Specialist Consultant Studies Compendium

South Coast Concrete Crushing and Recycling Pty Ltd

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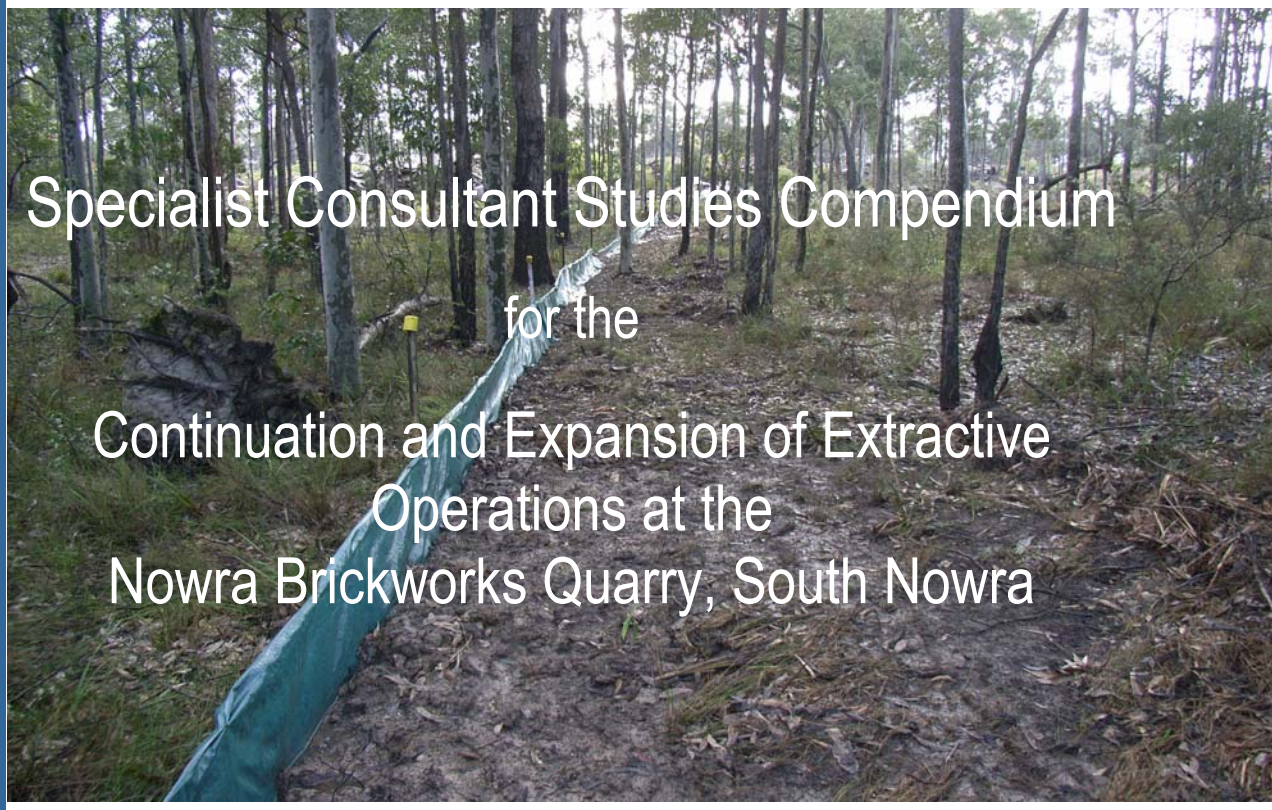

Specialist Consultant Studies Compendium

for the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

Prepared by:

R.W. CORKERY & CO. PTY. LIMITED

and

PLANNING
BUILDING
HERITAGE
LANDSCAPE
URBAN DESIGN
CITY PLAN SERVICES

February 2009

Index

Part 1 **Hydrology Assessment**
(Martens and Associates Pty Ltd)

Part 2A **Ecology Assessment**
(Gaia Research Pty Ltd)

Part 2B **Weed Management and Rehabilitation Strategy**
(Gaia Research Pty Ltd)

Part 3 **Traffic and Transportation Assessment**
(John Coady Consulting Pty Ltd)

Part 4 **Air Quality Assessment**
(Heggies Pty Ltd)

Part 5 **Noise and Blasting Assessment**
(Heggies Pty Ltd)

Part 6 **Aboriginal Heritage Assessment**
(Cultural Heritage Management Australia)

Part 7A **Soils Assessment**
(SEEC Morse McVey)

Part 7B **Erosion and Sediment Control Plan**
(SEEC Morse McVey)

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South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Hydrology Assessment

(Surface Water and Groundwater)

Prepared by

Martens & Associates Pty Ltd

January, 2009

Specialist Consultant Studies Compendium:
Part 1

Hydrology Assessment

(Surface Water and Groundwater)

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

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January, 2009

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CONTENTS

Page

EXECUTIVE SUMMARY 1-7

1 INTRODUCTION 1-9
- 1.1 Scope of Work 1-9
- 1.2 The Project Site 1-10
- 1.3 Current Operations 1-10
- 1.4 Overview of the Project 1-10
- 1.5 Previous Investigations 1-14
- 1.6 Relevant Planning Controls, Policy Objectives and Guiding Principles 1-15
- 1.7 Clarification of Reporting Terms 1-18

2 PROJECT SITE DESCRIPTION 1-18
- 2.1 Field Investigations 1-18
- 2.2 Existing Topography 1-20
- 2.3 Geology 1-21
- 2.4 Soil Profile 1-21
- 2.5 Climate 1-21
  - 2.5.1 Precipitation and Evaporation 1-21
  - 2.5.2 Temperature 1-22
- 2.6 Off-site Surface Water Catchments 1-22
- 2.7 Site Sub-catchments 1-23
  - 2.7.1 Existing Sub-catchments 1-23
  - 2.7.2 Post-development 1-23

3 STORMWATER MANAGEMENT STRATEGY 1-24
- 3.1 Existing Stormwater Management 1-24
  - 3.1.1 Overview 1-24
  - 3.1.2 Stormwater Quality 1-24
- 3.2 Stormwater Management Objectives 1-26
- 3.3 Stormwater Modelling 1-27
  - 3.3.1 Overview 1-27
  - 3.3.2 Modelling Approach 1-27
  - 3.3.3 Modelling Set-up and Inputs 1-27
- 3.4 Stormwater Management Measures 1-28
  - 3.4.1 Storage Reservoir 1-28
  - 3.4.2 Irrigation Field 1-33
  - 3.4.3 Stormwater Release Point 1-34
  - 3.4.4 Grassed Buffer Strips 1-34
- 3.5 Stormwater Modelling Results 1-34
- 3.6 Conclusion 1-35

4 FLOOD ASSESSMENT 1-36
- 4.1 Overview 1-36
- 4.2 Methodology 1-36
- 4.3 Results 1-37
  - 4.3.1 Hydrological Modelling 1-37
  - 4.3.2 Hydraulic Modelling 1-37
  - 4.3.3 Impact of Flooding on Development 1-38
  - 4.3.4 Impact of Development on Flooding 1-38
- 4.4 Conclusion 1-38

CONTENTS

Page

5 GROUNDWATER ASSESSMENT 1-38
5.1 Overview 1-38
5.2 Piezometer Installation Summary 1-39
5.3 Existing Groundwater Conditions 1-39
5.3.1 Groundwater Water Quality 1-39
5.4 Hydraulic Conductivity (K_{sat}) 1-40
5.5 Manual Groundwater Level Observations 1-41
5.6 Barometric Pressure 1-42
5.7 Detailed Groundwater Level Monitoring 1-42
5.8 Rainfall Influence 1-42
5.9 Groundwater Impact Assessment 1-43
5.9.1 Overview of Risks 1-43
5.9.2 Groundwater Modelling Methodology 1-44
5.9.2.1 Method 1-44
5.9.3 Groundwater Modelling Results 1-46
5.9.4 Interpretation of Results 1-47
5.9.5 Impact Assessment 1-52
5.10 Groundwater Extraction Licensing Requirements 1-52
5.11 Summary and Mitigation Measures 1-53

6 WATER AND SALT BALANCE ASSESSMENT 1-53
6.1 Overview 1-53
6.2 Modelling Methodology and Assumptions 1-54
6.3 Water and Salt Balance Assessment Results 1-55
6.3.1 Storage Reservoir Overflows 1-55
6.3.2 Storage Reservoir Levels 1-56
6.3.3 Storage Salinity Levels 1-56
6.3.4 Overland Flow Discharges 1-56
6.4 Salt Impacts Due to Irrigation 1-56
6.5 Conclusion 1-57

7 NOWRA CREEK IMPACT ASSESSMENT 1-57
7.1 Overview 1-57
7.2 Nowra Creek 1-57
7.2.1 Overview 1-57
7.2.2 Channel Sinuosity 1-58
7.2.3 Riparian Zone 1-58
7.2.4 Salt Impacts on Nowra Creek and Discharge Control 1-58
7.2.5 Riparian Management 1-58
7.2.6 Impact Assessment 1-59

8 REFERENCES 1-60

CONTENTS

Page

APPENDICES

Appendix A Hydrogeological/Stormwater Plan Set....1-65
Appendix B Pre-quarrying / Post-development MUSIC Modelling Output 1-75
Appendix C Existing-development / Post-development RAFTS Modelling Set-up and Output1-79
Appendix D HEC-RAS Hydraulic Existing-Development / Post-Development Modelling 1-105
Appendix E Recharge Testing 1-111
Appendix F Laboratory Report....1-115
Appendix G Coverage of EA Requirements 1-125

FIGURES

Figure 1 Locality Plan and Piezometer Locations 1-11
Figure 2 Project Site Layout....1-12
Figure 3 Stage 5 Development 1-14
Figure 4 Surrounding Land Use....1-23
Figure 5 Existing-development Music model set-up....1-29
Figure 6 Post-development with no treatment Music model set-up 1-30
Figure 7 Post-development with treatment Music model set-up 1-31
Figure 8 Scatter Plot of Groundwater Levels....1-42
Figure 9 Variation in Groundwater Level During Primary Monitoring Period at P7 and P3.1-43
Figure 10 Visual Modflow Model for the Maximum Development Scenario (Stage 5) 1-45
Figure 11 3D View of Model set-up prior to dewatering for Stage 5 1-45
Figure 12 Modelled Maximum Drawdown of the Piezometric Surface....1-46
Figure 13 Approximate Location of Registered Groundwater Bores....1-49
Figure 14 Approximate Location of Drainage Lines Relative to the Project Site. 1-57

TABLES

Table 1 Borehole / Piezometer Details....1-19
Table 2 Average Monthly Rainfall and Evaporation at Nowra Ran Air Station 1955 – 2000 1-21
Table 3 October, November and December, 2007 Precipitation Observations 1-22
Table 4 Average Maximum and Minimum Monthly Temperatures (°C) at Nowra RAN AIR STATION between 1955 - 2000....1-22
Table 5 Approximate Project Site Catchment Areas (ha)....1-24
Table 6 Surface Water Quality Summary....1-25
Table 7 Stormwater Quality Criteria....1-26
Table 8 Catchment Parameters used for MUSIC Modelling, Nowra Brickworks Quarry, Nowra, NSW....1-32
Table 9 Approximate Water Storage Facility Properties Assumed for Modelling Purposes 1-33
Table 10 Mean monthly irrigation volumes for 4 ha irrigation field....1-33
Table 11 MUSIC modelling summary results for load data. 1-35
Table 12 MUSIC modelling summary results for concentration data....1-35
Table 13 Summary of RAFTS Modelling....1-37
Table 14 Summary of HECRAS Modelling 1-37
Table 15 Groundwater Quality Monitoring Results....1-39

CONTENTS

Page

Table 16 Typical Electrical Conductivity Ranges....1-40
Table 17 Summary of Horizontal Ksat Results....1-40
Table 18 Summary of Manual Groundwater Level Measurements (m AHD)....1-41
Table 19 Local Bore Data within an Approximate 8km Radius from the Project Site (CANRI, 2007)....1-48
Table 20 Summary of Groundwater Impact Assessment....1-52
Table 21 Assumptions used in Water and Salt Balance Modelling....1-55
Table 22 Summary of Nowra Creek Riparian Zone....1-58
Table 23 Nowra Creek Impact Assessment....1-59
Table 24 Coverage of environmental assessment requirements....1-126

EXECUTIVE SUMMARY

Overview

This report describes the findings of a detailed hydrological investigation conducted for the continuation and expansion of extractive operations at the Nowra Brickworks Quarry ("the Project") located at South Nowra, NSW. The report was conducted to support an *Environmental Assessment* (EA) to accompany an application under Part 3A of the *Environmental Planning and Assessment Act 1979* for project approval. The report documents existing site surface water and groundwater regimes and assesses in detail, the likely impacts of the Project, which may come about principally through modifications to the local surface water and groundwater configurations. In addition to this, the report documents management and mitigation measures to ensure potential environmental risks associated with the Project are minimised to an acceptable level. The report has two main components, the first being surface water assessment and the second being groundwater assessment.

Stormwater Management

The proposed stormwater management system for the Project is designed to produce a net neutral or beneficial impact to the water quality of surrounding water courses as a result of stormwater runoff from the Project Site and was designed for the maximum development scenario.

Stormwater and groundwater from within the excavation area is to be collected by perimeter cut-off drains and pumped to the site dam for storage and subsequent re-use. Aside from re-use for quarry machinery and dust suppression, re-use will also involve directing water from the storage reservoir to an irrigation field. This irrigation field is proposed to primarily provide mitigation against the impacts of discharging saline water to Nowra Creek. Grass buffer strips are proposed to buffer the paved road in the north eastern portion of the site and also the storage/car parking area in the north western portion of the site. Stormwater not collected by the storage reservoir and excavation pit is to exit the site via non-concentrated overland flow. Reconstruction of natural contours during quarry rehabilitation will allow this.

Modelling indicates that no discharges from the 50ML storage reservoir will occur provided that:

- the maximum extraction area open to the water table at full extraction depth is less than or equal to 2.95ha;
- the maximum pervious area (in addition to the extraction pit area) which can drain to the extraction area is less than or equal to 2.95ha;
- surface flows from remaining sections of the Project Site are directed away from the storage reservoir;
- pre-quarry surface contours are reconstructed during the progressive rehabilitation process so that all surface water flows to the west, north west and north; and
- a 4ha irrigation field is installed.

Median salt concentration of irrigated water is 760 mg/L. This is considered slightly saline and suitable for irrigation for the duration of quarrying operations.

Flood Assessment

Hydrologic modelling and subsequent hydraulic modelling were completed to assess the impact of the Project on the flooding behaviour of Nowra Creek and the impact of flooding on the Project. Results indicated that the Project will have a negligible impact on the flooding behaviour of Nowra Creek. Similarly, results indicate that the flooding behaviour of Nowra Creek would have no impact on the Project.

Groundwater Assessment

An assessment of groundwater was undertaken to determine the likely impacts of the Project on surface water and groundwater regimes. The assessment was based on existing development / post-development finite difference groundwater modelling using "VISUAL MODFLOW" and was calibrated with observed head measurements.

Results indicate that for the maximum development scenario the 1m contour for drawdown is likely to be located at a distance of approximately 1 427m from the extraction area.

A steep cone of depression will form immediately around the extraction area once extraction proceeds below the regional groundwater table. Whilst modelling indicates that gradients, head levels and flow directions will change due to the Project, modelling indicates that it is unlikely that these changes will extend to such a distance that they will impact on surrounding bores. Field investigations and modelling have demonstrated that Nowra Creek is hydraulically decoupled from the deeper groundwater system (ie. is a 'losing' stream'). Local groundwater table lowering will therefore not interfere with creek flow regime or groundwater dependent ecosystems. Based on the completed groundwater assessment it is concluded that the risks associated with the Project are acceptable to ensure groundwater values are not compromised.

Water and Salt Balance Assessment

A detailed water and salt balance assessment was completed for the site to determine site storage reservoir operation, performance and the need for timing of potential surface water and groundwater discharges. Both the salt balance and water balance models were based on the same daily 50 year evaporation and rainfall record.

Results of the water balance and salt balance modelling indicate that no discharge will occur from the storage reservoir to Nowra Creek.

Creek Assessment

Flood modelling results, visual field inspections and a salt balance model for Nowra Creek were used to determine its suitability for receiving stormwater/groundwater discharge. Results of water balance and salt balance modelling indicate that there will be no need to discharge from the storage reservoir to Nowra Creek. Flood modelling, stormwater modelling results and visual field inspections indicate that Nowra Creek is capable of receiving overland flow stormwater discharge from the Project Site.

To ensure Nowra Creek is adequately buffered, it was concluded that a 40m Core Riparian Zone (indefinitely required) in conjunction with an additional 10m buffer be applied to the Creek.

1 INTRODUCTION

1.1 Scope of Work

This report describes the findings of a detailed hydrological investigation conducted for the continuation and expansion of extractive operations at the Nowra Brickworks Quarry, South Nowra, NSW (the "Project Site"). The report was conducted to support an *Environmental Assessment* (EA) to accompany an application for project approval under Part 3A of the *Environmental Planning and Assessment Act 1979*. The report documents existing site surface water and groundwater regimes and assesses in detail, the likely impacts of the Project, which may come about principally though modifications to the local surface water and groundwater configurations. In addition to this, the report documents management and mitigation measures to ensure potential environmental risks associated with the Project are minimised to an acceptable level. The report has two main components, the first being surface water assessment and the second being groundwater assessment.

This report is an amendment from an earlier version dated December, 2007 and has been prepared in response to issues raised in letters from the NSW Government Department of Water and Energy (21.02.2008) and Department of Environment and Climate Change (31.01.2008).

Primary objectives of the investigation include the following.

Surface Water Assessment:

1. Determine site and nearby (Nowra Creek) surface water chemical properties.
2. Undertake a site water balance assessment to determine water ingress volumes to the extraction area, site water consumption/loss rates and site water management requirements.
3. Document existing stormwater quality measures at the Project Site.
4. Develop an existing-development and post-development stormwater quality model (MUSIC model) and assess requirements for stormwater quality management for on-site storage/treatment prior to discharge (if required).
5. Assess likely impacts associated with stormwater discharge (if required) to Nowra Creek.
6. Document the existing condition of Nowra Creek and provide recommendations for creek management to ensure that the risks associated with the Project are minimised.

Groundwater Assessment:

1. Determine and evaluate site aquifer chemical and hydraulic properties.
2. Assess long-term site groundwater levels.
3. Evaluate the "value" of the groundwater resource in terms of quality and extent of local usage.
4. Refine the conceptual hydro-geological model developed in the preliminary investigation stage to extend to the local area.
5. Develop a finite element groundwater flow model to simulate the existing-development and post-development groundwater regime.

6. Assess long-term and short-term impacts of the Project on groundwater.
7. Recommend management and mitigation measures to ensure the Project does not adversely impact on the quality and quantity of local groundwater regimes.

1.2 The Project Site

The Project Site (Lot 464, DP 1058778) is located adjacent to and to the west of the Princess Highway at South Nowra, NSW and is occupied by two Mining Leases (ML 5087 and ML 6322). The Project Site is bordered by the Princess Highway and industrial development to east and Crown land to the west. **Figure 1** shows the Project Site location within its local context.

1.3 Current Operations

Current operations within the Project Site include:

- removal of vegetation and soil;
- extraction of weathered and unweathered shale;
- importation of quarry products for blending operations;
- importation of waste concrete, bitumen and brick material for recycling operations;
- crushing and screening of unweathered shale, blending and recycling materials;
- loading and despatch of quarry products; and
- progressive rehabilitation.

The former works have taken place on ML 5087 and ML 6322.

1.4 Overview of the Project

The Proponent proposes to continue and expand the extraction, blending, processing, transportation and progressive rehabilitation operations at the Nowra Brickworks Quarry for a period of 30 years. In summary, the proposed continued and expanded use of the Nowra Brickworks Quarry would incorporate the following activities (**Figure 2**).

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's car park before the amount of quarry products despatched from the Project Site exceeds 250 000t per year.
- Staged extraction of up to 7 000t per year of weathered shale material using an excavator from a proposed extraction area of approximately 15ha, incorporating an existing extraction area of approximately 2ha for direct sale to the Proponent's customers.

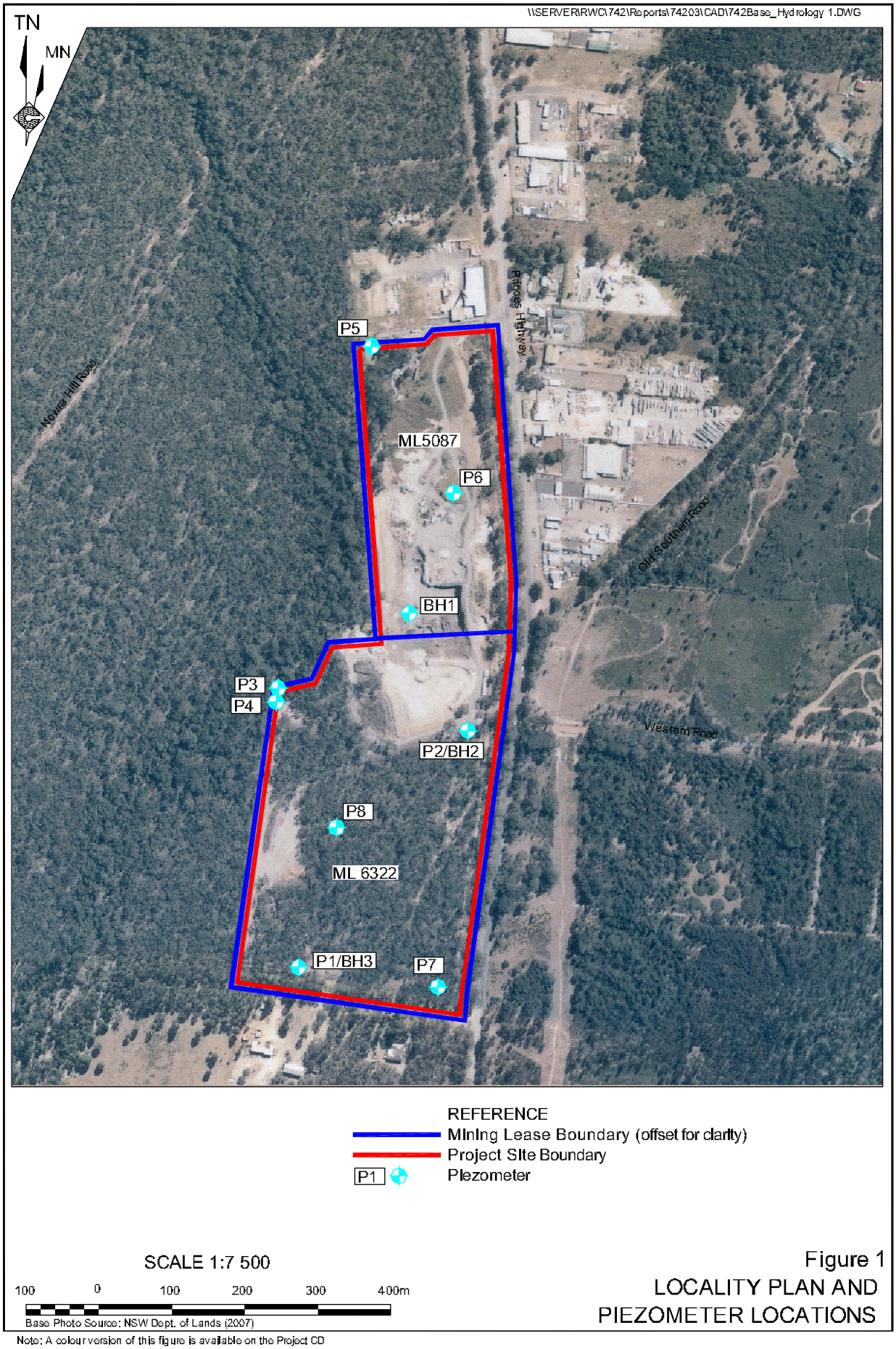

Figure 1
LOCALITY PLAN AND PIEZOMETER LOCATIONS

Note: A colour version of this figure is available on the Project CD

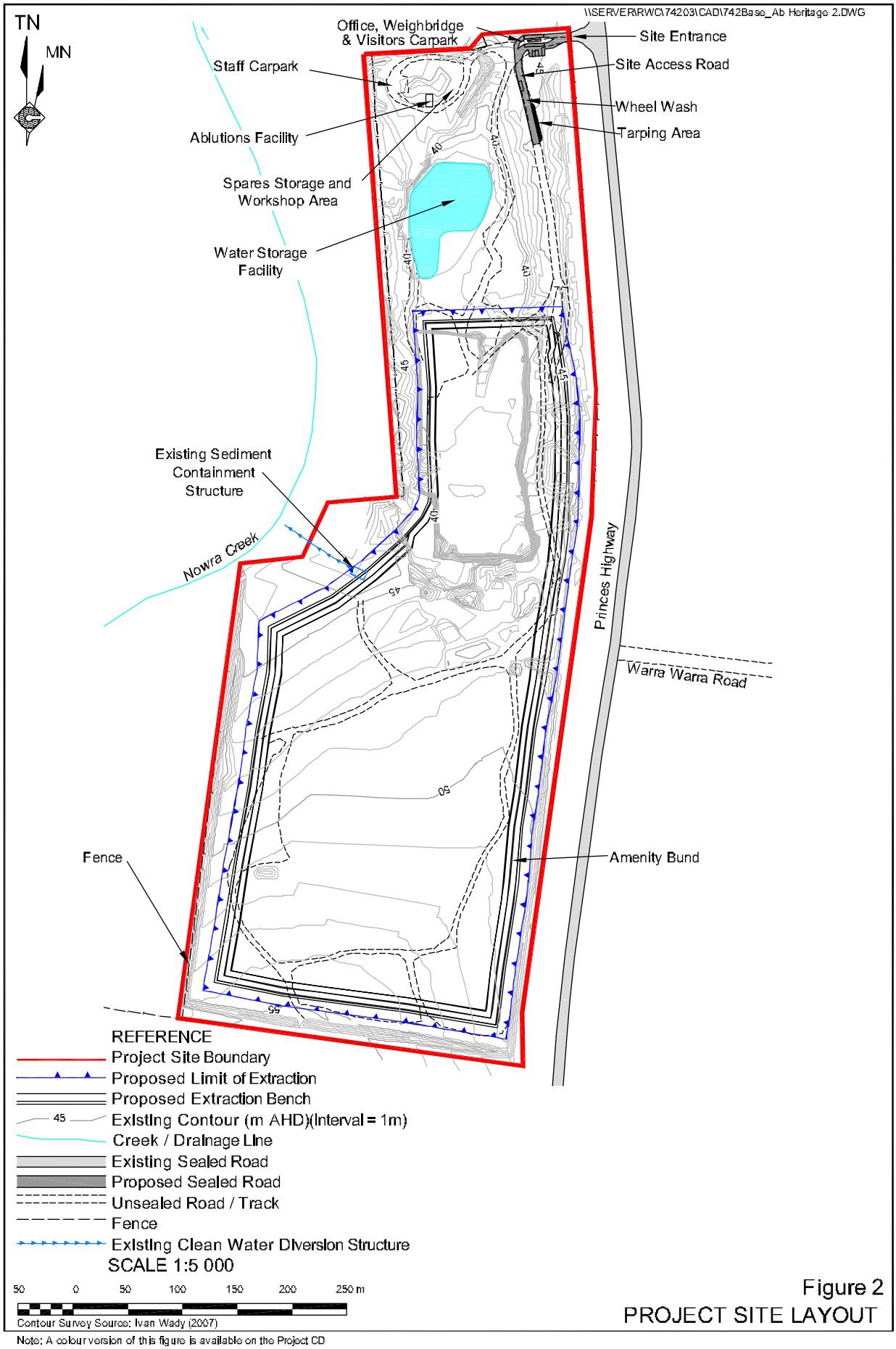

Figure 2
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

- Staged extraction of up to 350 000t per year of unweathered shale material ("extracted material") using drill and blast methods from the above extraction area for processing and blending to produce quarry products.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted and recycling materials to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A proportion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

For the purposes of modelling hydrology impacts, a maximum area of disturbance has been assumed. This corresponds with Stage 5 of the Project, identified in Section 2.4.5 and Figure 2.5 of the *Environmental Assessment*. **Figure 3** presents an overview of this stage. In summary, Stage 5 of the Project would incorporate:

- an extraction and Virgin Excavated Natural Material (VENM) placement area occupying the southern section of the Project Site;
- an area undergoing progressive rehabilitation;
- an area of completed rehabilitation; and
- areas disturbed for extraction-related infrastructure such as roads, offices, workshops and laydown areas.

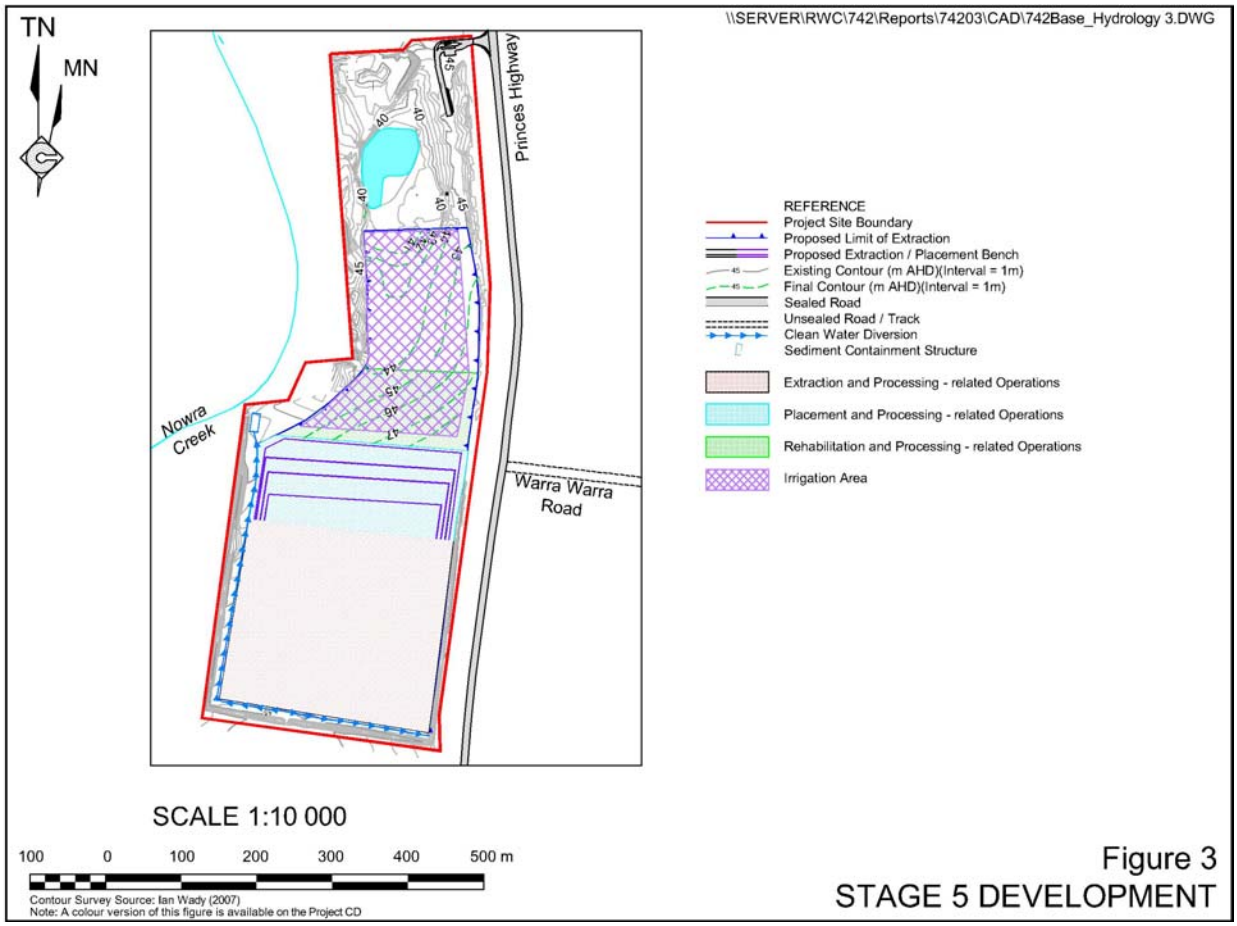

Figure 3
STAGE 5 DEVELOPMENT

1.5 Previous Investigations

A preliminary surface water and groundwater investigation was undertaken at the Project Site by Martens & Associates Pty Ltd (Report - P0701757JR01_V1) in August 2007. This investigation documented the Project Site's:

- existing surface water and groundwater regime;
- assessed potential impacts of the Project on surface water and groundwater; and
- determined areas where further investigation would be required.

The preliminary investigation was completed to accompany a *Preliminary Environmental Assessment* for the Project Site.

The preliminary investigation concluded that the following issues would require additional investigation to ensure environmental impacts and risks associated with the Project were minimised to an acceptable level.

<u>Surface Water</u>

- A water balance model will need to be prepared covering surface water and groundwater flows.

- A flood assessment may need to be conducted for Nowra creek in order to determine the likely impact on flood hydrology of the proposed ML 6322 operations.
- A stormwater management plan will need to be prepared.

Groundwater

- A more detailed field assessment of local groundwater conditions was recommended.
- A groundwater impact assessment would need to be prepared based on the preliminary information already provided and the additional information provided in (a) above.

Accordingly, this report addresses the above issues in detail to ensure surface water and groundwater impacts resulting from the Project are adequately assessed.

1.6 Relevant Planning Controls, Policy Objectives and Guiding Principles

The following planning controls, policy objectives and design principles have been considered in the development of surface water and groundwater strategies for the Project Site. These policies and principles generally underlie ideas and conceptual designs outlined in this report and are central to the ecological sustainability of the Project.

Surface Water

NSW Landcom (2004), Managing Urban Stormwater: Soils and Construction

This document provides guidelines for the management of sediment and erosion. Guidelines were developed with the intent to reduce pollution and land degradation through the application of control measures on a site by site basis.

NSW EPA (1998), Management Urban Stormwater: Treatment Techniques

This document forms part of a package of documents on managing urban stormwater published by NSW Government agencies in the late 1990's. This guideline aims specifically to provide guidance to stormwater planners and designers on the selection and functional (or conceptual) design of a range of structural stormwater quality management practices.

Managing Urban Stormwater: Council Handbook (NSW EPA 1997)

This handbook was prepared to assist local Council's in their preparation of Stormwater Management Plans (SMP's). Two objectives from Appendix H of the document are considered specifically relevant to the management of stormwater for the Project. That is, appropriate stormwater management should ensure:

- Implementation of 'best practice' stormwater management techniques; and
- No net increase in the average annual concentration of key pollutants, above that occurring under existing conditions.

National Water Quality Management Strategy: Australian Guidelines for Urban Stormwater Management (ANZECC, 2000)

This document provides a strategic framework for the appropriate integrated management of urban stormwater quality for the protection of public health and the environment. The main objective of this strategy is:

- *"To achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development."*

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is a philosophical approach to urban planning and design that aims to minimise the hydrological impacts of urban development on the surrounding environment. Stormwater management is an integral part of WSUD, directed at flood control, flow management, water quality improvements and opportunities to harvest stormwater and implement water conservation measures.

Key planning and design objectives encapsulated in Best Practice Water Sensitive Urban Design (WSUD) are as follows.

- Protect and enhance natural water systems.
- Integrate stormwater treatment into the landscape by incorporating multiple use corridors that maximise the visual and recreational amenity of the development.
- Protect water quality draining from developments.
- Reduce runoff and peak flows from developments by employing local detention measures and minimising impervious areas.
- Add value while minimising drainage infrastructure development costs.
- Provide an effective water conservation strategy, with consideration to wastewater and stormwater re-use and water demand reduction measures.

General WSUD principles have been applied to the Project Site stormwater management plan through:

- advocating site stormwater re-use;
- incorporating stormwater treatment into the landscape (irrigation field and storage reservoir);
- ensuring the treatment process is sufficient so that there is no adverse impact of receiving waters; and
- managing peak run-off volumes with on-site detention.

Water Quality and River Flow Environmental Objectives for Clyde River and Jervis Bay (NSW Department of Environment and Conservation)

Objectives of this strategy are primarily focused on agreed environmental values and long-term goals for surface waters. Objectives identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

Environmental values and long-term goals are compared with a range of water quality indicators to assess whether the current condition of our waterways supports those values and uses. The Objectives are consistent with the agreed national framework for assessing water quality set out in the ANZECC (2000) guidelines.

Groundwater

National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)

These guidelines form part of the National Water Quality Management Strategy. The objective of these guidelines is to provide a mechanism which allows state, territorial and commonwealth governments to develop policies which are tailored to specific legislative and resource management circumstances. The guidelines were developed to protect groundwater from contamination and to ensure that the beneficial uses and values of groundwater, including the following are not adversely impacted.

- Ecosystem protection.
- Recreation and aesthetics.
- Water for drinking water supply.
- Agricultural water.
- Industrial water.

Whilst these guidelines do not specifically nominate contaminant target criteria for the assessment of groundwater, they do recommend surface water target criteria (ANZECC, 2000) that are appropriate for assessing groundwater.

NSW State Groundwater Policy Framework Document (DLWC)

The objectives of this document are as follows.

- Slowing, halting or reversing any degradation of groundwater resources.
- Ensuring long term sustainability of the systems ecological support characteristics.
- Maintaining the full range of beneficial uses of groundwater resources.
- Maximising economic benefit to the Region, State and Nation.

Key policy principles in line with the above objectives are presented in the document.

NSW State Groundwater Quality Protection Policy (DLWC)

This document is a component of the NSW State Groundwater Policy. The policy's main objective is to ensure that groundwater resources within NSW are managed so that they can sustain the environmental, social and economic uses for stakeholders. Policies outlined in the document were designed to protect groundwater resources from pollution through implementation of appropriate management plans.

NSW State Groundwater Dependent Ecosystem Policy (DLWC)

This document outlines policies specifically designed to sustain, and where possible, restore ecosystems which rely on groundwater for survival. The document also outlines various types and locations of groundwater dependent ecosystems.

The Impact of Groundwater Use on Australia's Rivers – Exploring the technical, management and policy challenges (Australian Government, Land and Water Australia, 2007)

This document provides a general overview of groundwater processes and focuses on the link between surface water and groundwater, and provides an overview of the impacts of pumping adjacent to surface waters. The document also outlines recommendations for the future integrated management of water.

The Impact of Groundwater Use on Australia's Rivers – Technical report (Australian Government, Land and Water Australia, 2007)

This document provides further technical detail to the previous document and presents methods for calculating the impact of groundwater extraction on surface waters. The document is largely structured around case studies and as such is practical and applicable to the Project.

1.7 Clarification of Reporting Terms

Throughout this report, the terms existing-development and post-development are used for the purposes of modeling and reporting. In the context of modeling and reporting for this document the former terms are defined as follows.

- Existing-development – quarry prior to approval and subsequent expansion of operations.
- Post-development – quarry after approval and subsequent expansion of operations. This term is applicable for when the quarry is operating and for the purposes of modeling and reporting does not imply that the quarry operation, including rehabilitation is complete. In most cases the term post-development is referring to stage 5 of quarrying operations which is the maximum development scenario for the quarry from a hydrogeological perspective.

The term pre-quarrying is also used throughout the report and refers to the site in its natural state prior to any quarrying activities or other development taking place.

2 PROJECT SITE DESCRIPTION

2.1 Field Investigations

The preliminary investigation included:

- drilling of three boreholes, namely BH1, BH2 and BH3;
- installation of two piezometers, namely P1 and P2 at BH3 and BH2 respectively;
- manual dip metering and instrumented measurement of groundwater levels;
- preliminary pump testing; and
- inspections of Nowra Creek.

Site investigations for the purpose of this investigation (*Environmental Assessment*) were undertaken on 18 and 19 September 2007, 4, 5 and 24 October 2007 and 7 December 2007, and included the following.

- Walkover inspection of the Project Site to assess the existing site hydrological environment and determine any hydrological conditions that may have potential to impact on the Project and/or surrounding environment.
- Drilling of six boreholes and subsequent installation of 6 additional piezometers, namely P3, P4, P5, P6, P7 and P8 on 18 and 19 September 2007, to allow for monitoring of *in-situ* groundwater level. Piezometer construction methodology consisted of the following.
  - Construction from 50mm UPVC tubing, fitted with UPVC end cap and covered with geotextile cloth prior to installation. 6m of slotted well screen was used for each piezometer with the exception of P4 where 1.5m of well screen was used.
  - Piezometers were backfilled with clean, washed fine gravel, capped with a layer of bentonite pellets and sealed with rapid set concrete.
  - All instrumented piezometers were fitted with lockable galvanised steel monuments.
  - P8 was cased with 9m of 90mm pipe to below the soil/rock interface and was used as a pumping piezometer to the determine the drawdown cone of depression.

Refer to **Appendix A** (Sheet 3) for the location of each borehole / piezometer and Table 1 for borehole/piezometer details. Testing is summarised as follows.

- A single sample of groundwater was micro-purged from each piezometer on the 4th October, 2007 and analysed by laboratory for a range of chemical properties. Samples were taken from the middle of the water column at all piezometers with the exception of P4 which remained dry throughout the study period.
- Pump testing was undertaken on 4, 5 and 24 October 2007 and 7 December, 2007 at P8 and P3 to allow for assessment of aquifer hydraulic properties.

Table 1
Borehole / Piezometer Details

Borehole / Piezometer Number	Location			Maximum Depth (m)	Depth to Top of Screen (mbs)	Length of Screen (m)
	Longitude	Latitude	Elevation (m, AHD)			
BH3	150°36’01.49””	34°55’42.56””	55.30	28.0	22	6
BH2	150°36’11.88””	34°55’32.94””	48.70	28.0	22	6
P3	150°36’02.23””	34°55’30.49””	43.97	29.0	23	6
P4	150°36’02.23””	34°55’30.49””	43.97	3.5	2	1.5
P5	150°36’06.69””	34°55’16.05””	42.77	24.5	18.5	6
P6	150°36’11.24””	34°55’22.75””	38.88	23.0	17	6
P7	150°36’09.67””	34°55’44.30””	50.99	35.0	29	6
P8	150°36’05.60””	34°55’38.70””	50.00	33.6	NA	NA
BH1	150°36’09.32””	34°55’28.09””	32.10	13.0	NA	NA
Notes: [1] Longitude and Latitiude derived from iplan (DIPNR, 2003) and Google Earth and are approximate only.						

- Pump testing was undertaken on the 24th October, 2007 in an attempt to provide data for a "cone of depression" analysis at P8. Response was measured at P1, P3 and P2. Manual dip metering was used in conjunction with high resolution groundwater monitoring 'Divers' with a sampling interval of 5 seconds located within P7 and P3 to measure response. A barometric 'diver' or 'barodiver' was also installed within P1 to allow for data correction.
- Installation of two high resolution groundwater monitoring 'Divers' with a sampling interval of 10 minutes within P7 and P3 from 04.10.2007 to 07.12.2007. A 'barodiver' was installed in synchronization with the water level monitoring divers to allow for data correction.
- Collection of two water samples from Nowra Creek both upstream and downstream of the site and subsequent laboratory analyses to cover a range of chemical properties on 5th October, 2007. Follow up sampling completed on 7th December, 2007 comprised of 9 water samples from Nowra Creek and 1 surface water sample which was collected adjacent to the western site boundary. All follow up samples were analysed for pH, EC, NTU, Redox, DO and temperature on-site using water quality probes.
- Inspection of Nowra Creek to determine channel type, channel properties and floodplain properties.
- Completion of nine surveyed cross sections perpendicular to the drainage line by John Mendham Engineering Surveys Pty Ltd during October 2007, for flood modelling purposes.

