the analytes and parameters measured in the creeks in the vicinity of the mine. Results to date for pH and electrical conductivity are summarised in Figure 3.4 and Figure 3.5. Where available, these results have been benchmarked against other surface water quality sampling sites in the region, as discussed below. Total dissolved solids concentration has been used to estimate electrical conductivity in Tangarang Creek (Sites U1 and T1), multiplying concentration by 1.54.

Figure 3.4 and Figure 3.5 also show the ANZECC default trigger values for South-east Australia for slightly disturbed ecosystems (upland river). Further details on the ANZECC default trigger values are provided in Section 4.

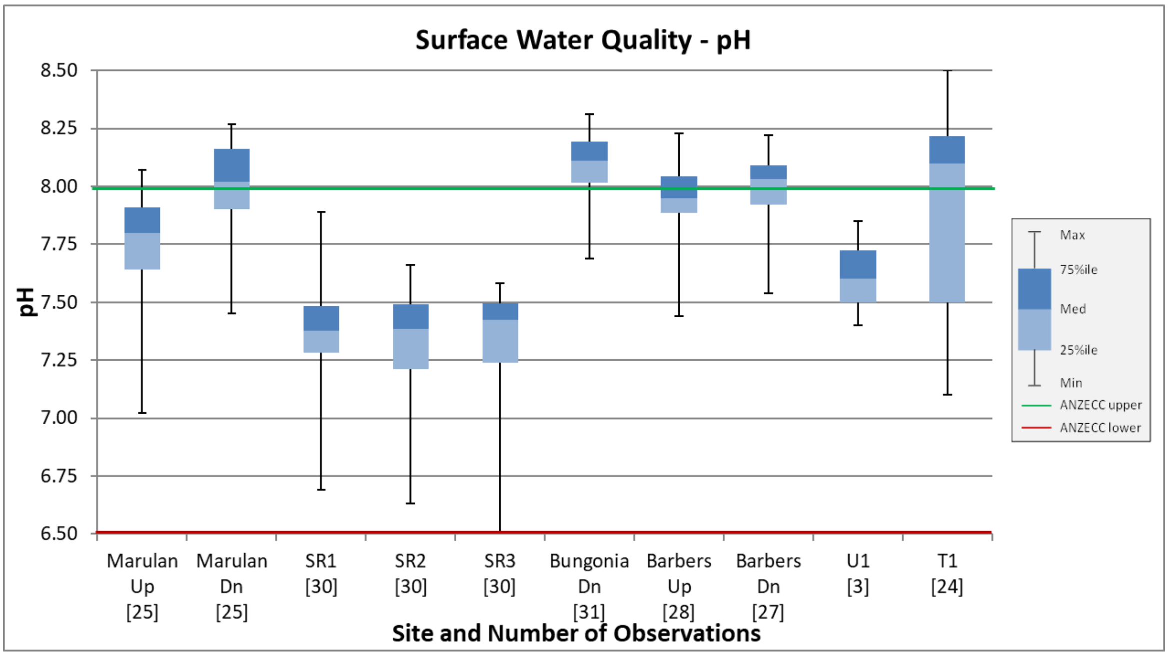

Figure 3.4: Surface Water Quality Monitoring Results – pH (Lab)

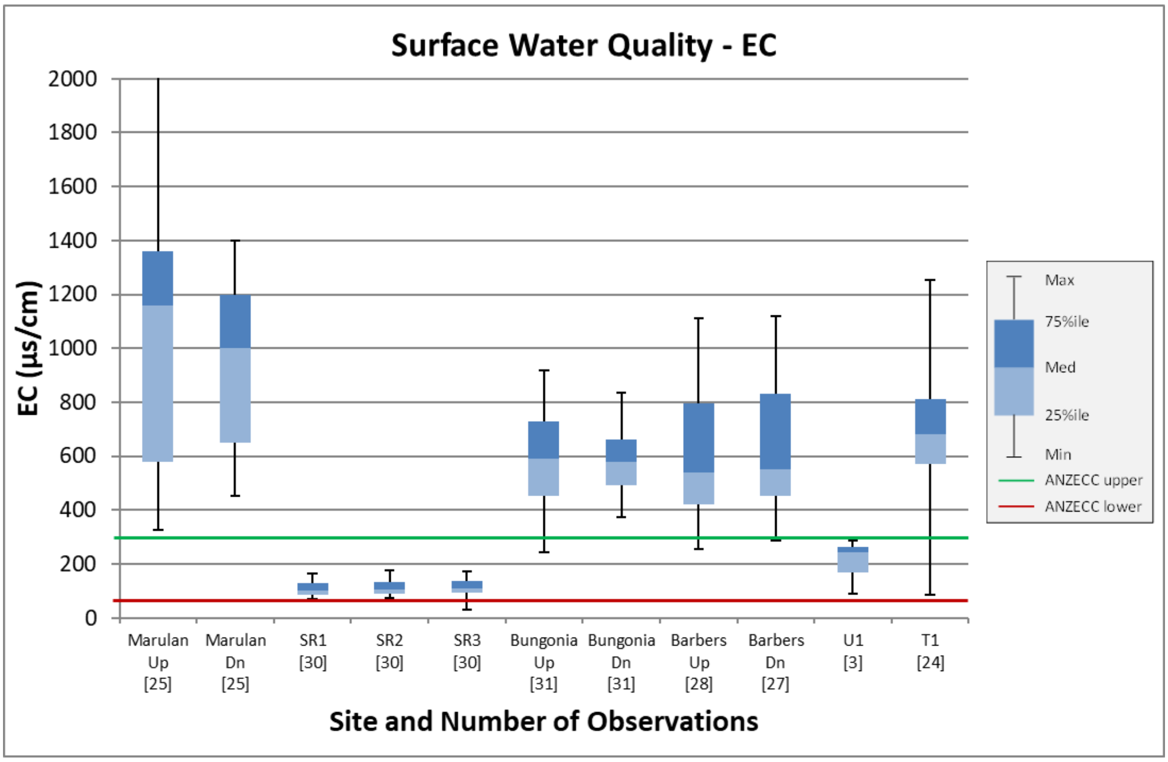

Figure 3.5: Surface Water Quality Monitoring Results – Electrical Conductivity

Key aspects of the Bungonia Creek water quality monitoring results are:

- pH is slightly alkaline, with a median value of 7.7 at the upstream site and 8.1 at the downstream site, slightly exceeding the upper ANZECC default trigger value for aquatic ecosystem protection
- salinity generally exceeds the default trigger value, with a median value of 589 µS/cm at the upstream site and 581 µS/cm at the downstream site
- suspended Solids had a median value of <5 mg/L at both the upstream and downstream sites.

Key aspects of the Barbers Creek water quality monitoring results are:

- pH is slightly alkaline, with a median value of 8.0 at both the upstream and downstream sites, slightly exceeding the upper ANZECC default trigger value
- salinity had a median value of 541 µS/cm at the upstream site and 553 µS/cm at the downstream site, exceeding the upper ANZECC default trigger value;
- suspended Solids ranges had a median value of <5 mg/L at both the upstream and downstream sites.

Key aspects of the Marulan Creek water quality monitoring results are:

- pH is slightly alkaline, with a median value of 7.8 at the upstream site and 8.0 at the downstream site, slightly exceeding the upper ANZECC default trigger value for aquatic ecosystem protection
- salinity demonstrated a median value of 1,160 µS/cm at the upstream site and 1,000 µS/cm downstream. The observed EC values exceed the ANZECC default trigger values and were much higher than the results for the other tributary creeks
- suspended Solids had a median value of 7 mg/L at the upstream site <5 mg/L at the downstream site.

Key aspects of the Tangarang Creek water quality monitoring results are:

- Limited upstream sampling in Tangarang, with flow only during 3 of the 24 scheduled samples
- pH is slightly alkaline, with a median value of 8.1 at T1, slightly exceeding the default trigger value
- median salinity of 683 µs/cm downstream (based on total dissolved solids). Salinity exceeds the ANZECC default trigger and were similar to the Marulan Creek samples
- suspended solids at T1 had a median value of <5 mg/L.

Key aspects of the Shoalhaven River water quality monitoring results (considering monitoring sites SR1, SR2 and SR3) are:

- pH at all three sites ranges had a median value of 7.4 and 80th percentile value of 7.5, which does not exceed the ANZECC default trigger value
- salinity had a median value of 103 - 110 µS/cm, which does not exceed the ANZECC default trigger value
- suspended Solids had a median value of <5 mg/L.

These results for pH, salinity and suspended solids are consistent with the water quality results reported by WaterNSW (Table 3.2).

Key statistics for pH and EC from the various monitoring sites on the waterbodies in the site vicinity are compared to the ANZECC default trigger values for ecosystems in Table 4.1 and Table 4.2 below. The analysis indicates that water quality in Marulan, Barbers and Bungonia creeks generally exceeds the default trigger values, while the water quality in the Shoalhaven River generally does not exceed the trigger values.

Water quality data collected from upstream and downstream sites demonstrate that water quality is not compromised by the mine. As such, there is no evidence that existing mine operations are adversely impacting the water quality in Barbers Creek or Bungonia Creek.

3.3 Regional Surface Water Quality

Monitoring results reported by WaterNSW for site E847 on the Shoalhaven River (Figure 2.4) over the last 5 years are summarised in Table 3.2.

Table 3.2: Water NSW monitoring results – Site E847

		2010/11	2011/12	2012/13	2013/14*	2014/15
Conductivity (uS/cm)	n	11	8	12	11	11
	Median	107	93	134	110	100
pH (field)	n	11	8	12	11	11
	Median	7.5	7.5	7.5	7	7.2
Suspended Solids (mg/L)	n	11	8	12	11	11
	Median	5	3.5	1	4	4

* Note - physico-chemical parameters were not monitored at E847 in 2013/14, results from station DTA5 are instead

In 1999, The Healthy Rivers Commission (HRC) Independent Inquiry into the Shoalhaven River System reported that the Middle Western division of the catchment has moderate water quality. Generally, it was found that dissolved oxygen was low, while some areas had high turbidity and salinity. Bacteria, nutrients and metals were found to be at levels that were acceptable in comparison to the default ANZECC Water Quality Guidelines for Fresh and Marine Waters (1992).

4 ANZECC Water Quality Criteria

For purposes of assessing the potential impact of mine operations on water quality, both the ANZECC water quality criteria and the targets set out in the Southern Rivers CAP are relevant considerations. The Southern Rivers CAP 2013 – 2023 recommends that the water quality criteria specified in the default ANZECC guidelines should be adopted as water quality objectives throughout the Shoalhaven catchment.

The ANZECC 2000 Guidelines move away from setting fixed single number water quality criteria, and emphasise water quality criteria that can be determined on a case by case basis, according to local environmental conditions. This is done through the use of local reference data and risk based decision frameworks. The Guidelines establish default trigger values that are set conservatively and can be used as a benchmark for assessing water quality.

For water whose environmental value is aquatic ecosystem protection, the Guidelines recommend that indicators be developed and adapted to suit the local area or region. Trigger values for a large range of toxicants are provided in Table 3.4.1 of the Guidelines.

Observations to date at SR1, SR2 and SR3 indicate that the water quality in the Shoalhaven River meets the ANZECC ecosystem protection levels (Table 4.2), while upstream, the contributing creeks do not (Table 4.1).

Table 4.1: Creek Water Quality and Default ANZECC Trigger Values

Analyte	Units	ANZECC Ecosystem[1] Default Trigger Values	No of samples	20th %ile		Median		80th %ile		No of samples	20th %ile		Median		80th %ile	
				Value	Complies	Value	Complies	Value	Complies		Value	Complies	Value	Complies	Value	Complies
			Marulan Creek Up							Marulan Creek Down						
pH		6.5 - 8.0	25	7.6	Y	7.8	Y	7.9	Y	25	7.8	Y	8.0	Y	8.2	N
EC	µs/cm	350	25	451	N	1160	N	1556	N	25	648	N	1000	N	1248	N
TN	mg/L	0.25	25	0.48	N	0.8	N	1.02	N	25	0.4	N	0.60	N	0.80	N
TP	mg/L	0.02	25	0.02	Y	0.03	N	0.08	N	25	0.01	Y	0.01	Y	0.02	Y
			Barbers Creek Up							Barbers Creek Down						
pH		6.5 - 8.0	28	7.8	Y	8.0	Y	8.1	N	27	7.9	Y	8.0	Y	8.1	N
EC	µs/cm	350	28	414	N	541	N	853	N	27	445	N	553	N	933	N
TN	mg/L	0.25	28	0.34	N	0.40	N	0.66	N	27	0.20	Y	0.50	N	0.60	N
TP	mg/L	0.02	28	0.01	Y	0.01	Y	0.01	Y	27	0.01	Y	0.01	Y	0.02	Y
			Bungonia Creek Up							Bungonia Creek Down						
pH		6.5 - 8.0	31	7.6	Y	7.7	Y	7.9	Y	31	7.9	Y	8.1	N	8.2	N
EC	µs/cm	350	31	447	N	589	N	743	N	31	481	N	581	N	682	N
TN	mg/L	0.25	28	0.50	N	0.80	N	1.36	N	31	1.50	N	2.3	N	3.6	N
TP	mg/L	0.02	28	0.01	Y	0.01	Y	0.02	Y	31	0.01	Y	0.01	Y	0.02	Y
			T1							U1						
pH		6.5 - 8.0	24	7.7	Y	8.1	N	8.3	N	3	7.5	Y	7.6	Y	7.8	Y
TP	mg/L	0.02	24	0.01	Y	0.01	Y	0.03	N	3	0.13	N	0.26	N	0.50	N

[1] South East Australia, slightly disturbed ecosystems, upland river

Table 4.2: Shoalhaven River Water Quality and Default ANZECC Trigger Values

Analyte	Units	ANZECC Ecosystem[1] Default Trigger Values	No of samples	20th %ile		Median		80th %ile		No of samples	20th %ile		Median		80th %ile		No of samples	20th %ile		Median		80th %ile	
				Value	Complies	Value	Complies	Value	Complies		Value	Complies	Value	Complies	Value	Complies		Value	Complies	Value	Complies	Value	Complies
			SR1							SR2							SR3						
pH	pH	6.5 - 8.0	30	7.3	Y	7.4	Y	7.5	Y	30	7.2	Y	7.4	Y	7.5	Y	30	7.2	Y	7.4	Y	7.5	Y
EC	µs/cm	350	30	84	Y	103	Y	139	Y	30	89	Y	105	Y	143	Y	30	94	Y	110	Y	146	Y
TN	mg/L	0.25	30	0.28	N	0.45	N	0.60	N	30	0.2	Y	0.4	N	0.5	N	30	0.3	N	0.45	N	0.62	N
TP	mg/L	0.02	30	0.01	Y	0.01	Y	0.02	Y	30	0.01	Y	0.01	Y	0.02	Y	30	0.01	Y	0.01	Y	0.02	Y

[1] South East Australia, slightly disturbed ecosystems, upland river

4.1 Proposed trigger levels

Downstream from the Marulan Limestone Mine in the Shoalhaven River, the default ANZECC trigger levels for ecosystem protection are appropriate for monitoring change in water quality.

Under existing conditions, the water quality of creeks (Barbers and Bungonia) contributing to the Shoalhaven River do not meet the ANZECC criteria for ecosystem protection. However, the data indicates that the water quality in these creeks is not negatively impacting the Shoalhaven River. Therefore proposed trigger levels based on a baseline dataset of water quality for the contributing creeks in the vicinity of the mine is appropriate.

Table 4.3 summarises the proposed trigger values to assess potential mining-induced impacts on water quality in creeks in the vicinity of the Marulan Limestone Mine.

Table 4.3: Proposed Water Quality 'Trigger' Values for Bungonia Creek and Barbers Creek

Indicator	ANZECC Default Trigger for Ecosystem Protection[1]	Water NSW Benchmarks for Catchment Streams	Proposed 'Triggers'
pH	6.5 – 8.0	6.5 – 8.0	6.5 – 8.5
EC (µS/cm)	350		1,600
Total nitrogen (mg/L)	0.25	0.25	4.0
Total phosphorus (mg/L)	0.02	0.02	0.03
Turbidity (NTU)	25	25	25

[1] Default trigger values for physical and chemical stressors for South-east Australia for slightly disturbed ecosystems (upland river)

5 References

ANZECC (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*

ERM (2011). *Peppertree Quarry Water Management Plan*

Attachment 1 Creek Surface Water Quality Data

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
pH	pH value	6.5	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	7.60	7.84	7.80	7.92	7.64	7.94	7.28	7.16	7.18	7.74	7.48
		8.0	Median	7.80	8.02	7.95	8.03	7.74	8.11	7.38	7.39	7.43	8.10	7.60
			80%ile	7.93	8.18	8.05	8.10	7.85	8.22	7.53	7.54	7.53	8.28	7.75
Sodium Adsorption Ratio	-	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	1.74	1.63	1.14	1.05	1.02	0.93	0.74	0.70	0.70		
			Median	2.68	1.98	1.33	1.21	1.33	1.13	0.83	0.81	0.81		
			80%ile	3.05	2.15	1.67	1.46	1.46	1.35	0.93	0.94	0.93		
Electrical Conductivity @ 25°C	µS/cm	350	Count	25	25	28	27	31	31	30	30	30	0[1]	0[1]
			20%ile	451	648	414	445	447	481	84	89	94	523	150
			Median	1160	1000	541	553	589	581	103	105	110	683	244
			80%ile	1556	1248	853	933	743	682	139	143	146	897	269
Total Dissolved Solids	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	293	421	269	290	290	313	55	58	61	340	98
			Median	754	650	352	359	383	378	67	69	72	444	159
			80%ile	1014	811	555	607	483	443	90	93	95	583	175
Suspended Solids	mg/L	N/A	Count	16	16	18	17	22	18	18	18	18	24	3
			20%ile	3	3	3	3	3	3	3	3	3	3	6
			Median	7	3	3	3	3	3	3	3	4	4	10
			80%ile	10	6	3	3	5	6	8	6	8	41	21
Total Hardness as CaCO3	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	23	3
			20%ile	104	183	106	119	122	150	20	22	22	135	51