Locations of piezometers and piezometer construction details are shown on the site plan in **Appendix A** (Sheet 3).

2.2 Existing Topography

Elevations across the Project Site generally decrease progressively towards the active extraction area from the Project Site's northern, eastern, southern, and northwestern boundaries.

A sub-catchment with an area of approximately 9.129ha in the southern section of the Project Site drains towards a surface drainage depression (Nowra Creek) located to the northwest of the Project Site.

Site elevations range from approximately 55m AHD near the Project Site's southern boundary to approximately 30.5m AHD on the quarry floor. The Project Site has low grades with average slopes of approximately 5-10%.

Several minor overland flow paths were observed on the Project Site during site investigations due to prolonged significant rainfall. Overland flow paths drained towards the extraction area, the Project Site's eastern boundary and Nowra Creek.

2.3 Geology

The Wollongong 1:250 000 Geological Series Sheet SI 56-9 (Geological Survey of NSW, 1966) indicates that the Project Site's bedrock is characterised as Permian aged siltstone, shale and sandstone from the Berry Formation. Borehole drilling and inspection of excavation exposures confirmed the presence of predominantly siltstone and shale bedrock.

2.4 Soil Profile

Reference to the 1:100 000 Kiama Soil Landscape Series Sheet 9028 indicates that soils within the Project Site are red solodic soils near drainage lines and yellow podzolic soils on crests and are underlain by siltstone. A proportion of the Project Site is mapped as a disturbed soil landscape group due to quarry operations.

2.5 Climate

2.5.1 Precipitation and Evaporation

Average monthly rainfall and evaporation data recorded at Nowra (Nowra Ran Air Station) between 1955 and 2000 are summarised below in **Table 2**. In all months, with the exception of June, evaporation exceeds precipitation. On average, the months of March and February produce the most rainfall with mean falls of 124.4mm and 119.7mm respectively.

Table 2
Average Monthly Rainfall and Evaporation at Nowra Ran Air Station 1955 – 2000

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	91.3	119.7	124.4	97.1	90.5	107.0	57.0	75.8	65.6	107.5	98.1	73.1	1107.1
Evap. (mm)	195.3	159.6	145.7	120	96.1	87	96.1	127.1	150	176.3	183	213.9	1750.1
Source: Australian Government Bureau of Meteorology, 2007													

It is noted that groundwater monitoring for the purpose of the detailed environmental assessment was undertaken throughout October, November and December, 2007. **Table 3** shows days when rain was observed between 1 October, 2007 and 7 December, 2007 at Nowra Ran Air Station. Total monthly rainfall of October, 2007 was 12mm (**Table 3**) and was 95.5mm lower than the mean rainfall of 107.5mm outlined in **Table 2**. It is unlikely that low rainfall throughout October (2007) would have influenced the results of this study with respect to field investigations.

Total monthly rainfall of November, 2007 was 115.2mm (**Table 3**) and was 17.1mm higher than the mean rainfall of 98.1mm outlined in **Table 2**. It is unlikely that higher than average rainfall throughout November (2007) would have influenced the results of this study with respect to field investigations.

Water balance, salt balance and stormwater modelling were completed for the Project Site. We note that the former modelling was undertaken using data from the same data set which was summarised to form **Table 2**. However, the data set which was used for modelling incorporated all available daily evaporation and rainfall data from 1 January 1970 to 31 December 2000. This data was extended to form a synthetic climate file with a 50 year record (1 January 1970 to 31 December 2019). This method provides a more comprehensive approach than using percentile data as it uses all daily data in a continuous model.

Table 3
October, November and December, 2007 Precipitation Observations

October														
Date[1]	**12**		**13**		**25**		**26**		**27**		**29**		**Total**	
Rainfall (mm)	2.4		3.0		2.4		2.8		0.4		1.0		12.0	
November														
Date[1]	**2**	**3**	**4**	**5**	**7**	**9**	**10**	**11**	**12**	**18**	**22**	**23**	**24**	**27**	**30**
Rainfall (mm)	0.2	10.4	24.6	5.2	19.6	22.4	3.6	0.2	0.2	0.6	8.6	12.8	3.6	1.2	2.0
December															
Date[1]	**1**					**4**						**7**			
Rainfall (mm)	0.4					7.4						10			
Notes: [1] Precipitation data is collected in the 24 hr time period prior to 9am of the date depicted. [2] No precipitation was recorded for days not listed.															
Source: Bureau of Meteorology – Nowra RAN Air Station															

2.5.2 Temperature

Average maximum and minimum monthly temperatures (°C) at Nowra Ran Air Station are outlined below in **Table 4**. It is noted that field investigations were undertaken throughout the months of September, October, November and December 2007 which have mean monthly maximum temperatures of 19.3, 21.5, 23.1 and 25.1°C respectively.

Table 4
Average Maximum and Minimum Monthly Temperatures (°C) at Nowra RAN AIR STATION between 1955 - 2000

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Av max Temp (°C)	25.8	25.8	24.5	22.1	19.0	16.4	15.8	17.1	19.3	21.5	23.1	25.1
Av min Temp (°C)	16.1	16.3	14.8	12.1	9.7	7.6	6.2	6.7	8.3	10.7	12.6	14.6
Source: Australian Government Bureau of Meteorology 2007												

2.6 Off-site Surface Water Catchments

Surface water catchments surrounding the Project Site do not significantly influence surface water hydrological regimes within the Project Site. A bund approximately 3m to 4m high surrounds the Project Site's eastern, southern and western boundaries. Consequently, the majority of runoff from neighbouring off-site catchments does not enter the Project Site. Conversely, it is likely that neighbouring catchments do influence site groundwater regimes. **Figure 4** presents the land use patterns surrounding the Project Site and various land types (rural, natural, industrial and land altered by quarry operations) relative to the Project Site.

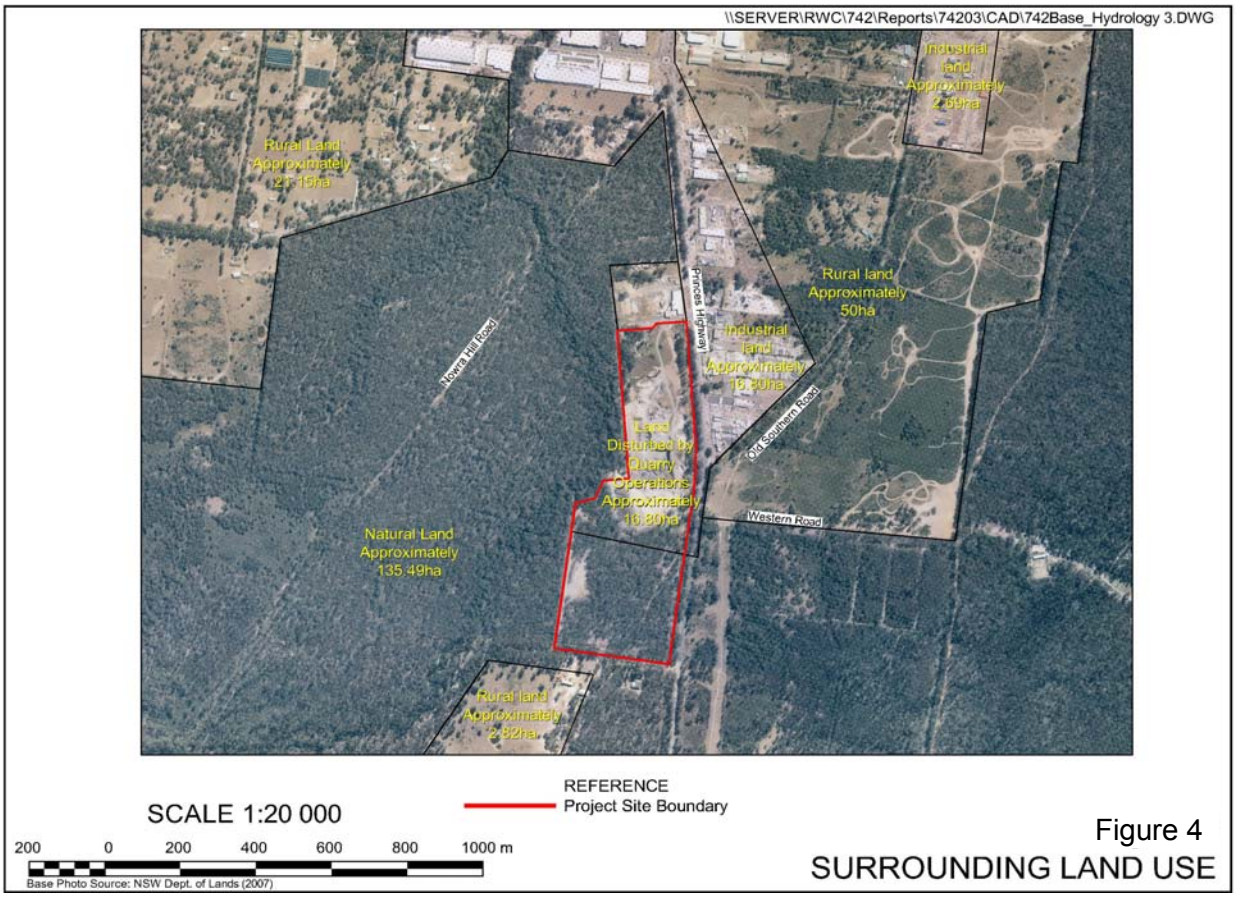

Figure 4
SURROUNDING LAND USE

2.7 Site Sub-catchments

2.7.1 Existing Sub-catchments

Existing development sub-catchments within the Project Site drain offsite to a drainage depression (Nowra Creek) to the west of the Project Site or drain to the existing extraction area / treatment wetland. Refer to **Appendix A** (sheet 4) for an existing development sub-catchment site plan which shows sub-catchment distribution and areas and **Table 5** for the approximate area of each existing development and post-development catchment.

2.7.2 Post-development

Post-development sub-catchments are to ensure the following:

- The maximum extraction area open to the water table at full extraction depth is less than or equal to 2.95ha.
- The maximum pervious area which can drain to the extraction area is less than or equal to 2.95ha.
- Surface flows are directed away from the storage reservoir.
- Pre-quarry surface contours are reconstructed during the progressive rehabilitation process so that all surface water flows to the west, north west and north.

Table 5
Approximate Project Site Catchment Areas (ha)

	Existing Development	Post-development
Drainage to excavation (ha)	11.955	5.900 (2.95 + 2.95)
Dam Surface Area (ha)	-	0.500
Drainage to dam (ha)	-	0.000
Drainage off-site (ha)	9.786	15.341
Total (ha)	**21.741**	**21.741**

3 STORMWATER MANAGEMENT STRATEGY

3.1 Existing Stormwater Management

3.1.1 Overview

At present, stormwater within the northern section of the Project Site drains to the extraction area. Stormwater collected from within the extraction area is then pumped to a Water Storage Facility with an area of approximately 4741m^2. At the time of writing, this Water Storage Facility is being expanded. The new Water Storage Facility will have an area of approximately 5 000m^2 when complete and capacity of approximately 50ML. All water within the existing Water Storage Facility is re-used onsite for dust suppression. Diversion structures, perimeter bunds, sediment fencing and dust suppression are also used to manage stormwater and sediment.

In the southern section of the Project Site, stormwater from Catchment 2 and Catchment 4 (**Appendix A** – sheet 4 – combined area of approximately 8.83ha without bunds and 9.129ha with bunds) drains off-site into Nowra Creek.

3.1.2 Stormwater Quality

Four samples of surface water collected were analysed for a range of chemical properties to determine suitable input parameters for stormwater modelling and to ensure treatment measures are designed to meet adopted design criteria. Eleven samples of surface water collected from Nowra Creek were also analysed. Refer to **Table 6** for a summary of results, **Appendix F** for a detailed laboratory report and **Appendix A** (sheet 5) for sampling locations.

Results indicate that Total Phosphorus concentration is below ANZECC (2000) trigger values for physical and chemical stressors in rivers of south-east Australia in slightly disturbed ecosystems for all but one sample (1757/C1). Sample 1757/C1 which was collected offsite and upslope of the Project Site has a value marginally above the ANZECC (2000) trigger values. MUSIC modelling (with inclusion of treatment structures) indicated that post-development Total Phosphorus concentration will be 0.032 mg/L and well below existing levels observed within the site and Nowra Creek.

Table 6
Surface Water Quality Summary

Sample Date	Sample ID	pH	EC (µs/cm) 1	TDS (mg/L) 2	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	BOD_5 (mg/L) 3	TSS (mg/L) 4	DO (mg/L) 5	Turbidity (NTU)	Temp C°
05.10.2007	1757/S1	8.2	7,900	4,345	<0.6	<0.05	<4	8	NA	NA	NA
	1757/S2	8.2	6,500	3,575	0.70	<0.05	<4	<5	NA	NA	NA
	1757/S3	7.9	8,000	4,400	53.00	<0.05	<4	29	NA	NA	NA
	1757/C1	6.6	250	138	1.70	0.08	<4	15	NA	NA	NA
	1757/C2	7.8	3,200	1,760	21.00	<0.05	4	20	NA	NA	NA
07.12.2007	1757/C3	6.4	2,050	1,128	NA	NA	NA	NA	2.36	28.0	20.1
	1757/C4	7.0	654	360	NA	NA	NA	NA	2.30	62.3	20.2
	1757/C5	6.9	1,168	642	NA	NA	NA	NA	3.20	28.3	21.0
	1757/C6	6.9	1,096	603	NA	NA	NA	NA	4.21	44.1	20.8
	1757/C7	6.0	290	160	NA	NA	NA	NA	3.60	89.6	20.5
	1757/C8	6.2	380	209	NA	NA	NA	NA	6.23	78.3	19.9
	1757/C9	5.9	247	136	NA	NA	NA	NA	5.93	64.4	21.4
	1757/C10	5.6	137	76	NA	NA	NA	NA	5.64	134.0	20.7
	1757/C11	5.7	123	68	NA	NA	NA	NA	5.72	45.1	20.9
	1757/S4 [8]	5.2	131	72	NA	NA	NA	NA	5.16	289.0	24.2
Project Site Geomean		8.1	7434	4089	2.81	<0.050	<4	10.51	NA	NA	NA
Nowra Creek Geomean		6.4	512	282	5.97	0.063	4	17.32	4.08	56.6	20.6

Notes: [1] Electrical Conductivity. [2] Total Dissolved Solids. [3] 5 day Bio-chemical Oxygen Demand. [4] Total Suspended Solids. [5] Dissolved Oxygen. [6] ####/C# - denotes creek water sample. [7.] ####/S# - denotes surface water sample. [8] Sample collected off-site and therefore not included in Project Site Geomean.

Total Nitrogen concentrations are generally elevated, with all samples being above the ANZECC (2000) trigger value. 1757/S3 returned a high concentration and was collected adjacent to machinery and a fuel container. Sample 1757/C1 which was collected offsite and upslope of the Project Site has a value above the ANZECC (2000) trigger values. MUSIC modelling (with inclusion of treatment structures) indicated that post-development Total Nitrogen concentration will be 0.71 mg/L and well below existing levels observed within the site and Nowra Creek.

Biochemical Oxygen Demand and total suspended solids are generally low for all samples and within recommended limits for discharge to streams (CALM, 1992).

Electrical conductivity and Total Dissolved Solid results indicate that certain samples maintain elevated salt levels. Samples 1757/S1, 1757S2, 1757/S3, 1757/C2, 1757/C3, 1757/C5 and 1757/C6 are slightly to moderately saline.

pH data indicates slight to moderate alkalinity for surface water samples and slight to moderate acidity for creek water samples.

Geometric mean Total Suspended Solid concentration with Nowra Creek is 17.32 mg/L and well above the concentration of 9 mg/L which was determined by post-development MUSIC modelling (with inclusion of treatment structures).

Dissolved Oxygen (DO) concentrations are low and indicative of low stream flow. The presence of large pools in the creek system is likely to have a significant influence of creek DO concentrations.

Turbidity concentrations are low to moderate. Temperature remains relatively consistent throughout the length of the reach of creek were samples were taken.

3.2 Stormwater Management Objectives

The following objectives were considered throughout the development of the concept stormwater management strategy.

1. National Water Quality Management Strategy targets (ANZECC, 2000) for lowland river (<150m altitude) ecosystems.
2. Less than or equal to existing development pollutant concentrations.
3. 45% retention of average annual Total Nitrogen and Total Phosphorus loads and 80% retention of average annual Suspended Solid loads (EPA, 1998).
4. Healthy Rivers Commission and Statement of Intent for the Shoalhaven River System objectives (adopts ANZECC, 2000 guidelines).

Table 7 summarises the Stormwater Quality Criteria that would be adopted for the Project.

Table 7
Stormwater Quality Criteria

Criteria	Total Nitrogen	Total Phosphorous	Suspended Solids
Pollution Load			
EPA (1998)	45 % retention of average annual load (57.75 kg/year)	45 % retention of average annual load (3.44 kg/year)	80 % retention of average annual load (2820 kg/year)
Pollution Concentration			
Less than or equal to pre-quarrying pollutant concentrations	≤0.72 (mg/L)	≤0.03 (mg/L)	≤9 (mg/L)
ANZECC (2000) Guide	0.5mg/L	0.05mg/L	NA
Adopted Load Target	**57.75 (kg/year)**	**3.44 (kg/year)**	**2820 (kg/year)**
Adopted Concentration Target	**≤0.72 (mg/L)**	**≤0.03 (mg/L)**	**≤9 (mg/L)**

The adopted design criteria (**Table 7**) are considered to be adequate to ensure that stormwater released from the Project Site does not adversely affect the receiving body of water (Nowra Creek). We note that salt is not capable of being modelled in MUSIC and is treated separately by daily water and salt balance modelling **(Section 6).**

It is also noted that at present, minimal stormwater from disturbed sections of the Project Site flows to natural drainage lines off site.

Litter is not considered to be a key pollutant at the Project Site since site operations are not open to the public and primarily concerned with shale extraction activities and drainage is internal.

3.3 Stormwater Modelling

3.3.1 Overview

The Model for Urban Stormwater Improvement Conceptualisation (*MUSIC*, Version 3.0.1) developed by the CRC for Catchment Hydrology was utilised to evaluate pre-quarrying and post-development key pollutant loads and concentrations emanating from the Project Site. Although the model is not a precise engineering tool, it provides a useful mechanism for investigating and refining the performance of a stormwater management scheme so that best management practices are achieved at a site. *MUSIC* uses algorithms to model various common types of stormwater quality improvement structures based on known performance data.

The adopted design criteria were used to assess various stormwater treatment measures to ensure that target criteria (**Table 7**) could be met.

3.3.2 Modelling Approach

Three scenarios were modelled.

1. Pre-quarrying - Catchment conditions prior to commencement of quarrying activities.
2. Post-development without treatment – Catchment conditions for the maximum likely development scenario (Stage 5 – Sheet 8 – **Appendix A**) without stormwater treatment measures implemented.
3. Post-development with treatment – Catchment conditions for the maximum likely development scenario (Stage 5 – Sheet 8 – **Appendix A**) with stormwater treatment measures implemented.

3.3.3 Modelling Set-up and Inputs

- Climate Data – A 50 year synthetic climate file was developed based on Nowra RAN Air Station observations and was used for modelling. This record included daily rainfall and evaporation for the entire data set and therefore is considered appropriate to take into account seasonal variations in rainfall in the vicinity of the Project Site.
- Existing development -To model existing development conditions the Project Site was represented as a single sub-catchment and linked to a receiving outlet node (**Figure 5**).

- Post-development without treatment - To model post-development conditions, the Project Site was represented as 7 sub-catchments and linked to a post-development receiving outlet node (**Figure 6**). Groundwater discharge was represented in this model using a user node constructed from imported data. Flow rate for the imported data was based on the groundwater inflow calculated in the water balance assessment (40KL/day) with pollutant concentrations based on site testing.
- Post-development with treatment - To model post-development conditions with treatment methods, the Project Site was represented as 7 sub-catchments and linked via a pond and buffer strips to a post-development receiving outlet node (**Figure 7**). Groundwater discharge was represented in this model using the same figures and method which was used for the post-development without treatment model.

  Surface water treatment modelling included:

  a) Passing water from catchments C3a and C3b identified in **Figure 7** into the 50 ML storage dam; and

  b) Irrigation of water from the 50 ML storage dam to the allocated 4 ha irrigation area and allocation of water from the storage dam to site surfaces for the purpose of dust suppression. The storage dam was assigned a total annual re-use of 102.3 ML/year based on the former re-use components. This annual re-use value was based on water balance results **(Section 6).**

Refer to **Table 8** for existing development and post-development catchment / land-use parameters used during MUSIC modelling.

3.4 Stormwater Management Measures

A range of stormwater management devices/structures have been incorporated into the stormwater management strategy.

3.4.1 Storage Reservoir

The water storage facility would provide both stormwater treatment and peak storm flow attenuation. Stormwater from within the extraction area is proposed to be pumped to the storage dam for detention, sedimentation and nutrient removal before re-use on-site.

A detailed sediment and erosion control plan prepared for the Project by Morse McVey (November, 2007) provided preliminary design details for site sediment basin requirements and concluded that the site sediment basin is to:

- have a total volume of 6 088m³; and
- contain a sediment settling zone of 6 048m³ and a sediment storage zone of 40m³.

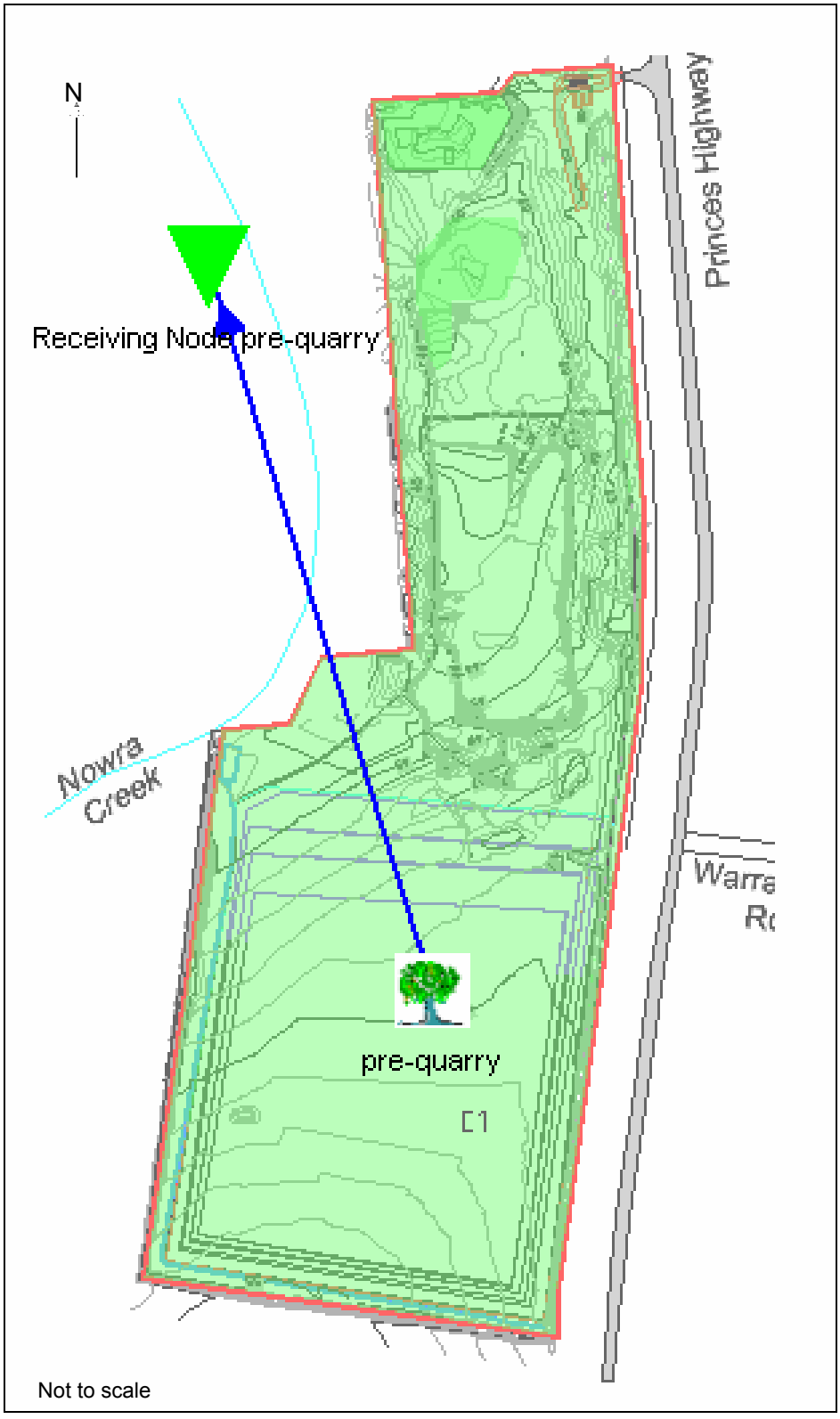

Figure 5
Existing-development Music model set-up

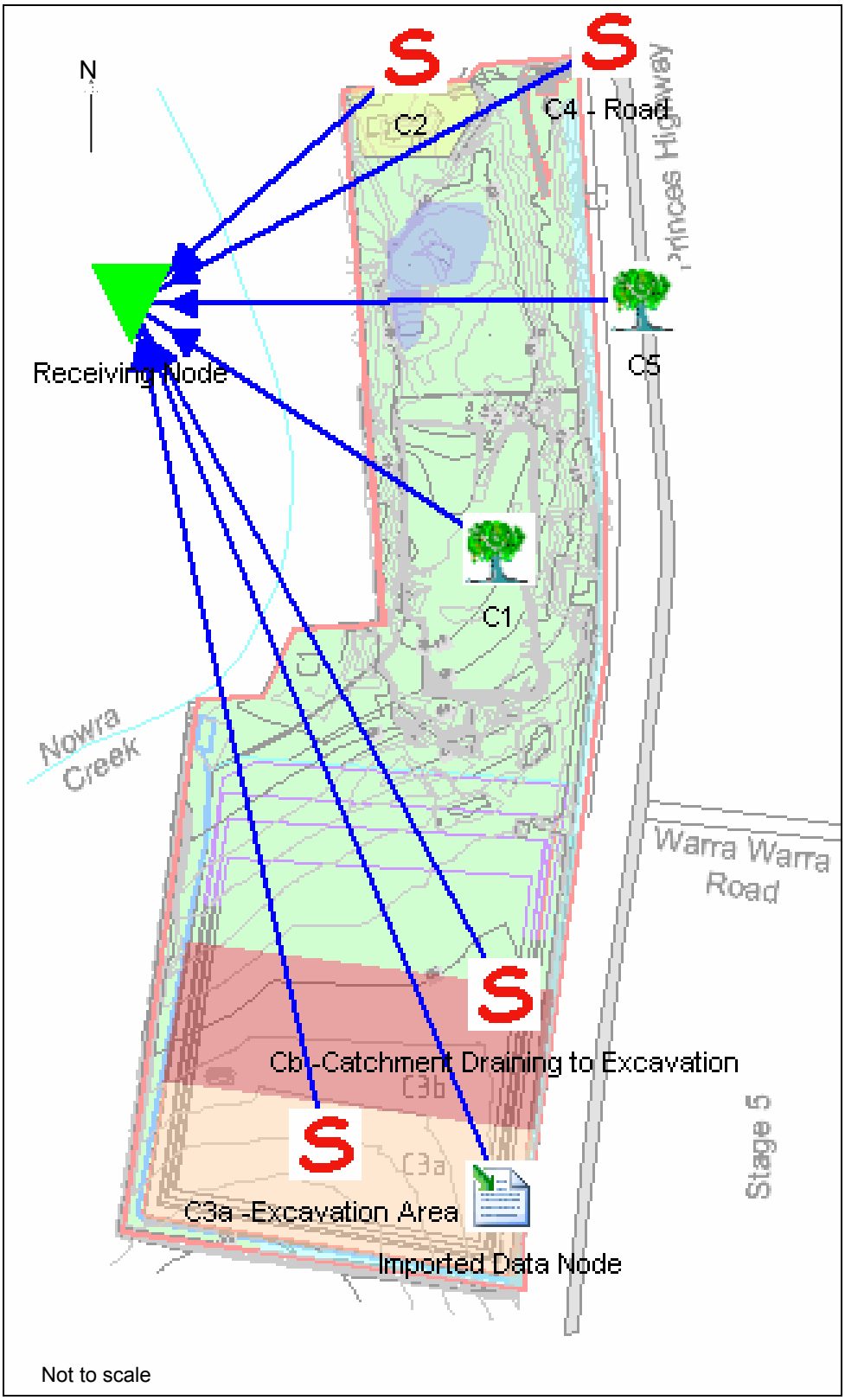

Figure 6
Post-development with no treatment Music model set-up

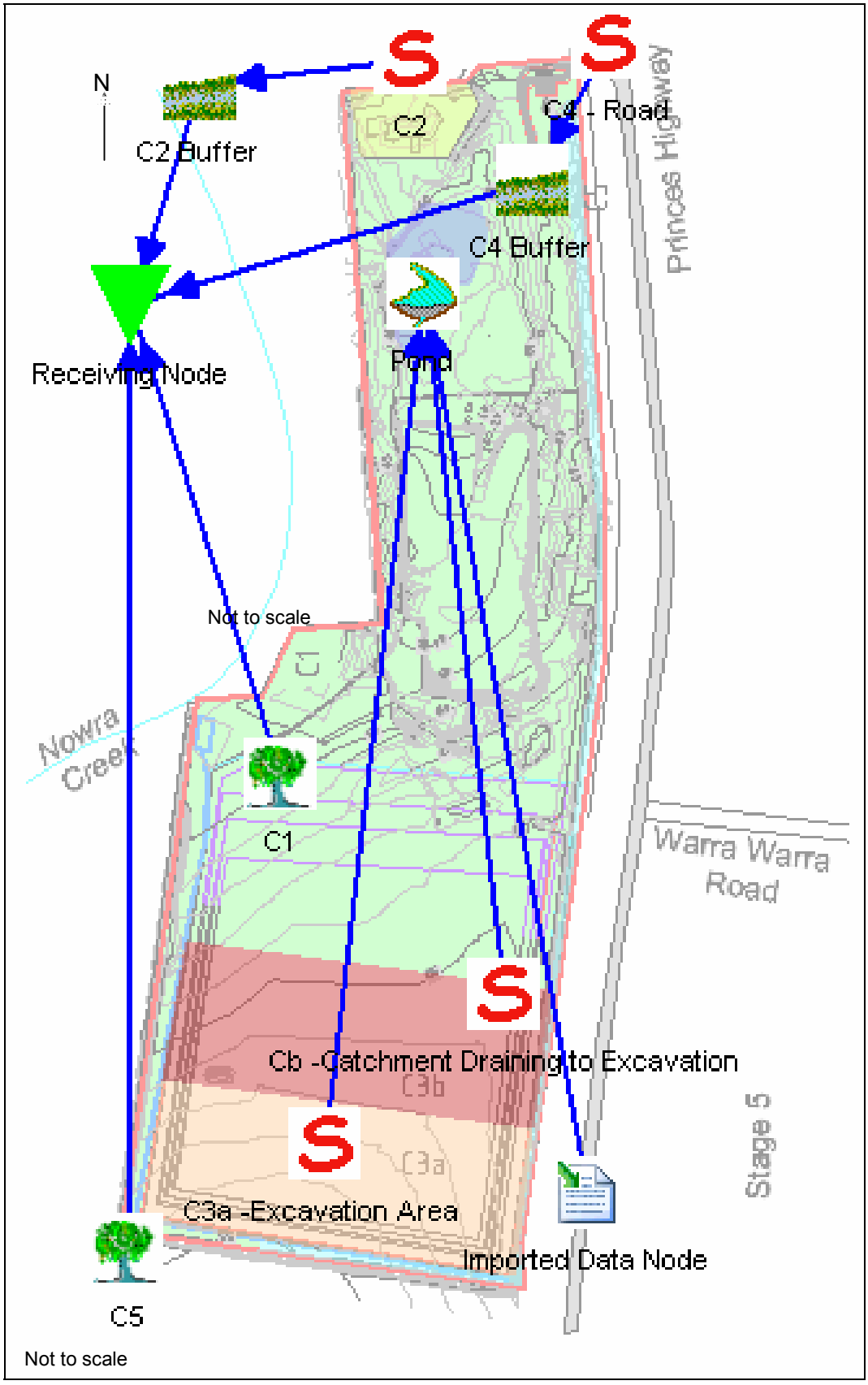

Figure 7
Post-development with treatment Music model set-up

Table 8
Catchment Parameters used for MUSIC Modelling, Nowra Brickworks Quarry, Nowra, NSW

Catchment	Landuse	Existing Development	Post-development
C1	Dirt Roads (ha)	-	-
	Sealed Roads (ha)	-	-
	Disturbed (ha)	-	-
	Bushland (ha)	21.324	14.127
	Disturbed Extraction Area (ha)	-	-
	Impervious Area %	0	0
	Ultimate Destination	-	Off-site
C2	Dirt Roads (ha)	-	-
	Sealed Roads (ha)	-	-
	Disturbed (ha)	-	-
	Bushland (ha)	-	0.458
	Disturbed Extraction Area + Immediate Surrounding Area (ha)	-	-
	Impervious Area %	-	2
	Ultimate Destination	-	Off-site (after treatment)
C3a + C3b	Dirt Roads (ha)	-	-
	Sealed Roads (ha)	-	-
	Disturbed (ha)	-	-
	Bushland (ha)	-	-
	Disturbed Extraction Area + Immediate Surrounding Area (ha)	-	C3a – 2.95, C3b – 2.95
	Impervious Area %	-	C3a - 99% (due to rock), C3b – 0%
	Ultimate Destination	-	Re-used on-site
C4	Dirt Roads (ha)	-	-
	Sealed Roads (ha)	-	0.103
	Disturbed (ha)	-	-
	Bushland (ha)	-	-
	Disturbed Extraction Area + Immediate Surrounding Area (ha)	-	-
	Impervious Area %	-	100
	Ultimate Destination	-	Off-site (after treatment)
C5	Dirt Roads (ha)	-	-
	Sealed Roads (ha)	-	-
	Disturbed (ha)	-	-
	Bushland (ha)	-	0.736
	Disturbed Extraction Area + Immediate Surrounding Area (ha)	-	-
	Impervious Area %	-	0
	Ultimate Destination	-	Off-site (after treatment)
Notes: [1.] Where % is not specified for a landuse value in column 2, values in columns 3 and 4 are in ha.			

The 50 ML surface water storage facility is capable of achieving the above design parameters.

After water collected from within the water storage facility has undergone sedimentation, it would be used for on-site dust suppression purposes and to irrigate the irrigation field. According to detailed water balance modelling (**Section 6**) no discharge to Nowra Creek from the storage reservoir will occur provided that;

- the catchment area open to the water table at full extraction depth is less than or equal to 2.95ha;
- the maximum pervious area draining to the extraction area is less than or equal to 2.95ha;

- surface flows will be directed away from the storage reservoir; and
- that pre-quarry surface contours are reconstructed during the progressive rehabilitation process so that all surface water flows to the west, north west and north.

A summary of basic design properties of the water storage facility which have been assumed for modelling purposes is provided in **Table 9.**

Table 9
Approximate Water Storage Facility Properties Assumed for Modelling Purposes

Property	Value
Catchment Area (ha)	5.9 (2.95 + 9.95)
Surface area (m^2)	5000
Extended detention depth (preliminary)	2 m
Approximate permanent pool volume (m^3)	47 000

3.4.2 Irrigation Field

A 4ha surface spray/surface drip irrigation field is proposed for the site. This irrigation field is proposed primarily for the purposes of providing mitigation against the impact of discharging potentially slightly to moderately saline water to Nowra Creek.

Stormwater from the site dam is proposed to be pumped to the 4 ha irrigation field which is to occupy the quarry in the vicinity of operation stages 4, 5 and 6 (**Appendix A**, sheet – 6 and 8). Once quarrying encroaches on the irrigation field it is to be relocated to the north on newly rehabilitated land. Preliminary specifications of the proposed irrigation field are shown below with a preliminary concept stormwater plan in **Appendix A** – sheet 6 and mean monthly irrigation volumes provided in **Table 10**.

To achieve stormwater treatment design criteria, completed modelling indicates that the following preliminary specifications will be required.

- Minimum irrigation area of 4ha.
- Surface spray or surface drip poly irrigation lines.
- Planted with suitable (or existing) vegetation (grass/eucalypts) depending on permanency of re-use field.

Table 10
Mean monthly irrigation volumes for 4 ha irrigation field

Mean monthly irrigation volume (ML/month)											
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
4.576	3.813	4.027	4.431	3.670	3.244	3.763	6.011	6.639	7.242	5.657	5.798
Notes: [1.] Based on water balance model results.											

Detailed water balance modelling indicates that the median salt concentration of irrigated water is 760 mg/L. This is considered slightly saline, within the range of salt levels found in local surface waters, and suitable for irrigation for the duration of quarrying operations.

Detailed design of the irrigation field should be provided at final design stage and include any specifications for poly irrigation lines, sprinklers and pumps.

3.4.3 Stormwater Release Point

Water balance assessment (**Section 6**) indicates that no discharge from the storage reservoir to Nowra Creek will occur. Consequently, no stormwater release point(s) at Nowra Creek are required. Overland flow will occur as per the pre-quarrying hydrological regime. This overland flow (non-concentrated) will not require a formal discharge point and will discharge to Nowra Creek via sheet flow. To facilitate this pre-quarry flow surface contours will need to be reconstructed during the progressive rehabilitation process so that all surface water flows towards Nowra Creek. This may require removal of the western bund or placement of pipes through the bund and filling to reinstate pre-quarrying contours and is to be specified at detailed design stage.

3.4.4 Grassed Buffer Strips

Grassed buffer strips are required to buffer the paved road in the northern portion of the site and also the equipment storage/staff car parking area. The paved road required a grassed buffer strip of 105 m long and 5 m wide and the equipment storage/staff car parking area requires a 145 m long and 16 m wide grassed buffer strip. The former grassed buffer strips are shown on the site plan in **Attachment A** (sheet 6).

3.5 Stormwater Modelling Results

Modelling results for pre-quarrying activities, post-development without treatment and post-development with treatment are summarised in **Table 11** and **Table 12**. Results indicate that treatment utilising the site's 50 ML storage reservoir and re-use of excess surface water by irrigation over a 4 ha irrigation field are capable of reducing mean pollutant concentrations to equal to or less than those modelled for the pre-quarrying scenario. Results also indicate that proposed treatment structures are capable of meeting pollution load retention targets.

Modelling demonstrates that the proposed conceptual stormwater management strategy is effective in reducing key water quality contaminant concentrations and loads and if implemented would serve to meet adopted design stormwater quality criteria. Modelling results indicate that ANZECC (2000) guidelines will not be compromised as mean post-development pollutant concentrations are lower than mean existing-development pollutant concentration.

Results confirm that the potential impact of suspended solids being discharged to Nowra Creek is likely to have no significant impact on the surface water environment within Nowra Creek. Water balance modelling in **Section 6** indicates that there will be no discharge from the site storage reservoir. Refer to **Appendix B** for pre-quarrying and post-development MUSIC modelling outputs.

Table 11
MUSIC modelling summary results for load data.

Scenario	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	Total Suspended Solids (kg/yr)
Pre-quarrying	48.5	3.81	3260
Post-development (no-treatment)	105.0	6.25	14100
Post-development (with treatment, storage reservoir, 4 ha irrigation field, buffer strips)	36.1	3.18	2270
Target	57.75	3.44	2820
Retention (%)	66	49	84
Compliance (y/n)	Yes	Yes	Yes

Table 12
MUSIC modelling summary results for concentration data

Scenario	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
Pre-quarrying	0.72	0.03	9
Post-development (no-treatment)	1.10	0.03	70
Post-development (with treatment, storage reservoir, 4 ha irrigation field)	0.70	0.03	9
Target	0.72	0.03	9
Compliance (y/n)	Yes	Yes	Yes

3.6 Conclusion

The proposed stormwater management strategy is practical, cost effective and, if implemented and appropriately maintained, will reduce key stormwater pollutants in-line with the adopted design criteria. All stormwater from developed areas of the Project Site will undergo some form of treatment before entering the existing watercourses or be contained within the site and used for re-use purposes.

The proposed system is an integral part of the Project Site's overall sustainability and demonstrates 'best management practice' solutions in-line with the principles of Water Sensitive Urban Design (WSUD) and Ecologically Sustainable Development (ESD). The proposed system realises the following benefits.

- The water storage facility would enable beneficial re-use of stormwater and would act as on-site detention and flow control structure and provide water quality treatment.
- The irrigation field will eliminate the need for the discharge of saline water from the storage reservoir to Nowra Creek.

4 FLOOD ASSESSMENT

4.1 Overview

A flood assessment was completed for Nowra Creek which flows adjacent to the western boundary of the Project Site. This was done for three primary reasons.

- To determine the extent of influence that the Project will have on local flooding behaviour.
- To determine the extent of influence that local flooding will have on the Project.
- To determine optimal location(s) for discharge points so that excess stormwater (if required) can be sustainably discharged into Nowra Creek.

4.2 Methodology

Methodology for flood assessment was as follows.

- Profiles of 9 channel cross sections were completed by John Mendham Engineering Surveys Pty Ltd during October and November 2007 for flood modelling purposes (**Appendix A** – sheet 7).
- The section of creek adjacent to the Project Site was "walked" on 24 October 2007 to examine creek morphology.
- Run-off flow rates were calculated using the hydrological model (XP-RAFTS). Sub-catchments were assigned in order to allocate appropriate flow rates for various sections of the creek for hydraulic modelling input.
  - Total catchment area was estimated to be approximately 142.8ha (existing development) and 135.12ha (post-development) on the basis of 1:25 000 topographic mapping and area measurement in CAD.
  - Manning's 'n' friction coefficient values were estimated and assigned to each sub-catchment based on visual field observations.
  - Percentage of sub-catchment impervious area was estimated on the basis of aerial photography.
  - Peak flow rate was determined for the critical duration 1:100 year ARI flood and probable maximum flood (PMF) (1:1 000,000 year ARI flood event).
  - Critical duration was determined iteratively by running a range of storm durations and was determined to be 120 minutes.
- A HECRAS 3.1.1 hydraulic model was prepared using the survey data and flow rate estimations for the critical duration 1:100 ARI flood and PMF.
  - Manning's 'n' friction coefficient values were assigned to the channel bed, bank and floodplain and were based on site observations.
  - Flow rates were assigned to sections based on completed hydrological modelling.
- The impact of flooding on the Project was assessed.
- The impact of the Project on flood behaviour was assessed.

4.3 Results

4.3.1 Hydrological Modelling

Results of hydrological modelling are summarised in **Table 13**. Refer to **Appendix C** for hydrological modelling (RAFTS) outputs.

Table 13
Summary of RAFTS Modelling

	Sub-catchment 1	Sub-catchment 2	Sub-catchment 3	Sub-catchment 4
Existing development area (ha)	70.83	40.29	11.20	12.81
Post-development area (ha)	70.83	32.61	11.20	12.81
Existing development 1:100 year ARI flow rate (m³/s) [1]	13.5	22.8	25.2	28.0
Post-development 1:100 year ARI flow rate (m³/s) [1]	13.5	21.6	24.4	27.1
Decrease to 1:100 year ARI flow rate (m³/s) [1]	0	1.1	0.8	0.8
Existing development PMF (m³/s) [1]	51.2	86.3	94.7	104.7
Post-development PMF (m³/s) [1]	51.2	82.0	90.7	100.7
Decrease to PMF flow rate (m³/s)	0	4.3	4.0	4.0

Notes: [1] Critical storm duration of 120 minutes.

4.3.2 Hydraulic Modelling

Results of hydraulic modelling are summarised in **Table 14**. Refer to **Appendix D** for hydraulic modelling (HECRAS) section outputs.

Table 14
Summary of HECRAS Modelling

	Nowra Creek Section Number [3]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Existing development 1:100 year ARI flood level (m AHD)	37.20	37.42	38.03	40.27	40.98	43.46	46.20	46.95	47.32
Post-development 1:100 year ARI flood level (m AHD)	37.17	37.41	38.01	40.25	40.95	43.42	46.20	46.95	47.32
Decrease to 1:100 year ARI flood level due to development (m)	0.03	0.01	0.02	0.02	0.03	0.04	0	0	0
Existing development PMF[4] (m AHD)	38.10	38.45	38.92	41.22	42.10	44.74	46.62	47.88	48.37
Post-development PMF[4] (m AHD)	38.07	38.41	38.88	41.18	42.04	44.68	46.62	47.88	48.37
Decrease to PMF[4] due to development (m)	0.03	0.04	0.04	0.04	0.06	0.06	0	0	0

Notes: [1] Critical storm duration of 120 minutes.
[2] Flow rate for hydraulic modelling (HECRAS) based hydrological modelling (**Table 11**).
[3] Sections numbers, refer to **Appendix A** – Sheet 7.
[4] PMF = Probable Maximum Flood

4.3.3 Impact of Flooding on Development

Review of cross section out-put for the critical duration 1:100 year ARI existing development and post-development flood indicates that flood waters would be contained within the floodplain at all sections. Post-development flood levels are marginally lower at some sections when compared to existing development levels by 0.01m to 0.04m due to a minor reduction in catchment area. Overall, this difference is considered negligible.

Review of cross section out-put for the critical duration existing development and post-development PMF indicates that flood waters are contained within the floodplain at all sections with the exception of cross Section 2. Post-development PMF levels are lower at some sections when compared to existing development levels by 0.03m to 0.06m due to a reduction in catchment area. Overall this difference is considered negligible. Hydraulic modelling indicates that local flooding will not encroach upon the development areas.

4.3.4 Impact of Development on Flooding

The catchment area of Nowra Creek will be temporarily reduced due to the Project by approximately 7.68ha for the duration of site operations. We note that given Nowra Creek is a 'stream' flow system with no real base flow, that this minor decrease will be compensated by overland flow run-off from the northern portion of the site.

4.4 Conclusion

On the basis of hydrological and hydraulic modelling, we make the following conclusions.

1. The Project would result in a negligible decrease in peak flow rate due to on-site detention of stormwater (through the extraction activities and water storage facility).
2. The Project would maintain natural environmental flows in Nowra Creek.
3. The Project would not encroach on flood liable land.

5 GROUNDWATER ASSESSMENT

5.1 Overview

A detailed groundwater assessment was conducted for the Project Site to enable groundwater related impacts of the Project to be thoroughly evaluated. In summary, the assessment involved the following.

- Installation of 8 piezometers and subsequent monitoring of groundwater levels.
- Establishment of an existing development and post development hydro-geological finite difference model using Visual MODFLOW Professional 4.2.
- Evaluation of groundwater inflows to the proposed extraction area required for the Project.
- Evaluation of dewatering impacts on local environment, regional environment and local potential/existing groundwater bores.

5.2 Piezometer Installation Summary

With three exceptions, piezometers were installed to a depth beyond the proposed depth of extraction. A summary of each piezometer installation is provided in Table 1.

We note that due to extremely wet ground conditions at the time of installation, some borehole collapse occurred at the borehole which was drilled to accommodate P5. This meant that piezometer penetration was somewhat less than the full extent of the borehole depth. P4 was installed at a shallow depth to examine shallow groundwater flows to Nowra Creek. We note that this was dry throughout the monitoring period and therefore suggests that shallow groundwater flow to Nowra Creek does not occur.

5.3 Existing Groundwater Conditions

5.3.1 Groundwater Water Quality

Groundwater samples were micro-purged from all piezometers on the 4 October 2007 and analysed for a range of chemical properties. All samples were collected from the central region of the water column. Refer to **Table 15** or a summary of groundwater quality monitoring results and **Appendix F** for the laboratory report.

Table 15
Groundwater Quality Monitoring Results

Parameter	P1	P2	P3	P5	P6	P7	P8	Geometric mean
pH	6.8	7.7	7.2	7.3	7.4	7.0	7.2	7.20
Electrical Conductivity (µS/cm)	9,100	5,700	12,000	9,500	5,400	11,000	11,000	8,730
Total Dissolved Salt (mg/L)	5,005	3,135	6,600	5,225	2,970	6,050	6,050	4,801
Nitrate-N (mg/L)	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10
Nitrite-N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TKN-N (mg/L) [2]	0.6	1.3	1.2	2.0	1.1	1.1	1.1	1.14
Ammonia-N (mg/L)	0.30	0.80	0.60	1.0	<0.10	0.90	1.0	≤0.54
TN-N (mg/L) [3]	0.7	1.4	1.3	2.1	1.2	1.2	1.2	1.24
TP-P (mg/L) [4]	<0.05	<0.05	<0.05	1.0	<0.05	<0.05	0.05	≤0.08
BOD_5 (mg/L) [5]	24	34	78	100	14	33	<4	≤27.46
TSS (mg/L) [6]	13	23	14	140	38	52	86	37.19

Notes: [1] P4 remained dry throughout the study period and therefore was not analysed. [2] Total Kjeldahl Nitrogen. [3] Total Nitrogen. [4] Total Phosphorus. [5] 5 day Biochemical Oxygen demand. [6] Total Suspended Solids.

The following provides a summary of the results of the groundwater quality monitoring.

- With the exception of P1, pH indicates neutral to slightly alkaline conditions for all samples. pH levels had a geometric mean of 7.2.
- Electrical conductivity (EC) for all samples was typical of moderately to highly saline water. These data indicate local geology is high in salt content and resulting groundwater which is saline. EC had a geometric mean of 8729.71µS/cm. This corresponds to a salt concentration of 4801 mg/L. Refer to **Table 16** for typical EC ranges.
- Total phosphorus (TP) concentration was ≤0.05mg/L for all samples with the exception of P5. This sample (P5) displayed a higher than anticipated TP concentration which may be attributable to sampling quality control or contamination via surface run-off entering the piezometer. Total phosphorus concentrations had a geometric mean of ≤0.08.
- Nitrite-N and nitrate-N concentrations were near to or below detection levels for all samples. Total Kjeldahl Nitrogen concentrations ranged from 0.6mg/L to 2.0mg/L with Total Nitrogen concentrations ranging from 0.7mg/L to 2.1mg/L.
- 5 day biochemical oxygen demand (BOD_5) levels were generally low with a geometric mean of 27.46mg/L.
- In summary, local groundwater is moderately to highly saline and generally maintains low pollutant levels.

Table 16
Typical Electrical Conductivity Ranges

Water type	Electrical conductivity (µS/cm)
Deionised water	0.5-3
Pure rainwater	<15
Freshwater rivers	0-800
Marginal river water	800-1600
Brackish water	1600-4800
Saline water	>4800
Seawater	≈51 500
Source: Waterwatch Australia (2005)	

5.4 Hydraulic Conductivity (K_{sat})

Hydraulic conductivity (K_{sat}) of the sites aquifer was determined at P8, P2 and P3. Detailed pump-test data and analysis reports are provided in **Appendix E** whilst a summary is provided below in **Table 17**.

Table 17
Summary of Horizontal K_{sat} Results

Piezometer	K_{sat} [1]	Test Date
2	0.00445	21.06.2007
3	0.00331	07.12.2007
8	0.07000	24.10.2007
Notes: [1] Taken as horizontal $K_{sat.}$		

We make the following comments with regard to K_{sat}.

- Geometric mean horizontal $K_{sat\ (h)}$ was determined to be approximately 0.01014m/day (1.1736 x 10^{-7}m/s) for the purposes of groundwater balance modelling.
- K_{sat} may vary with depth and is likely to vary for different areas of the Project Site due to changes in rock properties and the degree of rock fracturing.

  We expect $K_{sat\ (h)}$ to decrease with depth, and on the basis of visual inspection of the Project Site cuttings and local geology we expect $K_{sat\ (v)}$ to be significantly lower than $K_{sat\ (h)}$ and is assumed for modelling purposes to be 0.001014m/day (1.1736 x 10^{-8}m/s).

5.5 Manual Groundwater Level Observations

Manual groundwater level observations were made during each site inspection. Levels are provided in **Table 18** and accord with the results of detailed 'Diver' monitoring.

Table 18
Summary of Manual Groundwater Level Measurements (m AHD)

Date	P1	P2	P3	P4	P5	P6	P7	P8
Preliminary Environmental Assessment Period (PEAP)								
14.06.2007	42.80	-	-	-	-	-	-	-
21.06.2007	42.78	-	-	-	-	-	-	-
22.06.2007	42.70	35.9	-	-	-	-	-	-
28.06.2007	42.78	38.15	-	-	-	-	-	-
Environmental Assessment Period (EAP)								
4/10/2007	42.83	35.70	38.12	Dry	35.87	33.1	42.48	37.51
05/10/2007	-	35.70	38.12	Dry	-	-	-	37.49
24/10/2007	42.80	37.63	38.06	Dry	35.12	32.54	42.56	37.52
07/12/2007	42.77	-	38.44	-	-	-	42.49	-
Average (PEAP)	42.77	37.03	-	-	-	-	-	-
Average (EAP)	42.82	36.34	38.19	Dry	35.50	32.82	42.51	37.51
Average (combined)	42.78	36.69	38.19	Dry	35.50	32.82	42.51	37.51

Figure 8 presents a scatter plot of groundwater levels measured by dip meter throughout the *Preliminary Environmental Assessment* and *Environmental Assessment* periods.

With the exception of P2, manual dip metering results indicate that groundwater levels were relatively stable throughout the monitoring period. Based on the above, it is unlikely that groundwater levels fluctuate frequently and or significantly. We note that extended monitoring for a period of 1 year would be required to confirm the extent of seasonal groundwater fluctuations.

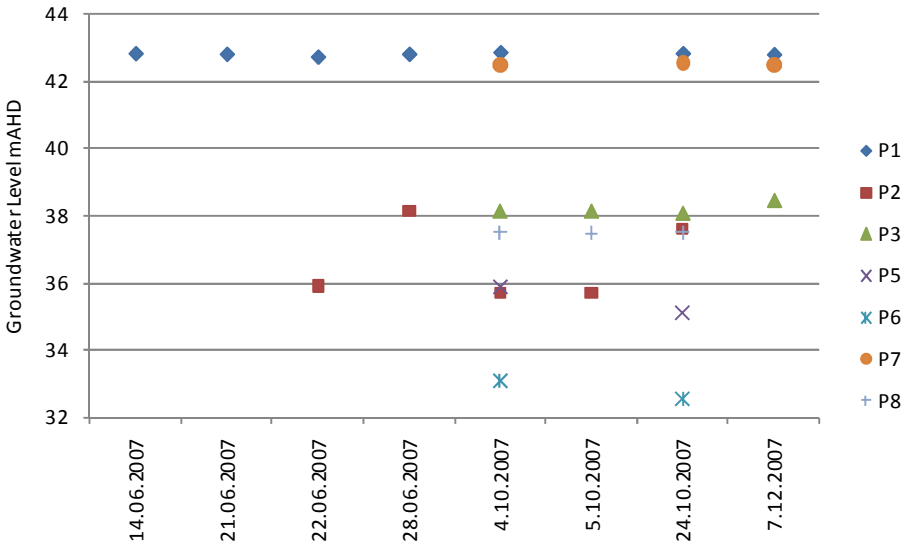

Figure 8
Scatter Plot of Groundwater Levels

5.6 Barometric Pressure

Mean daily barometric pressure measurements were obtained from Nowra BOM station and through the deployment of a barometric pressure data logger. Barometric pressure varied considerably during the primary observation period, fluctuating about a mean of approximately 1010 - 1015 hPa. These data were used to correct the 'Diver' pressure data.

5.7 Detailed Groundwater Level Monitoring

Daily groundwater level records were compiled from 10 minute sampling data collected from "divers" installed within P3 and P7. Results are summarised in **Figure** 9 with interpretation provided of results below.

- Groundwater levels showed a general decreasing trend over the monitoring period of 0.5-1.0 m.
- Minor daily fluctuations in groundwater levels of 0.05-0.10 m were observed.
- Very minor (<0.02 m) diurnal level fluctuations were observed.
- Seasonal fluctuations at the Project Site are likely to be in the order of 1-2 m.

5.8 Rainfall Influence

Incident rainfall is likely to have negligible impact on groundwater levels. Long-term seasonal evapotranspiration rates will affect groundwater recharge rates, although this will not have any local significant bearing on the outcomes of this study. On the basis of catchment properties and local geology groundwater recharge can be assumed to be approximately 5% of incident rainfall.

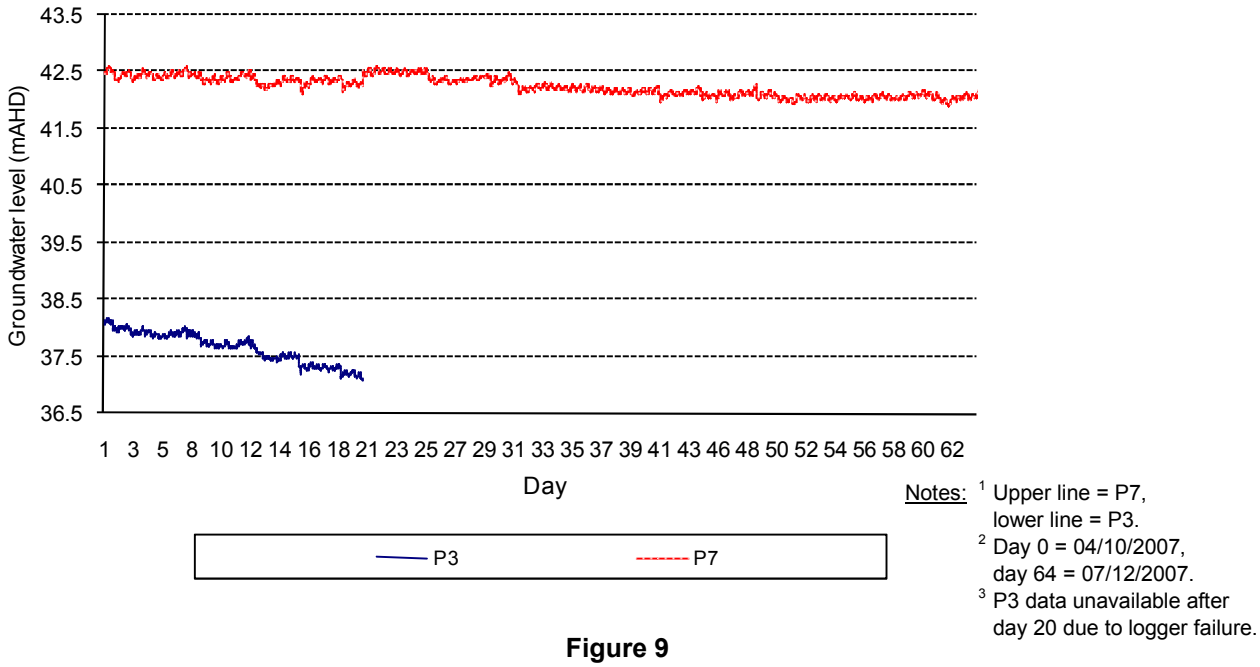

Figure 9
Variation in Groundwater Level During Primary Monitoring Period at P7 and P3.

5.9 Groundwater Impact Assessment

5.9.1 Overview of Risks

The Project has the potential to alter both surface water and groundwater regimes within the Project Site. This may come about through one of the following risks.

Changes to Surface Water Regimes

- Proposed dewatering and the associated "drawdown" may have the potential to alter groundwater/surface water interaction at Nowra Creek.

Changes to Groundwater Regimes

- Proposed dewatering and the associated "drawdown" may have the potential to impact on the economic, social and biodiversity value of the local groundwater resources due to the potential decreased yield of surrounding aquifers.
- Proposed dewatering and the associated "drawdown" may have the potential to impact on foundations of structures, although we note that this is highly unlikely due to separation distances and the groundwater being contained within siltstone rock.
- The Project would result in additional extraction of material below the observed groundwater level. This may potentially provide a mechanism for increased contamination of site groundwater. This could also potentially impact on the value of the local groundwater resources in terms of resource value.
- Backfilling of the extraction area may impact on groundwater flow regimes.

Groundwater Dependent Ecosystems

- Groundwater dewatering and the associated drawdown may have the potential to impact on groundwater dependent ecosystems (if present).

The significance of these potential risks is addressed in **Section 5.9.4.**

5.9.2 Groundwater Modelling Methodology

5.9.2.1 Method

The modelling approach undertaken included the following primary steps.

- Establishment of "Visual ModFlow" (Version 4.2) model of the study area (112.5ha). The study area used for modelling was a 750m by 1 500m rectangular area which was centred over the site. Surface terrain data were interpolated by 'Kriging' using Triangular Irregular Networks (Tin's) provided by a surveyor and extended using 1:25 000 topographic mapping to cover a wider study area.
- Calibration of the existing development groundwater model using monitored groundwater data.
- Boundary conditions assumed in the model were as follows.
  - Assumed groundwater levels of 12.5m below surface elevations along the eastern, western, northern and southern boundaries.
  - Existing development evapotranspiration rates were based on existing catchment conditions which included forest areas and cleared areas (extraction area).

A post-development model was created. This was essentially assumed to change the surface runoff rates, drawdown and evapotranspiration conditions within the study area. Post-development conditions were modelled for the maximum development scenario (Stage 5).

Extent of Dewatering

- The maximum development scenario (Stage 5 – see **Appendix A** – Sheet 8) was modelled to determine likely dewatering rates and the associated drawdown. Modelling assumed maximum extraction with no back-filling. Stage 5 was modelled because it will require the largest dewatering height (due to aquifer grade) and the largest area. Consequently, Stage 5 will require the largest volume of dewatering.
- Required dewatering volumes were calculated using a pit analytical inflow model (Marinelli and Niccoli, 2000) which estimates pit inflow from a steady state, unconfined, horizontally flowing, radial flowing and uniformly recharging aquifer. A coefficient of 0.75 was applied to the equation to address the flow direction and grade of the existing aquifer. Sichardt's equation (Powers, 1992) of $R_o = 3000(H-h)\sqrt{K}$ was used to confirm the radius of influence as this value was required for use in the Marinelli and Niccoli (2000) model. Using this Marinelli and Niccoli (2000) method, groundwater inflow for the maximum development scenario (stage 5) was estimated to be approximately 40KL/day.

- Drawdown cones were simulated in MODFLOW by placing extraction wells which delivered the required 40KL/day pit inflow volume.

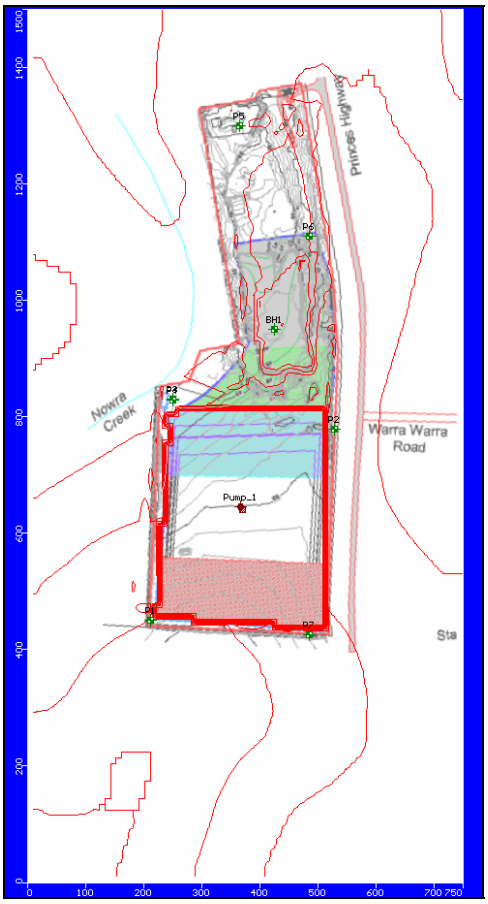

Figure 10: Visual Modflow Model for the Maximum Development Scenario (Stage 5)

Notes: [1] Head observation wells (P1 and P7) were moved slightly outside of the extraction area to allow the model to run and still make calibrations with those wells.

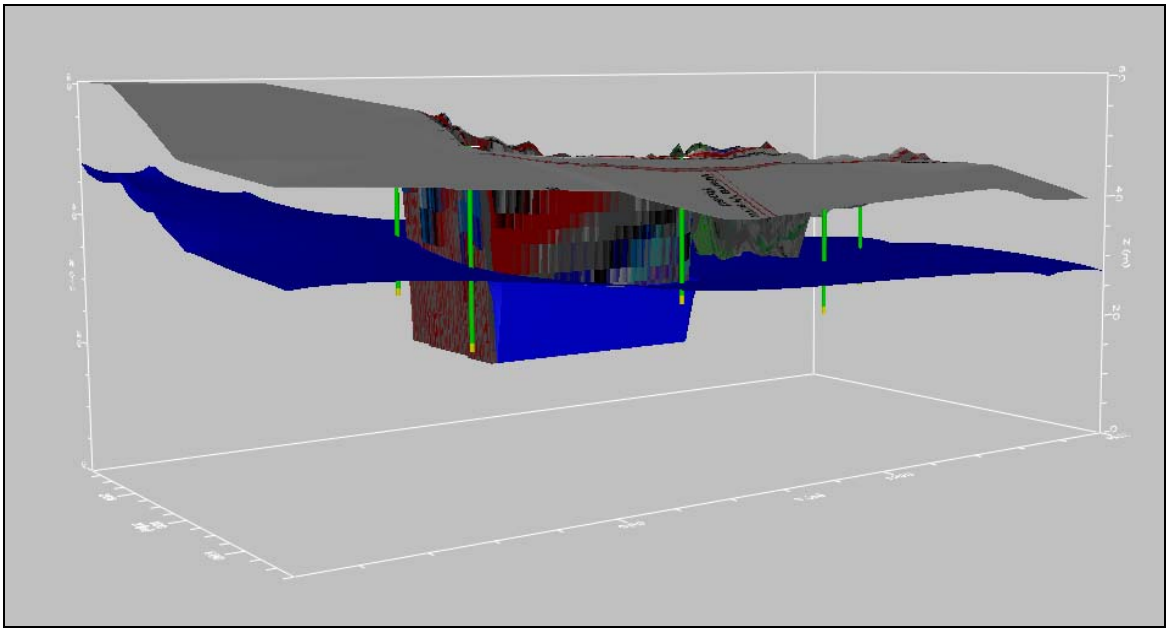

Figure 11: 3D View of Model set-up prior to dewatering for Stage 5

5.9.3 Groundwater Modelling Results

In summary, completed modelling indicates the following.

Existing Development

- Existing development modelling of the piezometric surface indicates that groundwater flows in a northerly to north-northeasterly direction with a gradient of approximately 0.008 (m/m) within the Project Site.
- Groundwater flow within the Project Site and wider study area appears to correspond with local surface topographic catchment characteristics.
- The Project Site is underlain by a relatively shallow unconfined aquifer approximately 5.5mbgl to 13mbgl.

Post-development

- Post-development modelling of the piezometric surface indicates that the 1m drawdown contour (approximately the resolution of the modelling) will be located approximately 1427m from the extraction boundary. A steep cone of depression is expected to form immediately around the extraction area as a result of the extraction and subsequent pumping. This will extend approximately 200 m from the extraction pit. Refer to **Figure 12** for a graph of drawdown for the maximum development scenario (stage 5).

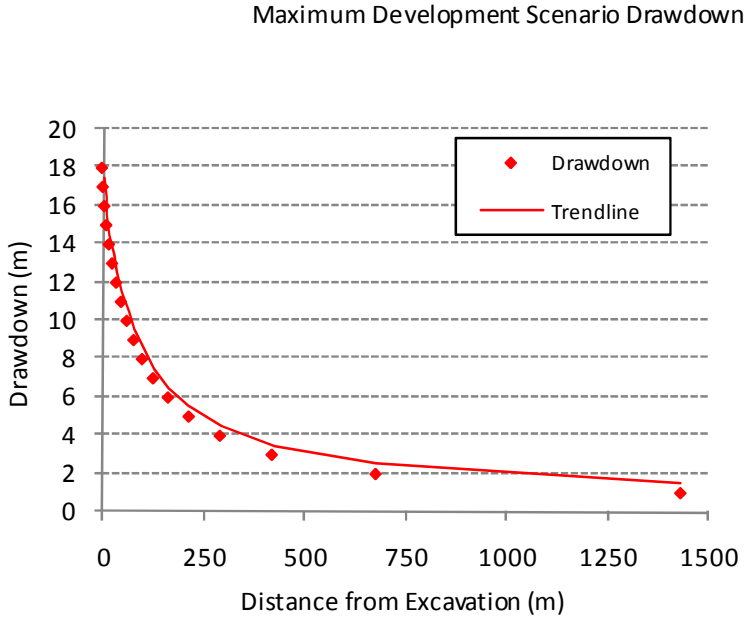

Figure 12
Modelled Maximum Drawdown of the Piezometric Surface

The following provides a brief summary of the results of the groundwater modelling.

- At the southern, northern, eastern and western model boundaries drawdown is expected to be approximately 3m, 2m, 4.5m and 4.5m respectively.
- Drawdown for the maximum development scenario (stage 5) in the area of Nowra Creek is expected to be a maximum 9m.
- It is noted that based on the area of extraction stages and the accompanying depth of groundwater, drawdown distance is likely to be lower for all other stages of development.
- The modelled piezometric surface indicates that groundwater to the west of the Project Site is likely to experience a minor local change in flow direction from the north-northeast to the east-north east. Regional flow direction is not expected to be altered.
- The modelled piezometric surface indicates that groundwater to the east of the Project Site will also experience a minor local change in flow direction to towards the extraction area. However, this change in direction is not as pronounced because existing development groundwater flow in the area of the Project Site flows towards the north-northeast to northeast direction. Flow direction in the area south of the Project Site does not change significantly.
- The piezometric surface gradient increases on all sides of the extraction area due to the Project. Gradient changes from approximately 0.0183 m/m to approximately 0.025 m/m in the southern section of the study area (south of the Project Site) and from 0.0094 m/m to 0.0171 m in the area west of the Project Site.
- No licensed wells occur within the steep drawdown (<200 m from extraction area) curve or highest impact area of the extraction area.

Refer to **Appendix A** (sheets 9-10) for plans showing existing-development and post-development vectors and piezometric surface/schematic sections and drawdown derived from the groundwater model.

5.9.4 Interpretation of Results

The following summarises the likely impacts of the Project on aspects of the groundwater-related environment in the vicinity of the Project Site.

Impact of dewatering on groundwater/surface water interaction at Nowra Creek

- The existing development piezometric surface generated by modelling indicates that groundwater is approximately 6.5m and 8.5m below the invert level of Nowra Creek. This indicates that Nowra Creek is a “losing stream” and is consequently not likely to be affected by local dewatering drawdown.
- The post-development piezometric surface generated by modelling indicates that drawdown will cause the piezometric surface to lower to a maximum of approximately 9m below existing groundwater levels at Nowra Creek.

- Based on the likely extent of dewatering, likely drawdown and the fact that Nowra Creek is likely to be a "loosing stream", we consider that there is no significant Project-related risk to surface water flows within Nowra Creek or other local water courses within 1 km of the extraction area.

Impact of dewatering and subsequent reduction of yield from local bores

- Local groundwater bore data from the NSW Natural Resource Atlas (CANRI, 2007) were examined within an approximate 8 km radius from the Project Site. This was done to assess the impact of proposed dewatering and the degree to which the saturated thickness of existing bores would be impacted upon. Refer to **Figure 13** for approximate locations of groundwater bores and **Table 19** for details.

Table 19
Local Bore Data within an Approximate 8km Radius from the Project Site (CANRI, 2007)

Borehole no.	Distance from site (km)	Longitude	Latitude	Hole depth (m)	Standing Water Level (m bgl)	Yield (L/s)
1	4.1	150 38' 44''	34 55' 10''	36.0	18.0	0.08
2	6.1	150 40' 9''	34 55' 26"	6.0	NA	NA
3	11.6	150 42' 1''	35 0' 33''	6.1	NA	NA
4	10.8	150 41' 13''	35 0' 52''	6.5	NA	NA
5	8.8	150 39' 3''	35 0 46''	22.75	9.0	0.20
6	10.3	150 38' 8''	34 53' 31''	NA	NA	NA
7	10.1	150 38' 20''	35 0' 55''	29.0	NA	0.51
8	7.3	150 36' 40''	34 59' 27''	120.0	9.0	0.30
9	8.3	150 34' 48''	35 0' 16''	66.7	12.0	0.25
10	6.8	150 33' 32''	34 58' 34''	24.0	6.0	7.0
11	10.0	150 30' 16''	34 58' 22''	83.2	48.70	5.05
12	7.9	150 31' 27''	34 57' 22''	57.0	4.5	0.38-0.57
13	6.0	150 32' 11''	34 55' 48''	42.0	NA	1.80
14	6.0	150 32' 7''	34 55' 38''	54.3	9.1	0.38
15	6.0	150 32' 7''	34 55' 27''	52.1	18.2	0.76
16	3.8	150 38' 16''	34 54' 34''	44.0	3.0	1.05
17	4.3	150 34' 58''	34 53' 23''	66.60	NA	NA
18	4.7	150 37' 50''	34 53' 29''	210.0	2.5	0.17
19	4.9	150 38' 8''	34 53' 31''	NA	NA	NA
20	6.3	150 39' 51''	34 54' 1''	8.0	NA	NA

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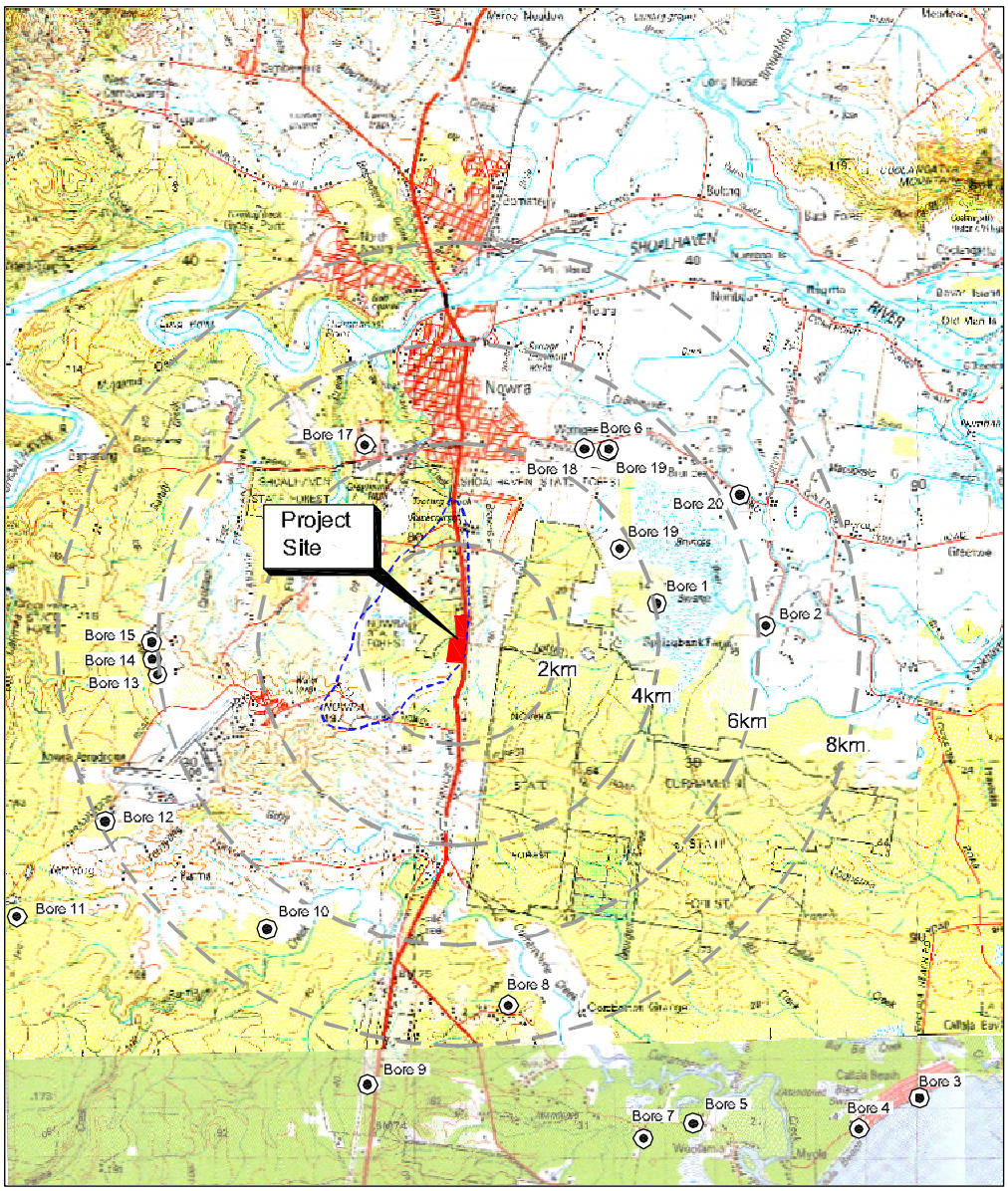

Figure 13
APPROXIMATE LOCATION OF REGISTERED GROUNDWATER BORES

Note: A colour version of this figure is available on the Project CD

- Completed modelling indicates that the 1m drawdown contour will extend to approximately 1400m from the extraction area boundary.
- Based on the completed bore search, extent of dewatering, modelled drawdown and the location of surrounding bores (nearest mapped bore is approximately 3.9km from the Project Site) we consider the risk associated with a loss in groundwater yield for registered bores in the vicinity of the Project Site to be negligible.
- We note that groundwater is generally of poor quality and slightly to moderately saline. It therefore represents a low value irrigation or potential resource. Potential future groundwater users within 1km of the extraction area are therefore not expected and the Project will not affect future potential uses.
- We note that Project extraction of groundwater is for a finite period and that temporary altered groundwater conditions will generally return to existing-development conditions at completion of groundwater extraction.

Impact of dewatering on surrounding foundations

Based on the extent of modelled drawdown, the Project Site's proximity to adjacent structures and the medium within which groundwater flows (siltstone) we consider the risk associated with dewatering and its impact on the foundations of neighbouring structures to be negligible and can be excluded from any further analyses.

Impact of potential groundwater contamination

- The surface area susceptible to potential contamination (from re-charge waters) will be made more readily available due to the Project due to a reduction in the distance between the ground surface and groundwater level. This surface area will also increase as a result of the Project due to the expansion of the excavated area.
- Potential sources of contamination are limited, but could possibly include fuel and oil required by machinery, vehicles and wastewater. However, the extent of potential contamination is likely to be minimal due to the nature of the extractive operations and should be able to be minimised through adequate site management.
- The anthropogenic value of the local groundwater resource is considered to be "low". This "low value" was assigned based on the likely predominant primary intended use (irrigation). Groundwater in the vicinity of the Project Site is moderately to highly saline and is therefore not considered valuable for irrigation purposes. Consequently, potential impact of minor contamination is unlikely to affect the anthropogenic value of the groundwater resource.
- The risk associated with potential groundwater contamination and its impact on the environment is considered to be minimal due to likely lack of connectivity between groundwater and Nowra Creek, the types and likely concentrations of potential contaminants, the nature of quarrying processes and high impermeability of the recharge surface area made available to contamination.

- The risk associated with contaminated surface waters re-charging groundwaters is also conceivable. However, the site stormwater strategy and the presence of a 50ML storage dam are considered likely to provide adequate near impermeable storage of surface waters prior to treatment and subsequent discharge.

Impact of mine backfilling of the extraction area on groundwater flow

- There is a potential for groundwater flow to experience changes in flow regime following backfilling of the extraction area.
- It is likely that changes to the flow regime will be primarily concerned with the velocity and direction of groundwater flow.
- Possible scenarios include either increased or decreased velocities in the in-filled extraction area and possible divergence of groundwater flow around the in-filled extraction area. Changes to the flow will be primarily dependent on the permeability of in-filling material.
- Provided fill is suitably engineered and free of contamination, it is considered unlikely that changes to the groundwater flow following rehabilitation will result in decreased groundwater value.

Impact of dewatering on Groundwater Dependent Ecosystems

The existence or otherwise of Groundwater Dependent Ecosystems (GDEs) in the vicinity of the Project Site was not determined. However, GDEs may generally be classified as follows.

1. Terrestrial Vegetation – Depends on shallow groundwater to sustain transpiration.
2. River Base Flow Systems – Base flow of certain streams may be important to stream character and ecosystems which rely on a certain stream character.
3. Aquifer and Cave Systems – hypogean life exists within different types of fractured/porous aquifers and cave systems.
4. Wetlands – groundwater discharge contributes to wetland flow.
5. Seepage/Springs – groundwater discharge springs can provide habitat for various ecosystems.

The following presents an assessment of the likelihood of occurrence of each of the identified classes of GDEs and an assessment of the likely impacts, if a GDE of that class were present.

The impact of dewatering on GDE 1 – “terrestrial vegetation” is considered to be negligible as aquifer modelling and monitoring indicates that the aquifer in the vicinity of the Project Site is approximately 5.5 to 13 mBGL and is maintained within siltstone rock. The depth of the aquifer and the aquifer bearing strata (siltstone rock) are generally considered impenetrable for terrestrial vegetation. Consequently, terrestrial vegetation in the area of the site is not likely to be dependent on the aquifer.

The impact of dewatering on GDE 2 – "river base flow systems" is considered to be negligible as aquifer modelling and monitoring has indicated that Nowra Creek may be classified as a "loosing stream". As a result, it does not depend on groundwater.

The impact of dewatering on GDE 3 – "aquifer and cave systems" is considered to be negligible as the aquifer bearing strata (siltstone rock) is considered relatively impermeable and not conducive for the formulation of caves. Whilst the aquifer bearing strata may be highly fractured in certain areas, the saline environment is considered unlikely to provide a suitable ecosystem for the majority of hypogean life.

The impact of dewatering on GDE 4 – "wetlands" is considered to be irrelevant as no groundwater dependent (ie. on this aquifer) wetlands exist within the vicinity of the modelled drawdown.

The impact of dewatering on GDE 5 – "seepage springs" is considered to be irrelevant as aquifer modelling/monitoring and the characterisation of Nowra Creek as a "loosing stream" indicates that seepage springs associated with this aquifer are not likely to exist within the area of the modelled drawdown of groundwater levels.

5.9.5 Impact Assessment

Table 20 summarises the results of the groundwater impact assessment.

Table 20
Summary of Groundwater Impact Assessment.

Potential Impact	Comment
Reduced flow to neighbouring wells / bores	No registered neighbouring wells / bores within modelled groundwater drawdown area.
Reduced groundwater flow to creek	The creek is considered to be hydrologically decoupled from the stream.
Reduced quality of groundwater system	Groundwater is of low quality/economic value. No impact on users is expected.
Risk of groundwater contamination from contaminated surface water	Surface water would be detained and treated on-site prior to discharge. Proposed quarrying activities have low pollutant generation rates.
Backfilling will alter groundwater flows.	This is unlikely to occur as backfilled material will be of a similar permeability to existing geological conditions.
Groundwater Dependent Ecosystem habitat removal	This is unlikely as assessment indicates that no Groundwater Dependent Ecosystems (that are dependent on this aquifer) are likely to be present with the drawdown extent.

5.10 Groundwater Extraction Licensing Requirements

In accordance with sections 56 and 57 of the Water Management Act (2000), the proponent will require an "aquifer access license" in order to undertake any dewatering of groundwater.

5.11 Summary and Mitigation Measures

The following comments provide recommended management measures which will mitigate any potential impacts on groundwater conditions within or adjacent to the Project Site.

Suitable dewatering design

- Pumps for dewatering purposes should be sized by a civil engineer or hydro-geological engineer. If possible pumps should be sized after the first stage of initial dewatering so that inflow rate into the extraction area can be accurately quantified.

Water quality/level monitoring

- Groundwater/Surface water quality from within the extraction area should be monitored on a quarterly basis to ensure site processes are not contaminating groundwater.
- Groundwater quality should be monitored at perimeter piezometers (where possible) on a quarterly basis to ensure contaminated groundwater is not leaving the Project Site and where possible provide groundwater baseline quality to allow perimeter samples to be compared with samples obtained from the extraction area.
- Groundwater levels should be monitored quarterly throughout the life of the development to allow for detection of potential drawdown around the Project Site's boundaries.
- We recommend installation of 3 permanent piezometers around the extraction perimeter. Data should be collected quarterly and reviewed annually for a period of 5 years. This will provide a valuable design data resource for the backfilling operations.

6 WATER AND SALT BALANCE ASSESSMENT

6.1 Overview

A water balance model was prepared for the Project Site to determine likely dewatering volumes, run-off volumes, re-use volumes and evaporation volumes. This was done in order to determine likely discharge (if required) frequencies and volumes from the quarry to Nowra Creek. The water balance was undertaken using a 50 year record of daily rainfall and evaporation for Nowra RAN Air Station. This data set incorporated all available daily evaporation and rainfall data from 01.01.1970 to 31.12.2000. This data was extended to form a synthetic climate file with a 50 year record (01.01.1970 to 31.12.2019). The water balance was prepared for the maximum development scenario (stage 5).

A daily salt load model was also incorporated into the water balance model in order to assess irrigation water quality and the risk of increased salinity levels within Nowra Creek due to any discharges of water from the Project Site. The salt budget input into the water balance model was derived from the same climate file which was used for the water balance model.

6.2 Modelling Methodology and Assumptions

Methodology for the water balance assessment involved the following.

- A 50 year record of daily rainfall and evaporation was imported into the daily time-step water balance model "WATCYCLE".
- Model inputs including impervious and pervious catchment areas, rainwater salt concentration, groundwater salt concentration, initial losses, on-going losses, storage reservoir properties, monthly crop factors, groundwater inflow and average daily demand (due to water re-use) for each month were entered into the model.
- Catchment areas used in modelling assumed a maximum extraction area open to the water table at full extraction depth of less than or equal to 2.95ha as well as a maximum additional pervious area draining to the extraction area of less than or equal to 2.95ha. It was also assumed that surface flows will be directed away from the storage reservoir and that pre-quarry surface contours are reconstructed during the progressive rehabilitation process so that all surface water flows to the west, north west and north.
- A 4 ha irrigation field was utilised in the model. Modelling assumed that irrigation would cease if there was more than 20 mm rainfall in the preceding day. In practice, irrigation will be undertaken on a demand basis and will be required, notably during summer periods even when substantially more rain falls than has been assumed.
- Daily irrigation rates were based on evapotranspirative demand derived from monthly ET rates. Refer to **Table 10** for expected monthly irrigation rates. The irrigation field was modelled so that the volume of water that the quarry has to discharge could be minimised and therefore provide mitigation against the impacts associated with discharging saline water. Details of the irrigation field are to be provided at detailed design stage. However, preliminary specification concludes that the irrigation field is likely to be either surface spray irrigation or surface drip irrigation to enable the irrigation field to be capable of being transported. This is required because the initial field location will occupy the site in the area of operations for stages 4, 5 and 6. Refer to Attachment A – sheet 8 for the approximate irrigation field position for various stages of the project.
- The model was then run with an assumed day 0 storage reservoir volume of 0 KL and run for the record of daily rainfall and evaporation (18250 days) to determine trends in overflow frequency, volumes and overflow salt concentrations.