[1] Electrical conductivity estimated based on TDS x 1.54

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	284	273	179	181	206	206	25	29	29	240	65
			80%ile	390	390	287	332	256	246	32	32	36	434	72
Bromide	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.143	0.215	0.148	0.147	0.128	0.124	0.018	0.019	0.019		
			Median	0.453	0.389	0.231	0.233	0.196	0.161	0.023	0.024	0.025		
			80%ile	0.615	0.457	0.311	0.323	0.263	0.222	0.027	0.031	0.031		
Hydroxide Alkalinity as CaCO3	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	0	0
			20%ile	1	1	1	1	1	1	1	1	1		
			Median	1	1	1	1	1	1	1	1	1		
			80%ile	1	1	1	1	1	1	1	1	1		
Carbonate Alkalinity as CaCO3	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	0	0
			20%ile	1	1	1	1	1	1	1	1	1		
			Median	1	1	1	1	1	1	1	1	1		
			80%ile	1	1	1	1	1	1	1	1	1		
Bicarbonate Alkalinity as CaCO3	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	0	0
			20%ile	75	132	83	101	95	107	18	21	22		
			Median	144	214	129	145	134	135	26	27	29		
			80%ile	163	287	192	226	175	166	35	34	35		
Total Alkalinity as CaCO3	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	0	0
			20%ile	75	132	83	101	95	107	18	21	22		
			Median	144	214	129	145	134	135	26	27	29		
			80%ile	163	287	192	226	175	166	35	34	35		
Sulfate as SO4 - Turbidimetric	mg/L	N/A	Count	24	24	28	27	31	31	30	30	30	0	0
			20%ile	11	8	6	9	16	26	1	1	1		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	18	10	8	16	21	37	2	3	3		
			80%ile	32	12	15	31	27	46	4	5	5		
Chloride	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	82	113	56	56	56	56	10	10	11	83	7
			Median	251	174	78	78	76	67	12	14	14	131	15
			80%ile	372	222	162	139	113	90	18	19	18	234	17
Calcium	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	19	34	20	25	31	41	4	4	4	33	10
			Median	51	58	36	39	55	56	5	5	5	51	11
			80%ile	70	69	56	70	70	69	6	6	7	69	13
Magnesium	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	14	24	13	14	11	12	3	3	3	10	3
			Median	36	35	20	21	15	16	3	4	4	35	4
			80%ile	52	55	35	38	20	19	4	4	4	44	4
Sodium	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	40	51	33	32	34	31	8	8	8	34	6
			Median	100	81	37	36	38	36	9	10	10	60	13
			80%ile	137	95	63	55	47	41	12	12	12	72	14
Potassium	mg/L	N/A	Count	25	25	28	27	31	31	30	30	30	24	3
			20%ile	4	2	2	2	2	2	1	1	1	2	6
			Median	6	3	3	3	2	2	1	1	1	3	13
			80%ile	7	4	4	3	3	3	2	1	2	4	14
Aluminium (Dissolved)	mg/L	0.055	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.030	0.028	0.020		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.020	0.005	0.005	0.005	0.005	0.005	0.050	0.055	0.045		
			80%ile	0.154	0.032	0.026	0.018	0.046	0.030	0.132	0.116	0.104		
Arsenic (Dissolved)	mg/L	0.013	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002		
Beryllium (Dissolved)	mg/L	ID	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Barium (Dissolved)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.056	0.077	0.036	0.036	0.039	0.041	0.010	0.010	0.010		
			Median	0.093	0.091	0.047	0.050	0.049	0.046	0.012	0.012	0.013		
			80%ile	0.138	0.098	0.082	0.088	0.059	0.052	0.015	0.015	0.015		
Cadmium (Dissolved)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Chromium (Dissolved)	mg/L	0.001	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Cobalt (Dissolved)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Copper (Dissolved)	mg/L	0.0014	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Lead (Dissolved)	mg/L	0.0034	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Manganese (Dissolved)	mg/L	1.9	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.012	0.006	0.004	0.003	0.001	0.003	0.006	0.006	0.006		
			Median	0.024	0.010	0.007	0.009	0.002	0.003	0.008	0.009	0.008		
			80%ile	0.049	0.020	0.029	0.035	0.003	0.005	0.013	0.013	0.012		
Molybdenum (Dissolved)	mg/L	ID	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Nickel (Dissolved)	mg/L	0.011	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Selenium (Dissolved)	mg/L	0.011	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			80%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
Strontium (Dissolved)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.113	0.167	0.098	0.099	0.111	0.126	0.022	0.022	0.024		
			Median	0.284	0.245	0.146	0.145	0.177	0.167	0.028	0.027	0.029		
			80%ile	0.384	0.322	0.233	0.241	0.209	0.198	0.035	0.038	0.036		
Vanadium (Dissolved)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			80%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
Zinc (Dissolved)	mg/L	8	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
			Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
			80%ile	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
Boron (Dissolved)	mg/L	0..370	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
			Median	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
			80%ile	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
Iron (Dissolved)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.138	0.045	0.025	0.025	0.025	0.025	0.168	0.148	0.150		
			Median	0.230	0.080	0.090	0.025	0.025	0.025	0.280	0.275	0.270		
			80%ile	0.438	0.252	0.158	0.094	0.084	0.120	0.352	0.352	0.322		
Aluminium (Total)	mg/L	0.055	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.030	0.005	0.005	0.005	0.020	0.005	0.078	0.060	0.068		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.070	0.010	0.010	0.020	0.030	0.010	0.120	0.125	0.145		
			80%ile	0.726	0.270	0.060	0.040	0.306	0.200	0.356	0.428	0.364		
Arsenic (Total)	mg/L	0.013	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			Median	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
			80%ile	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002		
Beryllium (Total)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			80%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Barium (Total)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.06	0.08	0.04	0.04	0.04	0.05	0.01	0.01	0.01		
			Median	0.09	0.10	0.05	0.05	0.05	0.05	0.01	0.01	0.01		
			80%ile	0.15	0.10	0.08	0.09	0.06	0.05	0.02	0.02	0.02		
Cadmium (Total)	mg/L	0.0002	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Chromium (Total)	mg/L	0.001	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			80%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
Cobalt (Total)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			80%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
Copper (Total)	mg/L	0.0014	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			Median	0.0010	0.0005	0.0005	0.0005	0.0005	0.0005	0.0008	0.0005	0.0005		
			80%ile	0.0030	0.0010	0.0010	0.0020	0.0020	0.0010	0.0020	0.0020	0.0020		
Lead (Total)	mg/L	0.0034	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			80%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
Manganese (Total)	mg/L	1.9	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01		
			Median	0.04	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.02		
			80%ile	0.10	0.03	0.04	0.04	0.00	0.01	0.02	0.02	0.03		
Molybdenum (Total)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			80%ile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Nickel (Total)	mg/L	0.011	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		
			80%ile	0.0010	0.0005	0.0010	0.0010	0.0007	0.0010	0.0006	0.0010	0.0010		
Selenium (Total)	mg/L	0.011	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			80%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
Strontium (Total)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.12	0.16	0.10	0.11	0.12	0.13	0.02	0.02	0.02		
			Median	0.27	0.27	0.17	0.15	0.19	0.17	0.03	0.03	0.03		
			80%ile	0.43	0.33	0.24	0.24	0.21	0.20	0.04	0.04	0.04		
Vanadium (Total)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
			80%ile	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
Zinc (Total)	mg/L	N/A	Count	25	25	28	27	29	31	30	30	30	0	0
			20%ile	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025		
			Median	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025		
			80%ile	0.0060	0.0025	0.0066	0.0025	0.0076	0.0025	0.0032	0.0025	0.0025		
Boron (Total)	mg/L	0.37	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
			Median	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
			80%ile	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
Iron (Total)	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.308	0.098	0.025	0.025	0.025	0.025	0.342	0.306	0.302		
			Median	0.460	0.150	0.135	0.070	0.025	0.025	0.505	0.480	0.480		
			80%ile	1.242	0.742	0.236	0.148	0.416	0.200	0.720	0.768	0.724		
Mercury (Dissolved Hg by FIMS)	mg/L	0.0006	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Mercury (Total Hg by FIMS)	mg/L	0.0006	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
			80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Silicon as SiO2	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	2.66	7.90	6.62	6.60	8.30	7.50	7.08	7.16	7.18		
			Median	7.60	12.10	9.10	9.30	9.70	8.20	9.00	9.00	9.10		
			80%ile	9.08	15.56	10.82	11.20	10.40	9.20	10.40	10.24	10.32		
Fluoride	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.20	0.20	0.10	0.10	0.05	0.10	0.05	0.05	0.05		
			Median	0.20	0.40	0.20	0.20	0.10	0.10	0.05	0.05	0.05		
			80%ile	0.30	0.50	0.20	0.20	0.10	0.10	0.10	0.10	0.05		
Nitrite + Nitrate as N	mg/L	0.7	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.01	0.04	0.02	0.03	0.20	1.22	0.01	0.01	0.01		
			Median	0.02	0.13	0.05	0.09	0.55	1.87	0.03	0.04	0.04		
			80%ile	0.05	0.25	0.18	0.19	1.11	2.87	0.05	0.06	0.07		
Total Kjeldahl Nitrogen as N	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	23	3
			20%ile	0.48	0.28	0.20	0.20	0.20	0.30	0.20	0.20	0.30	0.20	0.90
			Median	0.80	0.50	0.40	0.20	0.20	0.40	0.40	0.30	0.40	0.25	1.20
			80%ile	1.00	0.60	0.50	0.50	0.40	0.70	0.52	0.50	0.60	0.40	1.20
Total Nitrogen as N	mg/L	0.25	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	0.48	0.40	0.34	0.20	0.50	1.50	0.28	0.20	0.30		

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	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	0.80	0.60	0.40	0.50	0.80	2.30	0.45	0.40	0.45		
			80%ile	1.02	0.80	0.66	0.60	1.36	3.60	0.60	0.50	0.62		
Total Phosphorus as P	mg/L	0.02	Count	25	25	28	27	28	31	30	30	30	24	3
			20%ile	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.13
			Median	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.26
			80%ile	0.08	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.50
Total Anions	meq/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	3.79	5.94	3.39	3.77	4.06	4.34	0.71	0.78	0.79		
			Median	10.80	10.10	5.04	5.44	6.07	5.67	0.89	0.95	0.97		
			80%ile	14.50	12.48	8.80	9.45	7.03	6.29	1.31	1.24	1.32		
Total Cations	meq/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	3.85	6.06	3.61	3.84	4.04	4.48	0.77	0.81	0.85		
			Median	10.20	9.06	5.19	5.18	5.66	5.61	0.91	1.04	1.04		
			80%ile	13.92	12.12	8.55	9.44	7.07	6.60	1.21	1.23	1.31		
Ionic Balance	%	N/A	Count	25	25	27	26	27	31	0	0	0	0	0
			20%ile	0.77	1.47	1.18	0.61	0.27	1.20					
			Median	2.01	2.31	2.22	2.19	1.77	2.11					
			80%ile	3.41	3.51	3.55	4.44	3.96	3.57					
Total Organic Carbon	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	11.80	5.80	4.00	3.00	1.00	2.00	4.00	4.00	4.00		
			Median	13.00	8.00	5.50	4.00	2.00	2.00	6.00	5.50	6.00		
			80%ile	16.00	11.20	7.60	6.00	4.60	4.00	7.40	8.00	7.00		
Dissolved Oxygen	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	8.60	8.58	8.94	8.94	8.44	9.30	9.18	8.90	8.98		

	Unit	ANZECC Default Trigger Value	Statistic	Marulan Up	Marulan Dn	Barbers Up	Barbers Dn	Bungonia Up	Bungonia Dn	SR 1	SR 2	SR 3	T1	U1
			Median	9.30	9.30	9.80	9.40	9.65	10.00	9.75	9.80	9.80		
			80%ile	9.86	9.72	10.46	10.18	10.18	10.50	10.42	10.44	10.24		
Biochemical Oxygen Demand	mg/L	N/A	Count	25	25	28	27	28	31	30	30	30	0	0
			20%ile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
			Median	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
			80%ile	4.00	1.00	1.60	1.00	1.00	3.00	2.20	1.20	3.00		

** results under the minimum value able to be recorded were analysed as half that value e.g. Iron values under 0.05 were detailed as equal to 0.025*

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Annexure D Flow Regime in Marulan Creek

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1 Introduction

The construction of a dam has been proposed on Marulan Creek, within the project boundary along the creek as shown on Figure 1.1, to provide water for Marulan South Limestone Mine. This dam would replace the water currently being supplied from Tallong Weir. This annexure details the methodology used to assess the flow regime of Marulan Creek. This information has been used in the water balance analysis (Annexure B) to assess the reliability of supplementary supply for the limestone mine and the impact that the dam would have on the downstream flow.

There are no stream gauges on Marulan Creek which would allow direct analysis of the existing flow regime and to assess the impact of the dam on the existing flow regime. Therefore, hydrologic modelling has been undertaken to characterise the flow regime for Marulan Creek in the vicinity of the proposed dam. The modelling is based on flow data for nearby creeks with comparable geology, land-use and climate to the Marulan Creek catchment.

The Australian Water Balance Model (AWBM) was selected to model the flow regime as it is a well-recognised, standard model developed specifically for assessment of runoff from Australian catchments.

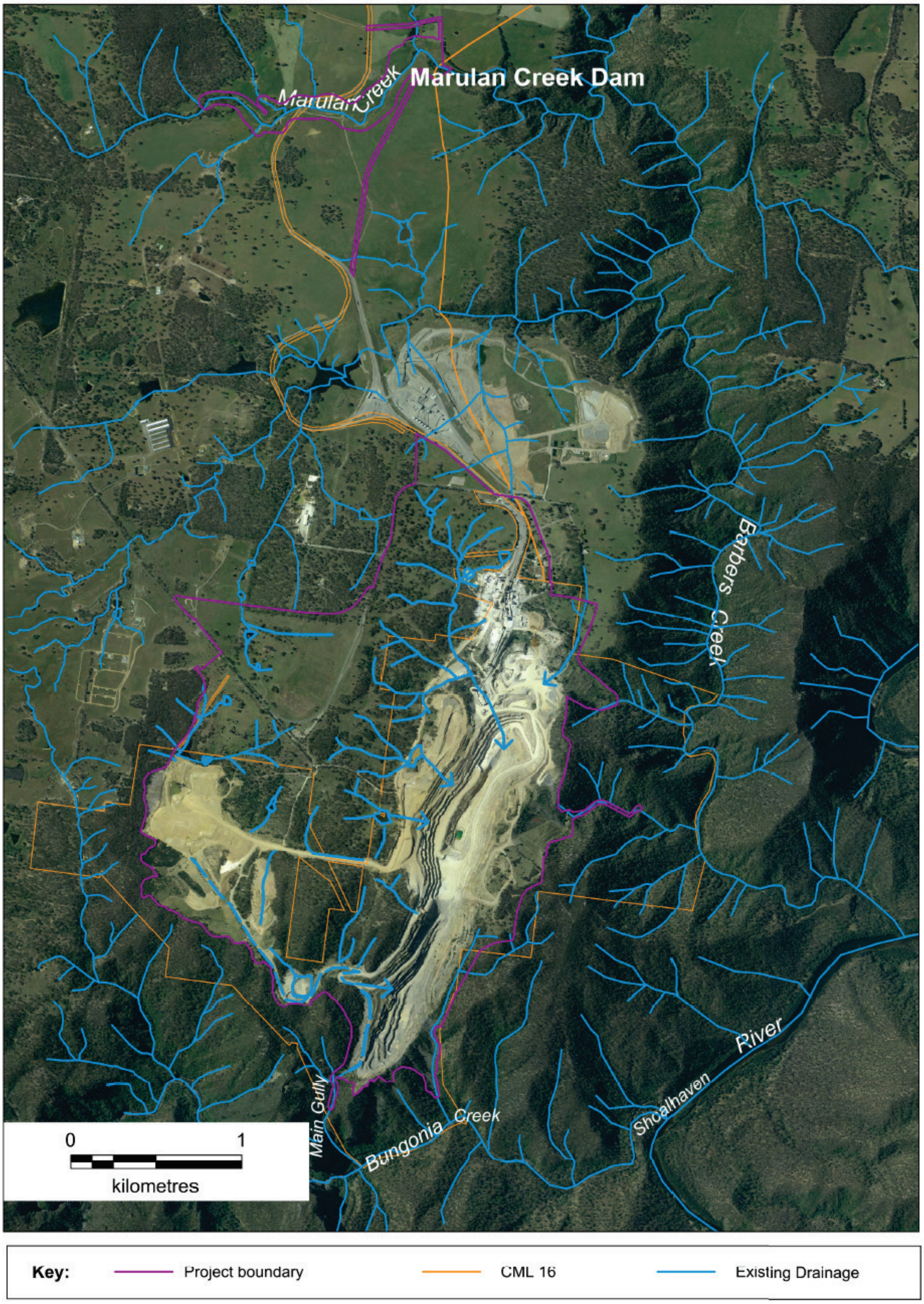


Figure 1.1: Location of Marulan Creek Dam

2 AWBM Rainfall-Runoff Model

AWBM is a catchment water balance model developed for Australian conditions (Boughton, 1984; Boughton and Carroll; 1993, Boughton, 2010) based on the principle of conservation of mass. The model uses rainfall and potential evapotranspiration data together with a representation of the hydrologic processes to generate an estimate of daily runoff from a catchment. Once the surface storage capacity of the catchment has been replenished by rainfall, runoff is generated. This is divided into surface runoff and baseflow.

Figure 2.1 is a schematic diagram of the model structure which is based on many decades of observed catchment behaviour. The AWBM uses three different capacities of surface storage covering partial areas of the catchment. The water balance of each surface store is calculated independently of the others. The model calculates the moisture balance of each soil store at daily time steps. At each time step, rainfall is added to each surface store and effective evapotranspiration is subtracted from each store. If the value of moisture retained in any of the three stores exceeds its capacity, the excess moisture becomes runoff.

The three parameters A1, A2 and A3 represent three partial areas of surface storage capacity, i.e. the proportion of the catchment that is draining to the surfaces stores of set depth C1, C2 and C3, respectively. The baseflow index (BFI) dictates how much of the excess is diverted to the baseflow store via recharge, and the baseflow runoff parameter K_{base} describes the rate at which water retained in the baseflow store is released and contributes to runoff. The K_{surf} parameter dictates the rate of release of water from the surface runoff routing store.

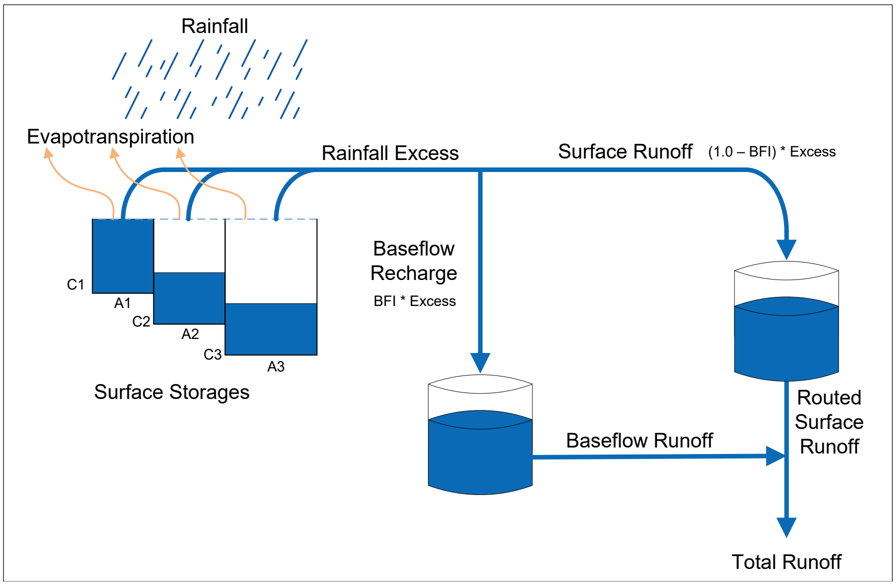


Figure 2.1: Schematic of AWBM Structure

Although the model represents A1, A2 and A3 as separate storages, Boughton (2010) reports that by analysis of a number of high quality data sets, it was found that the average value of surface storage capacity (Ave) was far more important for model calibration than the individual set of capacities and partial areas (where Ave = C1*A1 + C2*A2 + C3*A3). Boughton (2010) developed an average pattern that could be used to disaggregate Ave into three capacities (C1, C2 and C3 equal to 0.075*Ave, 0.762*Ave and 1.524*Ave) and three partial areas (A1 = 0.134, A2 = 0.433, A3 = 0.433).

3 Streamflow and Climate Data

This section describes the details of the streamflow, rainfall and potential evapotranspiration data used for the AWBM modelling of the Project area flow regime.

3.1 Streamflow Data

There is no continuous streamflow or peak flow data for Marulan Creek. It was therefore necessary to model nearby catchments to generate a set of representative AWBM parameters to reproduce the flow regime for Marulan Creek. The streamflow data was sourced from The NSW Office of Water website (NOW, 2014).

Table 3.1 lists the stations chosen to be used for AWBM modelling and the year each station opened and closed. For modelling purposes, only the years (July – June) with complete runoff records were used, as gaps in streamflow data cannot be reliably estimated using other sources. Refer to Attachment 1 for a bar chart illustrating period of available data.

Table 3.1: Streamflow Gauging Stations and Periods of Available Record

	Bungonia Creek at Bungonia	Kialla Creek at Pomeroy
Flow Station Number	215014	212040
Catchment Area (km^2)	164	96
Latitude	-34.8176	-34.6074
Longitude	149.9898	149.5442
Start Record	1981	1979
End Record	2014	2014
Years (July to June) with Complete Data Record (flow and rainfall)	21	26
Gauging Stn. Relative to Project Area	12 km south	43 km north-west

Figure 3.1 shows the location of the selected stream gauging stations.

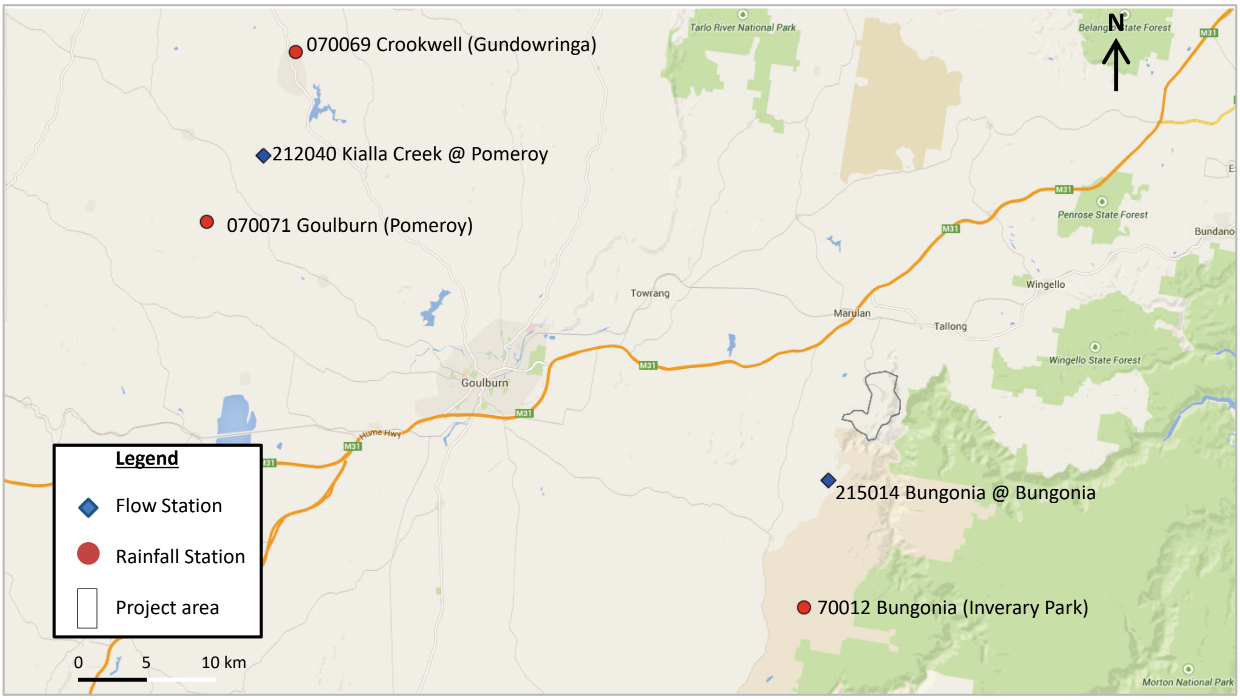


Figure 3.1: Map Showing Location of Streamflow and Rainfall Stations

3.2 Rainfall Data

The model calibration process is most robust in situations in which the rainfall record is derived from a location that is representative of the catchment. Rainfall data for use in AWBM modelling was sourced from Bureau of Meteorology (BoM) daily rainfall stations located in the same or nearby catchments to the flow stations listed in Table 3.1. The rainfall stations selected are listed in Table 3.2 and their locations shown in Figure 3.1.

Table 3.2: Summary of Relevant Bureau of Meteorology Rainfall Stations

Catchment	Rainfall Factor	Rainfall Stations	Latitude	Longitude	Record
Bungonia Creek	0.817	Bungonia (Inverary Park) (70012)	-34.9	149.97	1883-2014
Kialla Creek	1.171	Crookwell (Gundowringa) (70069)	-34.54	149.57	1945-2014
		Goulburn (Pomeroy) (70071)	-34.65	149.5	1901-2014

An average was taken of the daily rainfall values of stations within the vicinity of the particular flow gauge. Where there were gaps in the record supplied by the Bureau of Meteorology due to aggregated measurements over a number of days, the data was in-filled using the average over the number of days aggregated. See Attachment 1 for periods of available rainfall data.

The daily rainfall values were automatically scaled by the AWMB automatic model using the "auto scale" function, as recommended by Boughton (2012). The auto scale function strives to reduce the errors produced when estimating areal rainfall for input to the model. The values of these rainfall scaling factors are provided in Table 3.2.

3.3 Evapotranspiration Data

Areal potential evapotranspiration is the evapotranspiration that would occur if there was unlimited water supply from an area large enough that the effects of any upwind boundary transitions are negligible, and local variations are integrated to an areal average (Chiew et al., 2002).

As recommended by Boughton (2003), monthly areal potential evapotranspiration was input to the AWBM model. Areal potential evapotranspiration data was sourced from the digital version of the Climatic Atlas of Australia: Evapotranspiration (Version 1.0, Bureau of Meteorology, 2002). The monthly areal potential evapotranspiration values were used to calculate daily potential evapotranspiration values by dividing the monthly value by the number of days in each month.

3.4 AWBM Input Data

Table 3.3 lists the flow and climate data statistics adopted for the AWBM modelling.

The AWBM requires coincident daily streamflow and rainfall data. Based on the data availability summarised in Attachment 1, it can be seen that the availability of flow data was the limiting factor and dictated the calibration period.

Table 3.3: AWBM Input Data for Calibration Periods

Catchment Number	1		2	
Flow Station	Bungonia Creek		Kialla Creek	
Rainfall Stations	Bungonia (Inverary Park) (70012)		Crookwell (Gundowringa) (70069), Goulburn (Pomeroy) (70071)	
Catchment Area (km^2)	164		96	
Period (y)	21		26	
Modelling Period (July to June)	1981 - 1982 1984 - 1985 1987 - 1991 1994 - 1998	1999 - 2004 2006 - 2009 2010 - 2013	1979 - 1981 1984 - 1992 1994 - 2000 2001 - 2002	2003 - 2009 2010 - 2013
Ave Rainfall (mm/y)	644		394	
Ave Potential Evap (mm/y)	1381		1405	
Ave Flow (mm/y)	54		93	
% Runoff (Observed Mean Runoff / Mean Rainfall)	8%		24%	

4 Model Calibration and Validation

AWBM was utilised to generate a set of parameters describing the flow characteristics for the both Bungonia Creek at Bungonia and Kialla Creek at Pomeroy. The Leave-One-Out Cross Validation (LOOCV) procedure was used to guide the selection of the model parameters most representative of the actual flow regime. The modelling involved a three staged process, per Ladson (2008):

1. Automatic calibration
2. Validation (LOOCV procedure
3. Selection of parameters.

Further description of this process is provided below.

4.1 Automatic Calibration

The AWBM 2013 model selects a warm up period at the start of the data record and then runs the calibration for the remaining record. Default values are adopted for the baseflow and surface runoff parameters during the preliminary calibration of surface storage capacity. For the assessment period, the average surface storage capacity is then scaled up and down until the calculated runoff equals the actual runoff. Next, the BFI, K_{base} and K_{surf} parameters are first calibrated in that order, then a second time using a measure of difference between calculated and actual daily runoff hydrographs (Boughton, 2010).

Initially the model was set up and calibrated for the complete modelling period using the full data set, and a set of parameters generated ($Ave_{(all\ years)}$, $BFI_{(all\ years)}$, $K_{base(all\ years)}$, $K_{surf(all\ years)}$). This was achieved through the AWBM 2013 model's automatic calibration component, which generates parameters that describe the hydrological process when daily rainfall, monthly potential evapotranspiration and daily runoff are entered into the model. The output from the automatic calibration process is shown in the second column of Table 4.1.

The automatic calibration procedure uses a single parameter to represent a fixed pattern of surface storage capacities and partial areas represented by a single parameter (Ave). The model selects default values for A1, A2 and A3, 0.134, 0.433 and 0.433, respectively. Also, the values for C2, C2 and C3 are directly related (20*C1 = 2*C2 = C3), such that there is only one independent variable. Boughton (2010) reported that the average value of surface storage capacity was far more important to calibration than the individual set of capacities and partial areas. Accordingly, because the model parameters derived from were to be only used as a guide to parameters for the Project area, further disaggregation of A and C parameters was not attempted.

All daily values were entered directly into the model. The daily rainfall values were automatically scaled by the AWBM automatic model using the "auto scale" function, as recommended by Boughton (2012). The rainfall scaling factors for the two modelled catchments are outlined in Table 3.2.

The daily evapotranspiration values were scaled to 0.85 (to account for the reduction of actual evapotranspiration as the soil dries out). Applying a scale factor of 0.85 is an alternative to reducing the potential evaporation rate as the surface stores dry out (Boughton, 2010).

4.2 Validation (LOOCV Method)

The parameters were validated using the 'Leave one out cross validation' (LOOCV) procedure, a process which enables all available complete years of streamflow data to be utilised as described below.

The model was re-calibrated N times, where N represents the number of years of data. For i = 1 to N, the data for $year_{(i)}$ was omitted from the calculations. The model was then calibrated to the remaining points, with daily flow estimated and a set of model parameters derived ($Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$).

The LOOCV procedure produced N estimates of the model parameters. Of the N parameter sets, the minimum and maximum parameter values ($Ave_{(min)}$, $BFI_{(min)}$, $K_{base(min)}$, $K_{surf(min)}$ and $Ave_{(max)}$, $BFI_{(max)}$, $K_{base(max)}$, $K_{surf(max)}$) are listed in Table 4.1 to illustrate the range of results for each catchment. The N sets of parameters ($Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$ where i = 1 to N) provided an indication of the scatter in the parameter set.

AWBM has a spreadsheet version which was used to calculate the predicted runoff of the excluded year, $year_{(i)}$, using the parameter set generated when $year_{(i)}$ was omitted (i.e. $Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$). This method of model validation allows all data to be used.

As adopted by Boughton (2006), the Nash-Sutcliffe Coefficient of Efficiency (E) was used as a measure of model performance. Boughton (2006) notes that E is based on monthly runoff and is the most common measure for comparing modelled and recorded monthly runoff. It is a normalised statistic used to determine the relative magnitude of the residual variance compared to the measured data variance to indicate the predictive accuracy of the model (Nash & Sutcliffe, 1970, Moriasi et al., 2007). The value measures how closely the modelled results fit the 1:1 line, and is given by:

$$E = 1 - \frac{\sum_{t=1}^{T}(Q_o^t - Q_m^t)^2}{\sum_{t=1}^{T}(Q_o^t - \overline{Q_o})^2}$$

where:
T = final time-step period
t = individual time-step period
Q_o = Observed data
Q_m = Modelled data
$\overline{Q_o}$ = Average of observed data

The efficiency value can range from –∞ to 1, where 1 indicates a perfect match of modelled data to observed data (Nash & Sutcliffe, 1970, Moriasi et al., 2007). The results for the test sample (LOOCV) with the highest Nash-Sutcliffe Coefficient of Efficiency, when modelled using the parameters generated using all the other years ($Ave_{(max\ E)}$, $BFI_{(max\ E)}$, $K_{base(max\ E)}$, $K_{surf(max\ E)}$) are listed in Table 4.1.

4.3 Selection of Parameters

A spreadsheet AWBM was set up for the complete data set (i.e. N years of data). The estimated daily runoff and corresponding Nash-Sutcliffe Coefficient of Efficiency values were calculated for the following parameter sets generated through the test sample assessment process:

- $Ave_{(all\ years)}$, $BFI_{(all\ years)}$, $K_{base(all\ years)}$, $K_{surf(all\ years)}$
- $Ave_{(min)}$, $BFI_{(min)}$, $K_{base(min)}$, $K_{surf(min)}$
- $Ave_{(max)}$, $BFI_{(max)}$, $K_{base(max)}$, $K_{surf(max)}$

The LOOCV highest E parameter set (i.e. $Ave_{(max\ E)}$, $BFI_{(max\ E)}$, $K_{base(max\ E)}$, $K_{surf(max\ E)}$), (refer Section 4.2), was also modelled using the manual version of AWBM and the complete data set

Table 4.1 contains the parameter sets and the statistical analysis which was used as a basis for selecting the parameters that adequately describe the flow characteristics at Marulan South. The Nash-Sutcliffe Coefficient of Efficiency, based on monthly totals, provides a measure of the model performance.

Attachment 2 contains the flow duration curves and cumulative runoff curves plots for the catchments modelled with the adopted parameters, as listed in Table 4.1. Attachment 2 also contains scatter plots of the calculated versus actual monthly runoff.

Table 4.1: AWBM Results for Calibrated Catchments

Input Parameters and Analysis	Full Record	Min	Max	Adopted parameters – LOOCV (highest E)
Catchment 1: Bungonia Creek at Bungonia				
Average Capacity (mm)	74.6	72.1	81.2	74.0
C1	5.6	5.4	6.1	5.6
C2	56.9	54.9	61.9	56.4
C3	113.8	109.9	123.8	112.8
BFI	0.200	0.200	0.260	0.210
K_{base}	0.875	0.875	0.885	0.885
K_{surf}	0.260	0.070	0.260	0.260
E (monthly data)	0.779	0.774	0.790	0.778
R^2 (monthly data)	0.795	0.797	0.793	0.794
Actual Runoff (mm)	54.0	54.0	54.0	54.0
Calculated Runoff (mm)	54.5	56.1	50.4	54.8
Catchment 2: Kialla Creek at Pomeroy				
Average Capacity (mm)	10.8	2.8	11.5	10.7
C1	0.8	0.2	0.9	0.8
C2	8.2	2.1	8.8	8.1
C3	16.5	4.2	17.5	16.2
BFI	0.150	0.150	0.300	0.150
K_{base}	0.979	0.969	0.980	0.979
K_{surf}	0.350	0.010	0.440	0.330
E (monthly data)	0.238	0.130	0.259	0.238
R^2 (monthly data)	0.240	0.239	0.262	0.240
Actual Runoff (mm)	93.3	93.3	93.3	93.3
Calculated Runoff (mm)	93.7	168.8	89.4	94.5

5 Project Area Daily Flow Regime Modelling

Model parameters for Marulan Creek were derived based on the modelling results provided in Section 4 (refer to Attachment 3 for adopted modelled parameters). The adopted parameters were applied to long term historical climate data to estimate the daily flow regime for Marulan Creek. The modelled runoff for the representative catchments provide a best estimate of the "existing" conditions and form "baseline" conditions for use in the assessment of dam impacts and the subsequent assessment of residual impacts on flow and water resources. The process used to model the runoff in Marulan Creek is described below.

5.1 Marulan Creek AWBM Parameter Selection

For the purposes of assessing the daily flow regime in the Project area tributaries, an AWBM catchment scenario model was set up. This model used parameters to represent the runoff characteristics of Marulan Creek. The adopted parameters are listed in Table 5.2.

The parameters selected for Bungonia Creek and Kialla Creek catchments, through the model calibration and validation process described in Section 4, formed the starting point to derive the parameter sets for the catchment scenario. The modelling results were considered in conjunction with benchmark model parameters for the region. The benchmark parameters are derived from an Advisian model of Wingecarribee River between the Berrima Weir flow gauge and the Greenstead flow gauge Weir ("Berrima Model"). See Attachment 3 for adopted modelled parameters and benchmark parameters. Two other factors were taken into account in selecting appropriate AWBM model parameters:

- the general relationship between average annual rainfall and annual runoff
- the general relationship between average capacity and runoff.

Figure 5.1 shows the relationship between average annual rainfall and average annual runoff in the region, derived from the recorded data used for model calibration and benchmark parameters. Attachment 3 contains the rainfall and runoff data used in Figure 5.1.

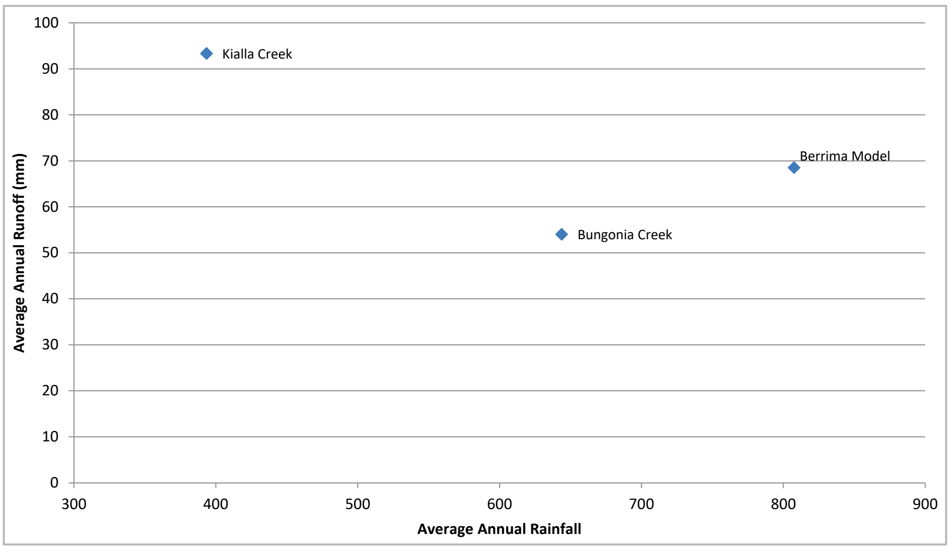


Figure 5.1: Runoff Characteristics of Catchments near Marulan Creek

An AWBM model was created for the Project area using the average BFI, K_{base} and K_{surf} parameters adopted for the Berrima Model and two catchments calibrated in Section 4 (listed in Table 5.1). The long term rainfall data for Marulan South (1813 – 2014) was used.

Table 5.1: AWBM Parameters used to Generate Runoff/ Average Capacity Relationship

	Ave	BFI	K_{base}	K_{surf}	E_f	R_f
Adopted Parameter	Varied	0.420	0.938	0.513	0.85	Varied

Successive runs of the model were made using different values of average capacity to generate the relationship between runoff and average capacity shown in Figure 5.2. Three curves were generated to reflect the rainfall scaling factors corresponding to the three calibrated catchments:

- Rf = 1.171, in line with Kialla Creek catchment
- Rf = 0.817, in line with Bungonia Creek catchment
- Rf = 1, in line with the Wingecarribee River catchment, between the Berrima Weir flow gauge and the Greenstead gauge (Advisian model).