Methodology for the salt balance component of the water balance model involved the following.

- Overflow discharges, salt loads and salt concentrations were calculated in the water balance model.

- The same sub-catchments which were used for RAFTS hydrological modelling were used in a MUSIC Model to generate daily discharge within Nowra Creek. It is noted that only sub-catchment area upstream of the discharge point was used to generate discharge within Nowra Creek. This is considered a conservative approach as catchments downstream of the discharge point will further dilute any additional salt loads contained within quarry discharged waters.
- Daily creek discharge, creek salt load and creek salt concentration were combined with daily overflow discharge, overflow salt load and overflow salt concentration. This was done to determine the combined creek discharge, combined creek salt load and combined creek salt concentration and was completed for everyday of the models 50 year climate record.

Assumptions used in the water and salt balance model are provided below in **Table 21**.

Table 21
Assumptions used in Water and Salt Balance Modelling

Water and Salt Balance Volume Assumptions			
	Source	**Volume (KL/day)**	**Comment**
Supply	Groundwater	40	Based on groundwater modelling
	Surface water	Varies with rainfall/run-off	Modelled on a daily basis
	Crusher	21.6	Excess run-off re-entering system
Demand	Site dust suppression	48 * 1.5	Current use multiplied by an expansion factor of 1.5. Demand only occurs on work days with rainfall <5mm
	Crusher	64.8	Water lost to evaporation, stockpile storage and transported off-site
	Site irrigation	Demand varies with evapotranspiration rate and season	Mean irrigation rate of 4 mm/day
Water and Salt Balance Concentration Assumptions			
Source		**Salt Concentration (mg/L)**	**Comment**
Pervious surface runoff		220	Assumed based on creek concentration
Impervious surface runoff		40	Assumed
Groundwater		4801	Based on site testing
Rainfall		25	Assumed
Nowra Creek		220	Actual geometric mean based on monitoring = 282 mg/L.

6.3 Water and Salt Balance Assessment Results

6.3.1 Storage Reservoir Overflows

Analysis of the water balance model's daily record (50 years) indicates that no discharge from the storage reservoir to Nowra Creek occurs on any day for the entire model record.

6.3.2 Storage Reservoir Levels

Analysis of the water balance model's daily record (50 years) indicates that the maximum storage volume reached in the 50ML storage reservoir is 38.505 ML. The mean storage volume is 4.072ML.

6.3.3 Storage Salinity Levels

Analysis of the salt balance model's daily record (50 years) indicates that the storage reservoir will have a median salt concentration of 760mg/L with an 85th percentile salt concentration of 1335 mg/L which occurs only infrequently when water levels within the storage reservoir are very low and therefore undiluted. A maximum salt concentration of 3875 mg/L occurs within the storage reservoir.

6.3.4 Overland Flow Discharges

No discharges from the excavation pit to Nowra Creek will occur. Surface water discharged via overland flow from other areas of the Project Site to Nowra Creek will include all water that is not collected by the excavation pit and the storage reservoir and their respective catchment areas. Surface water from these areas is likely to have a salt concentration in the order of 220 mg/L (ie. less than or equal to existing Nowra Creek salt concentration) and will generate no adverse salinity impacts for Nowra Creek.

6.4 Salt Impacts Due to Irrigation

A summary of the anticipated impacts associated with the proposed irrigation of the irrigation field with water from the storage dam is provided below.

- The concentration of salt within irrigation water is generally low (median of 760 mg/L) and is equivalent to domestic strength wastewater and similar in range to existing surface water monitored at the Project Site. Irrigation of this water is likely to have no detrimental effect on plants or soils in the irrigation area and is considered suitable for irrigation in accordance with Table 5.36 of Hazelton and Murphy (2007).
- Irrigation of water from the storage reservoir is considered sustainable for the duration of the proposed development. At completion, any excess salt accumulated in the soil profile will be leached (and therefore returned) to groundwater.
- The 4ha irrigation field is to be initially located in the south of the quarry in the vicinity of land dedicated to Stage 5 extraction works. Once quarrying works encroach on the 4ha irrigation field, the field is to be relocated to the north of the site where rehabilitation had taken place.
- Salt budget modelling indicates that irrigation on the 4 ha irrigation field is an effective means of eliminating the need for discharges from the storage reservoir to Nowra Creek. Consequently, the irrigation field acts to provide mitigation against potential salt impacts within Nowra Creek.

6.5 Conclusion

Analysis of the water balance model indicates that no discharges will occur from the storage reservoir to Nowra Creek provided that the assumptions that modelling relied upon are applied at the site.

7 NOWRA CREEK IMPACT ASSESSMENT

7.1 Overview

The risk associated with the Project impacting on Nowra Creek was assessed due to the proximity of Nowra Creek to the Project Site's north western boundary and the nature of the Project.

7.2 Nowra Creek

7.2.1 Overview

The section of creek parallel to the Project Site boundary has an average channel bed width of approximately 1.5m and a depth of approximately 0.8-1.0m. Channel width from top of bank to top of bank is similar to channel bed width and is estimated to average approximately 1.6m to 1.8m. Significant riparian vegetation and woody debris surround and occupy the channel. The creek and surrounding vegetation provide significant habitat values for native flora and fauna. Limited channel incision, bank erosion, channel widening and the significant portion of woody debris present in the channel, suggest the creek is in a generally good condition. Refer to **Figure 14** for the approximate location of drainage lines relative to the Project Site.

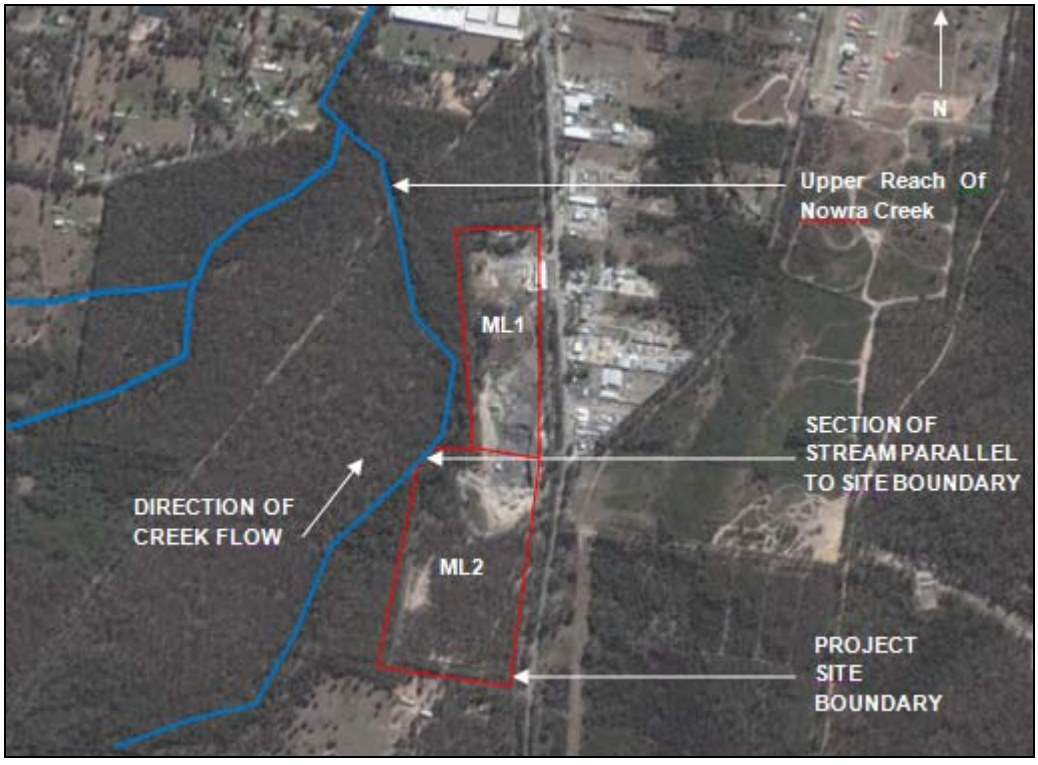

Figure 14: Approximate Location of Drainage Lines Relative to the Project Site (Source: Google images).

7.2.2 Channel Sinuosity

Sinuosity of the drainage line was calculated over a distance of 1km using available 1:25 000 topographic map data. Channel sinuosity (channel distance/straight line distance between the two points) was estimated to be approximately 1.11, indicating a slight to moderate meandering form. This is expected given the nature of local soil materials and indicates that channel straightening due to increased flow or catchment clearing has not taken place.

7.2.3 Riparian Zone

Nowra Creek presents a fully functional riparian zone including bed and in channel vegetation, bank/overbank vegetation, in channel woody debris and floodplain vegetation. A brief summary of riparian zonation is provided in **Table 22**. We are of the view that the riparian zone is in good condition and provides significant habitat.

Table 22
Summary of Nowra Creek Riparian Zone

Location	Description
Channel bed	Some vegetation, occasionally woody debris and leaf litter build up is present.
Banks	Vegetation (grasses present towards top of bank).
Overbank	Various species including Lamandra, other grasses and Melaleuca. Vegetation provides a dense coverage.

7.2.4 Salt Impacts on Nowra Creek and Discharge Control

Results from the water and salt balance model (**Section 6)** indicate that no discharges from the storage reservoir to Nowra Creek will occur. Consequently, adverse impact on Nowra Creek's ecology due to saline discharges from the storage reservoir to the creek will be avoided and no discharge control will be required.

7.2.5 Riparian Management

In consultation with Shoalhaven City Council, the former Department of Infrastructure, Planning and Natural Resources (DIPNR) undertook a Riparian Corridor Objective Setting (RCOS). The RCOS classified Nowra Creek as Category 1 – Environmental Corridor. The Main objective of this corridor is to provide biodiversity linkages. In accordance with this classification, existing vegetation should be protected and retained within 40m (Core Riparian Zone) of the creek.

We make the following recommendations with regard to Riparian Management of Nowra Creek.

- A 40m core riparian zone (CRZ) is to be applied to Nowra Creek in the section of creek adjacent to the Project Site with an additional 10m vegetated buffer (total buffer – 50m). It is noted that this CRZ is to be measured from the top of the bank of the Creek.

- Within the CRZ we recommend:
  - Exclusion of machinery traffic;
  - Exclusion of human traffic (where possible);
  - Bi-monthly inspection and subsequent removal of exotic species if required within the Project Site for the life of the project;
  - Planting of suitable native species in appropriate densities;
  - Details of specific vegetation management including species selection and works sequencing are to be provided by appropriately qualified flora and fauna consultants;
  - That the outer extent of the CRZ is marked with exclusion tape or fenced to ensure any quarry works/activities associated with the proposal do not disturb or intrude the riparian corridor.

If appropriately managed the CRZ would provide an enhanced habitat, stabilise local soils, reduce the risk of channel erosion and achieve enhanced in-stream water quality improvement. Refer to the site plan in **Appendix A** (sheet - 6) for the location of the CRZ.

7.2.6 Impact Assessment

Potential risks which may arise from the Project and adversely impact Nowra Creek are summarised in an impact assessment (**Table 24**). Impact assessment indicates that the Project is unlikely adversely impact Nowra Creek provided that the recommendations in this report are employed.

Table 23
Nowra Creek Impact Assessment

Risk	Comment
Extraction will dewater Nowra Creek	Not possible as creek invert is approximately 6.5 – 8.5m above the top of groundwater level. The creek and groundwater are hydrologically decoupled.
Reduced environmental flows due to decreased catchment area	Decreased catchment area will have a negligible impact on flows. Natural environmental flow regimes will be maintained through overland flow discharges in the form of run-off from rehabilitated portions of the site to the creek.
Increased creek erosion	Nowra Creek will not be modified by the proposal. Riparian buffer will ensure creek system integrity.
Loss of riparian habitat	No riparian habitat will be adversely impacted by the proposal due to adoption of a 40m Core Riparian Zone with an additional 10m buffer.
Stormwater discharge will result in creek erosion	Water balance modelling indicates that no discharges will occur from the storage reservoir to Nowra Creek.
Increased creek salinity due to site groundwater discharges.	Water balance modelling indicates that no discharges will occur from the storage reservoir to Nowra Creek.

8 REFERENCES

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APPENDICES

(No. of pages excluding this page = 66)

Appendix A	Hydrogeological / Stormwater Plan Set
Appendix B	Existing-development / Post-development MUSIC Modelling Output
Appendix C	Existing-development / Post-development RAFTS Modelling Set-up and Output
Appendix D	HEC-RAS Hydraulic Existing-Development / Post-Development Modelling
Appendix E	Recharge Testing
Appendix F	Laboratory Report
Appendix G	Coverage of EA Requirements

(Note: A full colour version of these Appendices are presented on the Project CD)

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Appendix A

Hydrogeological/Stormwater Plan Set

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HYDROGEOLOGICAL/STORMWATER PLAN SET
1 COVER SHEET
2 SITE PLAN
3 PIEZOMETER FIELD PLAN
4 PRE-DEVELOPMENT CATCHMENT PLAN
5 WATER QUALITY SAMPLING LOCATIONS
6 STORMWATER MANAGEMENT PLAN
7 NOWRA CREEK FLOOD STUDY SECTIONS
8 INDICATIVE DEVELOPMENT SEQUENCE
9 PRE-DEVELOPMENT PIEZOMETRIC SURFACE AND SCHEMATIC SEEPAGE FACE SECTIONS
10 POST-DEVELOPMENT PIEZOMETRIC SURFACE, VECTORS AND DRAWDOWN
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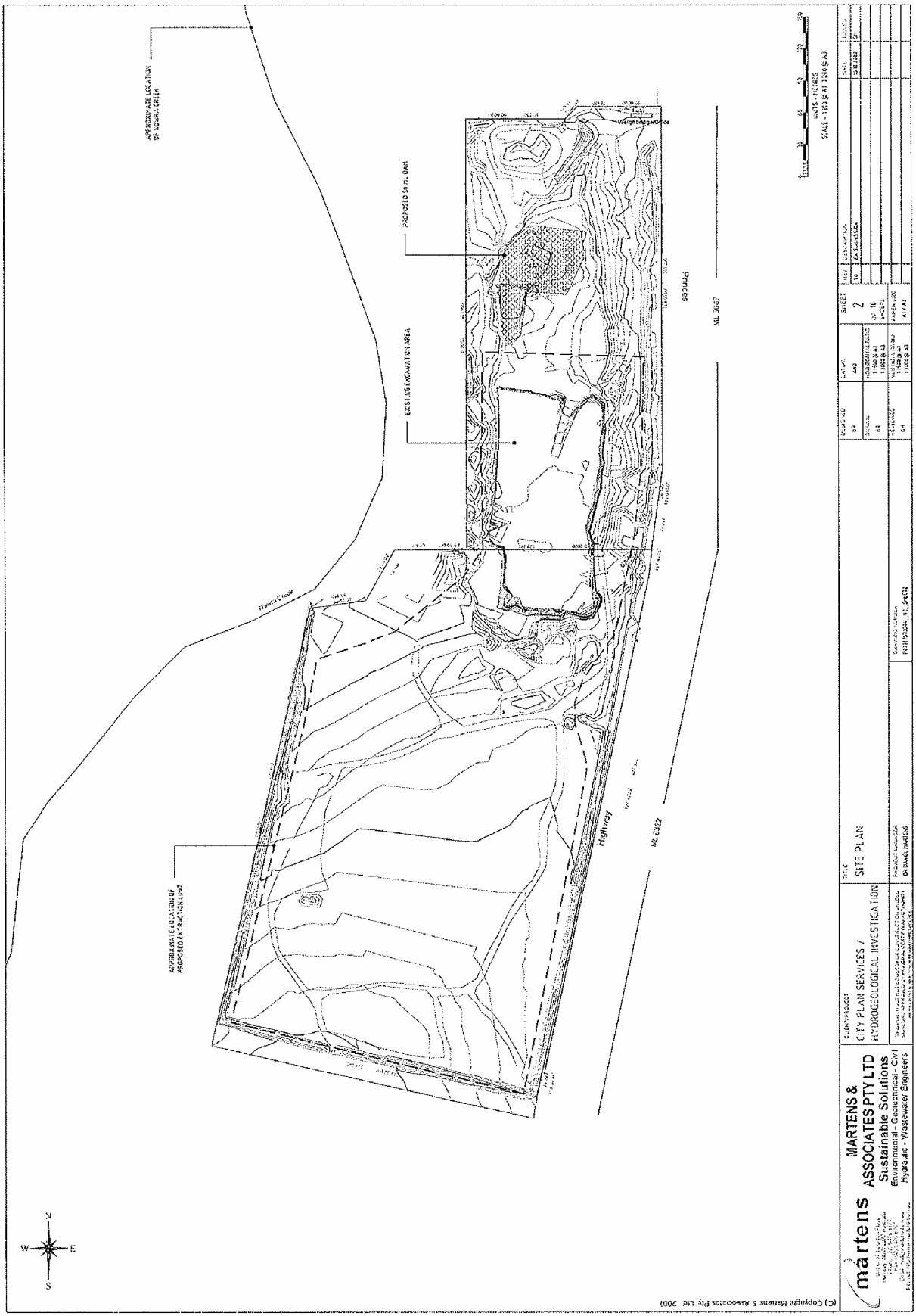
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PROPOSED 50 m. BUFFER
EXISTING EXCAVATION AREA
APPROXIMATE LOCATION OF PROPOSED EXTRACTION LIMIT
Nowra Creek
Highway
Princes
ML 5967
ML 6322
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SITE PLAN
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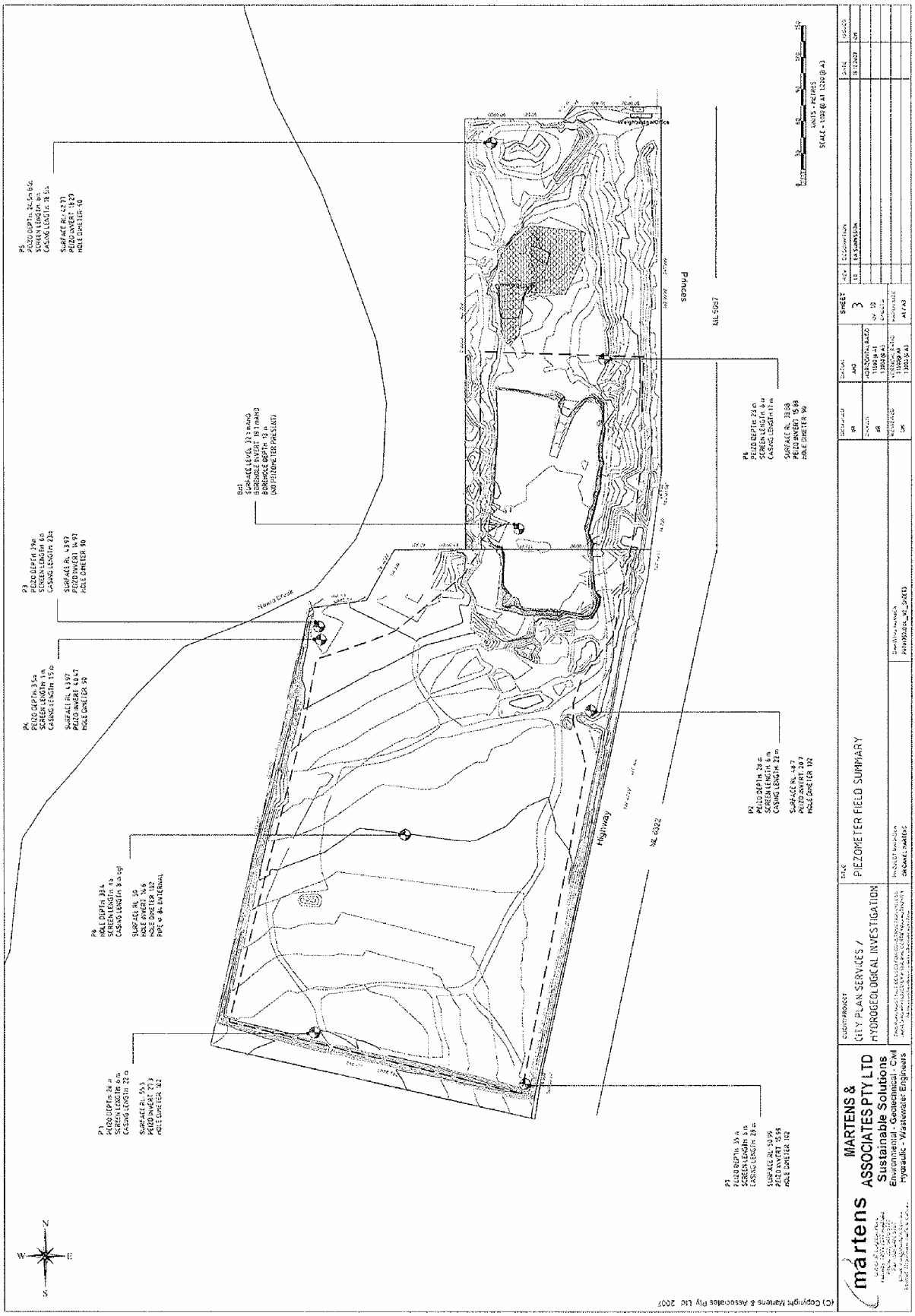
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PIEZOMETER FIELD SUMMARY
Nowra Bridge
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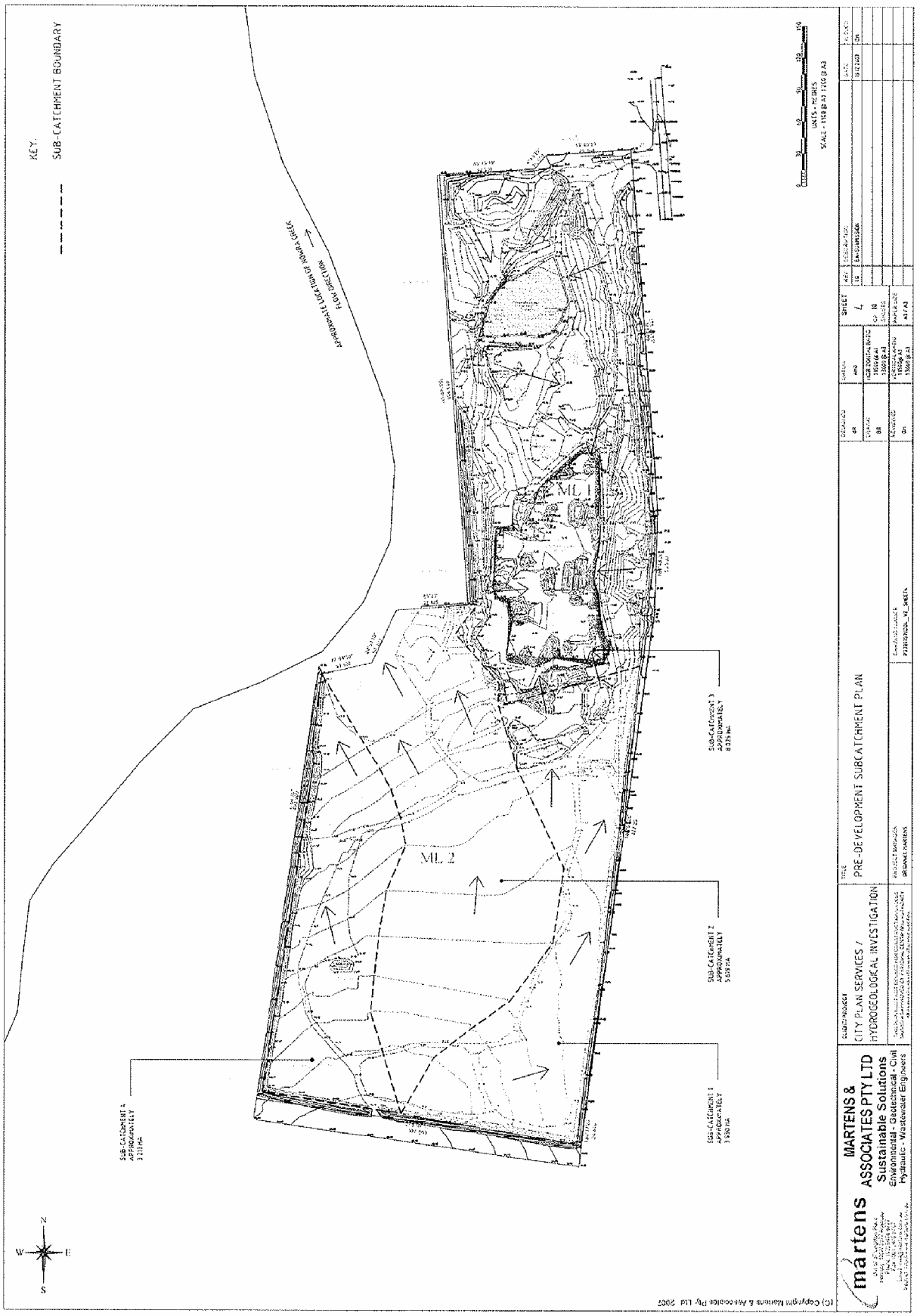
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APPROXIMATE FLOW DIRECTION
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ML 2
Sub-Catchment 1
APPROXIMATELY
3.21HA
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APPROXIMATELY
5.93HA
Sub-Catchment 3
APPROXIMATELY
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SHEET
4
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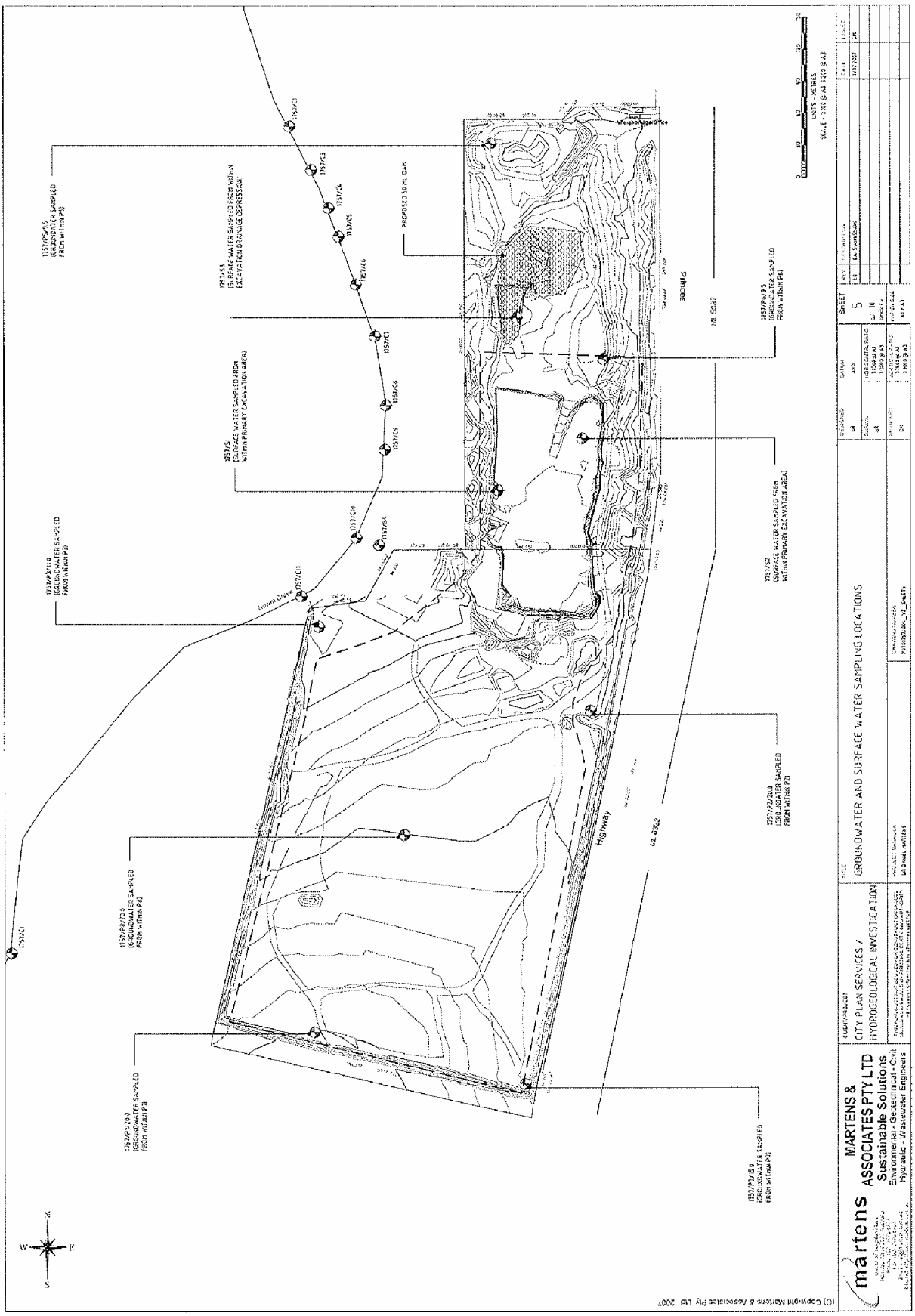
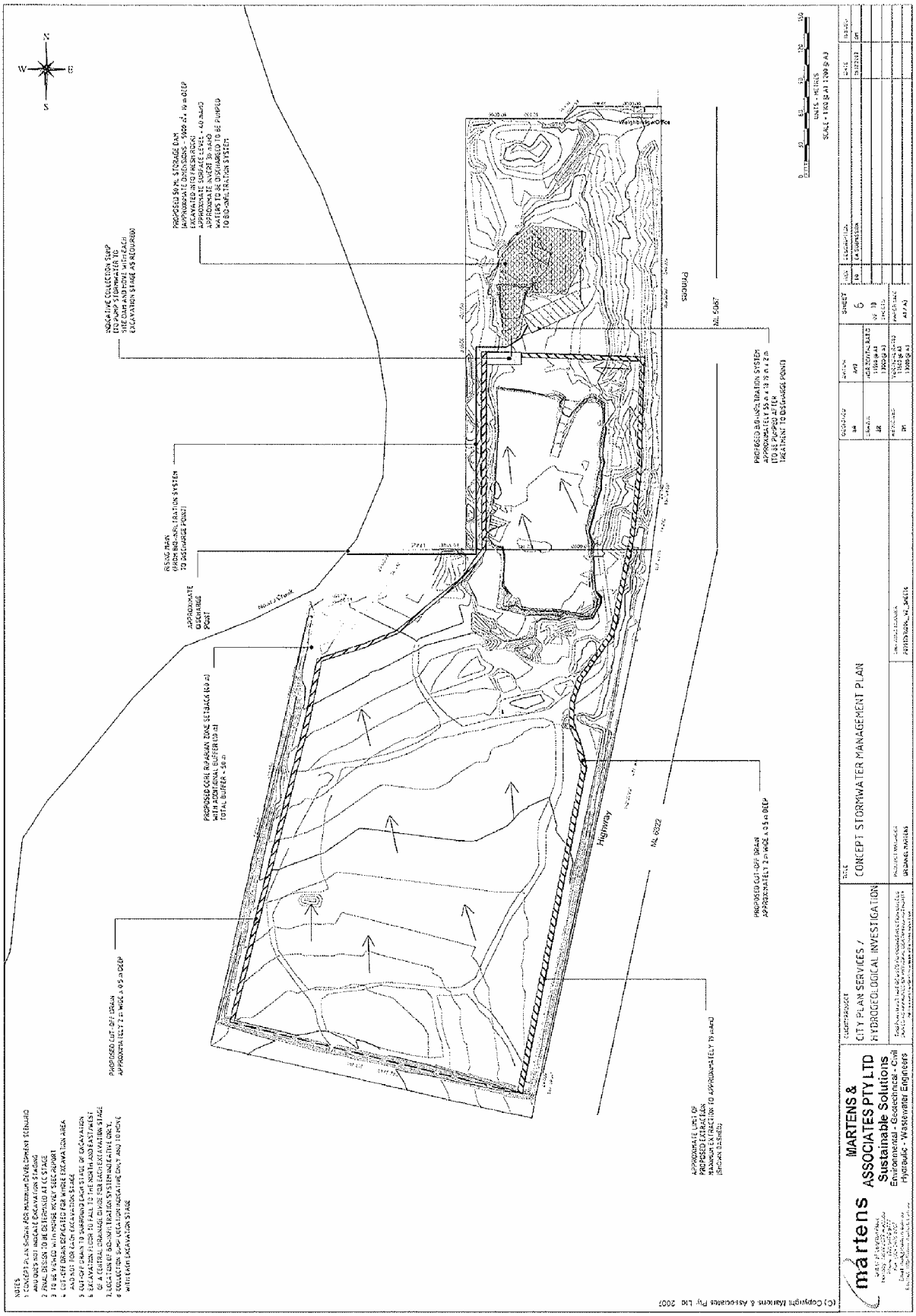
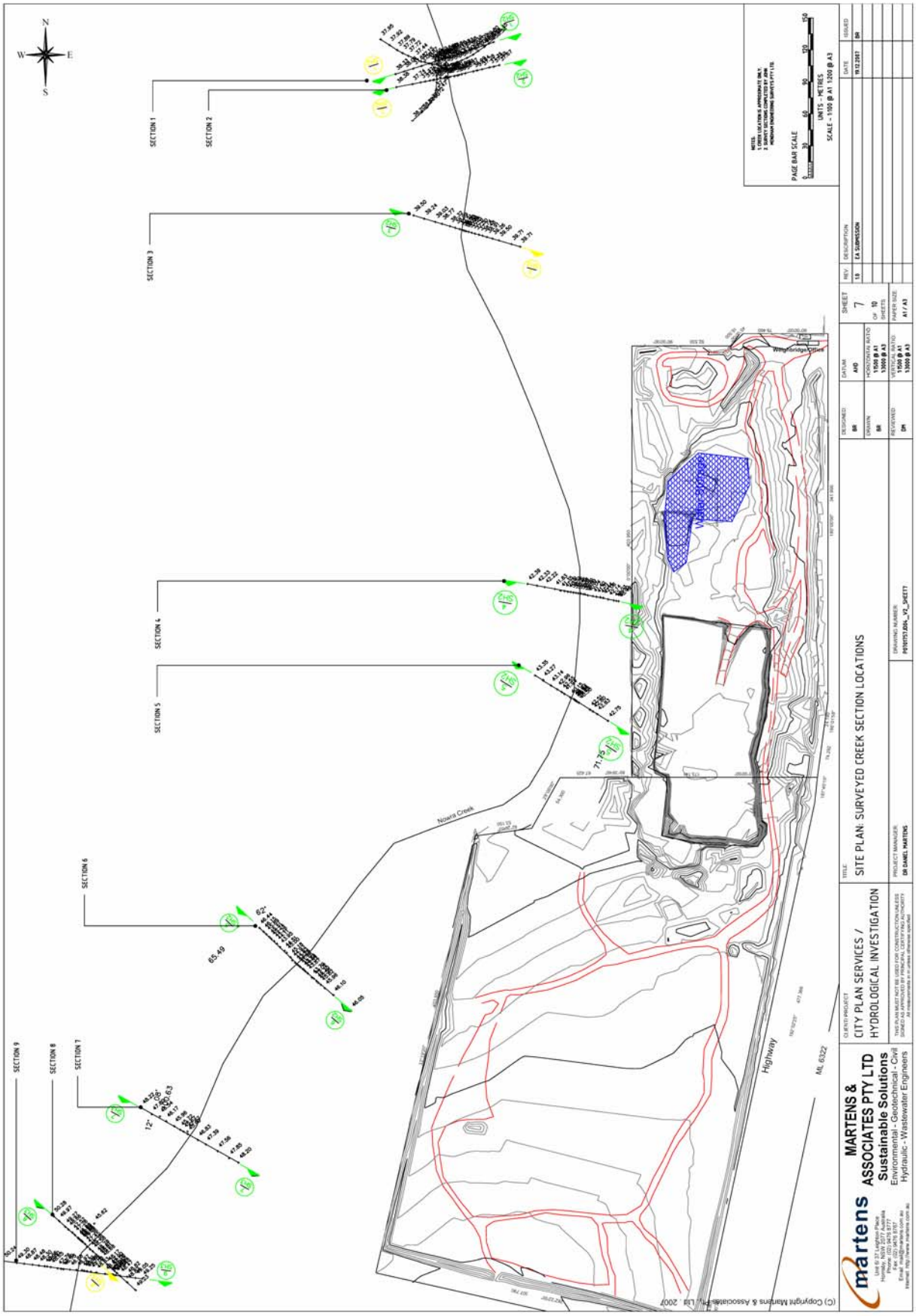

GROUNDWATER AND SURFACE WATER SAMPLING LOCATIONS
CITY PLAN SERVICES / HYDROGEOLOGICAL INVESTIGATION
MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Highway
Nowra Creek
PROPOSED 30 ML DAM
SURFACE WATER SAMPLED FROM WITHIN EXCAVATION DRAINAGE DEPRESSION
SURFACE WATER SAMPLED FROM WITHIN PRIMARY EXCAVATION AREA
GROUNDWATER SAMPLED FROM WITHIN PZ
N
S
E
W


CONCEPT STORMWATER MANAGEMENT PLAN
CITY PLAN SERVICES / HYDROGEOLOGICAL INVESTIGATION
MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers
Highway
ML 6022
ML 6067
Weighbridge Office
PROPOSED 50 ML STORAGE DAM
PROPOSED CUT-OFF DRAIN
PROPOSED GOAL BUFFER ZONE SETBACK (40 m)
PROPOSED BIO-INFILTRATION SYSTEM
RISING MAIN
(c) Copyright Martens & Associates Pty Ltd 2007

NOTES:
1. CONCEPT PLAN SHOWN FOR MAXIMUM DEVELOPMENT SCENARIO AND DOES NOT INDICATE EXCAVATION STAGING.
2. FINAL DESIGN TO BE DETERMINED AT DETAILED DESIGN STAGE.
3. ALL LEVELS TO BE IN METRES AHD. SEE ALSO NOTE 11.
4. CUT-OFF DRAIN DEPICTED FOR WHOLE EXCAVATION AREA AND NOT FOR EACH EXCAVATION STAGE.
5. CUT-OFF DRAIN TO SURROUND EACH STAGE OF EXCAVATION.
6. EXCAVATION FLOOR TO FALL TO THE NORTH AND EAST/WEST OF A CENTRAL DRAINAGE DIVIDE FOR EACH EXCAVATION STAGE.
7. COLLECTION SUMP LOCATION INDICATIVE ONLY AND TO MOVE WITH EACH EXCAVATION STAGE.
8. REFER TO GROUNDWATER REPORT BY MARTENS AND ASSOCIATES HYDROLOGY ASSESSMENT, DECEMBER, 2006.
10. MAXIMUM EXCAVATION AREA OPEN TO WATER TABLE AT FULL EXTRACTION DEPTH TO BE 2.95 HA.
11. MAXIMUM PERVIOUS CATCHMENT AREA DRAINING TO EXCAVATION TO BE 2.95 HA.
12. REHABILITATION WORKS TO RETURN SURFACE TO PRE-QUARRYING CONTOURS.
13. SURFACE FLOWS TO BE DIRECTED AWAY FROM SITE STORAGE DAM.
INDICATIVE COLLECTION SUMP (TO PUMP STORMWATER TO SITE DAM AND MOVE WITH EACH EXCAVATION STAGE AS REQUIRED)
PROPOSED 59 ML STORAGE DAM (APPROXIMATE DIMENSIONS - 5000 m² x 10 m DEEP EXCAVATED INTO FRESH ROCK)
APPROXIMATE SURFACE LEVEL - 40 mAHD
APPROXIMATE INVERT 30 mAHD
WATER TO BE USED ON SITE FOR DUST SUPPRESSION OR PUMPED TO IRRIGATION FIELD
Weighbridge Office
White Gums
Pinnacle
ML 5087
Nowra Creek
PROPOSED CORE RIPARIAN ZONE SETBACK (40 m) WITH ADDITIONAL BUFFER (10 m) TOTAL BUFFER - 50 m
PROPOSED CUT-OFF DRAIN APPROXIMATELY 2 m WIDE x 0.5 m DEEP
Highway
ML 6322
PROPOSED CUT-OFF DRAIN APPROXIMATELY 2 m WIDE x 0.5 m DEEP
APPROXIMATE LIMIT OF PROPOSED EXTRACTION MAXIMUM EXTRACTION TO APPROXIMATELY 19 mAHD (SHOWN DASHED)
APPROXIMATE LOCATION OF PROPOSED 6 HA IRRIGATION FIELD (SHOWN HATCHED TO RECEIVE WATER FROM SITE STORAGE RESERVOIR LOCATION SHOWN APPLICABLE FOR STAGES 1-3. IRRIGATION FIELD TO BE RE-SITED FOR STAGES 4-6. REFER TO SHEET 8 FOR LOCATION OF IRRIGATION FIELD FOR STAGES 4-6)
N
S
E
W
LINITS - METRES
SCALE - 1:500 @ A1 1:200 @ A3
martens
MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers
CLIENT/PROJECT
CITY PLAN SERVICES / HYDROGEOLOGICAL INVESTIGATION
TITLE
CONCEPT STORMWATER MANAGEMENT PLAN
PROJECT MANAGER
DR DANIEL MARTENS
DRAWING NUMBER
P07597.00A_VL_SHEET6
DESIGNED BR
DRAWN BR
REVIEWED DM
DATUM AHD
HORIZONTAL RATIO 1:500 @ A1 1:1000 @ A3
VERTICAL RATIO 1:500 @ A1 1:1000 @ A3
SHEET 6
OF 10 SHEETS
PAPER SIZE A1 / A3
REV 1.0
DESCRIPTION EA SUBMISSION
DATE 15.11.2007
ISSUED DM
(C) Copyright Martens & Associates Pty. Ltd. 2007


SECTION 1
SECTION 2
SECTION 3
SECTION 4
SECTION 5
SECTION 6
SECTION 7
SECTION 8
SECTION 9
Nowra Creek
Highway
ML 6322
SITE PLAN: SURVEYED CREEK SECTION LOCATIONS
CITY PLAN SERVICES / HYDROLOGICAL INVESTIGATION
MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers
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Appendix B

Pre-quarrying / Post-development MUSIC Modelling Output

(No. of pages excluding this page = 3)

pre-quarry - Receiving Node pre-quarry

All Data Statistics

19/12/2008 11:09:53 AM

Inflow

	mean	stddev	median	maximum	minimum	10 %ile	90 %ile
Flow (cubic metres/sec)	1.78E-3	14.5E-3	62.7E-6	0.666	0.00	3.82E-9	2.70E-3
TSS Concentration (mg/L)	8.83	9.99	7.84	233	0.00	4.87	11.9
Log [TSS] (mg/L)	0.915	0.172	0.904	2.37	0.428	0.736	1.08
TP Concentration (mg/L)	32.0E-3	14.6E-3	31.3E-3	0.313	0.00	19.2E-3	46.8E-3
Log [TP] (mg/L)	-1.49	0.139	-1.50	-0.505	-2.05	-1.67	-1.33
TN Concentration (mg/L)	0.717	0.286	0.708	2.82	0.00	0.440	1.05
Log [TN] (mg/L)	-0.140	0.131	-0.140	0.451	-0.815	-0.308	26.9E-3
TSS Load (kg/Day)	8.93	128	42.2E-3	9.22E3	0.00	2.60E-6	1.89
TP Load (kg/Day)	10.4E-3	0.122	172E-6	7.87	0.00	10.3E-9	7.48E-3
TN Load (kg/Day)	0.133	1.47	3.88E-3	125	0.00	239E-9	0.169
Gross Pollutant Load (kg/Day)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Post-development_without_treatment - Receiving Node