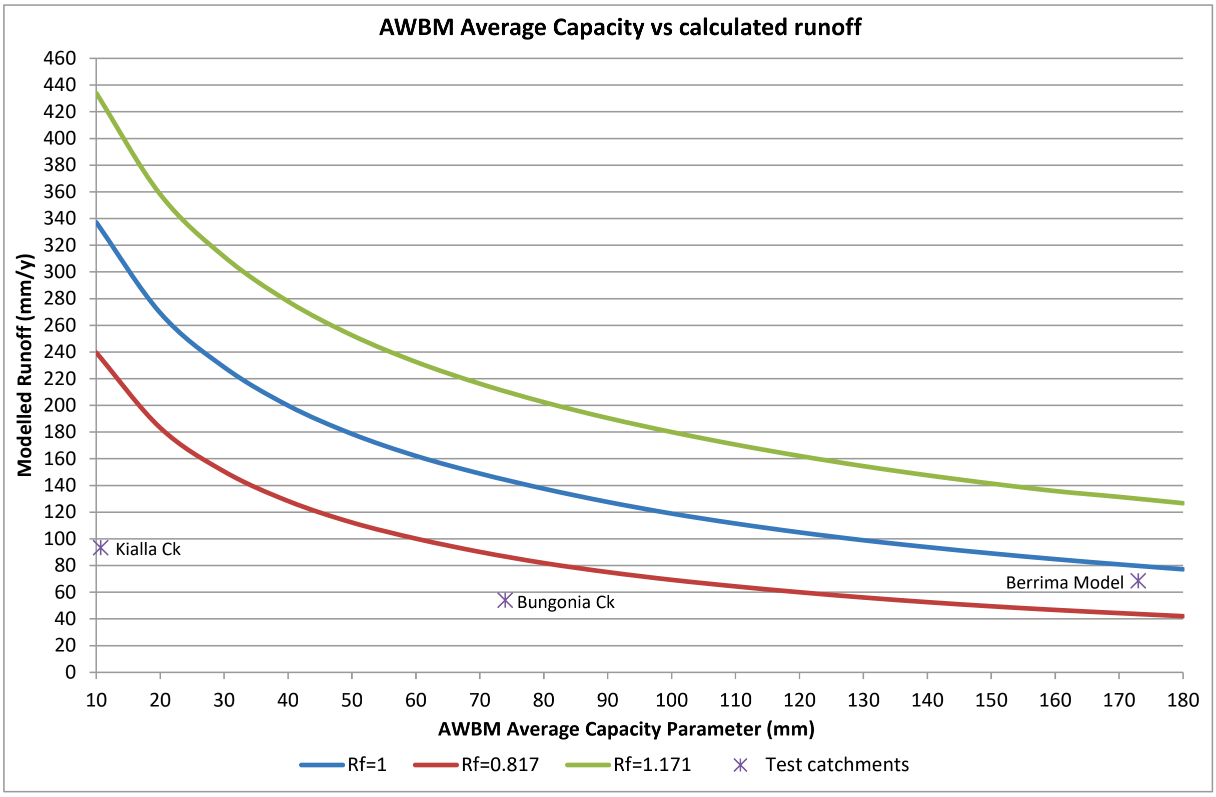


Figure 5.2: AWBM Average Capacity versus Calculated Runoff

The Rf = 1.171 curve indicates that at Marulan an average capacity of 10.7 mm gives a runoff of approximately 440 mm/year. This is inconsistent with the modelled runoff generated from the Kialla Creek calibration (an average capacity of 10.7 mm produces a runoff of approximately 93 mm/year). The Bungonia Creek modelled runoff and the Berrima Model more consistent with the respective runoff/ average capacity relationship.

Therefore, an average capacity parameter of 87 mm was selected for the Marulan Creek dam model. The Rf and BFI calculated for the Bungonia Creek calibration were also adopted. The K_{base} and K_{surf} values calculated during the Bungonia Creek calibration process were reduced to reflect that the Marulan Creek dam catchment is smaller than the Bungonia Creek catchment, and thus would have a smaller baseflow component.

Table 5.2 provides the AWBM parameters adopted for the Project area.

Table 5.2: AWBM Parameters Adopted for Marulan Creek

	Ave	BFI	K_{base}	K_{surf}
Adopted Parameter	87	0.21	0.2	0.1

The model was assessed to see if modelled high flow days accurately corresponded to recorded high rainfall events. A number of dates which had high recorded rainfall events between February 2012 and December 2014 have been provided by Peppertree Quarry. These dates, in addition to flow calculated using the parameters outlined in Table 5.2, are shown on Figure 5.3. It can be seen that high rainfall days correspond to days with a modelled high flow.

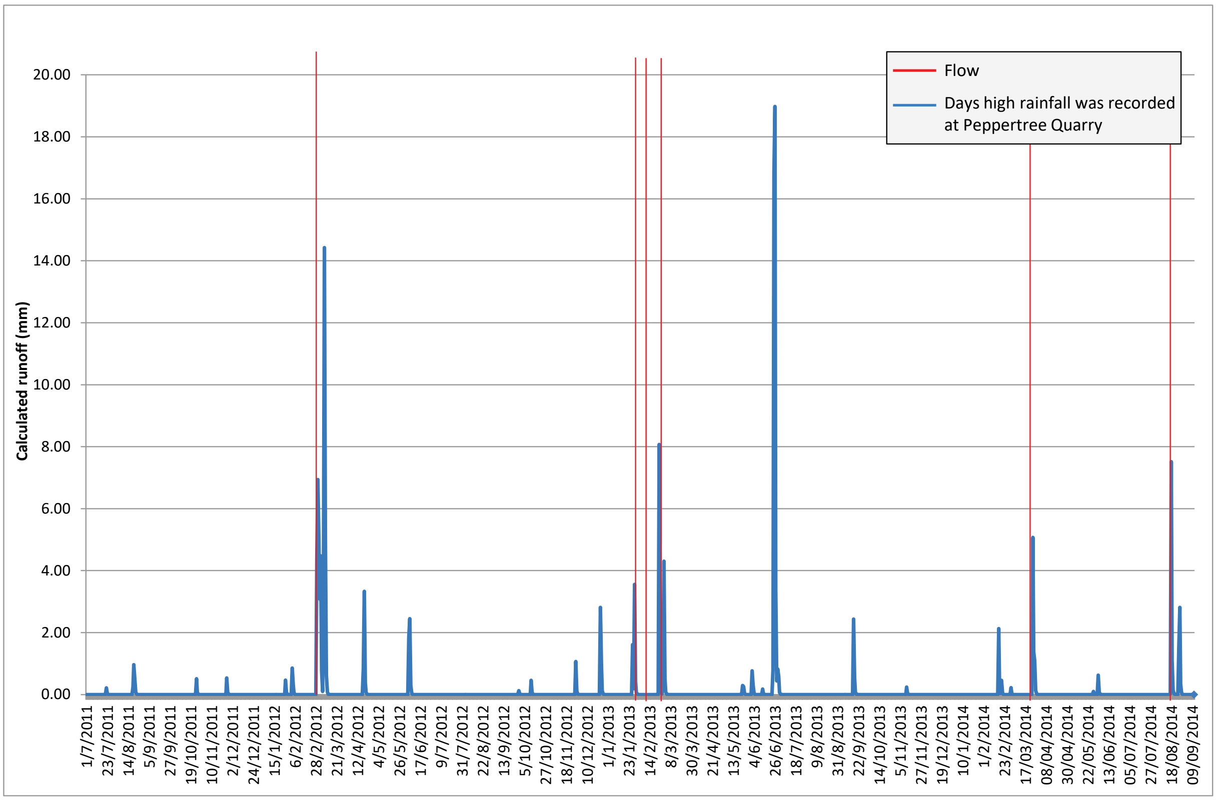


Figure 5.3: Rainfall Calibration

5.2 Marulan Creek Flow Regime

Daily flow models were created for the Marulan Creek dam catchment based on the adopted historical (amalgamated) climate record and the parameters listed in Table 5.2.

Table 5.3 provides a statistical summary of the modelled runoff for the representative catchments for the 131 years of climate data with the following climate statistics:

- average annual rainfall: 694 mm/year
- average annual areal potential evapotranspiration: 1,095 mm/year

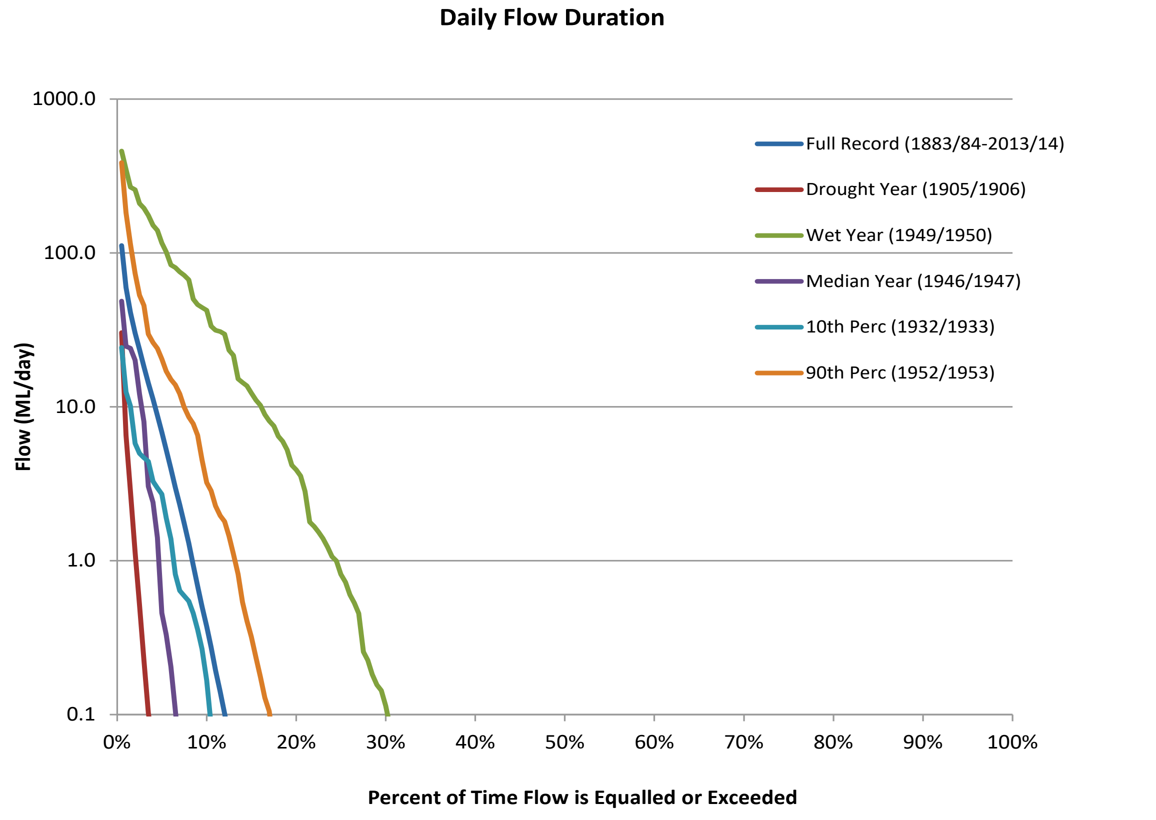
Daily and annual flow duration curves were created for the modelled runoff for each representative catchment to illustrate the flow patterns (see Figure 5.4). Each figure includes daily flow duration curves corresponding to the full climate record and for various years representing minimum, 10th percentile, median, 90th percentile and maximum modelled flow years. The annual runoff corresponding to each of these years is listed in Table 5.3.

Table 5.3: Summary Statistics for Modelled Runoff from Representative Catchments

Catchment Designation		
Area	(km^2)	19.2
Average Runoff	(mm/y)	53
Average Runoff	(ML/y)	1,023
Runoff as % of Rainfall		7.7
Minimum	(ML/y)	136
10th Percentile	(ML/y)	231
Median	(ML/y)	544
90th Percentile	(ML/y)	2,708
Maximum	(ML/y)	6,981

It can be seen that the daily flow duration curve for the complete record is a smoother line than the others. This is to be expected, as there are significantly more data points within the complete record, compared to flow duration over a single year, leading to less variation around the overall trend.

It should be noted that the modelled runoff from the Marulan Creek dam catchment is based on parameters derived from catchments with similar characteristics, not from the dam catchment itself. The flow characteristics presented in this report are, therefore, only illustrative of the volume and distribution of runoff that can be expected.



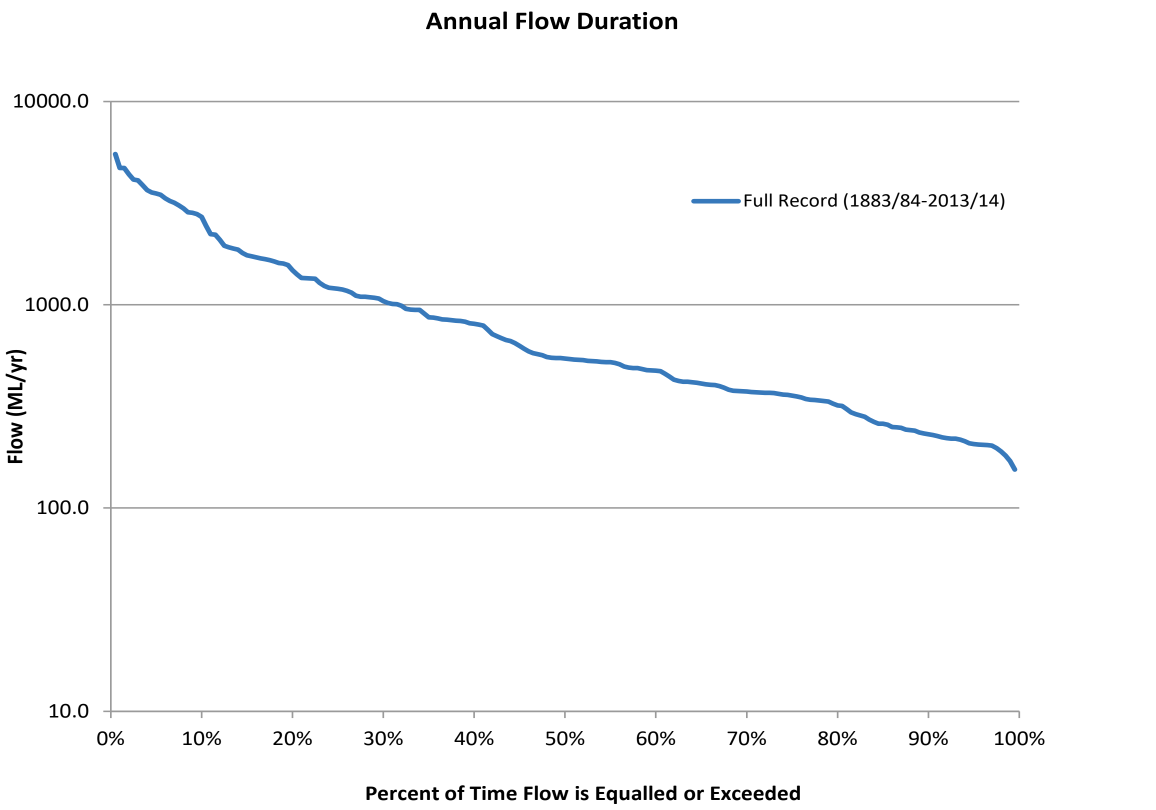


Figure 5.4: Flow Duration Curves for Marulan Creek Dam Catchment

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6 References

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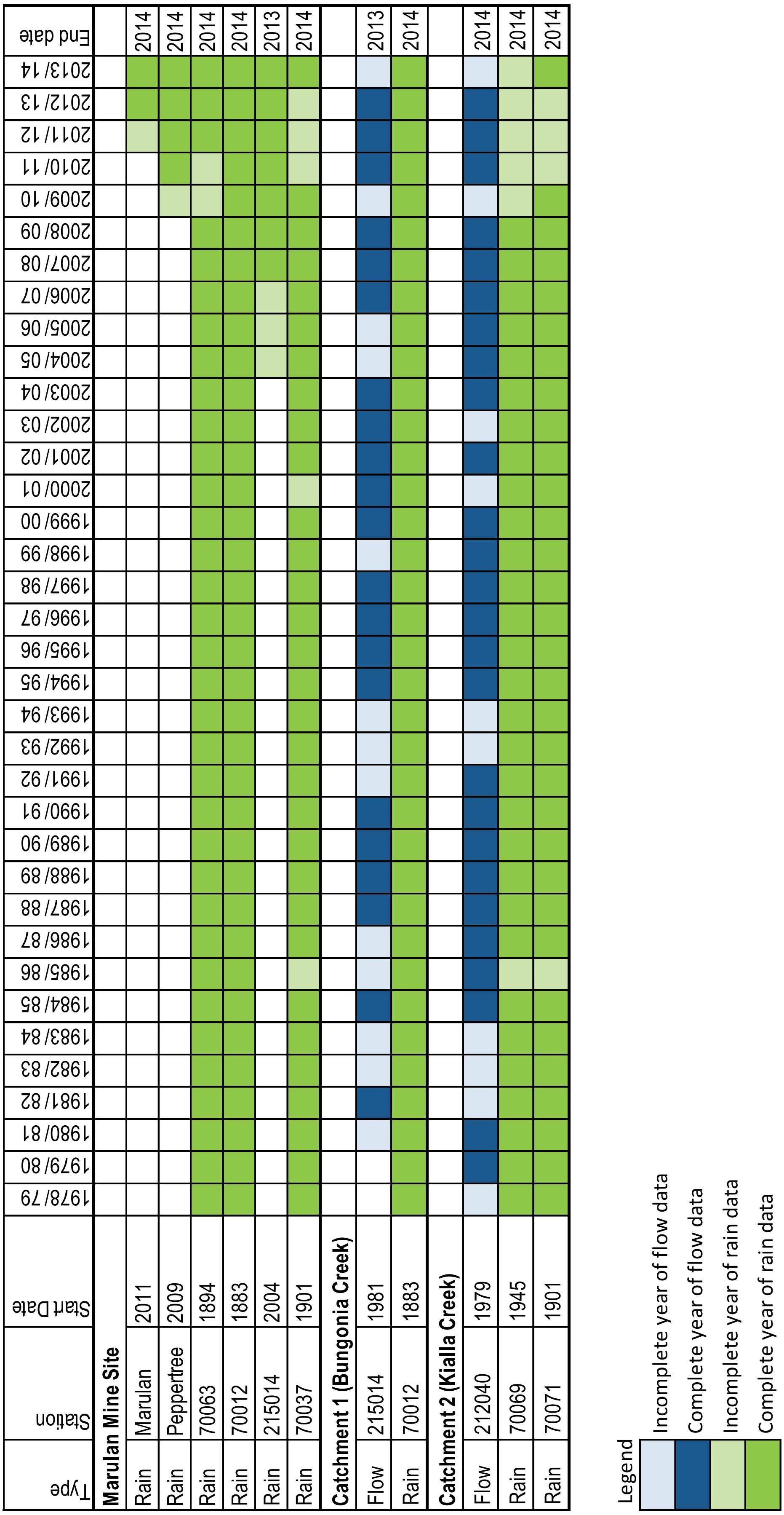
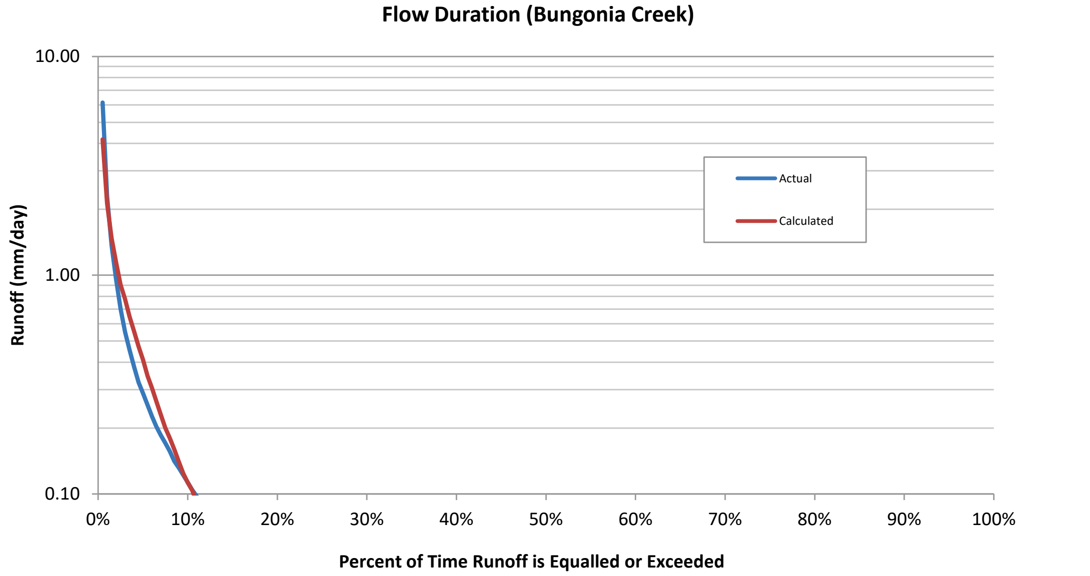
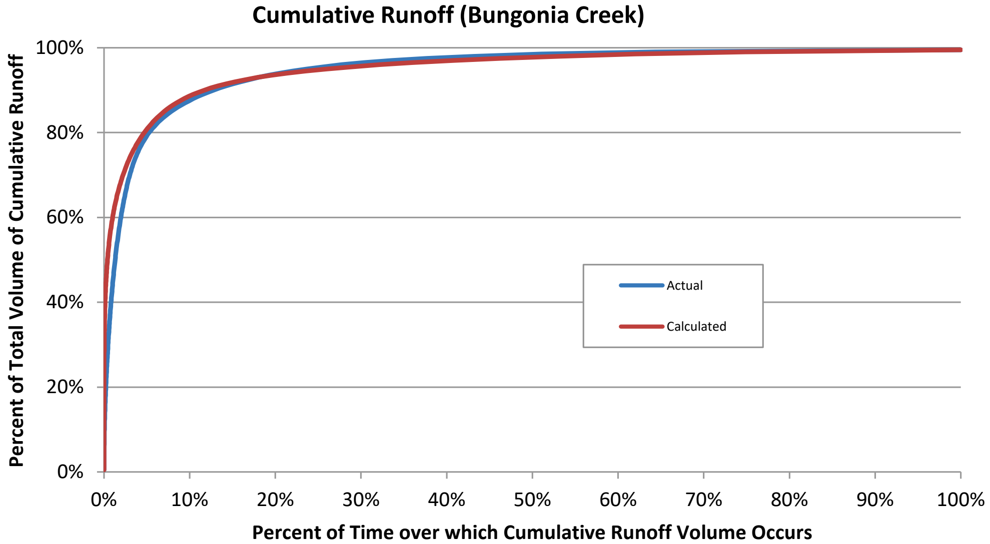
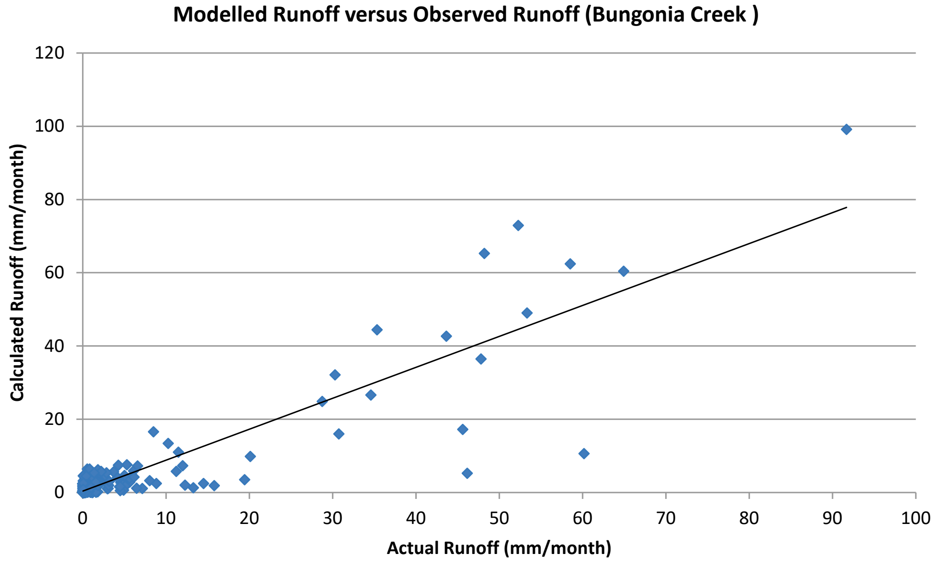
Attachment 1: Available Data Periods


Type
Station
Start Date
1978/ 79
1979/ 80
1980/ 81
1981/ 82
1982/ 83
1983/ 84
1984/ 85
1985/ 86
1986/ 87
1987/ 88
1988/ 89
1989/ 90
1990/ 91
1991/ 92
1992/ 93
1993/ 94
1994/ 95
1995/ 96
1996/ 97
1997/ 98
1998/ 99
1999/ 00
2000/ 01
2001/ 02
2002/ 03
2003/ 04
2004/ 05
2005/ 06
2006/ 07
2007/ 08
2008/ 09
2009/ 10
2010/ 11
2011/ 12
2012/ 13
2013/ 14
End date
Marulan Mine Site
Rain Marulan 2011 2014
Rain Peppertree 2009 2014
Rain 70063 1894 2014
Rain 70012 1883 2014
Rain 215014 2004 2013
Rain 70037 1901 2014
Catchment 1 (Bungonia Creek)
Flow 215014 1981 2013
Rain 70012 1883 2014
Catchment 2 (Kialla Creek)
Flow 212040 1979 2014
Rain 70069 1945 2014
Rain 70071 1901 2014
Legend
Incomplete year of flow data
Complete year of flow data
Incomplete year of rain data
Complete year of rain data

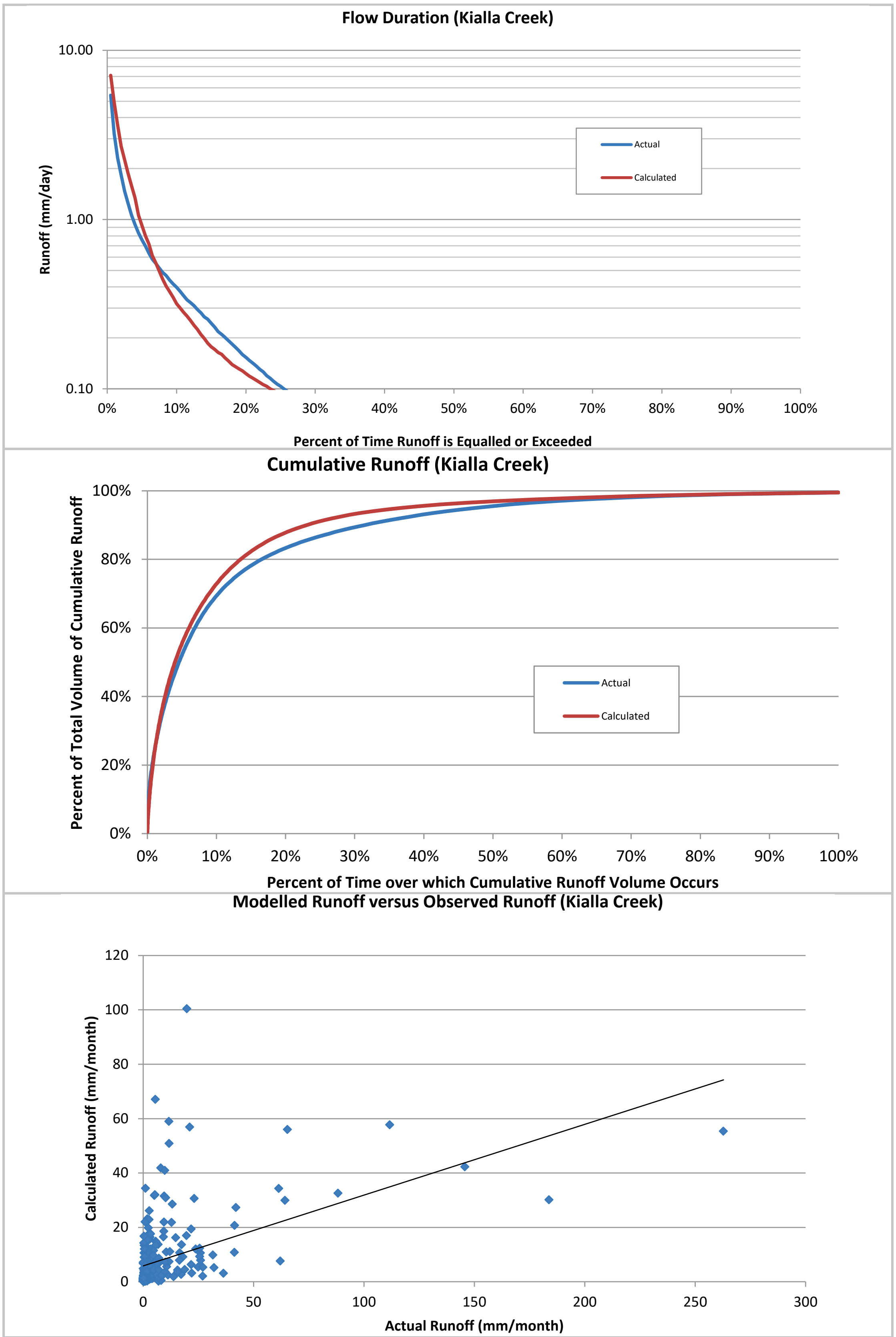
Attachment 2:
Modelling Results for Comparable Catchments







Modelling Results for Catchment 1 (Bungonia Creek 215014)



Modelling Results for Catchment 2 (Kialla Creek 212040)

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Attachment 3: Adopted Modelled and Published AWBM Parameters and Annual Rainfall and Runoff

Creek	Kialla Creek	Bungonia Creek	Wingecarribee River (between Berrima and Greenstead)
Station No	212040	215014	Greenstead: 212009 Berrima: 212272
Area (km2)	96	164	360.22 ($A_{Greenstead} – A_{Berrima}$)
Cal Start	1979	1981	1990
Cal End	2013	2009	2012
Years	26	21	22
NB: Only years with complete data used between Period Start and Period End date			
C1	0.8	5.6	13.0
C2	8.1	56.4	131.8
C3	16.2	112.8	263.7
A1	0.134	0.134	0.134
A2	0.433	0.433	0.433
A3	0.433	0.433	0.433
BFI	0.15	0.21	0.900
K_{base}	0.979	0.885	0.950
K_{surf}	0.33	0.26	0.950
E (month)	0.238	0.778	0.821
Rsqr	0.240	0.794	0.822
Ave Cap (ref)	10.7	81.2	173.0
Rainfall (m/y)	394	644	808
Evap (mm/y)	1405	1381	1143
Runoff (mm/y)	93	54	69
Runoff %	24%	8%	8%
Rf	1.171	0.817	1.000

Annexure E Flooding of Mine Pits: 2013 & 2015

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1 Introduction

In July 2013 and August 2015 heavy rainfall led to runoff from the catchments that drain to the north and south mine pits at the South Marulan Limestone Mine.

Records of the rainfall resulting water level in each mine pit and the subsequent drainage of water provide valuable information for the assessment of runoff from the contributing catchments and the bulk permeability of the floor of each pit.

This report provides:

- details of the rainfall that led to flooding in the pits
- the geometry of the pits
- the catchment areas draining to each pit
- the recorded water levels and implied volume of water received and subsequently drained on each occasion
- the implied drainage characteristics of each pit
- the implied runoff characteristics of different parts of the landscape.

2 Rainfall

2.1 July 2013

Rainfall occurred between 23 and 30 July 2013 with particularly heavy rainfall in the 24 hours to 9.00 am on 25 and 26. This led to flooding in both the North Pit and South Pit. Table 2.1 summarises the rainfall for the 24 hours up to 9.00 am on the listed date, while Figure 2.1 shows the cumulative rainfall for the month.

Table 2.1: South Marulan Rainfall – June 2013

Date	Rainfall (mm) to 9.00 am
23/06/2013	1.5
24/06/2013	18.5
25/06/2013	113.0
26/06/2013	43.0
27/06/2013	4.0
28/06/2013	1.0
29/06/2013	3.5
30/06/2013	2.5

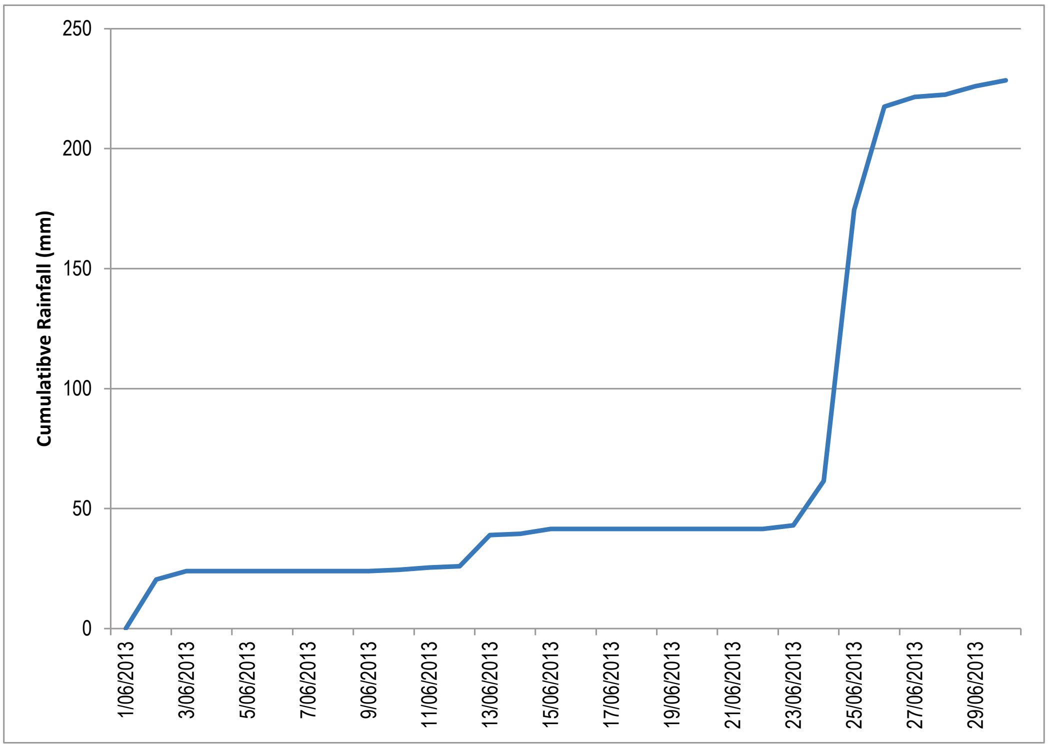


Figure 2.1: Cumulative Rainfall for South Marulan –June 2013

(Rainfall for 24 Hours up to 9.00 am)

2.2 August 2015

Heavy rainfall occurred on 25 and 26 August 2015 that led to flooding in both the North Pit and South Pit. Figure 2.2 summarises the rainfall for the 24 hours up to 9.00 am on the listed date, while Figure 2.2 shows the cumulative rainfall for the month.

Table 2.2: South Marulan Rainfall – August 2015

Date	Rainfall (mm) to 9.00 am
20/08/15	0.0
21/08/15	0.0
22/08/15	0.0
23/08/15	0.0
24/08/15	7.5
25/08/15	47.0
26/08/15	84.0
27/08/15	2.0
28/08/15	0.0
29/08/15	0.0
30/08/15	0.0
31/08/15	0.0

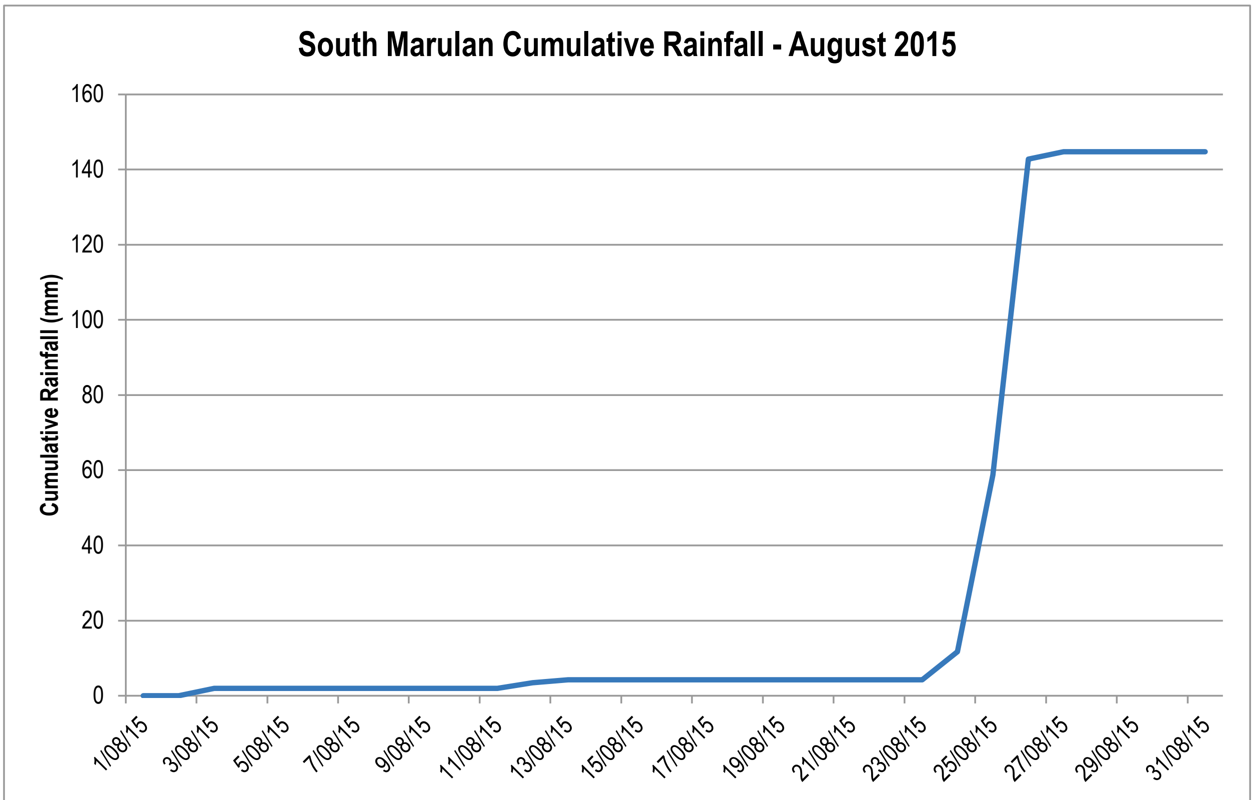


Figure 2.2: Cumulative Rainfall for South Marulan –August 2015

(Rainfall for 24 Hours up to 9.00 am)

3 Pit Geometry

The pit geometry is defined in terms of relationship between amount of water in the pit (head and volume) and area of the free water surface. The data describing pit geometry was provided by Boral (Gordon Atkinson). Data for North Pit varies for 2013 and 2015 flooding events as the geometry of the North Pit has changed due to mining, the geometry of the South Pit did not change between 2013 and 2015 events.