All Data Statistics 19/12/2008 11:11:21 AM

Inflow

	mean	stddev	median	maximum	minimum	10 %ile	90 %ile
Flow (cubic metres/sec)	2.95E-3	16.1E-3	647E-6	0.694	463E-6	463E-6	4.23E-3
TSS Concentration (mg/L)	69.6	163	36.8	5.89E3	8.34	20.1	125
Log [TSS] (mg/L)	1.62	0.334	1.57	3.77	0.921	1.30	2.10
TP Concentration (mg/L)	34.3E-3	24.2E-3	26.8E-3	2.13	15.6E-3	25.0E-3	52.3E-3
Log [TP] (mg/L)	-1.50	0.153	-1.57	0.329	-1.81	-1.60	-1.28
TN Concentration (mg/L)	1.10	0.638	1.11	25.8	0.110	0.745	1.14
Log [TN] (mg/L)	12.7E-3	0.146	45.5E-3	1.41	-0.957	-0.128	56.9E-3
TSS Load (kg/Day)	38.5	270	1.74	10.9E3	1.48	1.48	37.3
TP Load (kg/Day)	17.1E-3	0.150	1.58E-3	11.0	1.00E-3	1.00E-3	16.7E-3
TN Load (kg/Day)	0.289	1.84	57.9E-3	109	45.6E-3	45.6E-3	0.332
Gross Pollutant Load (kg/Day)	2.11	4.97	0.00	39.2	0.00	0.00	9.71

Post-development_with_treatment - Receiving Node

All Data Statistics 19/12/2008 11:08:50 AM

Inflow

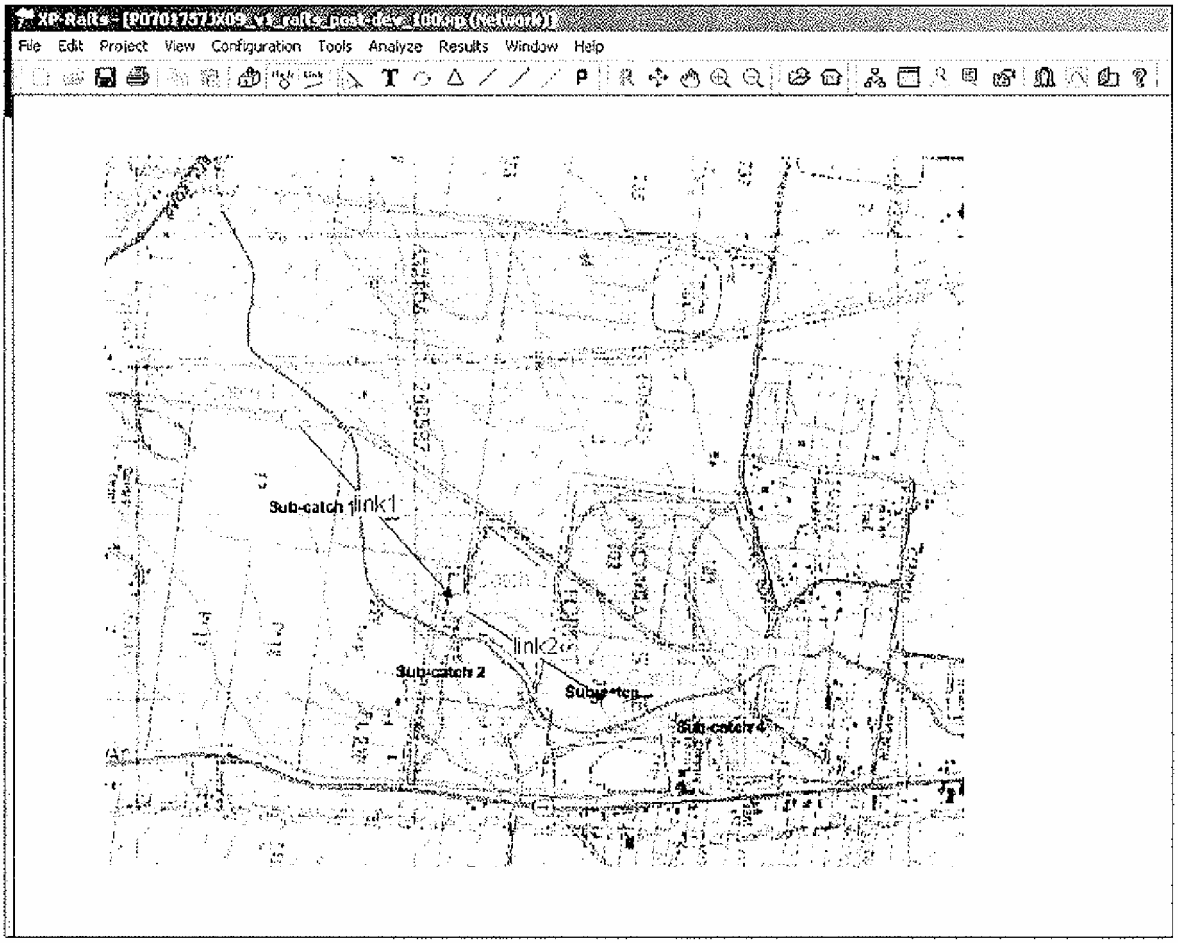
	mean	stddev	median	maximum	minimum	10 %ile	90 %ile
Flow (cubic metres/sec)	1.30E-3	10.7E-3	45.1E-6	0.493	0.00	9.61E-9	1.94E-3
TSS Concentration (mg/L)	8.55	8.94	7.96	189	0.00	5.44	10.6
Log (TSS) (mg/L)	0.911	0.179	0.900	2.28	-1.26	0.791	1.03
TP Concentration (mg/L)	31.2E-3	13.6E-3	31.6E-3	0.404	0.00	21.5E-3	42.1E-3
Log (TP) (mg/L)	-1.50	0.150	-1.49	-0.394	-3.69	-1.61	-1.37
TN Concentration (mg/L)	0.702	0.251	0.724	2.89	0.00	0.494	0.958
Log (TN) (mg/L)	-0.141	0.140	-0.132	0.461	-2.28	-0.250	-15.7E-3
TSS Load (kg/Day)	6.22	85.7	31.6E-3	4.91E3	0.00	1.89E-6	1.39
TP Load (kg/Day)	8.71E-3	0.139	126E-6	13.8	0.00	7.21E-9	5.46E-3
TN Load (kg/Day)	98.8E-3	0.908	2.89E-3	42.9	0.00	179E-9	0.124
Gross Pollutant Load (kg/Day)	3.17E-3	44.8E-3	0.00	1.37	0.00	0.00	45.7E-6

Appendix C

Existing-development / Post-development RAFTS Modelling Set-up and Output

(No. of pages excluding this page = 25)

Rafts Sub-catchment Existing Development Model Set-up



Rafts 1:100 year ARI Existing-development Flood Output

```
                    P0701757JX07_v1_rafts_pre-dev_100.out
 Run started at: 15th  November  2007  12:44:56


###############################################################################
#####
                          RUNTIME          RESULTS
###############################################################################
#####

Max. no. of links allowed =  2000

Max. no. of routng increments allowed = 25000

Max. no. of rating curve points = 25000

Max. no. of storm temporal points = 25000

Max. no. of channel subreaches =    25

Max link stack level =    25

Input Version number =          650

 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =           42.11
 ESTIMATED PEAK FLOW         (CUMECS) =      6.96
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =           70.61
 ESTIMATED PEAK FLOW         (CUMECS) =     11.99
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =           77.44
 ESTIMATED PEAK FLOW         (CUMECS) =     14.32
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =           85.22
 ESTIMATED PEAK FLOW         (CUMECS) =     15.87
 ESTIMATED TIME TO PEAK         (MINS) =     31.00



###############################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
###############################################################################
#####
```

P0701757JX07_v1_rafts_pre-dev_100.out

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 30.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 142.28
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 142.28

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1 (%)	% Impervious #2	Perm #1	Perm #2	B #1	B #2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	146.06	10.00	0.000	3.000	0.000	61.728	0.000	6.964	31.00	0.000
Catch 2	146.06	10.00	0.000	3.000	0.000	61.728	0.000	11.992	31.00	0.000
Catch 3	146.06	10.00	0.000	3.000	0.000	61.728	0.000	14.323	31.00	0.000
Catch 4	146.06	10.00	0.000	3.000	0.000	61.728	0.000	15.870	31.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 64.60
ESTIMATED PEAK FLOW (CUMECS) = 12.04
ESTIMATED TIME TO PEAK (MINS) = 60.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 107.9
ESTIMATED PEAK FLOW (CUMECS) = 20.48
ESTIMATED TIME TO PEAK (MINS) = 60.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 118.3
ESTIMATED PEAK FLOW (CUMECS) = 23.09
ESTIMATED TIME TO PEAK (MINS) = 56.00

LINK Catch 4 1.003

ESTIMATED VOLUME (CU METRES*10**3) = 130.1
ESTIMATED PEAK FLOW (CUMECS) = 25.62
ESTIMATED TIME TO PEAK (MINS) = 56.00

##
#####

Page 2

```
                    P0701757JX07_v1_rafts_pre-dev_100.out
Results for period from  0: 1.0  1/ 1/1990
                      to  5: 1.0  1/ 1/1990
################################################################################
#####

                                   ROUTING INCREMENT (MINS) =       1.00
                                   STORM DURATION (MINS)    =       60.
                                   RETURN PERIOD (YRS)      =       100.
                                   BX                       =    1.0000
                                   TOTAL OF FIRST SUB-AREAS  (ha) =     142.28
                                   TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                   TOTAL OF ALL SUB-AREAS (ha)    =     142.28

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2     #1    #2      #1   #2     #1    #2    #1   #2     No.
           (ha)             (%)           (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   47.444  0.000  2.000 0.000   .2000 0.000  .056 0.00  .2484 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)        ( mm )    (m^3/s)  Peak  mins
Catch 1   106.02 10.00 0.000  3.000 0.000  93.423  0.000  12.043  60.00 0.000

Catch 2   106.02 10.00 0.000  3.000 0.000  93.423  0.000  20.482  60.00 0.000

Catch 3   106.02 10.00 0.000  3.000 0.000  93.423  0.000  23.093  56.00 0.000

Catch 4   106.02 10.00 0.000  3.000 0.000  93.423  0.000  25.619  56.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          76.10
 ESTIMATED PEAK FLOW         (CUMECS) =     12.86
 ESTIMATED TIME TO PEAK         (MINS) =     67.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          127.3
 ESTIMATED PEAK FLOW         (CUMECS) =     21.81
 ESTIMATED TIME TO PEAK         (MINS) =     65.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          139.6
 ESTIMATED PEAK FLOW         (CUMECS) =     24.41
 ESTIMATED TIME TO PEAK         (MINS) =     61.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          153.5
 ESTIMATED PEAK FLOW         (CUMECS) =     27.06
 ESTIMATED TIME TO PEAK         (MINS) =     61.00
```

P0701757JX07_v1_rafts_pre-dev_100.out

```
##############################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
##############################################################################
#####

                                  ROUTING INCREMENT (MINS) =       1.00
                                  STORM DURATION (MINS)    =       90.
                                  RETURN PERIOD (YRS)      =      100.
                                  BX                       =    1.0000
                                  TOTAL OF FIRST SUB-AREAS  (ha) =     142.28
                                  TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                  TOTAL OF ALL SUB-AREAS (ha)    =     142.28
```

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1 (%)	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	83.033	10.00	0.000	3.000	0.000	110.45	0.000	12.856	67.00	0.000
Catch 2	83.033	10.00	0.000	3.000	0.000	110.45	0.000	21.809	65.00	0.000
Catch 3	83.033	10.00	0.000	3.000	0.000	110.45	0.000	24.406	61.00	0.000
Catch 4	83.033	10.00	0.000	3.000	0.000	110.45	0.000	27.057	61.00	0.000

```
 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          85.05
 ESTIMATED PEAK FLOW         (CUMECS) =     13.47
 ESTIMATED TIME TO PEAK         (MINS) =     80.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          142.3
 ESTIMATED PEAK FLOW         (CUMECS) =     22.76
 ESTIMATED TIME TO PEAK         (MINS) =     80.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          156.0
 ESTIMATED PEAK FLOW         (CUMECS) =     25.24
 ESTIMATED TIME TO PEAK         (MINS) =     68.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          171.5
```

P0701757JX07_v1_rafts_pre-dev_100.out
ESTIMATED PEAK FLOW (CUMECS) = 27.96
ESTIMATED TIME TO PEAK (MINS) = 68.00

##
#####

Results for period from 0: 1.0 1/ 1/1990
to 5: 1.0 1/ 1/1990
##
#####

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 120.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 142.28
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 142.28

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1 (%)	% Impervious #2	Perm #1	Perm #2	B #1	B #2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	69.564	10.00	0.000	3.000	0.000	123.58	0.000	13.471	80.00	0.000
Catch 2	69.564	10.00	0.000	3.000	0.000	123.58	0.000	22.759	80.00	0.000
Catch 3	69.564	10.00	0.000	3.000	0.000	123.58	0.000	25.242	68.00	0.000
Catch 4	69.564	10.00	0.000	3.000	0.000	123.58	0.000	27.961	68.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 98.03
ESTIMATED PEAK FLOW (CUMECS) = 12.66
ESTIMATED TIME TO PEAK (MINS) = 88.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 163.9
ESTIMATED PEAK FLOW (CUMECS) = 21.37
ESTIMATED TIME TO PEAK (MINS) = 87.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 179.8
ESTIMATED PEAK FLOW (CUMECS) = 23.51

```
                    P0701757JX07_v1_rafts_pre-dev_100.out
 ESTIMATED TIME TO PEAK          (MINS) =     83.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          197.7
 ESTIMATED PEAK FLOW          (CUMECS) =     26.00
 ESTIMATED TIME TO PEAK          (MINS) =     83.00



###############################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
###############################################################################
#####

                                   ROUTING INCREMENT (MINS) =       1.00
                                   STORM DURATION (MINS)    =       180.
                                   RETURN PERIOD (YRS)      =       100.
                                   BX                       =    1.0000
                                   TOTAL OF FIRST SUB-AREAS  (ha) =     142.28
                                   TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                   TOTAL OF ALL SUB-AREAS (ha)    =     142.28

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope     % Impervious     Perm        B        Link
 Label      #1     #2      #1    #2     #1    #2     #1    #2    #1   #2    No.
             (ha)              (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   47.444  0.000  2.000 0.000  .2000 0.000  .056 0.00  .2484 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )     (mm/h)        ( mm )     (m^3/s)  Peak  mins
Catch 1   54.052 10.00 0.000  3.000 0.000  143.91  0.000  12.665  88.00 0.000

Catch 2   54.052 10.00 0.000  3.000 0.000  143.91  0.000  21.367  87.00 0.000

Catch 3   54.052 10.00 0.000  3.000 0.000  143.91  0.000  23.512  83.00 0.000

Catch 4   54.052 10.00 0.000  3.000 0.000  143.91  0.000  25.997  83.00 0.000


 Run completed at: 15th  November  2007  12:44:56


 mik open         0
```

Rafts 1:100 year ARI Post-development Flood Output

```
                    P0701757JX09_v1_rafts_post-dev_100.out
 Run started at: 15th  November  2007  12:47:30


###############################################################################
#####
                          RUNTIME          RESULTS
###############################################################################
#####

Max. no. of links allowed =  2000

Max. no. of routng increments allowed = 25000

Max. no. of rating curve points = 25000

Max. no. of storm temporal points = 25000

Max. no. of channel subreaches =    25

Max link stack level =    25

Input Version number =          650

 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =           42.11
 ESTIMATED PEAK FLOW         (CUMECS) =      6.96
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =           66.42
 ESTIMATED PEAK FLOW         (CUMECS) =     11.57
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =           73.25
 ESTIMATED PEAK FLOW         (CUMECS) =     13.90
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =           81.03
 ESTIMATED PEAK FLOW         (CUMECS) =     15.45
 ESTIMATED TIME TO PEAK         (MINS) =     31.00



###############################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
###############################################################################
#####
```

P0701757JX09_v1_rafts_post-dev_100.out

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 30.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 135.12
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 135.12

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1 (%)	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	40.289	0.000	2.000	0.000	.2000	0.000	.054	0.00	.2225	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	146.06	10.00	0.000	3.000	0.000	61.728	0.000	6.964	31.00	0.000
Catch 2	146.06	10.00	0.000	3.000	0.000	61.728	0.000	11.572	31.00	0.000
Catch 3	146.06	10.00	0.000	3.000	0.000	61.728	0.000	13.903	31.00	0.000
Catch 4	146.06	10.00	0.000	3.000	0.000	61.728	0.000	15.450	31.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 64.60
ESTIMATED PEAK FLOW (CUMECS) = 12.04
ESTIMATED TIME TO PEAK (MINS) = 60.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 101.5
ESTIMATED PEAK FLOW (CUMECS) = 19.64
ESTIMATED TIME TO PEAK (MINS) = 59.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 111.9
ESTIMATED PEAK FLOW (CUMECS) = 22.33
ESTIMATED TIME TO PEAK (MINS) = 55.00

LINK Catch 4 1.003

ESTIMATED VOLUME (CU METRES*10**3) = 123.7
ESTIMATED PEAK FLOW (CUMECS) = 24.85
ESTIMATED TIME TO PEAK (MINS) = 55.00

##########
#####

Page 2

```
                    P0701757JX09_v1_rafts_post-dev_100.out
Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####

                                        ROUTING INCREMENT (MINS) =       1.00
                                        STORM DURATION (MINS)    =       60.
                                        RETURN PERIOD (YRS)      =      100.
                                        BX                       =    1.0000
                                        TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                        TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                        TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern         B        Link
 Label      #1     #2      #1    #2      #1    #2     #1    #2     #1    #2     No.
           (ha)              (%)           (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000   .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)        ( mm )    (m^3/s)  Peak  mins
Catch 1   106.02 10.00 0.000  3.000 0.000  93.423  0.000  12.043  60.00 0.000

Catch 2   106.02 10.00 0.000  3.000 0.000  93.423  0.000  19.638  59.00 0.000

Catch 3   106.02 10.00 0.000  3.000 0.000  93.423  0.000  22.328  55.00 0.000

Catch 4   106.02 10.00 0.000  3.000 0.000  93.423  0.000  24.852  55.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          76.10
 ESTIMATED PEAK FLOW         (CUMECS) =     12.86
 ESTIMATED TIME TO PEAK         (MINS) =     67.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          119.8
 ESTIMATED PEAK FLOW         (CUMECS) =     20.90
 ESTIMATED TIME TO PEAK         (MINS) =     63.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          132.0
 ESTIMATED PEAK FLOW         (CUMECS) =     23.56
 ESTIMATED TIME TO PEAK         (MINS) =     61.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          146.0
 ESTIMATED PEAK FLOW         (CUMECS) =     26.21
 ESTIMATED TIME TO PEAK         (MINS) =     61.00
```

P0701757JX09_v1_rafts_post-dev_100.out

```
#############################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
#############################################################################
#####

                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       90.
                                RETURN PERIOD (YRS)      =      100.
                                BX                       =   1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Perm        B        Link
 Label      #1     #2      #1    #2     #1    #2     #1    #2    #1   #2    No.
           (ha)              (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)       ( mm )     (m^3/s)  Peak  mins
Catch 1   83.033 10.00 0.000  3.000 0.000  110.45  0.000  12.856  67.00 0.000

Catch 2   83.033 10.00 0.000  3.000 0.000  110.45  0.000  20.898  63.00 0.000

Catch 3   83.033 10.00 0.000  3.000 0.000  110.45  0.000  23.559  61.00 0.000

Catch 4   83.033 10.00 0.000  3.000 0.000  110.45  0.000  26.210  61.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          85.05
 ESTIMATED PEAK FLOW         (CUMECS) =     13.47
 ESTIMATED TIME TO PEAK         (MINS) =     80.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          133.8
 ESTIMATED PEAK FLOW         (CUMECS) =     21.64
 ESTIMATED TIME TO PEAK         (MINS) =     71.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          147.5
 ESTIMATED PEAK FLOW         (CUMECS) =     24.40
 ESTIMATED TIME TO PEAK         (MINS) =     66.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          163.0
```

```
                    P0701757JX09_v1_rafts_post-dev_100.out
 ESTIMATED PEAK FLOW          (CUMECS) =     27.12
 ESTIMATED TIME TO PEAK          (MINS) =     66.00



################################################################################
#####


Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####


                                  ROUTING INCREMENT (MINS) =       1.00
                                  STORM DURATION (MINS)    =       120.
                                  RETURN PERIOD (YRS)      =       100.
                                  BX                       =    1.0000
                                  TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                  TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                  TOTAL OF ALL SUB-AREAS (ha)    =     135.12


     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2     #1    #2      #1    #2     #1    #2    #1   #2     No.
             (ha)              (%)           (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)        ( mm )     (m^3/s) Peak  mins
Catch 1   69.564 10.00 0.000  3.000 0.000  123.58  0.000  13.471  80.00 0.000

Catch 2   69.564 10.00 0.000  3.000 0.000  123.58  0.000  21.636  71.00 0.000

Catch 3   69.564 10.00 0.000  3.000 0.000  123.58  0.000  24.398  66.00 0.000

Catch 4   69.564 10.00 0.000  3.000 0.000  123.58  0.000  27.117  66.00 0.000


 LINK Catch 1          1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          98.03
 ESTIMATED PEAK FLOW          (CUMECS) =     12.66
 ESTIMATED TIME TO PEAK          (MINS) =     88.00

 LINK Catch 2          1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          154.2
 ESTIMATED PEAK FLOW          (CUMECS) =     20.29
 ESTIMATED TIME TO PEAK          (MINS) =     85.00

 LINK Catch 3          1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          170.2
 ESTIMATED PEAK FLOW          (CUMECS) =     22.51
```

```
                    P0701757JX09_v1_rafts_post-dev_100.out
 ESTIMATED TIME TO PEAK          (MINS) =     81.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          188.0
 ESTIMATED PEAK FLOW          (CUMECS) =     25.00
 ESTIMATED TIME TO PEAK          (MINS) =     81.00



################################################################################
#####


Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####


                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       180.
                                RETURN PERIOD (YRS)      =       100.
                                BX                       =    1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2      #1    #2      #1   #2     #1    #2    #1   #2     No.
           (ha)             (%)           (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )     (mm/h)       ( mm )     (m^3/s)  Peak  mins
Catch 1   54.052 10.00 0.000  3.000 0.000  143.91  0.000  12.665  88.00 0.000

Catch 2   54.052 10.00 0.000  3.000 0.000  143.91  0.000  20.287  85.00 0.000

Catch 3   54.052 10.00 0.000  3.000 0.000  143.91  0.000  22.512  81.00 0.000

Catch 4   54.052 10.00 0.000  3.000 0.000  143.91  0.000  25.005  81.00 0.000


 Run completed at: 15th  November  2007  12:47:31


 mik open         0
```

Rafts Probable Maximum Existing-development Flood Output

```
                    P0701757JX08_v1_rafts_pre-dev_PMF.out
 Run started at: 15th  November  2007  12:41:52


###############################################################################
#####
                          RUNTIME          RESULTS
###############################################################################
#####

Max. no. of links allowed =  2000

Max. no. of routng increments allowed = 25000

Max. no. of rating curve points = 25000

Max. no. of storm temporal points = 25000

Max. no. of channel subreaches =    25

Max link stack level =    25

Input Version number =          650

 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          120.8
 ESTIMATED PEAK FLOW         (CUMECS) =     29.53
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          201.6
 ESTIMATED PEAK FLOW         (CUMECS) =     50.85
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          220.9
 ESTIMATED PEAK FLOW         (CUMECS) =     59.30
 ESTIMATED TIME TO PEAK         (MINS) =     31.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          242.9
 ESTIMATED PEAK FLOW         (CUMECS) =     65.79
 ESTIMATED TIME TO PEAK         (MINS) =     31.00



###############################################################################
#####


Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
###############################################################################
#####
```

P0701757JX08_v1_rafts_pre-dev_PMF.out

```
                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       30.
                                RETURN PERIOD (YRS)      =  1000000.
                                BX                       =    1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     142.28
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     142.28
```

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1	% Impervious #2	Perm #1	Perm #2	B #1	B #2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	368.21	10.00	0.000	3.000	0.000	172.66	0.000	29.531	31.00	0.000
Catch 2	368.21	10.00	0.000	3.000	0.000	172.66	0.000	50.848	31.00	0.000
Catch 3	368.21	10.00	0.000	3.000	0.000	172.66	0.000	59.298	31.00	0.000
Catch 4	368.21	10.00	0.000	3.000	0.000	172.66	0.000	65.791	31.00	0.000

```
 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          188.4
 ESTIMATED PEAK FLOW         (CUMECS) =     46.85
 ESTIMATED TIME TO PEAK         (MINS) =     49.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          314.4
 ESTIMATED PEAK FLOW         (CUMECS) =     79.31
 ESTIMATED TIME TO PEAK         (MINS) =     48.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          344.4
 ESTIMATED PEAK FLOW         (CUMECS) =     88.62
 ESTIMATED TIME TO PEAK         (MINS) =     46.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          378.5
 ESTIMATED PEAK FLOW         (CUMECS) =     98.25
 ESTIMATED TIME TO PEAK         (MINS) =     46.00
```

```
################################################################################
#####
```

Page 2

P0701757JX08_v1_rafts_pre-dev_PMF.out
Results for period from 0: 1.0 1/ 1/1990
to 5: 1.0 1/ 1/1990
##
#####

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 60.
RETURN PERIOD (YRS) = 1000000.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 142.28
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 142.28

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	281.31	10.00	0.000	3.000	0.000	268.51	0.000	46.848	49.00	0.000
Catch 2	281.31	10.00	0.000	3.000	0.000	268.51	0.000	79.313	48.00	0.000
Catch 3	281.31	10.00	0.000	3.000	0.000	268.51	0.000	88.620	46.00	0.000
Catch 4	281.31	10.00	0.000	3.000	0.000	268.51	0.000	98.253	46.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 228.5
ESTIMATED PEAK FLOW (CUMECS) = 48.83
ESTIMATED TIME TO PEAK (MINS) = 55.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 381.5
ESTIMATED PEAK FLOW (CUMECS) = 82.45
ESTIMATED TIME TO PEAK (MINS) = 54.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 417.9
ESTIMATED PEAK FLOW (CUMECS) = 90.98
ESTIMATED TIME TO PEAK (MINS) = 47.00

LINK Catch 4 1.003

ESTIMATED VOLUME (CU METRES*10**3) = 459.3
ESTIMATED PEAK FLOW (CUMECS) = 100.87
ESTIMATED TIME TO PEAK (MINS) = 47.00

P0701757JX08_v1_rafts_pre-dev_PMF.out

```
################################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####

                                  ROUTING INCREMENT (MINS) =       1.00
                                  STORM DURATION (MINS)    =       90.
                                  RETURN PERIOD (YRS)      =  1000000.
                                  BX                       =     1.0000
                                  TOTAL OF FIRST SUB-AREAS  (ha) =    142.28
                                  TOTAL OF SECOND SUB-AREAS (ha) =      0.00
                                  TOTAL OF ALL SUB-AREAS (ha)    =    142.28

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2      #1   #2     #1   #2      #1   #2     #1   #2    No.
             (ha)              (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   47.444  0.000  2.000 0.000  .2000 0.000  .056 0.00  .2484 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)       ( mm )     (m^3/s)  Peak   mins
Catch 1   226.69 10.00 0.000  3.000 0.000  325.73  0.000  48.828  55.00 0.000

Catch 2   226.69 10.00 0.000  3.000 0.000  325.73  0.000  82.450  54.00 0.000

Catch 3   226.69 10.00 0.000  3.000 0.000  325.73  0.000  90.980  47.00 0.000

Catch 4   226.69 10.00 0.000  3.000 0.000  325.73  0.000  100.87  47.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          260.4
 ESTIMATED PEAK FLOW         (CUMECS) =     51.16
 ESTIMATED TIME TO PEAK         (MINS) =     63.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          435.1
 ESTIMATED PEAK FLOW         (CUMECS) =     86.32
 ESTIMATED TIME TO PEAK         (MINS) =     62.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          476.7
 ESTIMATED PEAK FLOW         (CUMECS) =     94.66
 ESTIMATED TIME TO PEAK         (MINS) =     60.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          523.8
```

P0701757JX08_v1_rafts_pre-dev_PMF.out
ESTIMATED PEAK FLOW (CUMECS) = 104.72
ESTIMATED TIME TO PEAK (MINS) = 59.00

##
#####

Results for period from 0: 1.0 1/ 1/1990
to 5: 1.0 1/ 1/1990
##
#####

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 120.
RETURN PERIOD (YRS) = 1000000.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 142.28
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 142.28

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1 (%)	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	47.444	0.000	2.000	0.000	.2000	0.000	.056	0.00	.2484	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	193.88	10.00	0.000	3.000	0.000	372.01	0.000	51.156	63.00	0.000
Catch 2	193.88	10.00	0.000	3.000	0.000	372.01	0.000	86.322	62.00	0.000
Catch 3	193.88	10.00	0.000	3.000	0.000	372.01	0.000	94.664	60.00	0.000
Catch 4	193.88	10.00	0.000	3.000	0.000	372.01	0.000	104.72	59.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 310.9
ESTIMATED PEAK FLOW (CUMECS) = 46.36
ESTIMATED TIME TO PEAK (MINS) = 74.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 519.7
ESTIMATED PEAK FLOW (CUMECS) = 77.92
ESTIMATED TIME TO PEAK (MINS) = 73.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 569.4
ESTIMATED PEAK FLOW (CUMECS) = 84.86

```
                    P0701757JX08_v1_rafts_pre-dev_PMF.out
 ESTIMATED TIME TO PEAK          (MINS) =     71.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          626.0
 ESTIMATED PEAK FLOW          (CUMECS) =     93.51
 ESTIMATED TIME TO PEAK          (MINS) =     70.00



################################################################################
#####


Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####


                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       180.
                                RETURN PERIOD (YRS)      =   1000000.
                                BX                       =     1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     142.28
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     142.28

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2      #1   #2      #1   #2     #1   #2    #1   #2     No.
           (ha)              (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   47.444  0.000  2.000 0.000   .2000 0.000  .056 0.00  .2484 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)       ( mm )     (m^3/s)  Peak  mins
Catch 1   155.15 10.00 0.000  3.000 0.000  446.70  0.000  46.357  74.00 0.000

Catch 2   155.15 10.00 0.000  3.000 0.000  446.70  0.000  77.920  73.00 0.000

Catch 3   155.15 10.00 0.000  3.000 0.000  446.70  0.000  84.856  71.00 0.000

Catch 4   155.15 10.00 0.000  3.000 0.000  446.70  0.000  93.513  70.00 0.000


 Run completed at: 15th  November  2007  12:41:52


 mik open         0
```

Rafts Probable Maximum Post-development Flood Output

```
                    P0701757JX10_v1_rafts_post-dev_PMF.out
 Run started at: 14th  November  2007  12:01:33


###############################################################################
#####
                          RUNTIME          RESULTS
###############################################################################
#####

 Max. no. of links allowed =  2000

 Max. no. of routng increments allowed = 25000

 Max. no. of rating curve points = 25000

 Max. no. of storm temporal points = 25000

 Max. no. of channel subreaches =    25

 Max link stack level =    25

 Input Version number =          650

  LINK Catch 1           1.000

  ESTIMATED VOLUME (CU METRES*10**3) =           120.8
  ESTIMATED PEAK FLOW         (CUMECS) =     29.53
  ESTIMATED TIME TO PEAK         (MINS) =     31.00

  LINK Catch 2           1.001

  ESTIMATED VOLUME (CU METRES*10**3) =           189.4
  ESTIMATED PEAK FLOW         (CUMECS) =     49.25
  ESTIMATED TIME TO PEAK         (MINS) =     31.00

  LINK Catch 3           1.002

  ESTIMATED VOLUME (CU METRES*10**3) =           208.7
  ESTIMATED PEAK FLOW         (CUMECS) =     57.70
  ESTIMATED TIME TO PEAK         (MINS) =     31.00

  LINK Catch 4           1.003

  ESTIMATED VOLUME (CU METRES*10**3) =           230.7
  ESTIMATED PEAK FLOW         (CUMECS) =     64.20
  ESTIMATED TIME TO PEAK         (MINS) =     31.00



###############################################################################
#####

 Results for period from  0: 1.0  1/ 1/1990
                       to  5: 1.0  1/ 1/1990
###############################################################################
#####
```

P0701757JX10_v1_rafts_post-dev_PMF.out

```
                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =        30.
                                RETURN PERIOD (YRS)      =   1000000.
                                BX                       =     1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     135.12
```

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1 (%)	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	40.289	0.000	2.000	0.000	.2000	0.000	.054	0.00	.2225	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	368.21	10.00	0.000	3.000	0.000	172.66	0.000	29.531	31.00	0.000
Catch 2	368.21	10.00	0.000	3.000	0.000	172.66	0.000	49.253	31.00	0.000
Catch 3	368.21	10.00	0.000	3.000	0.000	172.66	0.000	57.703	31.00	0.000
Catch 4	368.21	10.00	0.000	3.000	0.000	172.66	0.000	64.196	31.00	0.000

```
 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          188.4
 ESTIMATED PEAK FLOW         (CUMECS) =     46.85
 ESTIMATED TIME TO PEAK         (MINS) =     49.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          295.7
 ESTIMATED PEAK FLOW         (CUMECS) =     76.05
 ESTIMATED TIME TO PEAK         (MINS) =     47.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          325.7
 ESTIMATED PEAK FLOW         (CUMECS) =     85.48
 ESTIMATED TIME TO PEAK         (MINS) =     45.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          359.8
 ESTIMATED PEAK FLOW         (CUMECS) =     95.13
 ESTIMATED TIME TO PEAK         (MINS) =     45.00

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#####
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Page 2

P0701757JX10_v1_rafts_post-dev_PMF.out
Results for period from 0: 1.0 1/ 1/1990
to 5: 1.0 1/ 1/1990
##
#####

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 60.
RETURN PERIOD (YRS) = 1000000.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 135.12
TOTAL OF SECOND SUB-AREAS (ha) = 0.00
TOTAL OF ALL SUB-AREAS (ha) = 135.12

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	#2	Slope #1 (%)	#2	% Impervious #1	#2	Perm #1	#2	B #1	#2	Link No.
Catch 1	70.826	0.000	1.860	0.000	0.000	0.000	.050	0.00	.2913	0.000	1.000
Catch 2	40.289	0.000	2.000	0.000	.2000	0.000	.054	0.00	.2225	0.000	1.001
Catch 3	11.198	0.000	3.210	0.000	0.000	0.000	.060	0.00	.0986	0.000	1.002
Catch 4	12.811	0.000	1.000	0.000	2.300	0.000	.053	0.00	.1543	0.000	1.003

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	#2	Cont. Loss #1 (mm/h)	#2	Excess Rain #1 (mm)	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
Catch 1	281.31	10.00	0.000	3.000	0.000	268.51	0.000	46.848	49.00	0.000
Catch 2	281.31	10.00	0.000	3.000	0.000	268.51	0.000	76.048	47.00	0.000
Catch 3	281.31	10.00	0.000	3.000	0.000	268.51	0.000	85.480	45.00	0.000
Catch 4	281.31	10.00	0.000	3.000	0.000	268.51	0.000	95.128	45.00	0.000

LINK Catch 1 1.000

ESTIMATED VOLUME (CU METRES*10**3) = 228.5
ESTIMATED PEAK FLOW (CUMECS) = 48.83
ESTIMATED TIME TO PEAK (MINS) = 55.00

LINK Catch 2 1.001

ESTIMATED VOLUME (CU METRES*10**3) = 358.7
ESTIMATED PEAK FLOW (CUMECS) = 78.43
ESTIMATED TIME TO PEAK (MINS) = 53.00

LINK Catch 3 1.002

ESTIMATED VOLUME (CU METRES*10**3) = 395.1
ESTIMATED PEAK FLOW (CUMECS) = 87.75
ESTIMATED TIME TO PEAK (MINS) = 46.00

LINK Catch 4 1.003

ESTIMATED VOLUME (CU METRES*10**3) = 436.5
ESTIMATED PEAK FLOW (CUMECS) = 97.66
ESTIMATED TIME TO PEAK (MINS) = 46.00

Page 3

P0701757JX10_v1_rafts_post-dev_PMF.out

```
################################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####

                                  ROUTING INCREMENT (MINS) =       1.00
                                  STORM DURATION (MINS)    =       90.
                                  RETURN PERIOD (YRS)      =  1000000.
                                  BX                       =     1.0000
                                  TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                  TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                  TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2     #1    #2     #1    #2     #1    #2    #1   #2    No.
             (ha)             (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)       ( mm )     (m^3/s)  Peak  mins
Catch 1   226.69 10.00 0.000  3.000 0.000  325.73  0.000  48.828  55.00 0.000

Catch 2   226.69 10.00 0.000  3.000 0.000  325.73  0.000  78.430  53.00 0.000

Catch 3   226.69 10.00 0.000  3.000 0.000  325.73  0.000  87.749  46.00 0.000

Catch 4   226.69 10.00 0.000  3.000 0.000  325.73  0.000  97.659  46.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          260.4
 ESTIMATED PEAK FLOW         (CUMECS) =     51.16
 ESTIMATED TIME TO PEAK         (MINS) =     63.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          409.0
 ESTIMATED PEAK FLOW         (CUMECS) =     82.01
 ESTIMATED TIME TO PEAK         (MINS) =     61.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          450.6
 ESTIMATED PEAK FLOW         (CUMECS) =     90.65
 ESTIMATED TIME TO PEAK         (MINS) =     58.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =          497.7
                                  Page 4
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                    P0701757JX10_v1_rafts_post-dev_PMF.out
 ESTIMATED PEAK FLOW          (CUMECS) =    100.74
 ESTIMATED TIME TO PEAK          (MINS) =     58.00



################################################################################
#####

Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####

                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       120.
                                RETURN PERIOD (YRS)      =   1000000.
                                BX                       =     1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Perm        B        Link
 Label      #1     #2     #1    #2     #1    #2     #1    #2    #1    #2    No.
             (ha)              (%)          (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)       ( mm )     (m^3/s)  Peak   mins
Catch 1   193.88 10.00 0.000  3.000 0.000  372.01  0.000  51.156  63.00 0.000

Catch 2   193.88 10.00 0.000  3.000 0.000  372.01  0.000  82.006  61.00 0.000

Catch 3   193.88 10.00 0.000  3.000 0.000  372.01  0.000  90.654  58.00 0.000

Catch 4   193.88 10.00 0.000  3.000 0.000  372.01  0.000  100.74  58.00 0.000


 LINK Catch 1           1.000

 ESTIMATED VOLUME (CU METRES*10**3) =          310.9
 ESTIMATED PEAK FLOW          (CUMECS) =     46.36
 ESTIMATED TIME TO PEAK          (MINS) =     74.00

 LINK Catch 2           1.001

 ESTIMATED VOLUME (CU METRES*10**3) =          488.7
 ESTIMATED PEAK FLOW          (CUMECS) =     73.50
 ESTIMATED TIME TO PEAK          (MINS) =     71.00

 LINK Catch 3           1.002

 ESTIMATED VOLUME (CU METRES*10**3) =          538.4
 ESTIMATED PEAK FLOW          (CUMECS) =     80.55
                                Page 5
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                    P0701757JX10_v1_rafts_post-dev_PMF.out
 ESTIMATED TIME TO PEAK          (MINS) =     69.00

 LINK Catch 4           1.003

 ESTIMATED VOLUME (CU METRES*10**3) =           595.0
 ESTIMATED PEAK FLOW          (CUMECS) =     89.27
 ESTIMATED TIME TO PEAK          (MINS) =     69.00



################################################################################
#####


Results for period from  0: 1.0  1/ 1/1990
                    to  5: 1.0  1/ 1/1990
################################################################################
#####


                                ROUTING INCREMENT (MINS) =       1.00
                                STORM DURATION (MINS)    =       180.
                                RETURN PERIOD (YRS)      =   1000000.
                                BX                       =     1.0000
                                TOTAL OF FIRST SUB-AREAS  (ha) =     135.12
                                TOTAL OF SECOND SUB-AREAS (ha) =       0.00
                                TOTAL OF ALL SUB-AREAS (ha)    =     135.12

     SUMMARY OF CATCHMENT AND RAINFALL DATA
 Link      Catch. Area      Slope    % Impervious     Pern        B        Link
 Label      #1     #2      #1   #2      #1   #2     #1    #2    #1   #2     No.
             (ha)              (%)           (%)
Catch 1   70.826  0.000  1.860 0.000  0.000 0.000  .050 0.00  .2913 0.000  1.000

Catch 2   40.289  0.000  2.000 0.000  .2000 0.000  .054 0.00  .2225 0.000  1.001

Catch 3   11.198  0.000  3.210 0.000  0.000 0.000  .060 0.00  .0986 0.000  1.002

Catch 4   12.811  0.000  1.000 0.000  2.300 0.000  .053 0.00  .1543 0.000  1.003


 Link    Average  Init. Loss  Cont. Loss    Excess Rain   Peak    Time   Link
 Label  Intensity  #1    #2    #1    #2      #1    #2    Inflow   to     Lag
          (mm/h)    ( mm )      (mm/h)        ( mm )    (m^3/s)  Peak  mins
Catch 1   155.15 10.00 0.000  3.000 0.000  446.70  0.000  46.357  74.00 0.000