3.1 South Pit

South Pit has not been mined for a few years and the geometry of the pit remains the same for 2013 and 2015; and the elevation of the South Pit floor corresponds to the elevation of the final void at the cessation of mining. Table 3.1 and Figure 3.1 show the depth:area:volume relationship for the South Pit based on survey data provided by the mine.

Table 3.1: South Pit Geometry – 2013 and 2015

Water Surface Elevation (m AHD)	Head (m)	Cumulative volume (m^3)	Area (m^2)
364.00	0.00	0	0
364.50	0.50	996	1,093
365.00	1.00	3,096	8,827
365.50	1.50	11,532	16,560
366.00	2.00	20,220	17,094
366.50	2.50	29,140	17,628
367.00	3.00	38,273	18,075
367.50	3.50	47,626	18,522
368.00	4.00	57,173	18,946
368.50	4.50	66,951	19,370
369.00	5.00	76,913	19,742
369.50	5.50	87,064	20,114
370.00	6.00	97,398	20,498
370.50	6.50	107,910	20,881
371.00	7.00	118,546	21,287
371.50	7.50	129,308	21,693
372.00	8.00	140,198	22,099
372.50	8.50	151,216	22,505
373.00	9.00	162,364	22,910

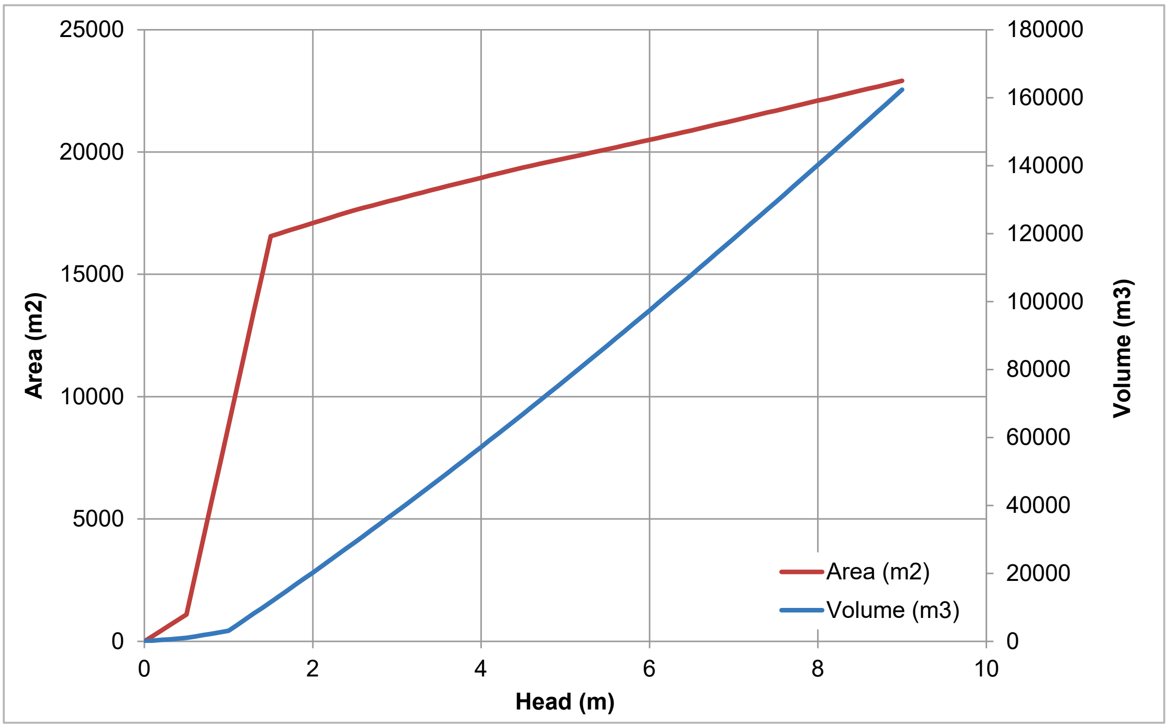


Figure 3.1: South Pit Geometry – 2013 and 2015

3.2 North Pit

Mining has continues in the North Pit since 2013. Table 3.2, Figure 3.2 and Figure 3.3 provide details of the geometry of the North Pit in 2013 and 2015 based on survey data provided by the mine.

Table 3.2: North Pit Geometry – 2013 and 2015

Head (m)	2013			2015		
	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)
0.5	435.5	266	461	433.5	0	
1.0	436.0	604	762	434.0	0	2,172
1.5	436.5	1,015		434.5	1,138	
2.0	437.0	1,487	1,028	435.0	2,395	2,732
2.5	437.5	2,039		435.5	3,840	
3.0	438.0	2,669	1,357	436.0	5,445	3,385
3.5	438.5	3,392		436.5	7,215	
4.0	439.0	4,209	1,748	437.0	9,151	4,059
4.5	439.5	5,280		437.5	11,256	
5.0	440.0	6,830	9,253	438.0	13,515	4,731
5.5	440.5	12,360		438.5	15,958	
6.0	441.0	19,161	19,477	439.0	18,566	5,430
6.5	441.5	29,053		439.5	21,402	

Head (m)	2013			2015		
	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)
7.0	442.0	39,294	23,000	440.0	24,479	9,943
7.5	442.5	50,911		440.5	29,946	
8.0	443.0	62,782	27,092	441.0	36,294	16,884
8.5	443.5	76,440		441.5	44,867	
9.0	444.0	90,315		442.0	53,768	20,225
9.5	444.5	104,415		442.5	63,975	
10.0	445.0	118,747	28,918	443.0	74,374	22,113
10.5	445.5	133,384		443.5	90,315	
11.0	446.0	148,211		444.0	104,415	
11.5	446.5	163,226		444.5	118,747	
12.0	447.0	178,427		445.0	133,384	
12.5	447.5	193,812		445.5	148,211	
13.0	448.0	209,378		446.0	163,226	
13.5	448.5	225,124		446.5	178,427	
14.0	449.0	241,047		447.0	193,812	
14.5	449.5	257,146		447.5	209,378	
15.0	450.0	273,418	33,431	448.0	225,124	
15.5	450.5	290,277		448.5	241,047	
16.0	451.0	307,328		449.0	257,146	
16.5	451.5	324,575		449.5	273,418	
17.0	452.0	342,019		450.0	290,277	
17.5	452.5	359,664		450.5	307,328	
18.0	453.0	377,512	36,186	451.0	324,575	

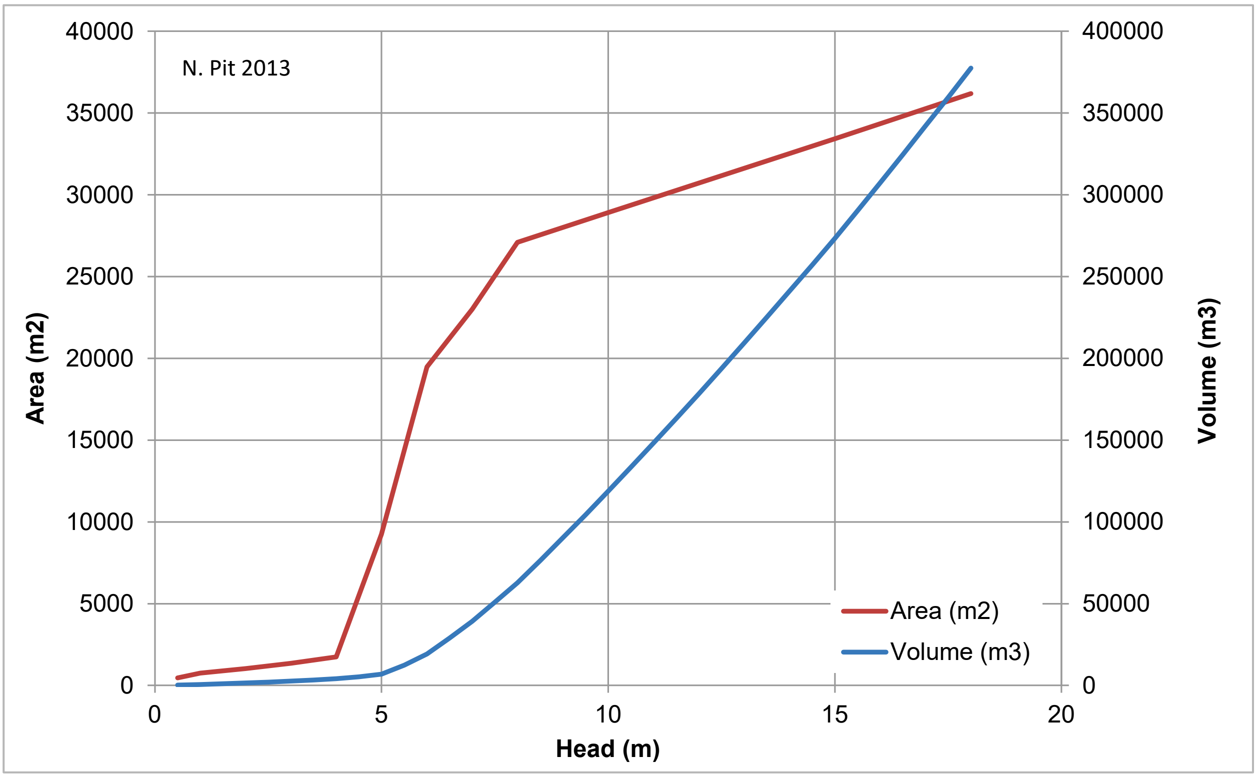


Figure 3.2: North Pit Geometry – 2013

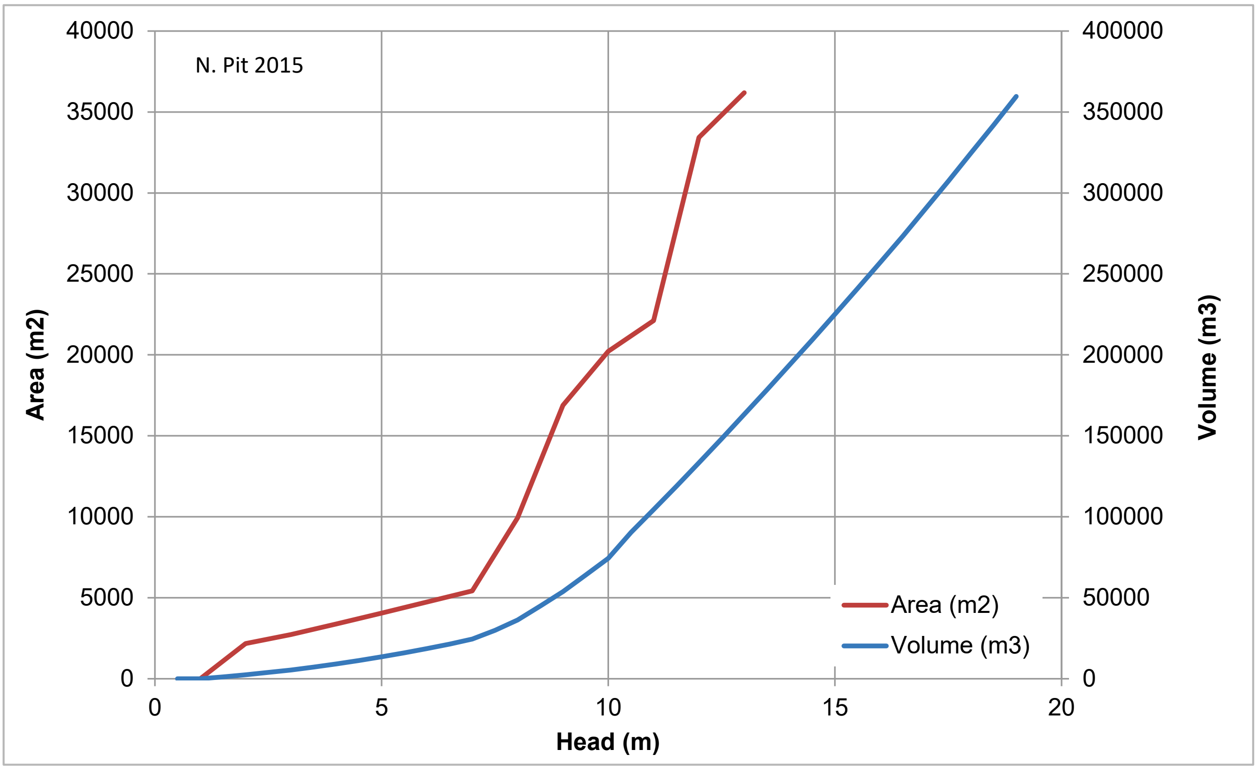


Figure 3.3: North Pit Geometry – 2015

4 Catchment Areas and Land Surfaces

4.1 Land Surfaces

The catchments draining to the mine pits contain a variety of land surfaces, each of which can be expected to have different response to rainfall. The surface and runoff characteristics of the different surfaces within the catchments draining to the mine pits are outlined below, together with an initial estimate of the long term runoff as a percentage of rainfall. Section 6 describes the process adopted for revising these initial estimates of runoff characteristics in order to be consistent with the volumes of water captured in the mine pits in July 2013 and August 2015.

Natural Vegetation

For purposes of assessing runoff characteristics, 'natural' vegetation is taken to include both forested areas and cleared land used for grazing.

Analysis of the relationship between rainfall and runoff for gauged catchments in the Southern Highlands (described in the Annexure D to the Surface Water Assessment) indicates that the long term average runoff in the vicinity of South Marulan can be expected to be about 7.7% of rainfall. However, for individual rainfall events, the runoff can be very different from this, depending on the preceding rainfall.

Overburden emplacement

Overburden emplacements are subject to progressive development that may be characterised as series of stages:

- bare overburden which has a high degree of porosity, but may exhibit high runoff characteristics due to slaking of the surface soil and the relatively steep slope
- shaped overburden that has been re-worked into a landform suitable for establishment of vegetation. In this state, the surface may be cultivated to provide a medium for vegetation establishment. The absence of vegetation means that evaporation only occurs from near the surface and elevated moisture content can be expected beneath a surface crust. In this state the surface will continue to exhibit high runoff characteristics.
- rehabilitated overburden that has established vegetation. The presence of vegetation means that moisture is taken up by the root system and the soil is more able to absorb rainfall that when the surface is bare. However, because of the relatively shallow depth of 'soil' and the steep slopes, a rehabilitated overburden emplacement can be expected to produce more runoff that the undisturbed natural landscape.

The technical literature is relatively sparse in relation to the runoff characteristics of overburden emplacements. The most comprehensive study (ACARP, 2001) relates to overburden on coal mines. The application of the range of runoff characteristics documented in that publication to the full historic climate record (July 1887 – June 2015) at South Marulan gives the runoff (as a percentage of rainfall) set out in Table 4.1.

Table 4.1: Runoff Characteristics of Overburden Emplacements

Surface Condition	Runoff as Percentage of Rainfall		
	Minimum	Average	Maximum
Bare Overburden	18%	22%	29%
Shaped Overburden	12%	15%	21%
Rehabilitated Overburden	7%	13%	16%

Haul Roads, Hardstand and Mine Infrastructure Areas

Haul roads and hardstand areas have compacted surfaces which tend to have low infiltration rates, and have limited water holding capacity in the surface layer and minor depressions. The Mine Infrastructure Area can be expected to have some sealed areas (roofs and roads), however, for runoff modelling purposes the Mine Infrastructure Area is lumped with haul roads and hardstand areas.

Parameters representing the soil moisture storage and runoff characteristics hardstand areas derived from (ACARP, 2001) and benchmarked against the runoff characteristics for hardstand areas in MUSIC (V5, eWater, 2012). Data from these sources, combined with rainfall from the full historic climate record (July 1887 – June 2015) give an average runoff of 63%.

Mine Pits

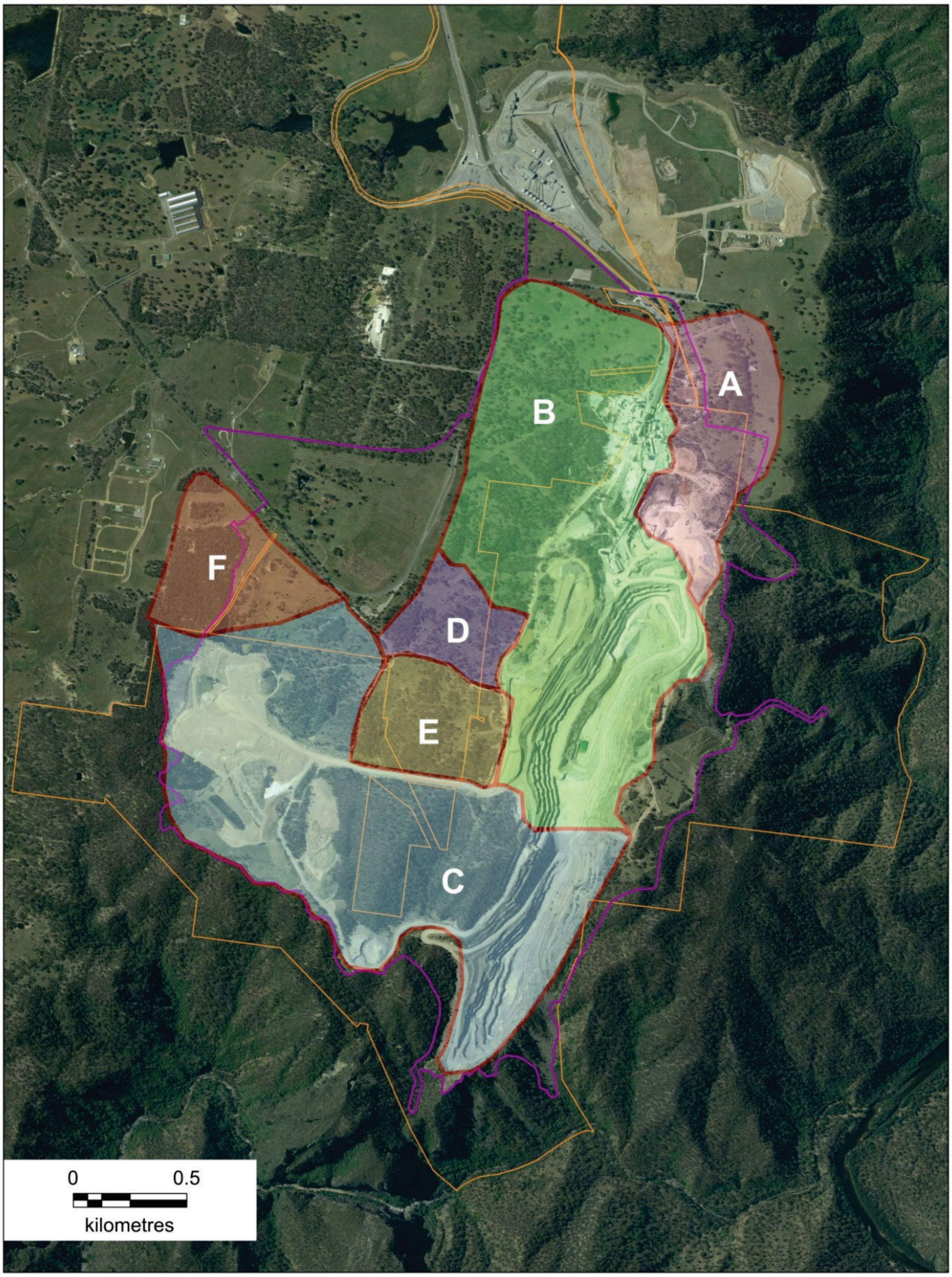
A typical mine pit is characterised by bare rock surfaces with some loose material in the base of the pit. Parameters representing the range of runoff characteristics hardstand areas derived from (ACARP, 2001) combined with rainfall from the full historic climate record (July 1887 – June 2015) give an average runoff of 49% with a range from 39% to 56%.