Catch 2   155.15 10.00 0.000  3.000 0.000  446.70  0.000  73.501  71.00 0.000

Catch 3   155.15 10.00 0.000  3.000 0.000  446.70  0.000  80.545  69.00 0.000

Catch 4   155.15 10.00 0.000  3.000 0.000  446.70  0.000  89.267  69.00 0.000


 Run completed at: 14th  November  2007  12:01:33


 mik open         0
```

Appendix D

HEC-RAS Hydraulic Existing-Development / Post-Development Modelling

(No. of pages excluding this page = 4)

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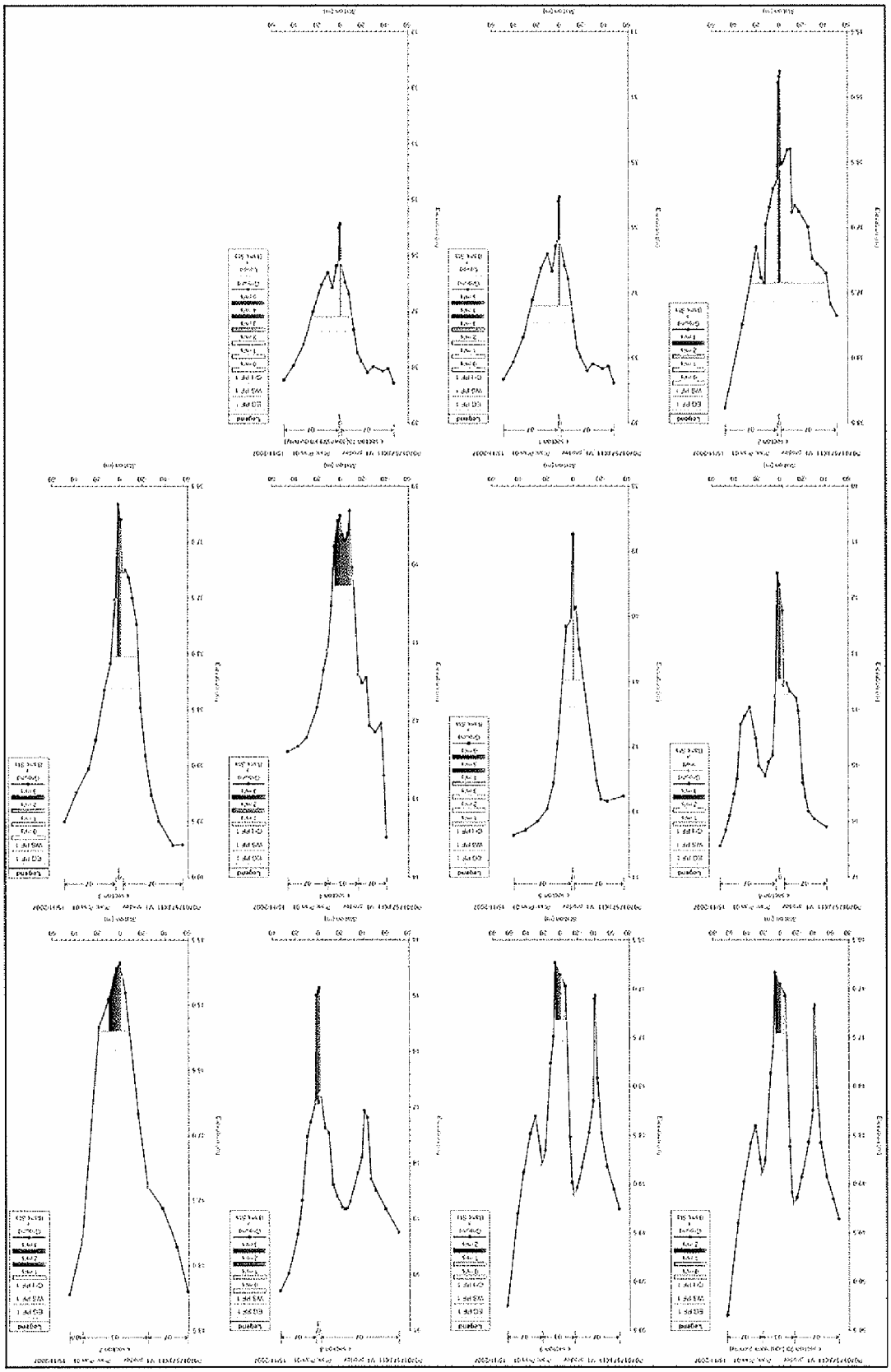
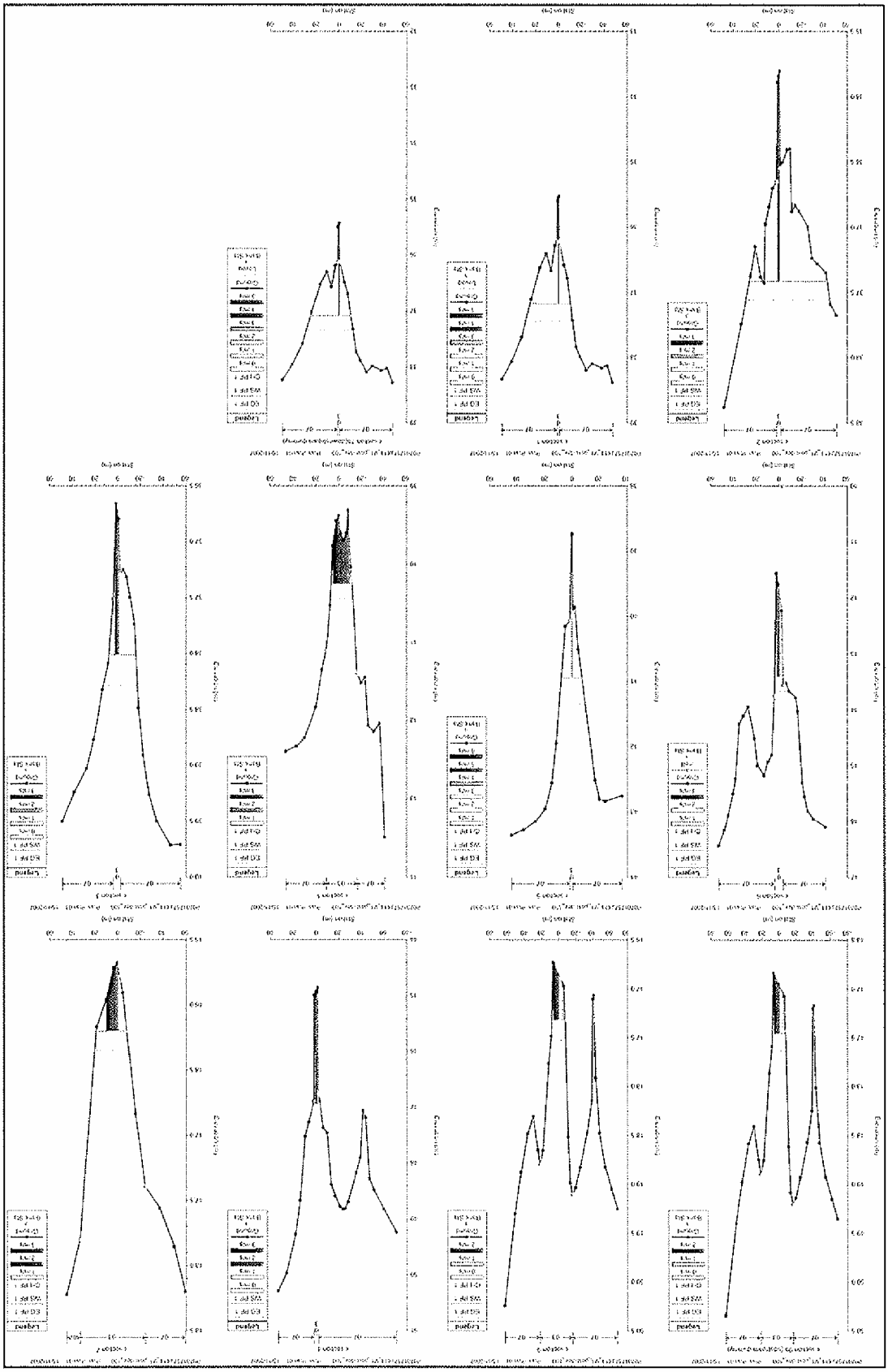
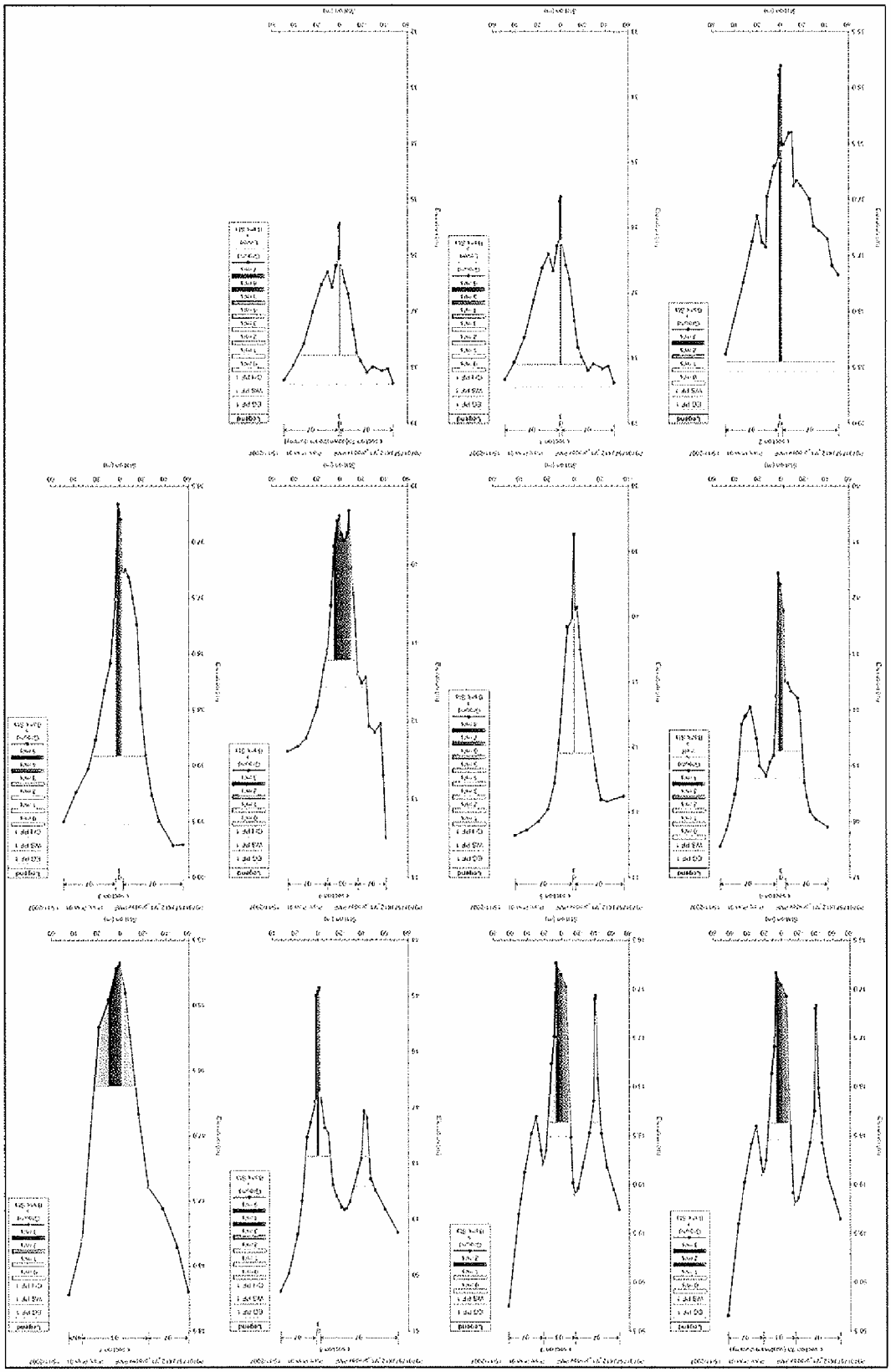
HECRAS 1:100 Year ARI Existing-development Flood Sections



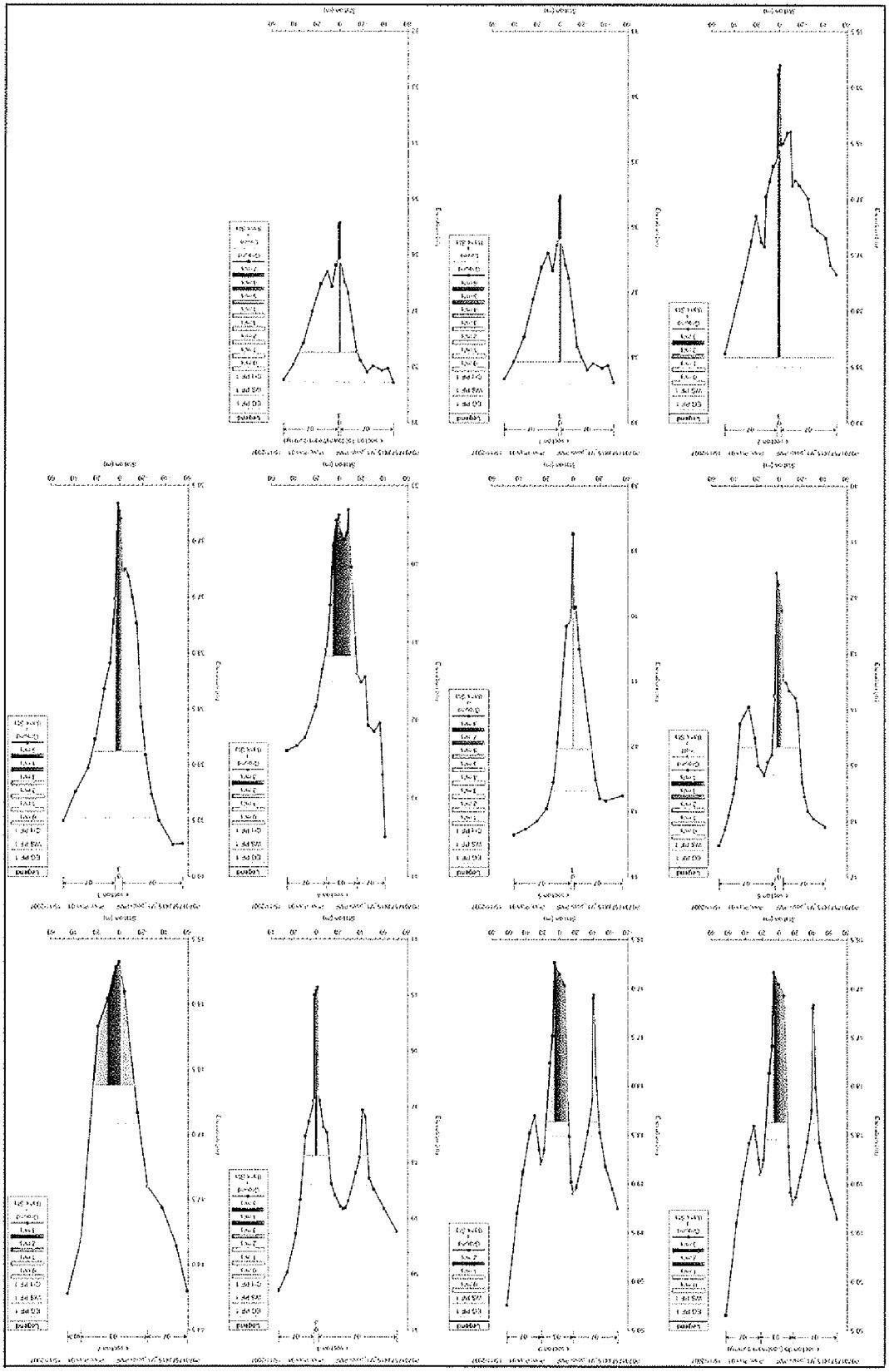
HECRAS 1:100 Year ARI Post-development Sections



HECRAS PMF Existing-development Sections



HECRAS PMF Post-development Sections



Appendix E

Recharge Testing

(No. of pages excluding this page = 3)

Single Bore Slug Test (Rising or Falling)

Method ST-13 Revised 7.3.2007

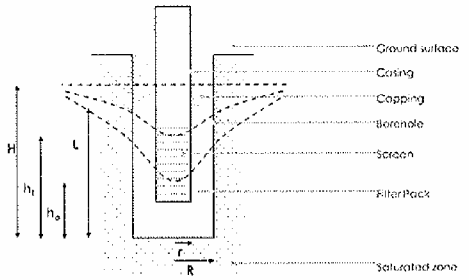
martens consulting engineers

PROJECT DETAILS

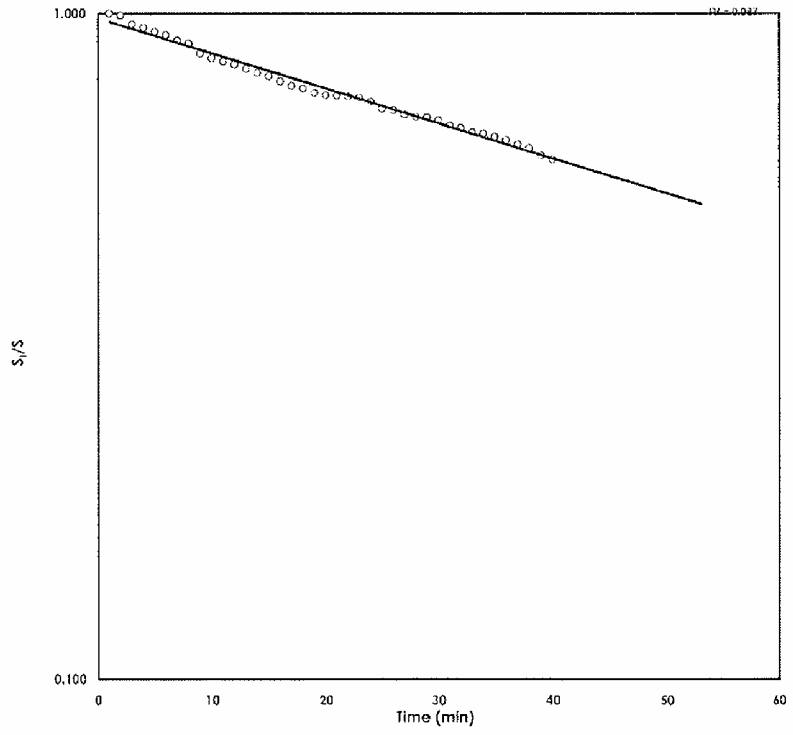
Project	Nowra Brickworks Quarry - Part 3a Application	Test Date	21.06.2007
Project Ref	P0701757JS05_V1	Field Testing	B.Rose
Borehole Ref	Piezometer P2	Data Analysis	B.Rose/D.Martens
Method	Hvorslev (1981)	Reviewed	D.Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	15.5	m
h_o - Water level reading at time = 0 (depth)	7.1	m
r - Casing radius	0.025	m
R - Bore radius	0.050	m
L - Length of open screen	6.00	m
T_o - Length of characteristic time	80.66	minutes
K_{sat} - Saturated hydraulic conductivity	0.00445	m/d



DATA PLOT



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Single Bore Slug Test (Rising or Falling)

Method 3F.13 Revised 7.3.2007

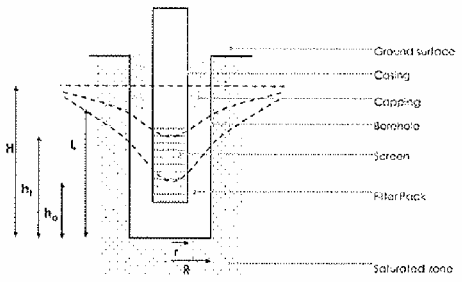
martens consulting engineers

PROJECT DETAILS

Project	Nowra Brickworks Hydrogeological Investigation	Test Date	24.10.2007
Project Ref	P0701757JST1_V5	Field Testing	BR/GT
Borehole Ref	P8	Data Analysis	29.10.2007
Method	Hvorslev (1981)	Reviewed	D. Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	13.3	m
h_o - Water level reading at time = 0 (depth)	20.3	m
r - Casing radius	0.050	m
R - Bore radius	0.050	m
L - Length of open screen	20.10	m
T_o - Length of characteristic time	7.70	minutes
K_{sat} - Saturated hydraulic conductivity	0.070	m/d



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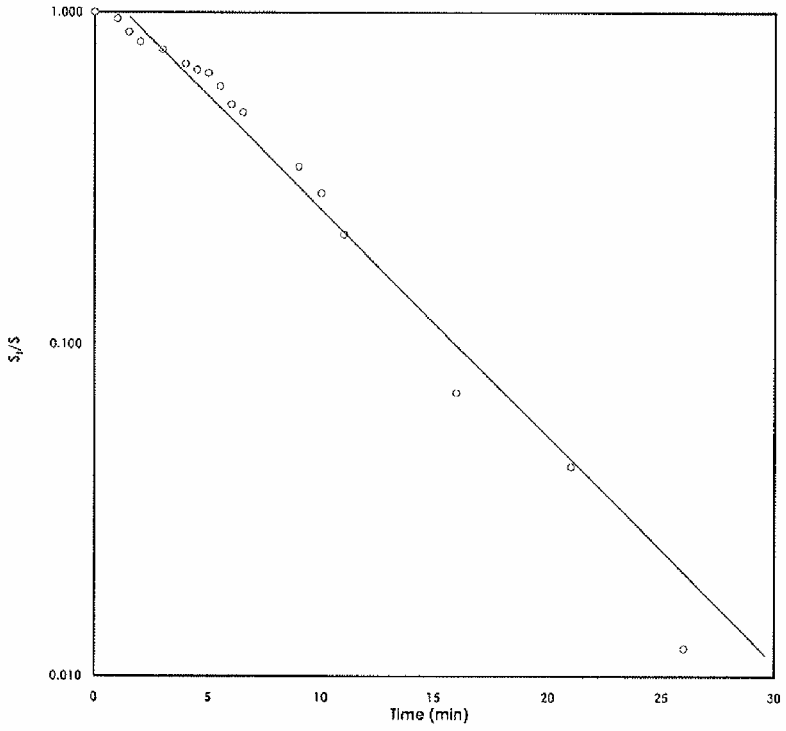

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Single Bore Slug Test (Rising or Falling)

Method SF-13 Revised 7.3.2007

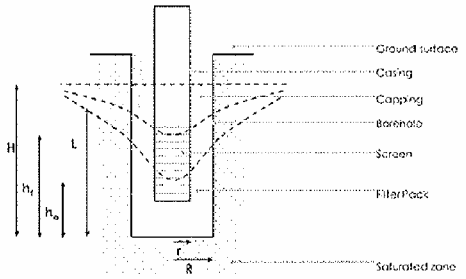
martens consulting engineers

PROJECT DETAILS

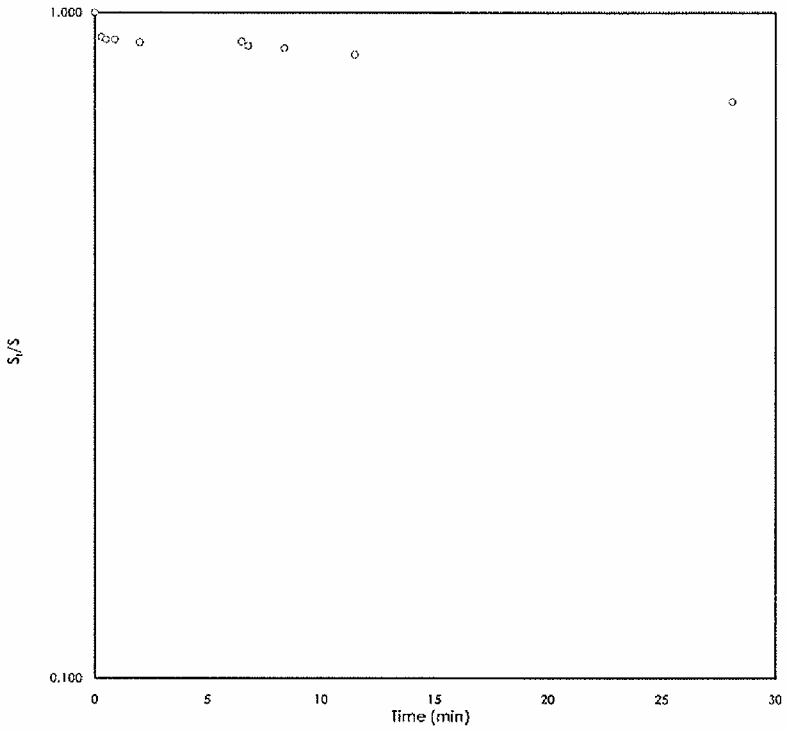
Project	Nowra Brickworks Quarry - Part 3a Application	Test Date	7.12.2007
Project Ref	P07017573S18 v1	Field Testing	B.Rose, D. Martens
Borehole Ref	P3	Data Analysis	10.12.2007
Method	Hvorslev (1981)	Reviewed	D. Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	6.0	m
h_o - Water level reading at time = 0 (depth)	13.4	m
r - Casing radius	0.025	m
R - Bore radius	0.045	m
L - Length of open screen	6.00	m
t_o - Length of characteristic time	131.01	minutes
K_{sat} - Saturated hydraulic conductivity	0.00331	m/d



DATA PLOT



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Appendix F

Laboratory Report

(No. of pages excluding this page = 8)

Envirolab Services Pty Ltd
ABN 37 112 535 645
54 Frenchs Rd Willoughby NSW 2068
ph 02 9958 5801 fax 02 9958 5803
email: tnotaras@envirolabservices.com.au

CERTIFICATE OF ANALYSIS 14228

Client:
Martens & Associates
6/37 Leighton Place
Hornsby
NSW 2077

Attention: Ben Rose

Sample log in details:

Your Reference:	P0701757-SCCCR
No. of samples:	12 Waters
Date samples received:	08/10/07
Date completed instructions received:	08/10/07

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by:	17/10/07
Date of Preliminary Report:	Not Issued
Issue Date:	23/10/07

NATA accreditation number 2901. This document shall not be reproduced except in full.
This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025.
Tests not covered by NATA are denoted with *.

Results Approved By:

Jacinta Hurst
Operations Manager

Envirolab Reference: 14228
Revision No: R 00

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Client Reference: P0701757-SCCCR

Ion Balance Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-1 1757/C1 5/10/2007 Water	14228-2 1757/C2 5/10/2007 Water	14228-3 1757/S1 4/10/2007 Water	14228-4 1757/S2 4/10/2007 Water	14228-5 1757/S3 4/10/2007 Water
Calcium - Dissolved	mg/L	9.0	57	140	120	110
Potassium - Dissolved	mg/L	4.5	13	21	20	27
Sodium - Dissolved	mg/L	32	680	1,600	1,200	1,800
Magnesium - Dissolved	mg/L	7.1	59	230	170	180
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	26	250	240	230	540
Sulphate, SO4	mg/L	19	410	940	890	790
Chloride (titration) - water	mg/L	49	740	2,400	1,900	2,400

Ion Balance Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-6 1757/P1/20.0 4/10/2007 Water	14228-7 1757/P2/20.0 4/10/2007 Water	14228-8 1757/P3/11.0 4/10/2007 Water	14228-9 1757/P5/9.5 4/10/2007 Water	14228-10 1757/P6/9.5 4/10/2007 Water
Calcium - Dissolved	mg/L	240	84	270	160	69
Potassium - Dissolved	mg/L	26	25	33	33	21
Sodium - Dissolved	mg/L	1,900	1,000	2,600	2,200	1,100
Magnesium - Dissolved	mg/L	390	110	450	270	110
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	480	340	580	590	890
Sulphate, SO4	mg/L	550	270	720	690	730
Chloride (titration) - water	mg/L	3,200	1,900	4,700	3,300	1,400

Ion Balance Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-11 1757/P7/15.0 4/10/2007 Water	14228-12 1757/P8/20.0 4/10/2007 Water
Calcium - Dissolved	mg/L	260	260
Potassium - Dissolved	mg/L	34	21
Sodium - Dissolved	mg/L	2,000	2,200
Magnesium - Dissolved	mg/L	390	390
Carbonate Alkalinity as $CaCO_3$	mg/L	<0.1	<0.1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	520	610
Sulphate, SO4	mg/L	490	490
Chloride (titration) - water	mg/L	4,000	4,200

Client Reference: P0701757-SCCCR

Miscellaneous Inorganics Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-1 1757/C1 5/10/2007 Water	14228-2 1757/C2 5/10/2007 Water	14228-3 1757/S1 4/10/2007 Water	14228-4 1757/S2 4/10/2007 Water	14228-5 1757/S3 4/10/2007 Water
pH	pH Units	6.6	7.8	8.2	8.2	7.9
Electrical Conductivity	µS/cm	250	3,200	7,900	6,500	8,000
Nitrate as N in water	mg/L	<0.1	16	<0.1	0.2	41
Nitrite as N in water	mg/L	0.04	0.70	<0.01	<0.01	4.2
Total Kjeldahl Nitrogen	mg/L	1.6	3.9	0.5	0.5	7.5
Ammonia as N in water	mg/L	<0.10	2.3	<0.10	<0.10	6.9
Total Nitrogen in water	mg/L	1.7	21	<0.6	0.7	53
Phosphorus - Total	mg/L	0.080	<0.05	<0.05	<0.05	<0.05
BOD5	mg/L	<4	4.0	<4	<4	<4
Total Suspended Solids @ 103-105^{O}C	mg/L	15	20	8	<5	29

Miscellaneous Inorganics Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-6 1757/P1/20.0 4/10/2007 Water	14228-7 1757/P2/20.0 4/10/2007 Water	14228-8 1757/P3/11.0 4/10/2007 Water	14228-9 1757/P5/9.5 4/10/2007 Water	14228-10 1757/P6/9.5 4/10/2007 Water
pH	pH Units	6.8	7.7	7.2	7.3	7.4
Electrical Conductivity	µS/cm	9,100	5,700	12,000	9,500	5,400
Nitrate as N in water	mg/L	0.1	<0.1	<0.1	<0.1	<0.1
Nitrite as N in water	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	0.6	1.3	1.2	2.0	1.1
Ammonia as N in water	mg/L	0.30	0.80	0.60	1.0	<0.10
Total Nitrogen in water	mg/L	0.7	1.4	1.3	2.1	1.2
Phosphorus - Total	mg/L	<0.05	<0.05	<0.05	1.0	<0.05
BOD5	mg/L	24	34	78	100	14
Total Suspended Solids @ 103-105^{O}C	mg/L	13	23	14	140	38

Miscellaneous Inorganics Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	14228-11 1757/P7/15.0 4/10/2007 Water	14228-12 1757/P8/20.0 4/10/2007 Water
pH	pH Units	7.0	7.2
Electrical Conductivity	µS/cm	11,000	11,000
Nitrate as N in water	mg/L	<0.1	<0.1
Nitrite as N in water	mg/L	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	1.1	1.1
Ammonia as N in water	mg/L	0.90	1.0
Total Nitrogen in water	mg/L	1.2	1.2
Phosphorus - Total	mg/L	<0.05	0.05
BOD5	mg/L	33	<4

Envirolab Reference: 14228
Revision No: R 00

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Client Reference: P0701757-SCCCR

Miscellaneous Inorganics Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ---------- 	 14228-11 1757/P7/15.0 4/10/2007 Water	 14228-12 1757/P8/20.0 4/10/2007 Water
Total Suspended Solids @ 103-105°C	mg/L	52	86

Client Reference: P0701757-SCCCR

Method ID	Methodology Summary
Metals.20 ICP-AES	Determination of various metals by ICP-AES.
LAB.6	Alkalinity - determined titrimetrically in accordance with APHA 20th ED, 2320-B.
LAB.9	Sulphate determined turbidimetrically.
LAB.11	Chloride determined by argentometric titration.
LAB.1	pH - Measured using pH meter and electrode in accordance with APHA 20th ED, 4500-H+.
LAB.2	Conductivity and Salinity - measured using a conductivity cell and dedicated meter, in accordance with APHA2510 20th ED and Rayment & Higginson.
LAB.55	Nitrate water extractable - determined colourimetrically based on EPA114A.
LAB.56	Nitrite water extractable - determined colourimetrically based on EPA116A.
Ext-020	Analysis subcontracted to Australian Government - National Measurement Institute. NATA Accreditation No: 198
LAB.57	Ammonia water extractable - determined colourimetrically based on EPA103A.
LAB.66	Total Nitrogen - Calculation sum of TKN and oxidised Nitrogen.
LAB.19	Suspended Solids - determined gravimetrcially by filtration of the sample, in accordance with APHA 20th ED, 2540-D.

Client Reference: P0701757-SCCCR

QUALITY CONTROL Ion Balance	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base || Duplicate || %RPD	Spike Sm#	Spike % Recovery
Calcium - Dissolved	mg/L	0.03	Metals.20 ICP-AES	<0.030	14228-2	57 || 56 || RPD: 2	LCS-W1	99%
Potassium - Dissolved	mg/L	0.03	Metals.20 ICP-AES	<0.030	14228-2	13 || 13 || RPD: 0	LCS-W1	98%
Sodium - Dissolved	mg/L	0.03	Metals.20 ICP-AES	<0.030	14228-2	680 || 680 || RPD: 0	LCS-W1	81%
Magnesium - Dissolved	mg/L	0.03	Metals.20 ICP-AES	<0.030	14228-2	59 || 60 || RPD: 2	LCS-W1	99%
Carbonate Alkalinity as $CaCO_3$	mg/L	0.1	LAB.6	<0.1	14228-2	<0.1 || <0.1	[NR]	[NR]
Bicarbonate Alkalinity as $CaCO_3$	mg/L	0.1	LAB.6	<0.1	14228-2	250 || [N/T]	LCS-W1	100%
Sulphate, SO4	mg/L	5	LAB.9	<5.0	14228-2	410 || [N/T]	LCS-W1	81%
Chloride (titration) - water	mg/L	20	LAB.11	<20	14228-2	740 || [N/T]	LCS-W1	96%
QUALITY CONTROL Miscellaneous Inorganics	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base || Duplicate || %RPD	Spike Sm#	Spike % Recovery
pH	pH Units	0.1	LAB.1	<0.10	14228-1	6.6 || 6.6 || RPD: 0	LCS-W1	100%
Electrical Conductivity	µS/cm	1	LAB.2	<1.0	14228-1	250 || 250 || RPD: 0	LCS-W1	102%
Nitrate as N in water	mg/L	0.1	LAB.55	<0.1	14228-1	<0.1 || [N/T]	LCS-W1	103%
Nitrite as N in water	mg/L	0.01	LAB.56	<0.01	14228-1	0.04 || [N/T]	LCS-W1	103%
Total Kjeldahl Nitrogen	mg/L	0.05	Ext-020	<0.05	14228-1	1.6 || 1.7 || RPD: 6	[NR]	[NR]
Ammonia as N in water	mg/L	0.1	LAB.57	<0.10	14228-1	<0.10 || <0.10	LCS-W1	102%
Total Nitrogen in water	mg/L	0.6	LAB.66	<0.6	14228-1	1.7 || 1.8 || RPD: 6	LCS-W1	96%
Phosphorus - Total	mg/L	0.05	Metals.20 ICP-AES	<0.05	14228-1	0.080 || [N/T]	LCS-W1	83%
BOD5	mg/L	2	Ext-020	<2.0	14228-1	<4 || <4	LCS-W1	99%
Total Suspended Solids @ 103-105^{O}C	mg/L	5	LAB.19	<5	14228-1	15 || 19 || RPD: 24	LCS-W1	95%

QUALITY CONTROL Ion Balance	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Carbonate Alkalinity as $CaCO_3$	mg/L	14228-1	<0.1 || <0.1	[NR]	[NR]
Bicarbonate Alkalinity as $CaCO_3$	mg/L	14228-1	26 || 24 || RPD: 8	[NR]	[NR]
Sulphate, SO4	mg/L	14228-1	19 || 19 || RPD: 0	14228-2	76%
Chloride (titration) - water	mg/L	14228-1	49 || 47 || RPD: 4	[NR]	[NR]

Envirolab Reference: 14228
Revision No: R 00

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Client Reference: P0701757-SCCCR

QUALITY CONTROL Miscellaneous Inorganics	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
pH	pH Units	14228-11	7.0 || 7.0 || RPD: 0	[NR]	[NR]
Electrical Conductivity	µS/cm	14228-11	11000 || 11000 || RPD: 0	[NR]	[NR]
Nitrate as N in water	mg/L	14228-11	<0.1 || [N/T]	14228-3	107%
Nitrite as N in water	mg/L	14228-11	<0.01 || [N/T]	14228-3	98%
Ammonia as N in water	mg/L	14228-11	0.90 || [N/T]	14228-3	112%
Total Suspended Solids @ 103-105^{O}C	mg/L	14228-11	52 || 57 || RPD: 9	[NR]	[NR]
QUALITY CONTROL Ion Balance	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD		
Chloride (titration) - water	mg/L	14228-11	4000 || 4000 || RPD: 0		
QUALITY CONTROL Miscellaneous Inorganics	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Nitrate as N in water	mg/L	14228-3	<0.1 || <0.1	[NR]	[NR]
Nitrite as N in water	mg/L	14228-3	<0.01 || <0.01	[NR]	[NR]
Ammonia as N in water	mg/L	14228-3	<0.10 || <0.10	[NR]	[NR]
Total Nitrogen in water	mg/L	14228-3	<0.6 || [N/T]	14228-1	98%

Client Reference: P0701757-SCCCR

Report Comments:
BOD/Total Kjeldahl Nitrogen analysed by NMI Report No: RN642458.
Total Nitrogen by calculation.
Asbestos analysed by: Not applicable for this job

INS: Insufficient sample for this test	NT: Not tested	PQL: Practical Quantitation Limit
RPD: Relative Percent Difference	NA: Test not required	LCS: Laboratory Control Sample
NR: Not requested	<: Less than	>: Greater than

Quality Control Definitions
Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike: A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample): This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria:
Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes and LCS: Generally 70-130% for inorganics/metals; 60-140% for organics and 10-140% for SVOC and speciated phenols is acceptable. Surrogates: Generally 60-140% is acceptable.

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Appendix G

Coverage of EA Requirements

(No. of pages excluding this page = 5)

Table 24
Coverage of environmental assessment requirements

ENVIRONMENTAL REQUIREMENTS RAISED BY THE DIRECTOR-GENERAL RELATING TO HYDROGEOLOGY AND HYDROLOGY (20/09/2007)	
	Relevant Section(s)
Key Assessment Requirements, namely:	
• *Hydrology:*	
- Include details of surface and groundwater impacts and a site water balance.	Section 3, 5, 6 and 7
- Include details of the proposed water management system including any creek diversions and sediment / water supply dams and water transfers to adjoining land.	Section 3
- Include a contingency strategy setting out the measures that would be implemented to minimise impacts on the supply of water (quality and quantity) to the environment and surrounding landowners.	Section 3, 6 and 7
References:	
• National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).	
• NWQMS Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC 2000).	
• Healthy Rivers Commission Report into Coastal Lakes and Statement of Joint Intent.	
• NSW Government Water Quality and River Flow Environmental Objectives for Clyde River and Jervis Bay.	
• The relevant targets within the State Water Management Outcomes Plan.	
• NSW Guidelines for Urban and Residential Use of Reclaimed Water (NSW Water Recycling Coordination Committee, 1993).	
• National Water Quality Management Strategy: Guidelines for Sewerage Systems – Effluent Management (ARMCANZ / ANZECC 1997).	Section 1.6, 3 and 5
• National Water Quality Management Strategy: Guidelines for Sewerage systems – Use of Reclaimed Water (ARMCANZ / ANZECC 2000).	
• Environmental Guidelines for the Utilisation of Treated Effluent by Irrigation (NSW DEC 2004).	
• Environmental and Health Protection Guidelines: 'Onsite Sewage Management for Single Households', February 1998 (Silver Book).	
• Managing Urban Stormwater: Soils and Construction (NSW Landcom, 2004).	
• Managing Urban Stormwater: Source Control (EPA 1998).	
• Managing Urban Stormwater: Treatment Techniques (EPA 1998).	
• EIS Guidelines (NSW DUAP 1996).	
• NSW State Groundwater Policy Framework Document (NSW Government 1997).	
• NSW State Groundwater Quality Protection Policy (NSW Government 1998).	
• NSW State Groundwater Dependent Ecosystems Policy (NSW Government 2002).	

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO HYDROGEOLOGY AND HYDROLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Environment and Climate Change (7/9/07)	The environmental outcomes for the project in relation to water should be: • there is no pollution of waters (including surface and groundwater) during construction or occupation of the site by the final users; • there is no inconsistency with any relevant Statement of Joint Intent established by the Healthy Rivers Commission; and • It is acceptable in terms of the achievement or protection of the River Flow Objectives and Water Quality Objectives.	Section 3, 5 and 6 Section 3 Section 3
	The *Environmental Assessment* must: • take into account and complement Shoalhaven City Council's Integrated Water Cycle Management Plan which is currently being developed; and • demonstrate that there is sufficient capacity to treat and manage the sewage that is generated by this development.	Section 3 na
Department of Lands (7/9/07)	A detailed field assessment of groundwater flows needs to be conducted prior to excavation, including the quantity of groundwater expected to yield from the 10m to 13m aquifer with the piezometric surface of 0.038m/m.	Section 5
	The impact and management of this water should be addressed for the period of operation of the quarry.	Section 3, 5 and 6.
	The likely behaviour of the groundwater surface following rehabilitation should be addressed.	Section 5.9.4
Department of Water and Energy (6/9/07)	The EA should clearly demonstrate that the proposed depths of quarry extraction will not impact upon and be able to maintain the integrity of Nowra Creek and adjoining riparian vegetation.	Section 5.9.4, and 7
	The EA should identify all water sources, water usage and water management details of the proposal are required, including design, layout, pumping and storage capacities, volumes of water to be used, all associated earthworks and infrastructure works etc.	Section 3, 6
	The EA should demonstrate how the proposed water demand and usage will impact on the surrounding water users including the water-dependent environment most notably, Nowra Creek.	Section 5.9, 6 and 7
	The EA will need to demonstrate the proposal's sustainability and its environmental merit.	Throughout report
	The EA should consider the issues outlined in the Groundwater Assessment Guidelines – Major Projects: Developments Impacting on Groundwater.	Section 5
	A license or licenses under Part 5 of the *Water Act, 1912* is / are required for each piezometer(s).	Piezometers are licensed
	If the excavation is deepened to a level that intercepts the groundwater table, groundwater licensing action will be triggered.	Section 5.10
Department of Water and Energy (6/9/07)	Any activities proposing the transfer of surface or groundwater from the quarry to adjoining lands / landuses will likely require licensing action. This matter should be clarified in the EA and specific details of any proposed off-site water use to be provided.	Section 5.10

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO HYDROGEOLOGY AND HYDROLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Natural Resources	The locations and conditions of any bores within 1 kilometre of the proposed development and the current and potential uses and users of groundwater in that area.	Section 5.9.4
	A baseline assessment of the local and regional groundwater systems based on a reasonable period of monitoring at appropriate locations including: • the depth to the water table, hydraulic gradient, flow directions and rates, location of any recharge areas and discharge sites; • the geological characteristics in the area in relation to the vulnerability of the groundwater to pollution; • the ambient quality of groundwater in the area; and • the presence of environmentally sensitive areas in the vicinity of the proposal site, determination of the occurrence of any threatened or endangered species, and identification of the likely interaction of these ecosystems or communities with groundwater.	Section 5 Section 5
	The potential for acid-related issues due to the presence of acid sulphate soils, if present in the area, considering impacts from the alteration of groundwater levels together with mitigation measures (including minimisation of disturbance of the material or the water table and treatment of disturbed soils or acid water), and details of the proposed monitoring program and response strategies should deleterious effects be observed.	Not Applicable
	The potential for contaminated soils to exist on the site, the potential direct or indirect effects on groundwater, the need for remediation (including the level of remediation, the proposed methods to be used and a monitoring program to assess the progress of the decontamination) and the results of any correspondence with the NSW Department of Environment and Climate Change.	Section 5
	An assessment of the potential risk of contamination of groundwater by activities associated with the development, including: • effects on groundwater recharge areas or aquifer intake areas; • the potential source of pollution, the likely transference of any pollutants to groundwater and measures to avoid contamination during construction and operation; • proposals for remediation should contamination occur; • an assessment of the potential impacts on existing and future uses of groundwater in the area considering both successful and unsuccessful site management and contaminant containment; and • an assessment of the adequacy of proposed construction and operational measures to prevent contamination of groundwater.	Section 5
	Any constraints on the proposal due to soil characteristics, with regard to the potential for lateral or vertical movement of contaminants, considering the permeability of the subsoil structure or surface sealing characteristics, and an assessment of the likelihood of vertical or lateral seepage or flow to neighbouring properties, natural waterbodies or groundwater.	Not applicable

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO HYDROGEOLOGY AND HYDROLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Natural Resources (Cont'd)	Identification of the location and nature of any rising groundwater levels or salinisation problems, if present in the area, and an assessment of the potential for the proposal to contribute to the progression or expansion of these impacts.	Section 6
	An assessment of the need to treat groundwater, stormwater, seepage water, tail water or process water prior to on-site use or discharge to meet beneficial use water quality objectives or other limits or guidelines, identification of the approvals required and details of the adequacy of protection provided by the proposal.	Section 3 and 6
	Predictions of the effects of dewatering or depressurisation on the local and regional groundwater systems, identification of the approvals required and details of the adequacy of protection provided by the proposal.	Section 5
	Definition of the potential impacts of any proposed water usage from a groundwater source (including on neighbouring users and environmental attributes), identification of the approvals required and details of the adequacy of protection provided by the proposal.	Section 5
	Advice on the potential impacts on species, populations, or ecological communities or their habitats (including threatened or endangered species) either directly, or indirectly through changes to the groundwater regime (flow, pressure, level or quality), and details of the adequacy of protection provided by the proposal.	Section 5.9.4
	Description of the proposed final use of the site and its compatibility with the surroundings, including: • the suitability of the site for the identified end use with regard to groundwater, permeability of soil and the type of material to be introduced to achieve any proposed final landform; • assessment of the potential groundwater impacts, long-term potential water quality problems and details of the proposed management if the final landform is proposed to include a recreation lake; • the general suitability of proposed soil material for rehabilitation purposes and the adequacy of measures to be adopted during the development of any final landform to prevent introduction of contaminated or unsuitable material; and • the adequacy of measures to ensure the groundwater will not become contaminated during and after the development of any final landform.	Section 5.9.4

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO HYDROGEOLOGY AND HYDROLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Natural Resources (Cont'd)	Details of a plan for the ongoing maintenance and monitoring of groundwater including: • the key information to be monitored, impact assessment criteria and the reasons for monitoring; • the monitoring locations, intervals and durations; • procedures to be undertaken if the monitoring indicates a non-compliance or abnormality; • internal reporting and links to management practices and action plans; • reporting procedures to relevant authorities; • the effectiveness of proposed management controls or mitigation measures; and • the means for verification of predicted impacts of the proposal.	Section 5
	Outlines of strategies to feed information from the monitoring programs back into the management practices and action plans to improve the environmental performance and sustainability of all components of the proposal.	Section 5 and 6
	Advice on the sustainability of the proposal described in terms of site-specific environmental performance requirements considering the vulnerability of the groundwater and the threats to other environmental factors.	Section 5
	Assessments of the cumulative impacts of the proposal with regard to any other activities with similar impacts in the area interacting with the environment, and specifically groundwater.	Section 5
Shoalhaven City Council (7/9/07)	A water balance model may be required and if so should be prepared by a suitable consultant and any impact on the nearest creek water quality assessed.	Section 6 and 7
	An effluent disposal / wastewater report should be prepared, particularly addressing the needs of staff on site and ensuring compliance with Shoalhaven City Council Development Control Plan No. 78 – Effluent Disposal for Unsewered Areas.	Not Applicable
	Measures for the control of stormwater should be outlined in a stormwater treatment plan which details the collection and mitigation of stormwater runoff and treatment of gross stormwater pollutants that will be generated during the operation of the proposed quarry.	Section 3

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Ecology Assessment

Prepared by

Gaia Research Pty Ltd

January, 2009

Specialist Consultant Studies Compendium:
Part 2A

Ecology Assessment

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

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CONTENTS

Page

DEFINITION OF TERMS 2A-8

1 INTRODUCTION 2A-9
- 1.1 Background 2A-9
- 1.2 The Project 2A-9
- 1.3 Study Objectives 2A-12
- 1.4 Description of Subject Site 2A-14
- 1.5 Previous Assessments Conducted on the Site 2A-14
- 1.6 Threatened Fauna and Flora in the Locality 2A-15

2 METHODS 2A-15
- 2.1 Fauna Assessment 2A-16
  - 2.1.1 Introduction 2A-16
  - 2.1.2 Elliott and Cage Trapping 2A-17
  - 2.1.3 Harp Trapping 2A-17
  - 2.1.4 Diurnal Herpetofauna Census 2A-17
  - 2.1.5 Diurnal Bird Census 2A-17
  - 2.1.6 Foot-Based Spotlighting 2A-19
  - 2.1.7 Nocturnal Call Playback 2A-19
  - 2.1.8 Amphibian Survey 2A-19
  - 2.1.9 Targeted Surveys 2A-19
  - 2.1.10 Incidental Observations 2A-20
- 2.2 Flora Surveys 2A-20
  - 2.2.1 Introduction 2A-20
  - 2.2.2 Targeted surveys for terrestrial orchids 2A-21

3 RESULTS 2A-21
- 3.1 Introduction 2A-21
- 3.2 Fauna detected 2A-23
  - 3.2.1 Introduction 2A-23
  - 3.2.2 Elliott and Cage Trapping 2A-23
  - 3.2.3 Harp Trapping 2A-23
  - 3.2.4 Diurnal Herpetofauna Census 2A-23
  - 3.2.5 Diurnal Bird Census 2A-23
  - 3.2.6 Foot-Based Spotlighting 2A-24
  - 3.2.7 Amphibian survey 2A-24
  - 3.2.8 Targeted Surveys 2A-24
  - 3.2.9 Incidental Observations 2A-25
- 3.3 Native Vegetation 2A-25
  - 3.3.1 Introduction 2A-25
  - 3.3.2 Targeted Searches for Threatened Species of Terrestrial Orchids 2A-25

4 ASSESSMENT OF IMPACTS 2A-27
- 4.1 Preliminary Impact Assessment 2A-27
- 4.2 Detailed Impact Assessment 2A-31
- 4.3 EPBC Act (1999) 2A-35
- 4.4 SEPP 44 ..... 2A-36

5 DISCUSSION 2A-36

CONTENTS

Page

6 BIODIVERSITY OFFSET STRATEGY 2A-37
6.1 Introduction 2A-37
6.2 Biodiversity Offset Areas 2A-37
6.2.1 Northern Biodiversity Offset Area 2A-37
6.2.2 Southern Biodiversity Offset Area 2A-38
6.3 Vegetation with the Offset Areas 2A-38
6.4 Management of the Biodiversity Offset Areas 2A-40
6.5 Term of the Biodiversity Offset Strategy 2A-40
6.6 Assessment of the Biodiversity Offset Strategy 2A-41
7 CONCLUSIONS 2A-45
8 RECOMMENDATIONS 2A-46

TABLES

Table 1 Threatened Fauna and Flora Recorded within 5kms of Subject Site 2A-15
Table 2 Details of Effort for Systematic Surveys 2A-16
Table 3 Systematic and Targeted Survey Methods 2A-16
Table 4 Summary of Fauna Detected During the Survey 2A-23
Table 5 Birds Detected During the Systematic Survey 2A-24
Table 6 Description of Select Sites where *Cryptostylis hunteriana* located in the Shoalhaven 2A-27
Table 7 Description of Sites where *Genoplesium baueri* located in the Shoalhaven 2A-27
Table 8 Preferred Habitat of Select listed Threatened Species 2A-29

FIGURES

Figure 1 Subject Site and Surrounding Land Uses 2A-10
Figure 2 Location of the Subject Site, Associated Mining Leases and Biodiversity Offset Areas 2A-11
Figure 3 Subject Site Layout 2A-13
Figure 4 Location of Trapping and Flora Survey Sites 2A-18
Figure 5 Location of Hollow Bearing Trees 2A-22
Figure 6 Location of Threatened Terrestrial Orchids 2A-28
Figure 7 Location of Grey-headed Flying Fox Camps 2A-32
Figure 8 Biodiversity Offset Areas 2A-39

APPENDICES

Appendix 1 Director-General's Requirements for the Proposal 2A-53
Appendix 2 Fauna Detected on the Site 2A-57
Appendix 3 Native Flora located on the Subject Site and offsite offset 2A-61
Appendix 4 Hollow-bearing Trees located on the Subject site and the Southern Biodiversity Offset Area 2A-65
Appendix 5 Plot Data for Vegetation Quadrats 2A-69
Appendix 6 Curriculum Vitae of Participating Consultants 2A-75
Appendix 7 Offset in principle agreement 2A-85

EXECUTIVE SUMMARY

Fauna and flora surveys were conducted at part Lot 464 DP 1058778, Princes Highway, South Nowra (the "Subject Site") in relation to a proposed expansion of the Nowra Brickworks Quarry. The surveys utilised systematic and targeted methods in order to find species listed under the *Threatened Species Conservation Act 1995* (TSC Act) and the *Environmental Planning & Assessment Act 1979* (EP&A Act). One Threatened species, the Grey-headed Flying Fox *Pteropus poliocephalus,* listed in Schedule 2 of the TSC Act was detected on site. The Square-tailed Kite *Lophoictinia isura*, listed on Schedule 2 of the TSC Act was detected approximately 0.5 kilometres to the west of the Subject Site and probably nests close to the site. No endangered ecological communities currently listed in the TSC Act were located. No species currently listed in the *Environment Protection and Biodiversity Conservation Act 1999* were found within the Subject Site.

The proposed expansion of the quarry would necessitate the removal of approximately 7.4 hectares of Spotted Gum forest including 35 hollow-bearing trees. The action will not have a significant impact on threatened species but adds to the cumulative loss of habitat in the region. Although the ability to reduce the level/extent of impact is small for this proposal, there are a number of measures that may be adopted to protect the habitat for fauna and rehabilitate the site.