4.2 Catchment Areas

Boral advises that the catchment areas draining to the mine pits have remained relatively constant over the period 2013 to 2015. Figure 4.1 shows the main catchment areas in the vicinity if the mine pits. In consultation with site staff, the following drainage arrangements have been adopted:

- Catchment A drains to Barbers Creek via the eastern side of the North Pit
- Catchment B drains to the North Pit
- Catchment C drains towards the South Pit, but site staff consider that runoff from some of this area may bypass the pit as seepage through previous overburden emplacement or redirection by the haul road
- Catchment D drains to a large existing sediment dam
- Catchment E drains to Main Mine Dam 1
- Catchment F drains to a water storage formed upstream of the Western Overburden Emplacement.

For purposes of assessing the runoff reporting direct to the mine pits, only catchments B and C have been considered.



Key: Project boundary — CML 16 — Catchment boundaries

Figure 4.1: Catchments in the Vicinity of the South Marulan Mine Pits

The area of each land surface type draining to each pit are summarised in Table 4.2 below.

Table 4.2: Contributing Catchment Areas

Land Type	Area Draining to Pits (ha)	
	North Pit (B)	South Pit (C)
Natural Vegetation	85	115
Overburden Emplacement/Bare	25	33
Haul Roads and Hardstand Areas	0	2.5
Hard Stand and Mine Infrastructure Area	18	0.0
Mine Pit	55	40

5 Water Levels and Volumes

Increased water levels in both North and South Pits were observed during two separate rainfall events: 24 to 26 June 2013 and 24 to 26 August 2015. For the 2013 flooding event, only anecdotal information is available - estimated maximum water table elevation in the North Pit. During the 2015 flooding event regular photographs were taken and a pressure transducer was located in South Pit until 3/9/2015 and then moved to North Pit (until 11/9/2015). The pressure transducer data combined with visual observation and photographic records of water levels in both pits provides valuable information suitable for estimation of:

- runoff characteristics of the contributing catchments
- seepage rates in the floor of the North Pit and South Pit.

5.1 July 2013 – North Pit

The available records of the flood water level in the North Pit following heavy rainfall in late June 2013, comprise photographs such as that in Figure 5.1 from which the water level has been estimated. It is not clear from the mine records whether Figure 5.1 represents the maximum water lever, or was taken after the level had receded. Figure 5.2 is a contour plot of the geometry of the North Pit in 2013, with the inferred/observed water level (443 m AHD) marked in white.

Figure 5.1: North Pit - View to "Centre Ridge", Water Level at ~443 m AHD (25/6/2013, 4.00 pm)

Based on the photograph of the July 2013 event (Figure 5.1), the water in the North Pit reached an elevation of approximately 443 m AHD (Figure 5.2) with a level of 8 m above pit floor and an estimated volume of 63 ML.

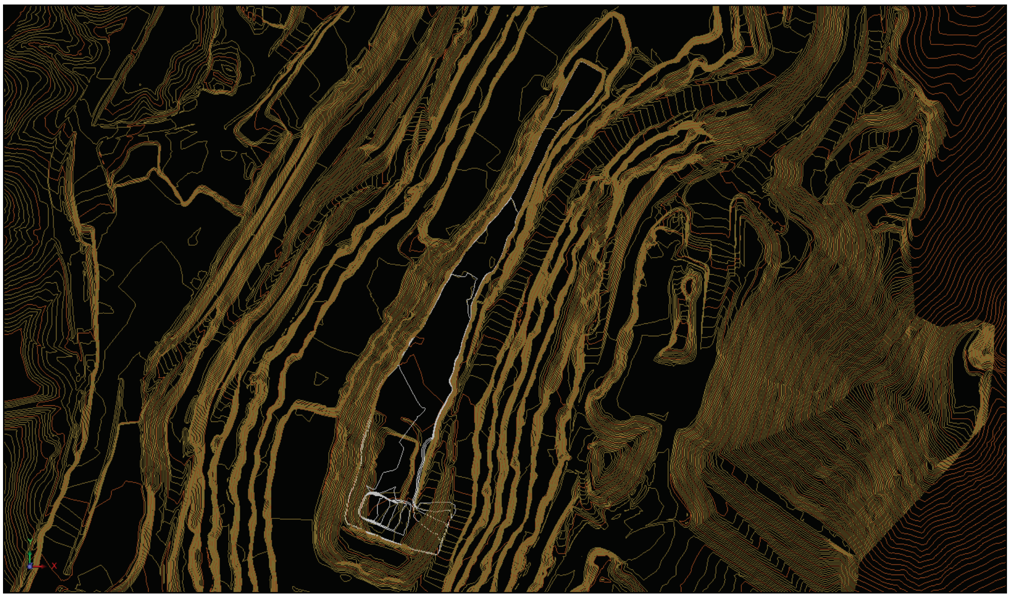


Figure 5.2: Observed Water Level in North Pit (July 2013).

Source: 2013-14 AEMR (Boral, 2014)

5.2 July 2013 – South Pit

No photographs of the peak water elevation of the South Pit are available. The information provided by the Marulan Mine staff indicates that the water which accumulated in the South Pit disappeared in a 'couple of days' or 'in less than one week's time'.

5.3 August 2015 – North Pit

During the 2015 flooding event, the water elevation in the North Pit peaked following maximum rainfall on 26/8/2015. The maximum elevation of accumulated runoff water is estimated to be between 444 and 444.5 m AHD.

The first actual observation of water level in North Pit was made approximately one day later, on 27/8/2015 at 8.42 am (see Figure 5.3 and Table 5.1). This observation was used to estimate the water level (Figure 5.4) and accumulated volume of runoff water at that time. In total, the water in the North Pit was photographed four times between 27/8 and 7/9/2015. Each of the observations was used to estimate water level in the pit (Table 5.1).

From 3/9/2015, the drop of the water level in the North Pit was further documented using the pressure transducer located on the pit floor. The maximum accumulated volume of water during the event was 104.4 ML (water elevation of 444.5 m AHD), estimated volume of water on 10/9/2015 was 11.3 ML (water elevation of 437.5 m AHD). The water elevation in the North Pit dropped by 7 m in 15 days and the North Pit lost about 93 ML of water.

Table 5.1: Estimated Water Level Elevation from Photographs – North Pit, August 2015

Date & time	Head Above Pit Floor (m)	Water Surface Elevation (m AHD)
27/08/2015 8:42	10.0	443.0
2/09/2015 13:17	7.4	440.4
3/09/2015 11:53	6.6	439.6
7/09/2015 9:45	5.5	438.5

Table 5.2: Measured Water Level Elevation from Transducer Records – North Pit, August 2015

Date & time	Head Above Pit Floor (m)	Water Surface Elevation (m AHD)
4/09/2015 0:00	10.4	439.4
5/09/2015 0:00	9.9	438.9
6/09/2015 0:00	9.4	438.4
7/09/2015 0:00	8.9	437.9
8/09/2015 0:00	8.7	437.7
9/09/2015 0:00	8.5	437.5
10/09/2015 0:00	8.4	437.4

Figure 5.3: North Pit – View Due North from "Centre Ridge" (27/8/2015, 8.42 am)

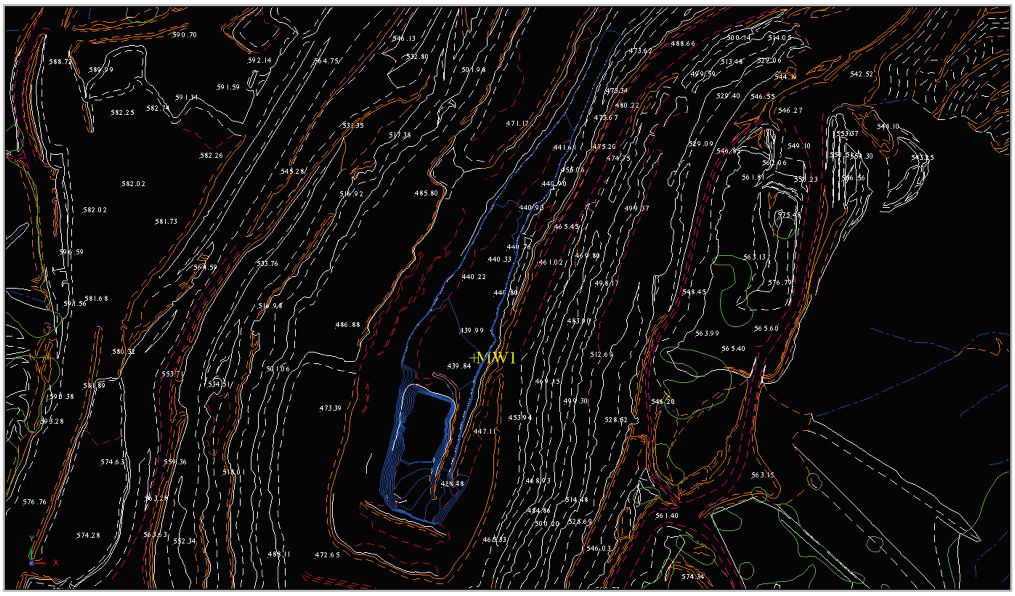


Figure 5.4: Estimated Maximum Elevation of Water in North Pit (August 2015) – Contours

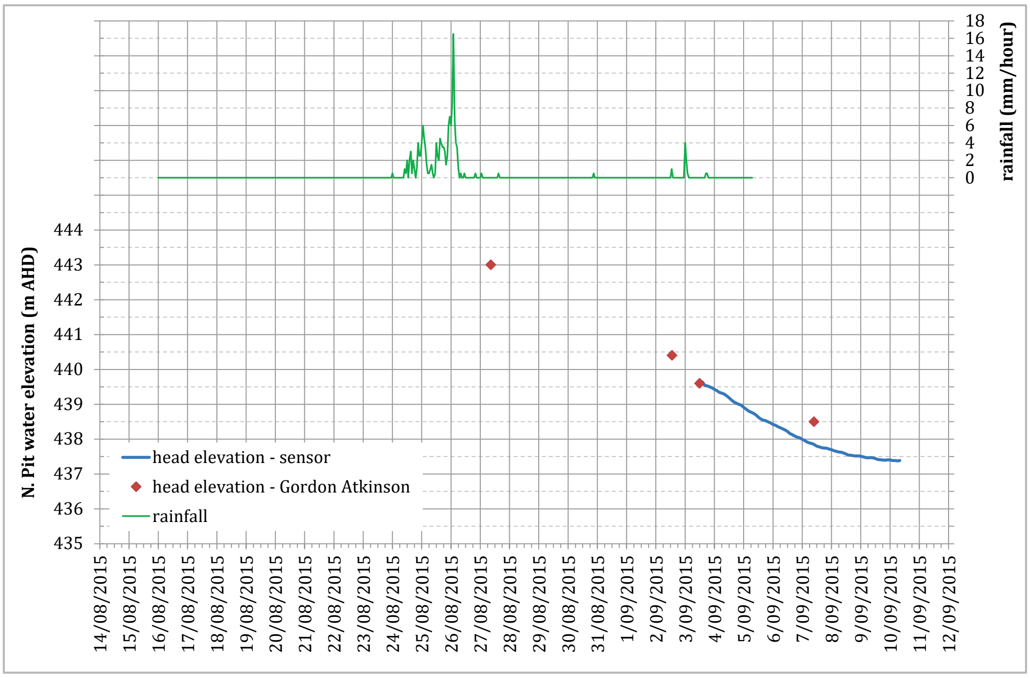


Figure 5.5: Rainfall and Water Level in the North Pit (August 2015)

5.4 August 2015 – South Pit

The elevation of the accumulated runoff in the South Pit was documented visually (see Figure 5.6) as well as using the pressure transducer located in the deepest part of the South Pit. The elevation data recorded by the pressure transducer (Figure 5.7) indicate that the water in the South Pit did not accumulate as much as in the North Pit. Because of faster discharge through the pit floor, the water reached only 0.5 m above the baseline level and returned to the pre-flooding conditions in about 3 days.

Figure 5.6: South Pit – 26/8/2015 – view from the eastern ramp

Table 5.3: Measured Water Level (Pressure Transducer) – South Pit, August 2015

Date & time	Head above pit floor (m)	Water table elevation (m AHD)
25/08/2015 0:00	0.85	364.85
25/08/2015 12:00	0.91	364.91
26/08/2015 0:00	1.07	365.07
26/08/2015 12:00	1.03	365.03
27/08/2015 0:00	1.00	365.00
27/08/2015 12:00	0.89	364.89
28/08/2015 0:00	0.84	364.84
28/08/2015 12:00	0.83	364.83
29/08/2015 0:00	0.80	364.80
29/08/2015 12:00	0.81	364.81
30/08/2015 0:00	0.78	364.78
30/08/2015 12:00	0.81	364.81
31/08/2015 0:00	0.80	364.80
31/08/2015 12:00	0.80	364.80

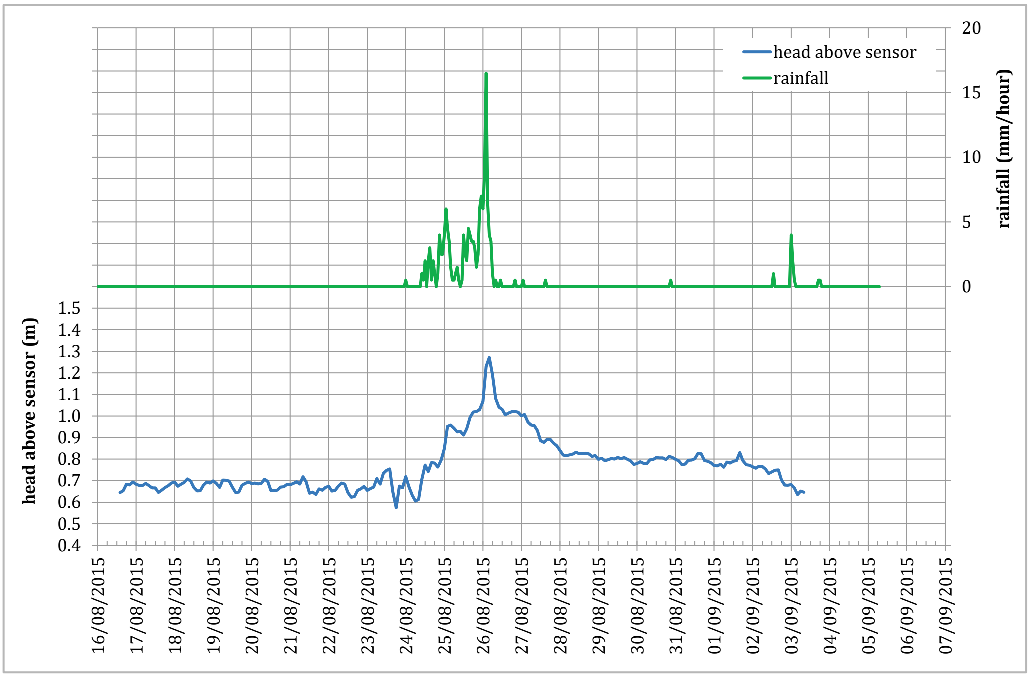


Figure 5.7: Rainfall and Water Level in the South Pit (August 2015)

6 Runoff Characteristics

The date and time that photograph in Figure 5.1 was taken are not known and are note useful for purposes of validating the modelled runoff. The most reliable data is the water level estimates based on the series of photographs taken in the North Pit following the heavy rainfall between 9.00 am on 24 August and 9.00 am on 26 August 2015, which form the basis for Figure 5.5. The first photograph was taken at 8.45 am on 27 August, some 24 hours after rainfall had ceased.

As shown by the relationship between rainfall and water level in Figure 5.7, peak water level in the South Pit occurred at about 4.00 am on 26 August, about 2 hours after the heaviest rainfall at 2.00 am. Assuming similar time of concentration for the both catchments (similar total area and slopes), it is likely that the peak water level in the North Pit occurred before 9.00 am on 26 August. From Figure 5.5, the inferred peak water level would have been in the range of 443.5 m AHD to 444.0 m AHD corresponding to water volume in the pit in the range of 90 ML to 104 ML (from Table 3.2).

The rainfall:runoff model (AWBM) was run for the range of parameters that give rise to the various runoff characteristics described in Section 4.1. In order to account for antecedent rainfall before the storms of interest and eliminate any model 'warm-up' effects, the model was run using the daily rainfall from November 2009 to August 2015 (which includes both periods when there was recorded flooding). By adopting the model parameters that gave the minimum volume of runoff reaching the North Pit (Section 4.1), the estimated volume in the pit was 102 ML, which is within the range of the estimated maximum volume immediately following the storm after accounting for some drainage through the base of the pit during the storm.

Based on these model parameters, the estimated volume of runoff reporting to the North Pit and South Pit for the storms of June 2013 and August 2015 are set out in Table 6.1 and Table 6.2. These estimates should be interpreted with caution, particularly for the South Pit. While the base of the South Pit is recognised as being more permeable than the North Pit (see Section 5.2), the inferred total runoff into the south pit following the August 2015 storm (74 ML) is not consistent with the maximum recorded increase in water level of 0.6 m (Figure 5.7). Even if only the runoff from the pit itself was considered (about 46 ML or 63% of the total), the discrepancy remains.

Table 6.1: Estimated Runoff Volume up to 9.00 am on the Listed Date (2013)

Date	North Pit (ML)	South Pit (ML)
24/06/2013	10	6
25/06/2013	102	75
26/06/2013	48	42

Table 6.2: Estimated Runoff Volume up to 9.00 am on the Listed Date (2015)

Date	North Pit (ML)	South Pit (ML)
25/08/2015	22	16
26/08/2015	80	58

7 Drainage Characteristics of Mine Pits

A simple spreadsheet model was used to estimate the bulk conductivity of the North and South Pit floors. The flood events of July 2013 and August 2015 were used as 'calibration' events for the spreadsheet model.