The "on site" ameliorative measures include retaining approximately three hectare of land supporting trees. The retained bushland is located on the north-west of the Subject site, an area within six metres of the inside toe of the perimeter bunds and in an area 40 metres from the bank of Nowra Creek. This will conserve approximately 32 hollow-bearing trees on the Subject site and help protect the riparian area. Felling of the trees will be done during winter when threatened species are not nesting or caring for young. A suitably qualified fauna consultant will be present when the hollow-bearing trees are felled to either relocate fauna to adjacent bushland or rescue injured animals. The felled non-hollow bearing tress would be mulched or broken up and directly placed on areas undergoing rehabilitation, or stockpiled for later use during progressive rehabilitation. Sections of hollow-bearing trees to be removed will be preserved and relocated to areas undergoing progressive rehabilitation or areas within the riparian buffer zone beside Nowra Creek, or stockpiled for later use during progressive rehabilitation. The site requires a long term rehabilitation and remediation program and this has been prepared.

The "off site" ameliorative measures include the protection of approximately 17 hectares of Spotted Gum forest to the south-west of the Subject site. The majority of this land is within Lot 229 (10.3 hectares) and the residual in Lot 228 (6.7 hectares). Lot 229 supports 26 hollow-bearing trees and will protect habitat in the upper catchment of Nowra Creek. Lot 228 supports 12 hollow-bearing trees. The habitat to be conserved off site is contiguous with that retained within the South Coast Correctional Centre site and the Subject site. The proposed off-set strategy with link to a broader conservation objective of protecting a riparian and habitat linkage.

DEFINITION OF TERMS

Within this report the following terms are defined.

- ***Subject Site*** means the area directly affected by the proposal.
- ***Subject area*** means the Subject Site and any additional area, which may be affected by the proposal.
- ***Direct impacts*** are those that directly affect the habitat and individuals.
- ***Local population*** of resident fauna species comprises those individuals known or likely to occur in the study area, as well as any individuals occurring in adjoining areas (contiguous or otherwise) that are known or likely to utilise habitats in the study area.

1 INTRODUCTION

1.1 Background

This report was commissioned by South Coast Concrete Crushing and Recycling Pty Ltd to assess and document the impact of the proposed continued and expanded use of the Nowra Brickworks Quarry on threatened species of fauna and flora within Lot 464 DP 1058778, Princes Highway, South Nowra. The site comprises two mining leases (ML5087 and ML6322) ("the Subject Site") (**Figures 1** and **2**). ML5087 is approximately 7.3 hectares in size and ML6322 is approximately 14.7 hectares in size. The western perimeter of ML5087 and a large portion of the perimeter of ML6322 supports native vegetation. The area of native vegetation proposed to be removed by the Project is approximately 7.4 hectares.

The Subject Site is zoned Rural 1(b) – Rural "B" (Arterial and Main Road Protection) Zone, with a small portion of the Subject Site zoned Rural 1(f) – Rural "F" (Forest) Zone.

This report was prepared by Mr Garry Daly, Director of Gaia Research Pty Ltd. Mr Daly was assisted by Ms Rebecca Rudd of the same Company and Mr Alan Stephenson. The CVs of Messrs Daly and Stephenson and Ms Rudd are presented in **Appendix 6**.

1.2 The Project

The Project continued and expanded use of the Nowra Brickworks Quarry would, in summary, incorporate the following activities (**Figure 3**).

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark prior to the annual production from the quarry reaching 250 000t.
- Staged extraction of shale material ("extracted material") from a proposed extraction area of 15.0ha, incorporating an existing extraction area of approximately 2.0ha. Weathered shale material would be extracted using an excavator and stockpiled or direct loaded into road registrable trucks for transportation to the quarry's customers. Unweathered shale material would initially be blasted before being extracted using an excavator. Extraction operations would generally progress from north to south.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted material to produce saleable products.

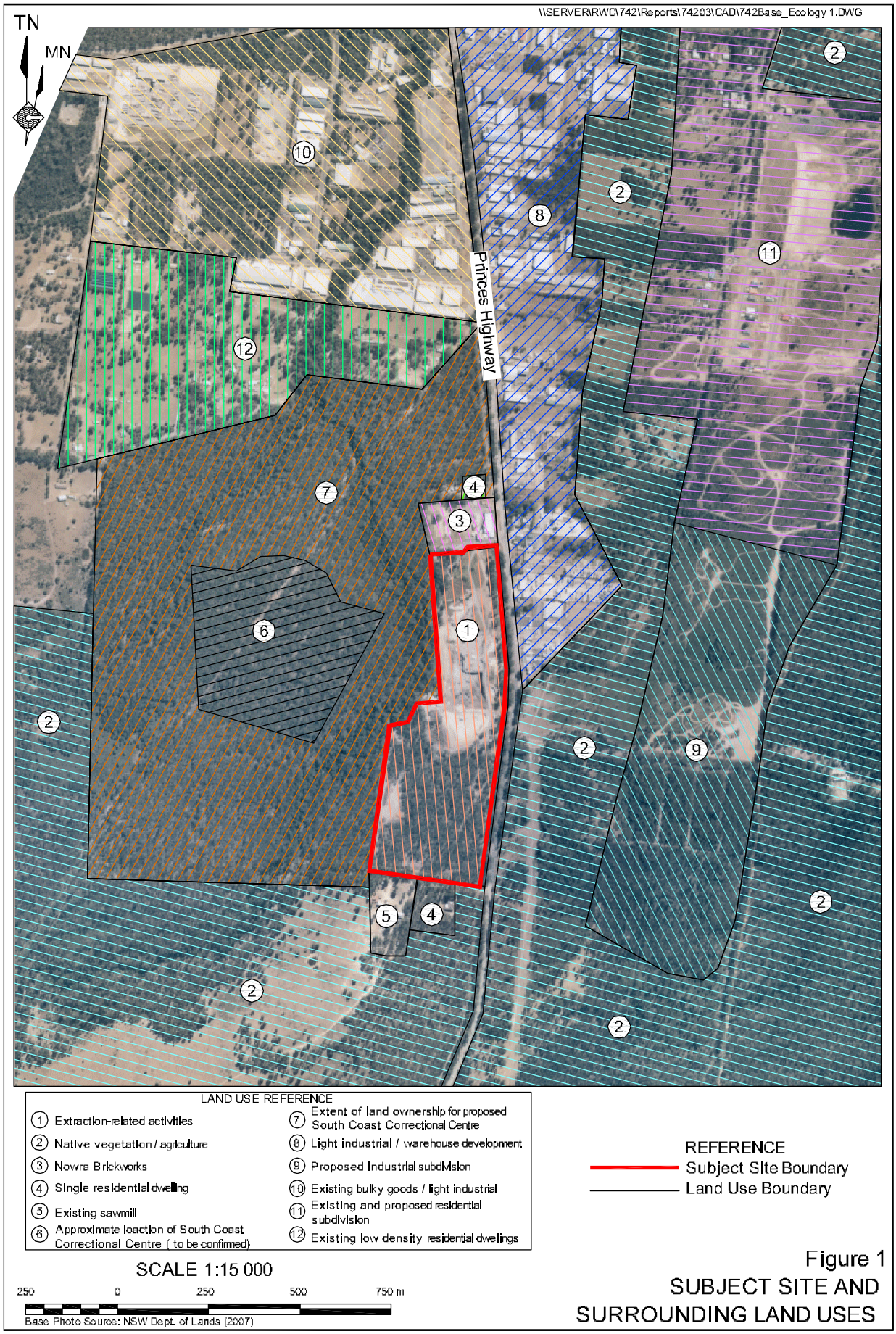

Figure 1
SUBJECT SITE AND SURROUNDING LAND USES

Note: A Colour Version of this figure is available on the project CD

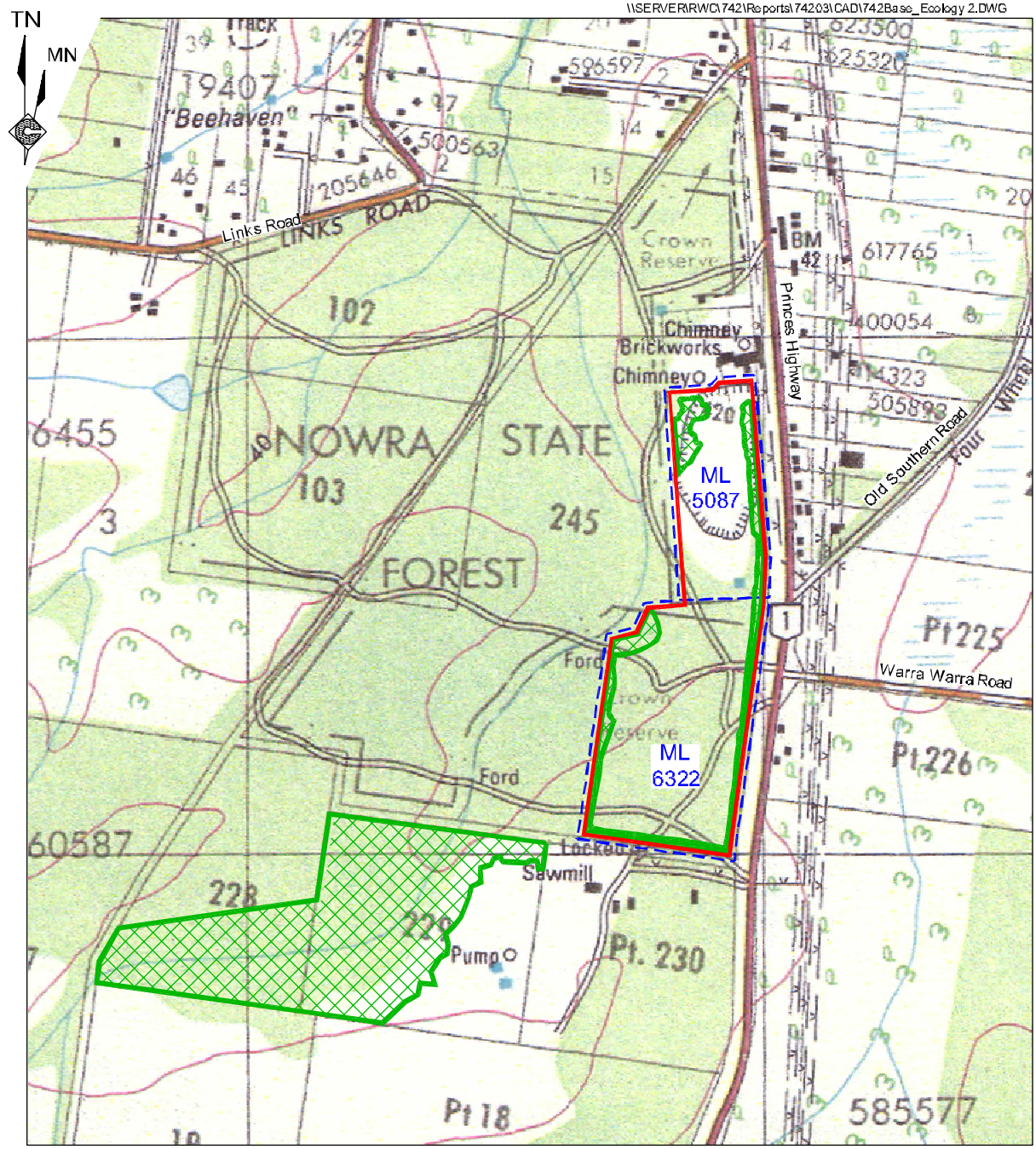

Figure 2
LOCATION OF THE SUBJECT SITE, ASSOCIATED MINING LEASES AND BIODIVERSITY OFFSET AREAS

Note: A Colour Version of this figure is available on the project CD

- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A portion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

In addition, the Project would involve the removal of approximately 7.4 ha of Spotted Gum forest.

The following assessment forms a component of an *Environmental Assessment* prepared in support of an application for planning approval for the continuation and expansion of extractive operations within ML5087 and ML6322 under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Under the *Threatened Species Conservation Act 1995* (TSC Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) surveys for species/ecological communities listed under these Acts must be conducted and an assessment of the impact of the proposal on those species/ecological communities must be undertaken prior to consent being granted. This report details the species of fauna and flora that occur within the Subject Site and applies the relevant portions of the above Acts to listed species / ecological communities that may occur or were detected on or adjacent to the Subject Site.

1.3 Study Objectives

The objectives of the study were to:

- assess the Subject Site and Study area for threatened species and endangered ecological communities as listed under State and Commonwealth legislation;
- conduct systematic surveys for fauna and flora;
- assess the local and regional significance of select threatened species that were either detected on or adjacent to the site or may utilise the site based on known habitat preference;

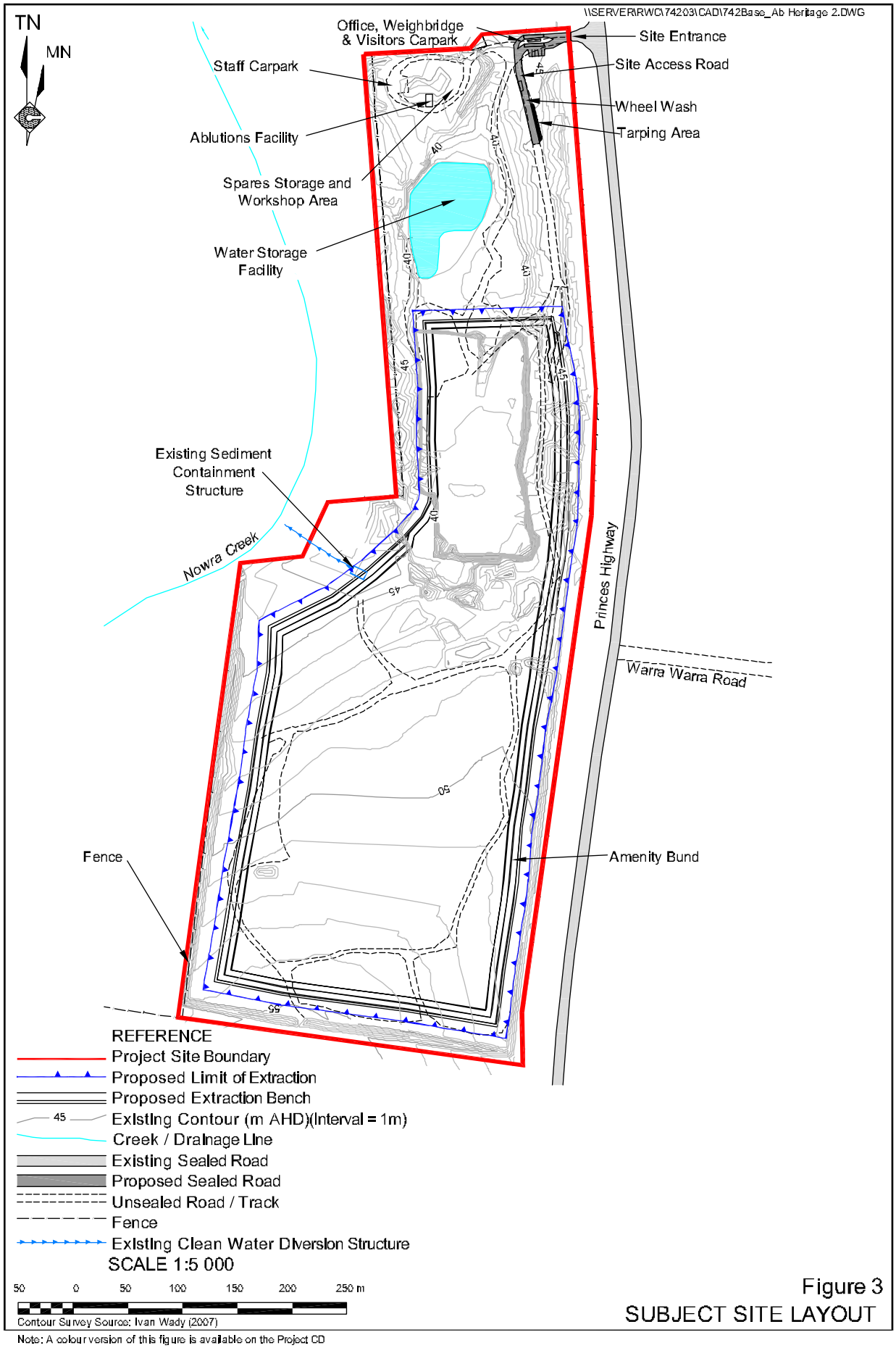

Figure 3
SUBJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

- identify fauna habitat of conservation significance;
- apply the seven part test in Section 5A of the EP&A Act, as amended by the TSC Act as part of the Part 3A assessment to determine whether there is likely to be a significant impact on threatened species or their habitat and endangered ecological communities;
- apply Part 9 of the EPBC Act to determine whether there is likely to be a significant impact on a matter of national significance; and
- provide data from the surveys in an excel spreadsheet as per requirement under the scientific licence issued by the Department of Environment and Climate Change (DECC).

1.4 Description of Subject Site

The Subject Site occupies part of Lot 464 DP 1058778, Princes Highway, South Nowra (Huskisson 1: 25,000 topographic map Lat 34° 55' 30", Long 150° 36' AMG 281000 6132700, altitude 40 m AHD) and is situated on the south coast of NSW, six kilometres south of the Shoalhaven River. The Subject Site has, thin poorly drained clayey soils derived from Nowra Sandstone (Hazelton, 1993). Rock outcrops are absent.

The endemic vegetation within the Subject Site may be classified as Coastal Lowlands Cycad Dry Shrub Dry Forest - *Corymbia maculata / Macrozamia communis,* Forest Ecosystem 9 according to Thomas *et al.* (2000). The forest has been logged and much of the sub-canopy is regrowth. Based on diameter at breast height, the trees are in the order of forty years old. Although there is evidence of selective logging a number of older trees remain that contain hollows that provide habitat for fauna.

The forest is contiguous with that to the west, but is interrupted by the Princes Highway to the east, a saw milling plant to the south and the Nowra brickworks to the north **(Figure 1).** The connecting bushland to the west of the Subject Site is proposed to be developed for the South Coast Correctional Centre. The South Coast Correctional Centre site is composed of several lots and the total area is approximately 115 hectares of bushland. The proposed gaol site is connected to bushland to the south and west, but linkages elsewhere such as along Nowra Creek are tenuous.

1.5 Previous Assessments Conducted on the Site

A fauna assessment has previously been conducted within the Subject Site for the continued operation of the quarry in accordance with State Environmental Planning Policy (SEPP) No. 37 – Continued Mines and Extractive Industries (Daly, 1995). This work required assessment of the impact of the quarry operations at that time, under the EP&A Act, on threatened fauna in accordance with SEPP 37. The assessment included targeted searches for the Yellow-bellied Glider *Petaurus australis* by spotlighting, broadcast of call playback and searches for incised trees. Searches were also conducted for the Green and Golden Bell Frog *Litoria aurea* beside a dam within the Subject Site. The assessment at that time did not consider expansion of the existing quarry requiring the removal of native vegetation. Subsequently, when the then seven part test was introduced under the EP&A Act, a conclusion was reached that the operation of the quarry within the existing disturbed areas would not cause a significant effect to threatened fauna.

Daly (1995) recommended that the Subject Site should be remediated after it had completed functioning as a quarry. Recommended remediation included revegetation with endemic species, utilising seed of local provenance, providing ponds for the Green and Golden Bell Frog *Litoria aurea* and large rocks as refuge habitat for reptiles and amphibians.

In addition, a *Weed Management and Rehabilitation Plan* (the "Part 3B Report") has been prepared by Gaia Research Pty Ltd. The Part 3B Report is reproduced as Part 3B of the *Specialist Consultant Studies Compendium* and this report assumes compliance with the recommendations of the Part 3B Report.

1.6 Threatened Fauna and Flora in the Locality

Records from DECC's Atlas of NSW Wildlife and the author's records indicate the threatened species listed in **Table 1** have been found within five kilometres of the Subject Site. In addition DECC state in their list of requirements provided to the Department of Planning that the Midge Orchid *Genoplesium baueri* and Grey-headed Flying Fox *Pteropus poliocephalus* is to be considered in the assessment (**Appendix 1**).

Table 1
Threatened Fauna and Flora Recorded within 5kms of Subject Site

Threatened Species / Ecological Community	Scientific Name	TSC Act Schedule
Koala	*Phascolarctos cinereus*	2
Yellow-bellied Glider	*Petaurus australis*	2
Black Bittern	*Ixobrychus flavicollis*	2
Australasian Bittern	*Botaurus poiciloptilus*	2
Square-tailed Kite	*Lophoictinia isura*	2
Bush-stone Curlew	*Burhinus grallarius*	1
Glossy Black Cockatoo	*Calyptorhynchus lathami*	2
Gang-gang Cockatoo	*Callocephalon fimbriatum*	2
Powerful Owl	*Ninox strenua*	2
Regent Honeyeater	*Xanthomyza phrygia*	1
Green and Golden Bell Frog	*Litoria aurea*	1
Pouched Greenhood Orchid	*Pterostylis gibbosa*	1
Leafless Tongue Orchid	*Cryptostylis hunteriana*	1
Nowra Heath Myrtle	*Triplarina nowraensis*	2
Source: DECC Atlas of NSW Wildlife		

2 METHODS

The methods utilised by Gaia Research during the preparation of this report adhere to those defined under the *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities (Working draft*), prepared by the Department of Environment and Conservation (2004) and the *Draft Guidelines for Threatened Species Assessment* prepared by the (then) Department of Environment and Conservation and Department of Primary Industries (2005). The assessment for determining impact on threatened species considers those detailed in *Threatened Species Assessment Guidelines* prepared by the Department of Environment and Climate Change (2007).

The dataset produced during this survey is compatible with those generated during the comprehensive regional assessment of forests undertaken by the Department of Environment and Climate Change (previously the NPWS and DEC) as a prelude to the regional forestry agreement in NSW.

2.1 Fauna Assessment

2.1.1 Introduction

Surveys for fauna were conducted from 2 August to 3 October 2007 (see Sections 2.1.2 to 2.1.9 and **Table 2**). The site-based and targeted survey methods are summarised in **Table 3**. Systematic surveys were based around a 2 ha (100 x 200 m) site termed a transect. Three small mammal trapping transects were set within the Spotted Gum forest. Four harp traps were set at various locations in order to capture insectivorous bats (**Figure 4**). The locations of the sites were recorded by global positioning system in AMG Datum 66, UTM co-ordinates in Zone 56.

Table 2
Details of Effort for Systematic Surveys

Activity	Elliott Trapping	Harp Trapping	Herpetofauna Census [2]	Diurnal Bird Survey [2]	Call Playback	Spotlight Survey	Amphibian Search
Date and Time [1]	25 to 27 Sept. 2007	25 to 27 Sept. 2007	9.00h to 10.00h on 25 Sept. 2007	8.20h to 8.40h on 25 Sept. 2007	17.50h to 18.55h on 2 Aug. 2007	18.15h to 18.55h on 2 Aug. 2007 and 19.00-19.40h on11 March 2008	19.05h to10.35h on 2 Oct. 2007 and 19.50-19.57 h on 11 March 2008
Weather	Fine, cool	Fine, cool	Fine	Fine, still.	Fine, still.	Fine, still.	

Note 1: Times are in Eastern Standard Time, Locations are in AMG datum 66.
The location of the Elliott traps were Line 1: Easting 280901 Northing 6132225, Line 2: Easting 280871 Northing 6132118 and Line 3: Easting 280789 Northing 6132309
The location of the Harp traps were Easting 280868 Northing 6132089, Easting 280683 Northing 6132075 and Easting 280797 Northing 6132394
Note 2: The bird census was undertaken at line 3. The herpetofauna survey was undertaken within lines 1 and 2.
Note 3: Targeted surveys were undertaken across the entire Subject Site.

Table 3
Systematic and Targeted Survey Methods

Method	Standard effort
Elliott and cage trapping (per transect)	Ten A size traps set on the ground at twenty metre intervals for 3 days. Two cage traps baited with sardines/peanut butter/oats.
Bat trapping	One harp trap set for three nights within 100 metres of each transect, plus an additional harp trap was set across a potential flight path for two nights.
Diurnal herpetofauna census	0.5 hectare (50 x 100 metre) searched for one-person hour.
Diurnal bird census	2 hectares (100 x 200 metre) searched for 20 minutes.
Foot based spotlighting	40 minute spotlight survey along roads within 200 metres of the Subject Site.
Targeted searches for trees incised by Yellow-bellied Glider	Searches of Red Bloodwood, Spotted Gum and Grey Gum stems – particularly young trees.
Searches for chewed cones of *Allocasuarina littoralis*.	Rolling searches for cones chewed by Glossy Black Cockatoo.
Searches for Koala scats	Searches under Grey Gums (as per SEPP 44) for Koala scats
Searches for white-wash	Searches under large hollow-bearing trees for evidence of nesting large forest owls.
Targeted inspections of hollows	Dusk surveys of hollows for microbat roost trees and nesting Gang Gang Cockatoo and or Glossy Black Cockatoo.

All species located within or adjacent to the Subject Site are recorded in **Appendix 2**.

2.1.2 Elliott and Cage Trapping

Three lines each consisting of ten A size Elliott traps were set for three consecutive days on the ground at twenty metre intervals on each transect and baited with a mixture of peanut butter and rolled oats (**Figure 4**). The traps were placed under bushes or other vegetation so that they were protected from direct sunlight and were checked daily during the early morning to minimise stress to captured animals from heat/ants. Traps were set from 25 to 27 September 2007.

Two cage traps were set along each transect and baited with the above mentioned mixture and set for the same period. These larger traps (55 x 20 x 20 cm) were set at one end and half way along each transect. The location of the mammal trapping transects are given in **Table 2** and shown in **Figure 4.**

2.1.3 Harp Trapping

One harp trap was erected within 100 metres of each of the Elliott trapping transects from 25 to 27 September 2007. The location of the harp traps are given in **Table 2** and shown in **Figure 4.** In addition one harp trap was set from the 26 to 27 September 2007 (Location Easting 280958, Northing 6132298, Datum = AMG66). The effort was eleven trap nights. The traps were checked daily in the early morning.

Anabat was not included in the survey. The results of ANABAT should not be taken as being conclusive. Some species have specific call signals but others can be confused if the call is incomplete (e.g. the Large Bentwing Bat may be confused with the Large Forest Bat *Vespadelus darlingtoni*). Calls of some species (especially high flyers such as the Greater Broad-nosed Bat) may be from animals that are foraging over the site and not roosting on the site. To partially over come this limitation dusk surveys were conducted on hollows by several observers in order to locate roost sites. In addition the seasonal breeding and temporal movements of several species of bat means that specific prescriptions can be adopted to reduce the potential impact on seasonally active animals (see Recommendations).

2.1.4 Diurnal Herpetofauna Census

The herpetofauna census involved a 60 minute search effort between Elliot trapping lines one and two. The search was conducted on 25 September 2007 between 9.00 and 10.00 EST. During herpetofauna searches, active animals were observed as they basked or foraged. Searches also involved lifting fallen logs, corrugated iron, rubbish and searching leaf litter.

2.1.5 Diurnal Bird Census

Diurnal birds were surveyed for a period of 20 minutes within a 2 hectare area along Transect 3 in the Spotted Gum forest. Bird surveys were conducted on the morning of 25 September 2007. Birds detected outside the 2 hectare plot were also recorded. Animals were identified by their species-specific calls and by direct observation.

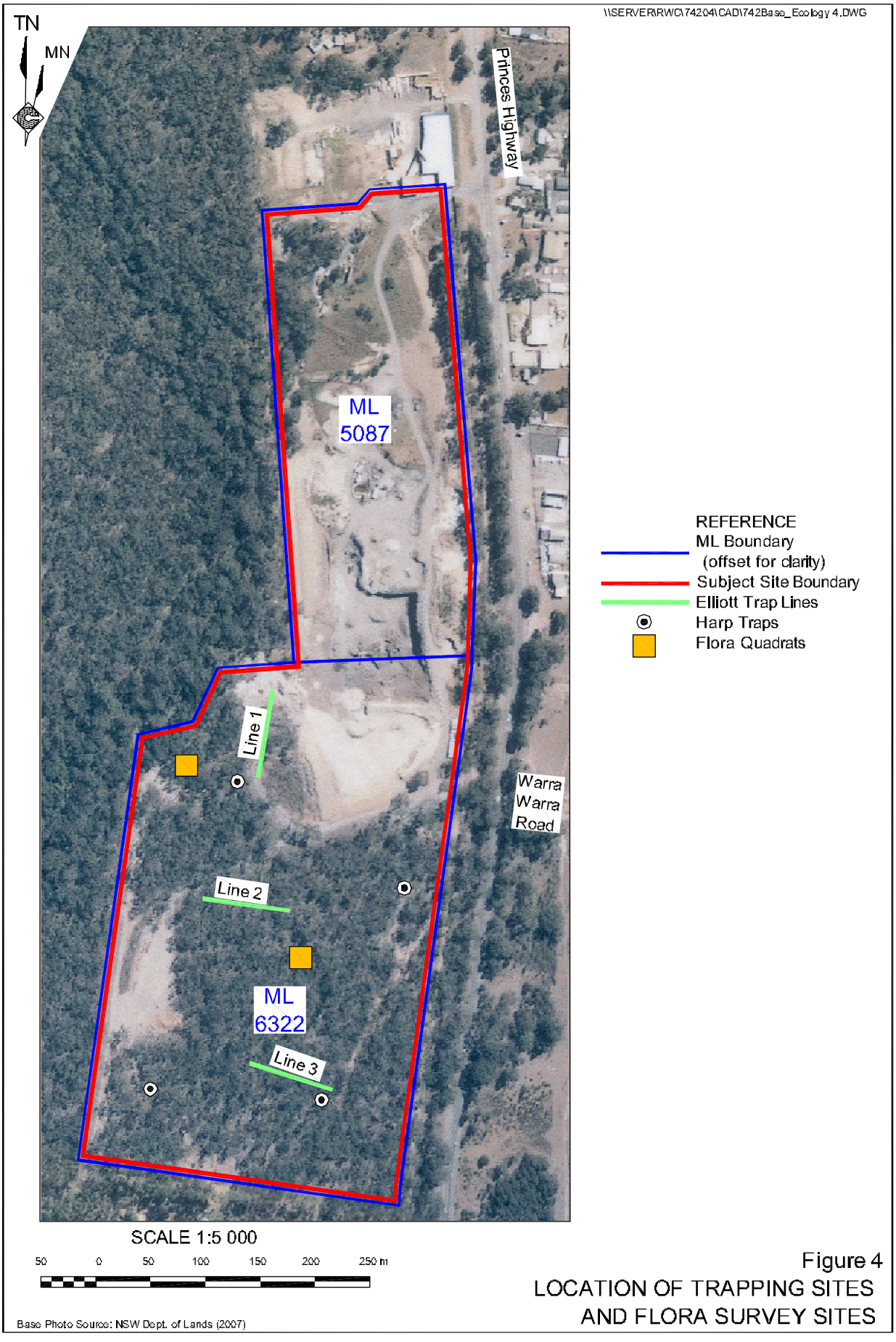

Figure 4
LOCATION OF TRAPPING SITES AND FLORA SURVEY SITES

2.1.6 Foot-Based Spotlighting

Spotlighting was conducted for arboreal mammals for 40 minutes over the entire 9.5 ha of remnant bushland from 18.15h to 18.55h on 2 August 2007. An additional search was conducted on 11 March 2008 from 19.00-19.40h.

2.1.7 Nocturnal Call Playback

Nocturnal birds and mammals are often detected when they vocalise to proclaim their territory or during social interaction. This behaviour is exploited when surveying by broadcasting pre-recorded calls to elicit a response if that particular species is within the immediate area.

Call playback was given in the following order.

- Powerful Owl *Ninox strenua.*
- Barking Owl *N. connivens*.
- Masked Owl *Tyto novaehollandiae*.
- Sooty Owl *Tyto taeniolatus.*
- Koala *Phascolarctos cinereus.*
- Bush Stone Curlew *Burhinus grallarius.*
- Yellow-Bellied Glider *Petaurus australis*.

The calls were broadcast through car stereo system on 2 August 2007. No spotlights were operated during the playback but the immediate area was spotlit after the cessation of the playback.

2.1.8 Amphibian Survey

A nocturnal survey of amphibians was undertaken for thirty minutes on 2 October 2007 and seven minutes on 11 March 2008 around the dams within the Subject Site. Additional surveys were make during the day at ephemeral ponds beside the perimeter bunds. The surveys conducted around the ponds involved the identification of tadpoles whereas those conducted around the dams involved the identification of adult frogs, tadpoles and species specific calls.

2.1.9 Targeted Surveys

Targeted surveys were conducted for Yellow-bellied Gliders *Petaurus australis* on the Subject Site and the adjoining bushland to the west of the Subject Site by searching for incised trees. This glider incises certain species of 'gum' tree to procure sap, which forms parts of the species diet. In the Shoalhaven Local Government Area (LGA), south of Tomerong the Yellow-bellied Glider primarily incise Red Bloodwood *C. gummifera*. Searches for incised trees were made during rolling foot censuses.

Dusk surveys were conducted for Yellow-bellied Gliders as they emerged from hollow bearing trees. The Yellow-bellied Glider typically calls immediately after departing the den tree and this behaviour is useful in detecting the species at a site and also in locating the den trees. Dusk surveys were conducted from 17.50h to18.15h on 2 August 2007 and from 18.40h to 17.05h on 22 October 2007.

Targeted searches were made for Glossy Black Cockatoo by searching for the chewed cones of the Black She Oak *Allocasuarina littoralis.* The chewed cones give an indication that the species feed at certain sites. Dusk surveys were conducted for birds returning to nesting hollows. Glossy Black Cockatoo breeding season is mainly March to August (Crome and Shields 1992) and Gang Gang Cockatoo breed from October to January (Chambers 1995). Dusk surveys were conducted for birds returning to nesting hollows from 17.50h to18.15h on 2 August 2007, 18.40h to 17.05h on 22 October 2007 and from 18.11-19.00h 11 March 2008. The dusk survey conducted on 11 March 2008 coincided with the nesting period for the Powerful Owl.

Targeted searches were made for trees utilised by large forest owls for nesting by searching the base of all hollow-bearing trees for 'white-wash'. The spattered white exudate of owls is an indication that the tree is in use by nesting birds. The dusk survey conducted on 11 March 2008 coincided with the nesting period for the Powerful Owl.

Targeted searches were made for Koala by searching for their scats at the base of large gum trees. In additional scratches on smooth barked trees, such as Spotted Gum and Grey Gum were examined as Koala make many small scratch marks on the trees that they climb as opposed to large scratch marks made by the Lace Monitor.

2.1.10 Incidental Observations

Further observations of animals were made in addition to those during systematic and/or targeted surveys.

2.2 Flora Surveys

2.2.1 Introduction

The flora surveys were conducted on 3 April and during August and September 2007 (14 December). Plant identifications were made according to nomenclature used in Harden (1990, 1991, 1992 and 1993). Recent name changes outlined in issues of *Cunninghamia* and *Telopea* were used where applicable. The conservation significance of species was established with reference to Briggs and Leigh (1999) and the TSC Act.

The vegetation surveys consisted of two components. The first provided an inventory of species and the second quantified data on structure, disturbance and species present within two standard 20 x 20 metre quadrats. The vegetation was searched using a general botanic survey method, as outlined by York, Binns and Shields (1991), in order to establish an inventory of most plant species occurring in the Subject Site and to determine the location and extent of vegetation types.

All vegetation stands in the study area were surveyed using the general botanic survey method outlined by DEC (2004), which in this case included a minimum of two 100m traverses over the Spotted Gum forest. The relatively small size of the site means that a number of short traverses were conducted over the site. Specific searches for plant species of conservation significance were then carried out in potential habitat using the "Random Meander Technique" (Cropper, 1993).

The second survey method follow those described by Taws (1997), Thomas *et al.* (2000) and NPWS (2002). These methods include the collection of floristic, structural, and physical data in two 400 square metre quadrats (usually 20 x 20 m). Floristic data recorded in each quadrat include a list of all vascular plant species present and a visual estimation of the cover abundance of each species according to a modified Braun-Blanquet system of cover abundance classes (Poore 1955). The survey effort was in accordance with the minimum DECC guidelines (DEC, 2004), that is, 2 quadrats per 2-50 hectares of stratification unit. The location of the quadrats is given in **Figure 5**. All species located within the quadrats are listed in **Appendix 3**.

2.2.2 Targeted surveys for terrestrial orchids

A terrestrial orchid specialist, Mr A. Stevenson, conducted searches for *Oligochaetochilus gibbosus* (syn *Pterostylis gibbosa*) by walking transects over the Subject Site on 3 August 2007, 17 and 27 September 2007 and 22 October 2007. In addition, Mr Stevenson undertook targeted surveys for *Cryptostylis hunteriana* on 14 December 2007.

Searches could not be conducted for *Genoplesium baueri* as this species is found in flower from late February to almost mid-April. For *Genoplesium baueri* an assessment has been made of the known occurrences in the Shoalhaven in respect to habitat (associated vegetation and soil) allowing a consideration of the likely occurrence on site.

3 RESULTS

3.1 Introduction

The habitat for fauna within the Subject Site consisted of approximately 7.4 hectares of Spotted Gum forest. The forest had a variety of age classes. The majority of trees were regrowth from previous logging activities being in the order of 40 years old (based on diameter at breast height and soil type). However 67 trees were of sufficient age to contain hollows **(Appendix 4)**, many of which were of dimension to cater for forest dependant fauna. Thirty five of these trees would be disturbed by the Project. Fallen logs were present on the forest floor. Piles of logs and stumps that had been deposited on the site occurred in a stockpile.

The bunds around the perimeter of the Subject Site cause water to pool. These ephemeral ponds, plus those created as a result of other disturbances, provided breeding sites for amphibians such as the Bleating Tree Frog *Litoria dentata,* Common Eastern Froglet *Crinia signifera* and Striped Marsh Frog *Limnodynastes peroni.* Permanent water was present in the quarry dams, which was utilised by several species of duck and Peron's Tree Frog *Litoria peroni* for breeding.

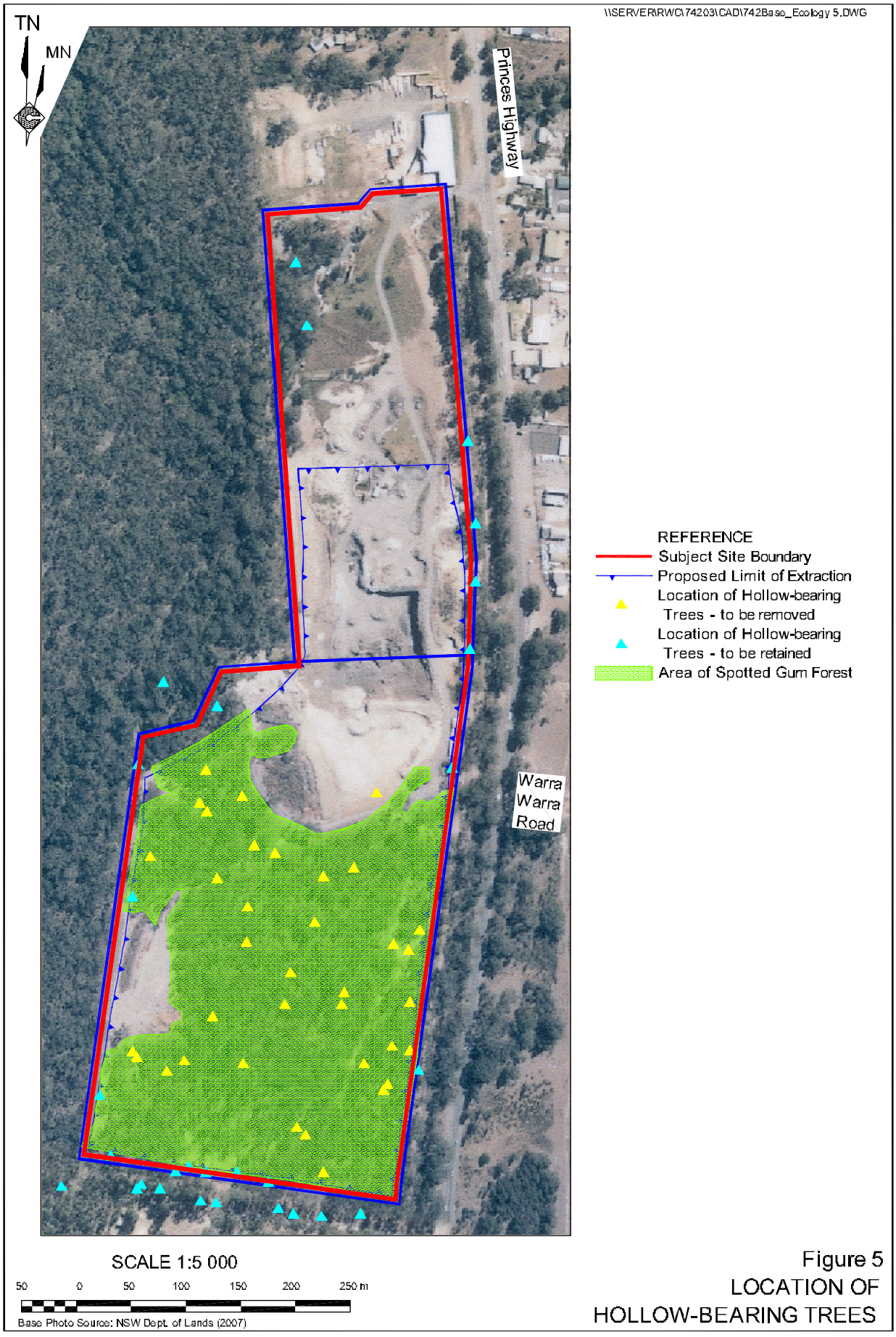

Figure 5
LOCATION OF HOLLOW-BEARING TREES

3.2 Fauna detected

3.2.1 Introduction

The current survey detected 62 species of vertebrate including five frog, four reptile, 44 birds and eleven species of mammal. A summary of the results of the fauna survey are presented in **Table 4**, with a list of all fauna species identified presented in **Appendix 2**. The Grey-headed Flying Fox *Pteropus poliocephalus* was observed flying over the site and heard foraging in flowering Spotted Gum beside the Subject site. This species is listed under Schedule 2 of the TSC Act as threatened.

In addition to the species identified within the Subject Site, a pair of Square-tailed Kites *Lophoictinia isura* was observed approximately five hundred metres to the west of the site. This species is currently listed under Schedule 2 of the TSC Act as threatened.

Table 4
Summary of Fauna Detected During the Survey

Vertebrate group	Species detected during survey
Frog	5
Reptile	4
Bird	44
Mammal - non flying	8 (2 exotic)
Mamma - bats	3
Total	63

3.2.2 Elliott and Cage Trapping

No animals were caught in the Elliott traps. One Lace Monitor *Varanus varius* was caught in the cage traps. The capture rate was very low for the Shoalhaven region (Daly unpub. data).

3.2.3 Harp Trapping

Three Little Forest Bats *Vespadelus vulturnus* were caught in the harp traps over eleven trap nights. The relatively low species diversity and density may have been a result of the low temperatures, which would have restricted the activity of insectivorous bats.

3.2.4 Diurnal Herpetofauna Census

One species of reptile was observed during the systematic survey, the Grass Skink *Lampropholis delicata.* Nine individual lizards were observed during the search. In addition, the scratch marks of the Lace Monitor were observed on large hollow Spotted Gums.

3.2.5 Diurnal Bird Census

Twenty species of bird were detected during the diurnal survey (**Table 5**). Incidental observations and indirect evidence revealed the presence of an additional 24 species within and adjacent to the Subject Site. The site has a relatively high species diversity of birds.

Table 5
Birds Detected During the Systematic Survey

Species	Number detected	Method of Detection [1]
Rainbow Lorikeet	1	H
Galah	1	H
Sacred Kingfisher	1	H
Superb Fairywren	1	o
Striated Thornbill	3	o
Yellow Thornbill	2	o
Spotted Pardalote	1	h
Eastern Yellow Robin	1	H
White-throated Treecreeper	1	H
Rufous Whistler	1	H
Grey Fantail	2	o
Red Wattlebird	1	o
Yellow-faced Honeyeater	4	h
Eastern Spinebill	1	h
Noisy Friarbird	2	o
Black-faced Cuckoo Shrike	2	o
Olive-backed Oriole	1	H
Magpie Lark	2	o
Silvereye	2	o
Indian Myna	1	H
Species Total	20	
Note 1: On site o = observed, h = heard call. Outside site H = heard call		

3.2.6 Foot-Based Spotlighting

A Common Brushtail Possum *Trichosurus vulpecula* and Grey-headed Flying Fox were observed during the spotlight survey conducted on the 11 March 2008. The Grey-headed Flying Fox were foraging in the flowering Spotted Gum on and beside the site.

3.2.7 Amphibian survey

Searches for Green and Golden Bell Frog
No Green and Golden Bell Frogs (GGBF) were detected during the searches of the dams in the quarry or the ephemeral ponds beside the bunds on the south-east of the Subject Site. If GGBF exists on site it is highly likely that they would have been observed or heard calling. It is also likely that metamorphling frogs would have been observed during the search on the 11 March 2008. The species of frog detected were Bleating Tree Frog *Litoria dentata*, Peron's Tree Frog *L. peroni*, Striped Marsh Frog *Limnodynastes peroni*, Common Eastern Froglet *Crinia signifera* and Bibron's Toadlet *Pseudophryne bibronii*.

3.2.8 Targeted Surveys

Dusk surveys of potential den sites
No possums, gliders, large forest owls, Bush Stone Curlew, Gang-gang Cockatoo or Glossy Black Cockatoo were observed or heard call during the dusk surveys. Microbats were observed at dusk. The size and flight pattern of the bats suggested that they were species of *Vespadelus.*

Searches for incised trees
No trees located on or adjacent to the Subject Site had been incised by the Yellow-bellied Glider.

Searches for cracked Casuarina cones
No cracked cones of Black She Oak *Allocasuarina littoralis* were located.

Searches for white-wash
No white-wash was located at the base of hollow trees.

3.2.9 Incidental Observations

Species observed or heard opportunistically were recorded. The species observed and type of observation is detailed in **Appendix 2**.

3.3 Native Vegetation

3.3.1 Introduction

Within the Subject Site, approximately 50% of the remaining native vegetation has been removed as a result of previous clearing. The majority of the operational mining lease ML5087 has been cleared, but about 90% of ML6322 is covered with Spotted Gum forest of various age classes. During the survey 81 native species of plant were located, including five ferns, one cycad, 45 dicotyledons and 30 monocotyledons. In addition thirty species of exotic weeds were located (Gaia Research, 2007a and b). No Endangered Ecological Communities or species listed under the TSC Act were located within the Subject Site.