Given our understanding of runoff volumes to both pits, time it took for the water to seep through the pit floor and dimensions of the pits, discharge rates and volumes can be calculated for both pits. The model parameters can be then adjusted, so that the calculated discharge curves match the actual, observed discharge curves (Figure 5.5 and Figure 5.7).

The conceptual setup and spreadsheet model parameters are presented in Figure 7.1.

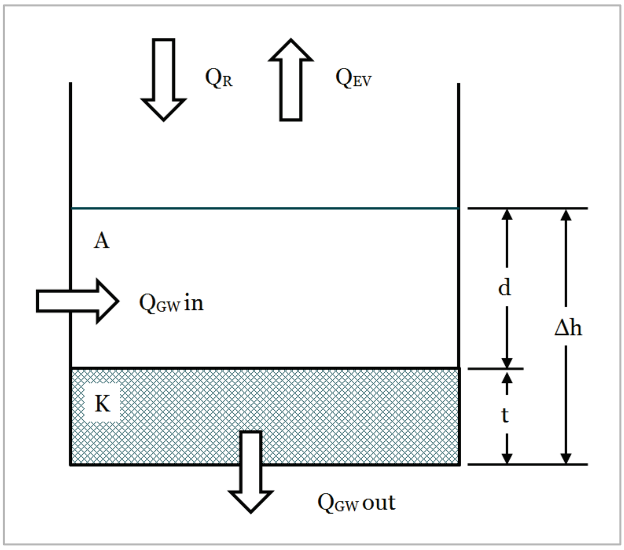


Figure 7.1: Conceptualization of the Pit Floor Seepage Calculations

Where:

Q_R	– inflow – rainfall and runoff
Q_{EV}	– loss – evaporation
Q_{GW} in	– inflow – groundwater
Q_{GW} out	– loss – groundwater
K	– bulk vertical hydraulic conductivity of pit floor
A	– area of the lake/flooded pit floor
d	– depth of water
t	– saturated thickness of the South Pit floor
Δh	– head gradient

Outflow from the pit can be then calculated as:

$$Q_{GW}out = K \times A \times \frac{\Delta h}{t}$$

7.1 South Pit

The observed discharge through the South Pit floor was very fast – based on the data obtained from the pressure transducer placed in the South Pit, the runoff water disappeared in less than 3 days (the volume and head peaked in the early hours of 26/8/2015 and by the end of 29/8/2015 the accumulated runoff was gone.

Because of the coarseness of the spreadsheet model (heads and volumes were calculated on daily basis) the model over predicts the calculated head. In order to use the model as an estimation tool for the bulk vertical conductivity of the South Pit floor, the calibration concentrated on replicating the ***time*** necessary to discharge the accumulated water and replication of the discharge trend (see Figure 7.2), rather than attempting to match the head.

The calculated seepage loss through the South Pit floor for the August 2015 flooding event is presented in Table 7.1.

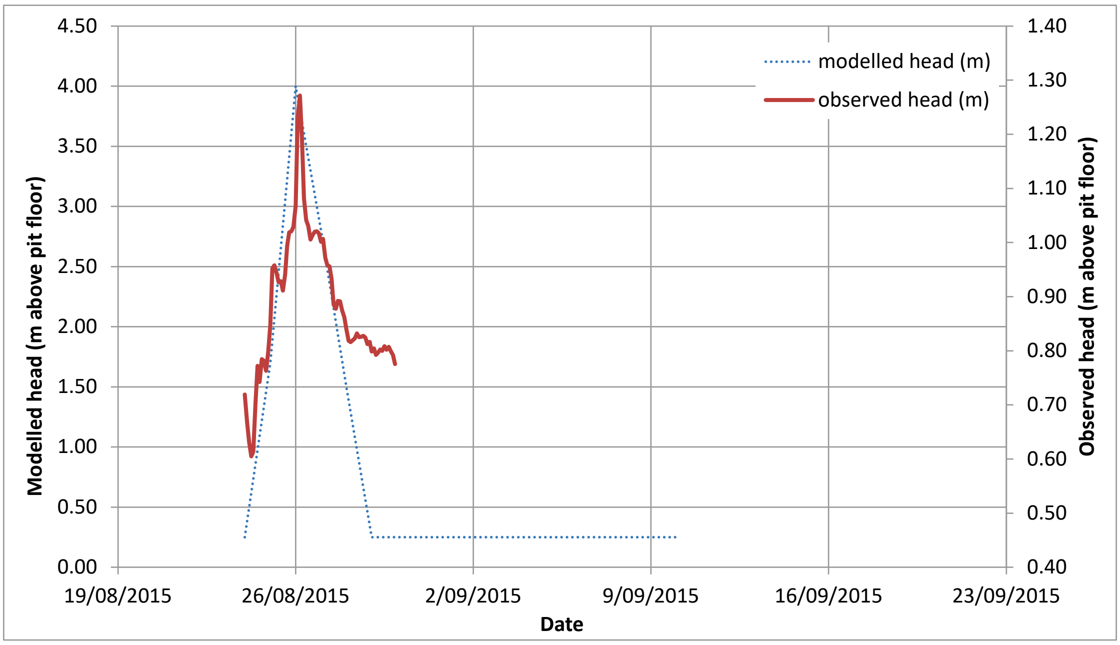


Figure 7.2: Measured and Modelled Head in the South Pit (August 2015)

Table 7.1: Calculated Seepage Loss through the South Pit Floor (August 2015)

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
24/08/2015	0	7.5	3.4	0.10	219	274
25/08/2015	16,000	47.0	3.4	1.70	16,774	1,6297
26/08/2015	58,000	84.0	3.4	4.00	18,946	25,036
27/08/2015	0	2.0	3.4	2.70	17,807	23,117
28/08/2015	0	0.0	3.4	1.40	15,013	10,659
29/08/2015	0	0.0	3.4	0.10	219	274
30/08/2015	0	0.0	3.4	0.10	219	274

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
31/08/2015	0	0.0	3.4	0.10	219	274
1/09/2015	0	0.0	3.4	0.10	219	274
2/09/2015	0	0.0	3.4	0.20	219	274
3/09/2015	0	0.0	3.4	0.10	219	274
4/09/2015	0	0.0	3.4	0.10	219	274
5/09/2015	0	0.0	3.4	0.10	219	274
6/09/2015	0	0.0	3.4	0.10	219	274
7/09/2015	0	0.0	3.4	0.20	219	274
8/09/2015	0	0.0	3.4	0.10	219	274
9/09/2015	0	0.0	3.4	0.10	219	274
10/09/2015	0	0.0	3.4	0.10	219	274

Parameters calibrating the model for in terms of the speed of discharge were:

Q_{GW} in = 300 m^3/day;

K = 1.25 m/day (value lies between 1.0 and 1.5 m/day).

7.2 North Pit

Because of the accumulated volume and discharge speed in the North Pit, the spreadsheet model was better suited for the conditions of the North Pit than the South Pit. The model parameters (namely K and Q_{GW}in) were calibrated against the water elevation data obtained by direct and indirect measurement (see Section 5.3). The modelled decrease of water table in the North Pit during the August 2015 flooding event is presented in Figure 7.3.

Parameters 'calibrating' the model are:

Q_{GW} in = 1,200 m^3/day;

K = 0.5 m/day.

All other parameters were obtained from the field measurements (head above the pit floor, rainfall, pan EV) or calculated from the field data (runoff volume, intermittent volume of water in the pit, area of the flooded pit). The calculated seepage rates during the flooding event are presented in Table 7.2.

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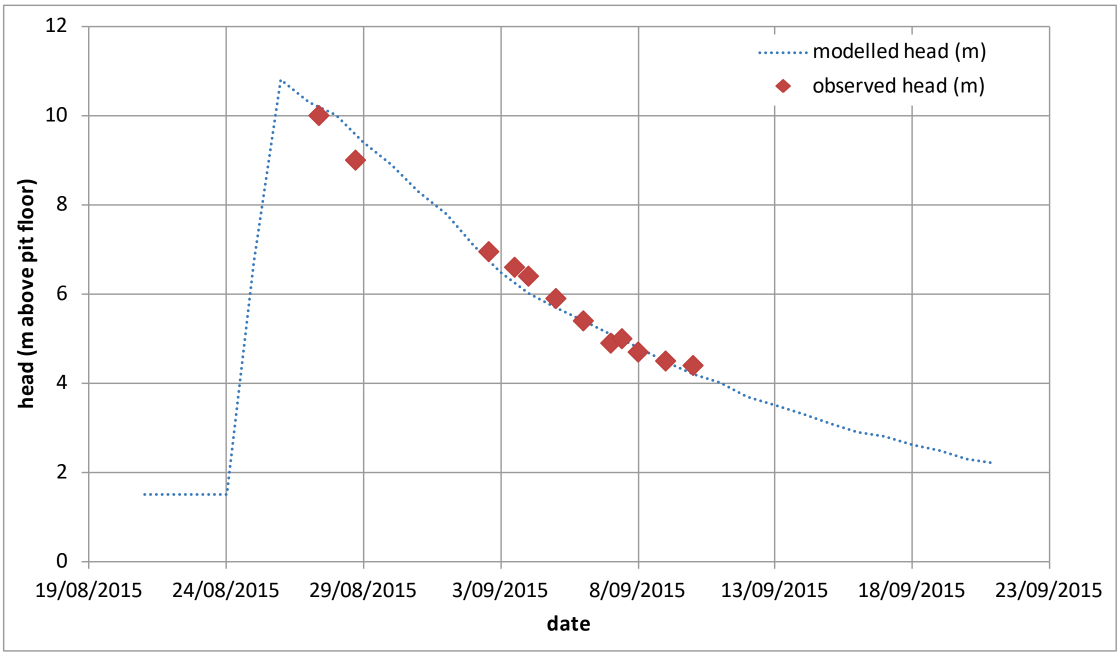

Figure 7.3: Measured and Modelled Head in the North Pit (August 2015)

The rates of the groundwater inflow (Q_{GW} in) are consistent with the results obtained by the regional numerical model; however the bulk hydraulic conductivity of the limestone pit floor is higher than previously suggested by the pumping tests on bores MW1 and MW2.

Table 7.2: Calculated Seepage Loss through the North Pit Floor (August 2015)

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
24/08/2015	0	7.5	3.4	1.5	2,452	1,196
25/08/2015	22,000	47	3.4	6.7	8,589	4,706
26/08/2015	80,000	84	3.4	10.8	23,924	13,808
27/08/2015	0	2	3.4	10.3	22,792	13,073
28/08/2015	0	0	3.4	10	22,113	12,636
29/08/2015	0	0	3.4	9.4	20,980	11,899
30/08/2015	0	0	3.4	8.9	19,891	11,210
31/08/2015	0	0	3.4	8.3	17,886	10,004
1/09/2015	0	0	3.4	7.8	15,496	8,611
2/09/2015	0	0	3.4	7.1	10,637	5,858
3/09/2015	0	0	3.4	6.5	7,687	4,200
4/09/2015	0	0	3.4	6	5,430	2,948
5/09/2015	0	0	3.4	5.7	5,220	2,823
6/09/2015	0	0	3.4	5.4	5,011	2,699
7/09/2015	0	0	3.4	5.1	4,801	2,575
8/09/2015	0	0	3.4	4.8	4,597	2,456
9/09/2015	0	0	3.4	4.5	4,395	2,339

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
10/09/2015	0	0	3.4	4.2	4,193	2,223
11/09/2015	0	0	3.4	4	4,059	2,145
12/09/2015	0	0	3.4	3.7	3,857	2,030
13/09/2015	0	0	3.4	3.5	3,722	1,954
14/09/2015	0	0	3.4	3.3	3,587	1,878
15/09/2015	0	0	3.4	3.1	3,452	1,803
16/09/2015	0	0	3.4	2.9	3,320	1,729
17/09/2015	0	0	3.4	2.8	3,254	1,692
18/09/2015	0	0	3.4	2.6	3,124	1,620
19/09/2015	0	0	3.4	2.5	3,059	1,584
20/09/2015	0	0	3.4	2.3	2,928	1,512

7.3 Final Void

The Final Void will be created by mining in the North Pit to the elevation of the current South Pit floor and extending the pit into the eastern and western sides. Part of the South Pit floor will be covered by spoil. The shape of the final void was provided by Boral and the pit geometry is presented in Table 7.3 below.

Table 7.3: Final Void Geometry – Post Closure

Water Surface Elevation (m AHD)	Head (m)	Cumulative volume (m^3)	Area (m^2)
366	1	191,643	191,520
367	2	393,202	201,560
368	3	596,568	203,366
369	4	801,765	205,196
370	5	1,008,925	207,161
371	6	1,218,053	209,127
372	7	1,428,979	210,926
373	8	1,641,634	212,655
374	9	1,856,105	214,471
375	10	2,072,581	216,476
380	15	3,206,150	248,606
385	20	4,503,975	263,711
390	25	5,852,958	273,823
395	30	7,275,186	306,271
400	35	8,900,745	329,756
410	45	12,343,524	374,185
420	55	16,246,611	400,273
430	65	20,529,529	450,379
440	75	25,198,953	507,471

Water Surface Elevation (m AHD)	Head (m)	Cumulative volume (m^3)	Area (m^2)
450	85	30,461,601	537,662
460	95	36,155,692	597,082
470	105	42,284,504	635,033
480	115	49,151,429	699,192
490	125	56,551,342	777,965

As the Final Void is going to be effectively created by joining the North and South Pits, the hydraulic properties of the Final Void are to be 'inherited' from the existing properties of the North and South Pits. The seepage from the Final Void can be calculated as sum of seepages from the zones formerly representing the North and South Pits, keeping their distinct hydraulic properties. The conceptualisation of this case is presented in Figure 7.4.

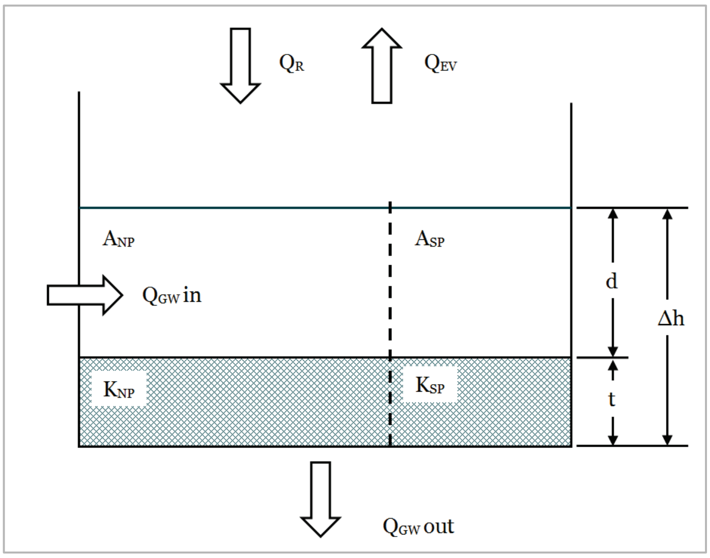

Figure 7.4: Conceptualisation of the Pit Floor Seepage Calculations – Final Void

Where:

Q_R	– inflow – rainfall and runoff
Q_{EV}	– loss – evaporation
Q_{GW} in	– inflow – groundwater
Q_{GW} out	– loss – groundwater
K_{NP}	– bulk vertical hydraulic conductivity of North Pit floor
K_{SP}	– bulk vertical hydraulic conductivity of South Pit floor
A_{NP}	– area of the lake/flooded pit floor representing former North Pit
A_{SP}	– area of the lake/flooded pit floor representing former South Pit
d	– depth of water
t	– saturated thickness of the Final Void floor
Δh	– head gradient

Outflow from the Final Void can be then calculated as:

$$Q_{GW}out = [(K_{NP} \times A_{NP}) + (K_{SP} \times A_{SP})] \times \frac{\Delta h}{t}$$

The overall volume of outflow depends on areas and vertical K of individual pits. The ratio between the North and South Pit floor area within the Final Void was estimated to be between 70% (NP): 30% (SP) and 95% (NP): 5% (SP). The sensitivity of the seepage calculations with respect to the change in the ratio between North and South Pits conditions is explored in Figure 7.5.

With the increasing area representing North Pit, the overall seepage rate decreases. The 'worst case scenario' is that the whole Final Void inherits North Pit parameters. The difference of seepage rate between the 30% of South Pit and 0% of South Pit is approximately 30% decrease in seepage from the Final Void.

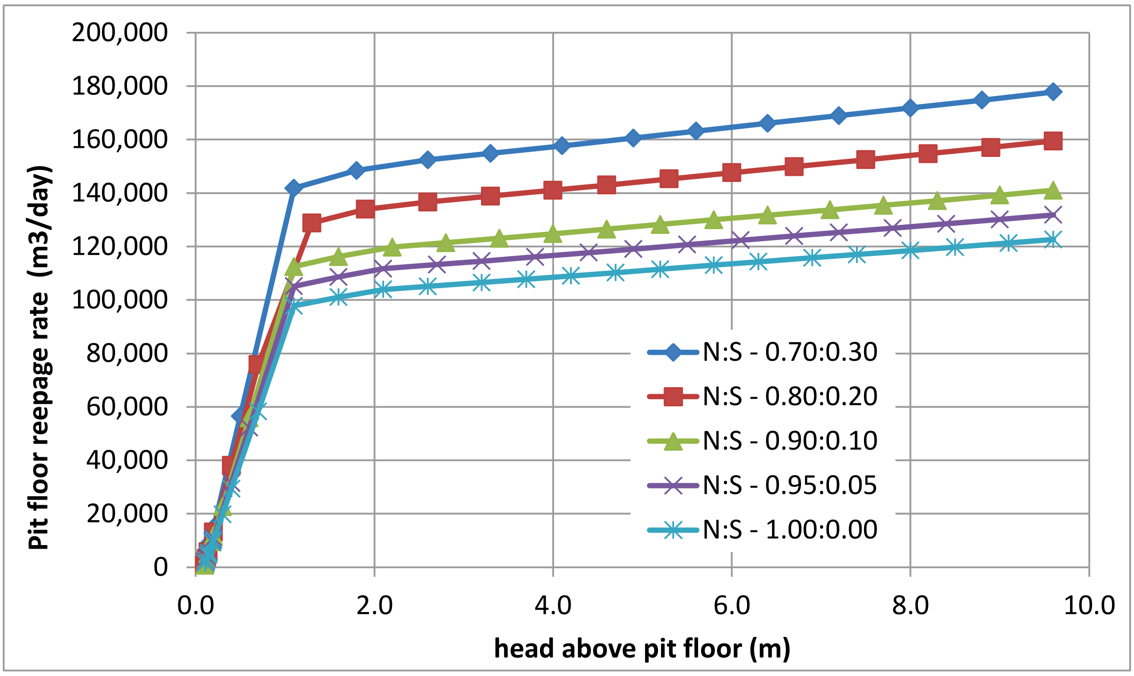

Figure 7.5: Final Void Head to Seepage Volume Ratio.

8 References

ACARP (2001). *Water Quality and Discharge Predictions for Final Void and Spoil Catchments*, Report prepared by PPK for Australian Coal Association Research Program

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Boughton, W. (2010). *Rainfall-Runoff Modelling with the AWBM*. Engineers Media, Crows Nest.

Annexure F Geotechnical Advice

Advisian

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