The remnant vegetation within the Subject Site may be classified as Forest Ecosystem 9: Coastal Lowlands Cycad Dry Shrub Dry Forest - *Corymbia maculata / Macrozamia communis* (Thomas *et al.*2000). Spotted Gum is the tallest and most abundant species, with Grey Ironbark *Eucalyptus paniculata*, Woollybutt *Eucalyptus longifolia,* White Stringybark *Eucalyptus globoidea,* Red Bloodwood *C. gummifera* and Grey Gum *E. punctata* occurring as isolated trees or small stands. The canopy attains 25 metres in height, with individual Spotted Gums reaching to 30 metres. The midcanopy and shrub layers are sparse and the ground cover consists of *Lepidosperma laterale* and several species of *Lomandra.* This forest has been heavily logged and most trees were regenerated following this previous disturbance. A list of species observed within the Subject Site is presented in **Appendix 3**.

3.3.2 Targeted Searches for Threatened Species of Terrestrial Orchids

A targeted survey for *Oligochaetochilus gibbosus* was conducted on 3 August 2007 within the Subject Site and the Worrigee Nature Reserve, approximately 2 km to the north-east of the Subject Site. Species of orchid detected on the Subject Site during this survey included:

- *Tropilis aemula* (syn *Dendrobium aemulum*);
- *Pterostylis nutans* (flowers);

- *Pterosylis accuminata* (rosettes);
- *Thelymitra* spp. (leaves and buds);
- *Calochilus* sp. (leaves);
- *Acianthus fornicatus* (deceased flowers);
- *Corybas* sp. (leaves); and
- *Myrmechila* sp. leaves (syn *Chiloglottis*).

Rosettes of *Oligochaetochilus gibbosus* were located in Worrigee Nature Reserve and some plants had flower buds forming indicating that, if present on the Subject Site, the species would have emergent leaves at the time of assessment and would have been observed.

A second targeted search for threatened terrestrial orchids on 17 September 2007 identified the following species.

- *Calochilus robertsonii* (in flower);
- *Prasophyllum brevilabre* (in flower);
- *Glossodia major* (in flower);
- *Cyanicula caerulea (*in flower)*;*
- *Pterostylis curta* (in flower);
- *Pterostylis nutans (*deceased flowers*);*
- *Acianthus fornicatus* (deceased flowers);
- *Pterostylis* sp. (rosettes and rosettes with emerging stems);
- *Eriochilus cucullatus* (leaves); and
- *Tropilis aemula* (deceased flowers).

No additional species were located during searches on the 27 September or 22 October 2007.

A targeted search for *Cryptostylis hunteriana* was conducted for two hours on 14 December 2007. The following three species were located, two in bud and one a deceased flower.

- *Dipodium sp*.
- *Calochilus sp.*
- *Thelymitras sp.*

The Subject Site is considered unsuitable for the Leafless Tongue Orchid *Cryptostylis hunteriana* based on soil type and associated vegetation. *Cryptostylis hunteriana* has been located at various locations in the Shoalhaven as detailed in **Table 6** and indicated on **Figure 6**. These sites generally have thin, often waterlogged sandy soils and the associated vegetation is heath-sedgeland. The Subject Site has clayey soil derived from Nowra Sandstone with an overstorey of Spotted Gum forest and a relatively sparse ground cover. In addition, no species of the *Cryptostylis* genus were located on site, which indicates the pollinating vector is almost certainly absent from this site.

The Subject Site is considered unsuitable for the Midge Orchid *Genoplesium baueri* based on soil type and associated vegetation. *Genoplesium baueri* has been located at various locations in the Shoalhaven as detailed in **Table 7** and indicated on **Figure 6**.

Table 6
Description of Select Sites where *Cryptostylis hunteriana* located in the Shoalhaven

Site	Eastings	Northings	Alt. [1]	Substrate	Pop. [2]	Associated Vegetation
Baptist Church	287650	6115250	20	Wandrawandian siltstone	90	Hake-Banksia scrub and depauperate C. gummifera
Stockland - Vincentia	286440	6115600	10	Grey clay soil	112	Dry sclerophyll to low heath and sedgeland
Burrill Lake	264300	6179200	20	Grey clay	5	Low native grasses
Leebold Hill	273300	6149100	600	Sandy	1	*Leptospermum-Melaleuca* with sedge
One Tree Bay	277800	6109100	10	Sandy loam	1	*Leptospermum* with native grass groundcover
Illaroo Road	276400	6141800	70	Sandy loam	1	Eucalypt-Casuarina forest with dense grass groundcover
Lot 155 Naval College Rd, Vincentia	286500	6115450	25	Sandy-loam	2	Eucalypt-Casuarina forest with moderately dense grass groundcover

Note 1: Alt. = Elevation (m AHD)
Note 2: Pop = Maximum population size recorded.

Table 7
Description of Sites where *Genoplesium baueri* located in the Shoalhaven

Site	Eastings	Northings	Alt. [1]	Substrate	Pop. [2]	Associated vegetation
Bomaderry Creek	278900	61 41000	60	Grey Clay-Loam	9	Dry sclerophyll and *Leptospermum* with light to moderate grass ground cover
Callala	290300	6125400	20	Dark Wet Loam	72	Heavy *Melaleuca* canopy with dense sedge and grass understorey
Yarran Road	271300	6118000	190	Fine Yellow Clay and Silt	12	Dry Sclerophyll with *Xanthorrhoea* and light grasses

Note 1: Alt. = Elevation (m AHD)
Note 2: Pop = Maximum population size recorded.

4 ASSESSMENT OF IMPACTS

4.1 Preliminary Impact Assessment

There was no evidence of the following threatened species within the Subject Site.

- Koala.
- Yellow-bellied Glider.
- Powerful Owl.
- Masked Owl.
- Gang-gang Cockatoo.
- Glossy Black Cockatoo.
- Australasian Bittern.
- Black Bittern.
- Regent Honeyeater.
- Pouched Greenhood Orchid.
- Leafless Tongue Orchid.
- Midge Orchid.
- Nowra Heath Myrtle.

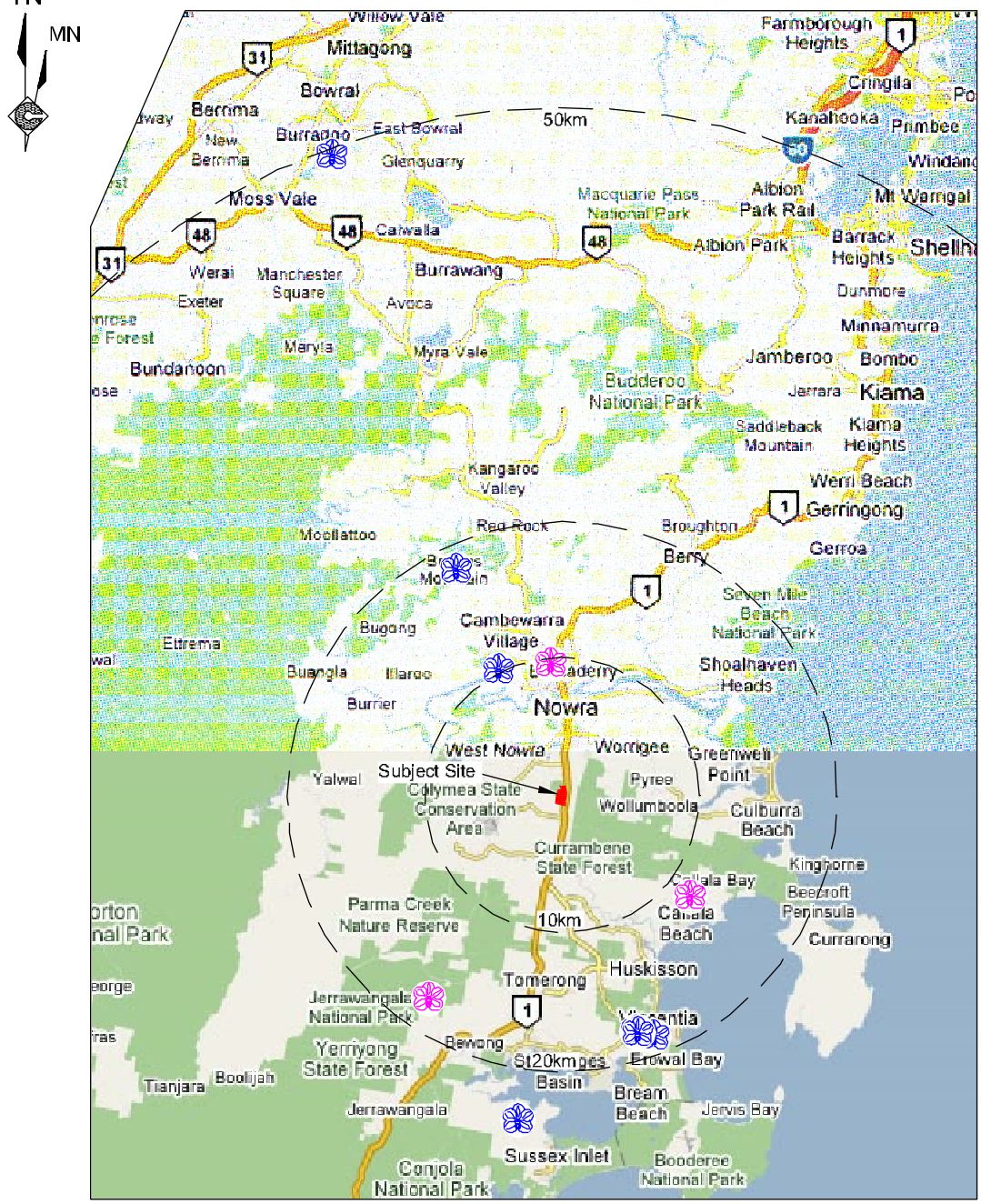

Figure 6
LOCATION OF THREATENED TERRESTRIAL ORCHIDS

Note: A colour version of this figure is available on the Project CD

The known habitat of these species within the Shoalhaven Local Government Area is summarised in **Table 8.** This information is provided to allow an assessment of the likelihood of these species occurring on site. A more comprehensive description of preferred habitat and likely distribution for many of the species of threatened fauna has been prepared by the author in the text *Threatened Fauna in the Shoalhaven* (Daly *et al.,* 2000).

The absence of arboreal and scansorial (ground dwelling) mammals within the Subject Site indicates that there is a low probability of large forest owls such as the Powerful Owl and Masked Owl using the site. As a result, the impact of the Project upon these species is considered not to be significant.

Based on habitat preference and current distribution the Yellow-bellied Glider probably used the site prior to logging and clearing. However, there was no evidence of the species occurring on the Subject Site (via sap feed trees) within the recent past. The forest may have been cleared to such an extent that this species no longer occurs within the immediate area. The recent clearing of the Nowra Goal site makes recolonisation more unlikely. As a result, the impact of the Project upon this species is considered not to be significant.

Table 8
Preferred Habitat of Select listed Threatened Species

Page 1 of 2

Threatened Species	**Habitat Preference within the Shoalhaven**
Koala	Prefers Swamp Mahogany and Forest Red Gum forests on the coastal plain and Stringybark and Manna Gum forest within Morton Nature Reserve near Sassafras.
Yellow-bellied Glider	Prefers Grey Gum – Red Bloodwood and Spotted Gum forests on the coastal plain.
Grey-headed Flying Fox	Prefers rainforest, Red Bloodwood and Spotted Gum forests on the coastal plain.
Black Bittern	Prefers dense stands of Swamp Oak beside rivers.
Australasian Bittern	Prefers large freshwater wetlands with abundant emergent aquatic vegetation.
Bush-stone Curlew	Prefers open Spotted Gum forests, beside creeklines or coastal headlands.
Square-tailed Kite	Prefers coastal woodland and open forest.
Glossy Black Cockatoo	Prefers coastal woodland and open forest with an abundance of Black Oak.
Gang-gang Cockatoo	Prefers various eucalypt forests on the coast and ranges.
Powerful Owl	Prefers tall open forests with an abundance of arboreal mammals.
Regent Honeyeater	Prefers River Oak forest, Blackbutt forest and coastal woodlands.
Green & Golden Bell Frog	Prefers coastal freshwater and semi-saline wetlands and lagoons.
Pouched Greenhood Orchid	Prefers open Spotted Gum forest in Worrigee Nature Reserve, thin poorly drained clayey soils derived from Wandrawandian Siltstone.
Leafless Tongue Orchid	Prefers heath and open forest on soil mostly derived from sandstone.
Midge Orchid	Prefers woodland and open forest on soil mostly derived from sandstone.
Nowra Heath Myrtle	Prefers wet sedgeland heathland on heavy soils.
Source: Daly *et al.* (2000), A. Stevenson (unpublished data)	

Prior to the Red Fox colonising the Shoalhaven in 1907 (Elliott, 1938) the site was probably used by the Bush Stone Curlew and a record was made of a pair of birds (nesting) a few kilometres to the north-west of the quarry a few years ago (P. Craven DECC pers. comm.). However, this species is now extremely rare in the region (and State) because they nest on the ground and the young and highly susceptible to predation by Red Fox. The probability of Bush Stone Curlew occurring within the Subject Site is considered low. As a result, the impact of the Project upon this species is considered not to be significant.

There were no Black She-oaks present within the Subject Site and few within the adjoining bushland to the west of the site. The probability of Glossy Black Cockatoo occurring within the Subject Site is considered low. As a result, the impact of the Project upon this species is considered not to be significant.

There were very few trees listed on Schedule 2 of the SEPP 44 (Grey Gum) that constitutes potential feed trees for the Koala. The probability of the Koala occurring within the Subject Site is considered low. As a result, the impact of the Project upon this species is considered not to be significant but will add to the cumulative fragmentation of dispersal habitat.

The habitat on site is considered unsuitable for the Black Bittern and Australasian Bittern. Black Bittern are associated with riparian forest containing She-oaks beside flowing creeks and rivers and Australasian Bittern are associated with wetlands containing emergent macrophytes. As a consequence of the habitat on site, the probability of these species occurring within the Subject Site is considered very low. As a result, the impact of the Project upon this species is considered not to be significant.

The site is suitable for the Regent Honeyeater as this species is known to feed on flowering Spotted Gum (Elliott, 1938). However, the Regent Honeyeater has had a drastic decline in population over the last fifty years and is currently a rare vagrant in the Shoalhaven. As a consequence, the probability of this species occurring within the Subject Site is considered low. As a result, the impact of the Project upon the Regent Honeyeater is considered to not to be significant but part of the cumulative impact of this species.

The habitat on site is considered suitable for the Green and Golden Bell Frog as this species readily colonises disturbed habitats including quarries. However, this species has had a marked contraction in range over the last forty years, probably associated with the frog chytrid disease *Bactrachochytrium dendrobatiodis,* and evidence indicates that the distribution and density of the Crookhaven floodplain key population has further declined in the last decade. Green and Golden Bell Frog had been found about two kilometres to the east of the Subject Site within the Rotten Creek catchment, but none were detected during this or a previous assessment (Daly, 1995). The project will remove potential habitat for this species but since it has never been found on site the impact of the Project upon this species is considered not to be significant.

The habitat within the Subject Site is considered unsuitable for the Nowra Heath Myrtle, Leafless Tongue Orchid and Midge Orchid. The Nowra Heath Myrtle occurs in boggy wetland areas, the Leafless Tongue Orchid occurs in thin, often waterlogged sandy soils and the associated vegetation is heath-sedgeland and the Midge Orchid occurs in a variety of habitat types (**Table 7**) none of which are similar to that of the Subject Site. The habitat of the Subject Site is very similar to that of the Pouched Greenhood Orchid within Worrigee Nature Reserve (NR). However, targeted searches failed to locate any Pouched Greenhood during a period when the species was flowering at Worrigee NR. The Pouched Greenhood Orchid has a very limited distribution in the Shoalhaven and does not appear to occur within the Subject Site. As a result, the impact of the Project upon this species is considered not to be significant.

Based on habitat and field observations during the course of this assessment three threatened species are highly likely to forage within the Subject Site. They are the Grey-headed Flying-fox, Square-tailed kite and Gang-gang Cockatoo. These species will be considered in more detail below.

4.2 Detailed Impact Assessment

Section 5A of the EP & A Act, as amended by the TSC Act, sets out the factors to be considered in deciding whether there is likely to be a significant effect on threatened species, populations or communities and or their habitat as a result of a proposed development.

The factors of assessment:

(a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction,

This factor relates to those species listed in Part 1 and Part 4 of Schedule 1 and Part 1 of Schedule 1A and Part 1 of Schedule 2 of the TSC Act, and Part 1 and Part 4 of Schedule 4 of the *Fisheries Management Act 1994* (FM Act).

No species listed in Part 1 and Part 4 of Schedule 1 of the TSC Act were detected. However three species, namely the Grey-headed Flying Fox, Square-tailed Kite and Gang-gang Cockatoo listed on Part 1 of Schedule 2 have been detected close to the site and, based on home range and habitat, are expected to forage adjacent to the site on occasion.

Grey-headed Flying Fox

The Grey-headed Flying Fox is primarily a summer breeding migrant to the Shoalhaven and the population size is highly dependant on the flowering of key gum trees that constitute food resources for the bats. The main food sources in the Shoalhaven include nectar from Spotted Gum and Red Bloodwood, and the fruit of the Morton Bay Fig *Ficus macrophylla* and Superb Fig *F. superba* (G. Daly pers. obs.). Other species regularly used for food sources include the Swamp Mahogany *E. robusta,* Coastal Banksia *B. integrifolia* and Saw-toothed Banksia *B. serrata* and the exotic Cocos Palm *Arecastrum romanzoffianum*.

The location of nine temporary camps between Helensburgh and Batemans Bay have been detailed in Gaia Research (2000) and recently a camp has formed at Bomaderry Creek. The most significant camps (based on estimation of size) are those at Yatteyattah and Kioloa (Parry-Jones 1993). The closest camps to the Subject Site are located at Budgong, Bomaderry Creek and Comerong Island (**Figure 7**).

When in flower the Spotted Gum forest within the Subject Site provides foraging habitat for the Grey-headed Flying Fox. At the time of the assessment the Spotted Gums began to flower in March 2008. During the spotlight survey on the 11 March 2008 Grey-headed Flying Fox were observed flying over the site and animals were heard squabbling as they foraged in flowering trees adjacent to the site. Approximately 3,000 Grey-headed Flying Fox camp at Bomaderry Creek bushland at the time.

Square-tailed Kite

The Square-tailed Kite is a seasonal breeding migrant to the Shoalhaven (Daly and Evision 1996). The species occurs in coastal and sub-coastal forests, particularly those on fertile soils and with an abundance of passerines (Marchant and Higgins 1993). They feed mostly on small birds and foliage insects but occasionally take small mammals and lizards (Marchant and Higgins 1993).

Figure 7
LOCATION OF GREY-HEADED FLYING FOX CAMPS

Note: A Colour Version of this figure is available on the project CD

The Square-tailed Kite was detected adjacent to the Subject Site. One bird was seen near the electricity easement approximately 500 m to the west of the quarry. The bird circled to about 300 metres altitude and was then joined by a larger (female) animal. The pair then circled to an altitude of about 500 m and then did a number of chase and dive motions. They continued at ascent to about 800 m and then glided south-west. The behaviour was considered a nuptial flight, suggesting that the pair may nest close by. The Square-tailed Kite has been regularly observed in the area, especially during late summer when they migrate north (G. Daly unpub. data).

Square-tailed Kite nest in mature live trees, often near water. The nest is placed in a fork of a large limb, which is usually horizontal (Marchant and Higgins 1993). Breeding in New South Wales occurs from August to early November (Marchant and Higgins 1993). There is a high probability that the Square-tailed Kite nests close to the Subject Site because there are a high density and species diversity of small birds in the area (**Table 5** and **Appendix 2**) and large trees on the land adjacent to the Subject Site beside Nowra Creek.

Gang-gang Cockatoo

The Gang-gang Cockatoo is distributed from southern Victoria through south- and central-eastern New South Wales (Shields and Crome 1992). In summer, the Gang-gang Cockatoo occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. In winter, the Gang-gang Cockatoo occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas (Shields and Crome 1992). The species undertake nomadic as well as seasonal movements and may occur at apparently random points within their range.

The Gang-gang Cockatoo requires hollows in the trunks or large limbs of large trees in which to breed (Gibbons 1999, Gibbons and Lindenmayer 2000). Breeding usually occurs in tall mature sclerophyll forests that have a dense understorey, and occasionally in coastal forests. Nests are most commonly recorded in eucalypt hollows in live trees close to water (Beruldsen 1980). Breeding usually occurs between October and January (Chambers 1995). The Spotted Gum forest within the Subject Site is considered to provide foraging and potential (through low probability) nesting habitat for the Gang-gang Cockatoo.

Threatened species of microbat

Based on published data on habitat preference and the author's own experience with harp trapping in the region for over a decade and ANABAT surveys for five years, there is a possibility that five threatened species of micro-bat may forage on site. There are the Large Bentwing Bat, Eastern Free-tail Bat, Greater Broad-nosed Bat, Fishing Bat and Yellow-bellied Sheathtail Bat.

To reduce the potential impact on these species clearing will be undertaken during winter, a season when the Large Bentwing Bat would be in winter cave roosts and the seasonal migrant Yellow-bellied Sheathtail Bat would not be in the area. A minimum buffer of 50m should be provided from the centre line of Nowra Creek in accordance with the *Shoalhaven Local Environment Plan 1985*. This should protect riparian habitat that would be used by the Fishing Bat. The site may be used by the Eastern Free-tail Bat, Greater Broad-nosed Bat. To reduce potential impacts clearing of trees that may be used as nursery roost sites will be done in winter.

Summary

Although the Spotted Gum forest represents habitat for the Grey-headed Flying Fox, Square-tailed Kite and Gang-gang Cockatoo, the removal of 7.4 hectares is not likely to have an adverse impact on the life cycle of these species such that a viable local population of these migratory or nomadic species is at risk of extinction. In addition, clearing of vegetation will be done in winter, outside the breeding season of the Square-tailed Kite, Gang-gang Cockatoo and microbats.

(b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction,

No endangered populations listed in Part 2 of Schedule 1 of the TSC Act or Part 2 of Schedule 4 of the FM Act, were found on site.

in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or
(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

No endangered ecological communities listed under Part 3 of Schedule 1 of the TSC Act or Part 3 of Schedule 4 of the FM Act, and no critically endangered ecological communities listed under Part 2 of Schedule 1A of the TSC Act or Part 2 of Schedule 4A of the FM Act were found on site.

(c) in relation to the habitat of a threatened species, population or ecological community:
(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and
(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and
(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality,

i) The extent of habitat alteration associated with the extension of ML 6322 is approximately 7.4 hectares.

ii) The proposed action further fragment the existing habitat.

iii) The existing bushland within the Subject Site is not critically important to the long-term survival of threatened species in the locality.

(d) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly),

The DECC website was searched for critical habitat listed in the Register of Critical Habitat kept by the Director General of Department of Environment and Climate Change. Currently (September 2007) critical habitat has been declared for Little Penguin population at Sydney's North Harbour, Mitchell's rainforest snail in Scotts Island Nature Reserve, Wollemi Pine and Gould's Petrel. There are two recommendations for critical habitat one for the Eastern suburbs Banksia scrub endangered ecological community and the Bomaderry Zieria within the Bomaderry Creek bushland.

The proposal shall not have an adverse effect on critical habitat.

(e) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan,

A recovery plan has not been prepared for the Grey-headed Flying-fox, Gang-gang Cockatoo or Square-tailed Kite. However, any action to remove potential, foraging or dispersal habitat would not be consistent with the objectives or actions within any recovery plan, should one be developed.

(f) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The proposed action will require the removal of 7.4 hectares of Spotted Gum forest. The removal of native vegetation is considered a key threatening process under Part 4 of the TSC Act.

Based on the current data the proposal will not have a significant effect on listed threatened species within the Subject Site.

4.3 EPBC Act (1999)

Under Part 9 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), any action that has, or is likely to have, a significant impact on a matter of National Environmental Significance (NES), is subject to a referral and assessment process and may progress only with the approval of the Commonwealth Minister for Environment. An action is defined as a project, development, undertaking, activity (or series of activities), or alterations to any of these. The EPBC Act currently identifies seven matters of national environmental significance.

- World Heritage properties.
- National Heritage places.
- Ramsar wetlands of international importance.
- Listed threatened species and ecological communities.
- Listed migratory species.
- Commonwealth marine areas.
- Nuclear actions.

There are two listed migratory species that may use the site on occasion, the Black-faced Monarch *Monarcha melanopsis* and the Rufous Fantail *Rhipidura rufifrons*. Both species are breeding spring migrants in the Shoalhaven Local Government Area with nesting occurring primarily beside creeks in tall open forest and rainforest (G. Daly pers. obs.). Based on habitat preference there is a likelihood that one of these species, the Rufous Fantail, may nest beside Nowra Creek and birds would certainly pass through the site as they migrate. One action to mitigate the area of disturbance is the provision of a 50 metre buffer from Nowra Creek. This will conserved potential breeding habitat for the Rufous Fantail. As a consequence of this proposal the direct impacts on listed threatened species and ecological communities and listed (JAMBA and CAMBA) migratory species is considered to be unlikely. Consequently, a referral to DEH under the EPBC Act is not warranted. By applying the Commonwealth's criteria for significance the proposed development does not need to be referred to the Commonwealth Minister for the Environment.

4.4 SEPP 44

The Koala has lost such a significant amount of its habitat in NSW that in 1995 a separate State Environmental Planning Policy (SEPP) was introduced to aid the conservation of the species. The aim of this policy is for Local Government to identify "Core Koala Habitat" and to encourage these areas to be included in environment protection zones (Department Of Planning Circular No. B35). Shoalhaven City Council is listed on Schedule 1 of SEPP 44 to which this SEPP applies.

Shoalhaven City Council has not produced a Plan of Management for Koala. The Subject Site contains Grey Gum, which is a nominated ‘feed tree species’ listed in Schedule 2 of SEPP 44. The proportion of Grey Gum within the Subject Site constitute less than 15% of the total number of trees in the upper strata in portions of the land. No Koala scats or scratches were detected on trees within the Subject Site. Based on these facts SEPP 44 does not apply to the Subject Site.

5 DISCUSSION

The objective of this assessment is to provide information to enable decision makers to ensure that developments deliver the following environmental outcomes as specified by DEC and DPI (2005) guidelines.

1. Maintain or improve biodiversity values (i.e. no net impact on threatened species or native vegetation).
2. Conserve biological diversity and promote ecologically sustainable development.
3. Protect areas of high conservation value (including areas of critical habitat).
4. Prevent the extinction of threatened species.
5. Protect the long-term viability of local populations of a species, population or ecological community.
6. Protect aspects of the environment that are matters of national environmental significance.
7. Be consistent with the principle pertaining to the potential bio-certification of the Nowra / Bomaderry Structure Plan.

The measures that would be implemented to mitigate adverse impacts associated with the Project include the retention of trees within five metres of the inside of the bunds located around the perimeter of the site. A minimum buffer zone of 50 m will be placed from the centre line of Nowra Creek to protect riparian vegetation. This will retain some habitat (including a number of hollow-bearing trees) and reduce the risk of erosion. The bunds are currently being revegetated with endemic vegetation (Gaia Research 2007a), which will mitigate the impacts to a small degree and help stabilise the soil. However, the nature of the proposal is such that direct impacts can not be avoided or mitigated.

The Project would involve the removal of approximately 7.4 hectares of native vegetation, including 35 hollow bearing trees (**Appendix 4**). Clearing of trees must be done in winter during a period that is outside the breeding seasons for threatened species of bird and bat. Given the field surveys only detected the Grey-headed Flying Fox within the Subject Site the Project would not have a significant effect on the long term survival of threatened species in the region. However, the loss of 7.4 hectares of Spotted Gum forest will add to the cumulative loss of habitat within the local area and will not protect or restore biodiversity, ecological integrity and natural capital throughout the district as stated as a principle of the Nowra-Bomaderry Structure Plan (SCC 2006). DEC and DPI (2005) guidelines state that where measures to avoid and mitigate are not possible, then offset strategies need to be considered.

6 BIODIVERSITY OFFSET STRATEGY

6.1 Introduction

The advice of the Department of Environment and Climate Change has been sought during preparation of the strategy and it is anticipated that the DoP would seek the concurrence of the DECC when determining the adequacy of the strategy. In accordance with DEC / DPI (2005), the Project has, to the greatest extent possible, sought to avoid and then mitigate adverse, Project-related impacts on the biodiversity values of the Project Site. The Project would remove approximately 7.4 hectares of Spotted Gum Forest. Section 2.16.9 of the *Environmental Assessment* describes the proposed Biodiversity Offset Strategy. In summary, the strategy seeks to protect and enhance an area of more than twice this size within and in the vicinity of the Subject Site. The location area, description of the biodiversity values and method of securing the offset are provided below.

6.2 Biodiversity Offset Areas

6.2.1 Northern Biodiversity Offset Area

Sections of Spotted Gum Forest within the Project Site would be retained and incorporated into the Northern Biodiversity Offset Area. This would include:

- the north-western section of the Project Site;
- the bund areas and
- the riparian area adjacent to Nowra Creek.

In total, the Northern Biodiversity Offset Area would be approximately three ha (**Figure 8**). The offset areas would include 38 hollow-bearing trees (**Appendix 4**).

The riparian area adjacent to Nowra Creek would be critically important for the offset strategy as it would help to protect water quality with Nowra Creek, preserve several large hollow-bearing Spotted Gum, one large Grey Ironbark that supports Ironbark Orchids *Tropilis aemula* and a stand of mature Burrawangs *Macrozamia communis,* that are host to Birds Nest Ferns *Asplenium australasicum,* Necklace Fern *Asplenium flabellifolium,* Hares Foot Fern *Davallia pyxidata* and Elk Horn *Platycerium bifurcatum* subsp *bifurcatum.* These species of fern were only located in this area.

6.2.2 Southern Biodiversity Offset Area

The Southern Biodiversity Offset Area would comprise approximately 17ha of native vegetation adjacent to and to the southwest of the Subject Site. The Southern Biodiversity Offset area would comprise part Lots 228 and 229, DP 755952 (**Figure 8**).

The above land is owned by Mrs V. Goodsell and an 'in principal' arrangement has been entered into between Mrs Goodsell and the Proponent to lease the subject land for the period that the offset is required (**Appendix 7**). A formal, binding agreement between Mrs Goodsell and the Proponent would be negotiated within 12 months of the receipt of project approval, should it be granted. At this stage, the Proponent anticipates that the lease would include terms that would prevent the lease from being terminated by the lessor or subsequent owners of the land.

6.3 Vegetation with the Offset Areas

Vegetation within the Northern Biodiversity Offset Area is described previously.

Vegetation within the Southern Biodiversity Offset Area was assessed for species composition, structure and in particular the number of hollow-bearing trees. The vegetation may be classified as Spotted Gum forest with a higher density of Grey Ironbark and Woollybutt than the Subject site. The vegetation within the Southern Biodiversity Offset Area has also been logged and, in general the trees are not as large in diameter as those that occur on the Subject site. However, approximately 38hollow bearing trees occur within the proposed offset area (**Appendix 4**). This compares with approximately 35 hollow-bearing trees that would be disturbed during the life of the Project.

The location of the Southern Biodiversity Offset Area is considered to be favourable because it covers the riparian zone within the upper catchment of Nowra Creek. The offset area includes a wide variation in soil moisture content, and, consequently, a variation in species diversity, with Paperbarks *Melaleuca decora* and *M. styphelioides* and Woollybutt being common within the creek bed and Grey Ironbark being common on the banks. Fallen timber is abundant and 26 hollow-bearing trees were located and marked (**Appendix 4** and **Figure 8**). In addition, the proposed offset area has an intact and diverse canopy and shrub layer, however, grazing has resulted in adverse impacts to the ground cover present (**Appendix 3**).

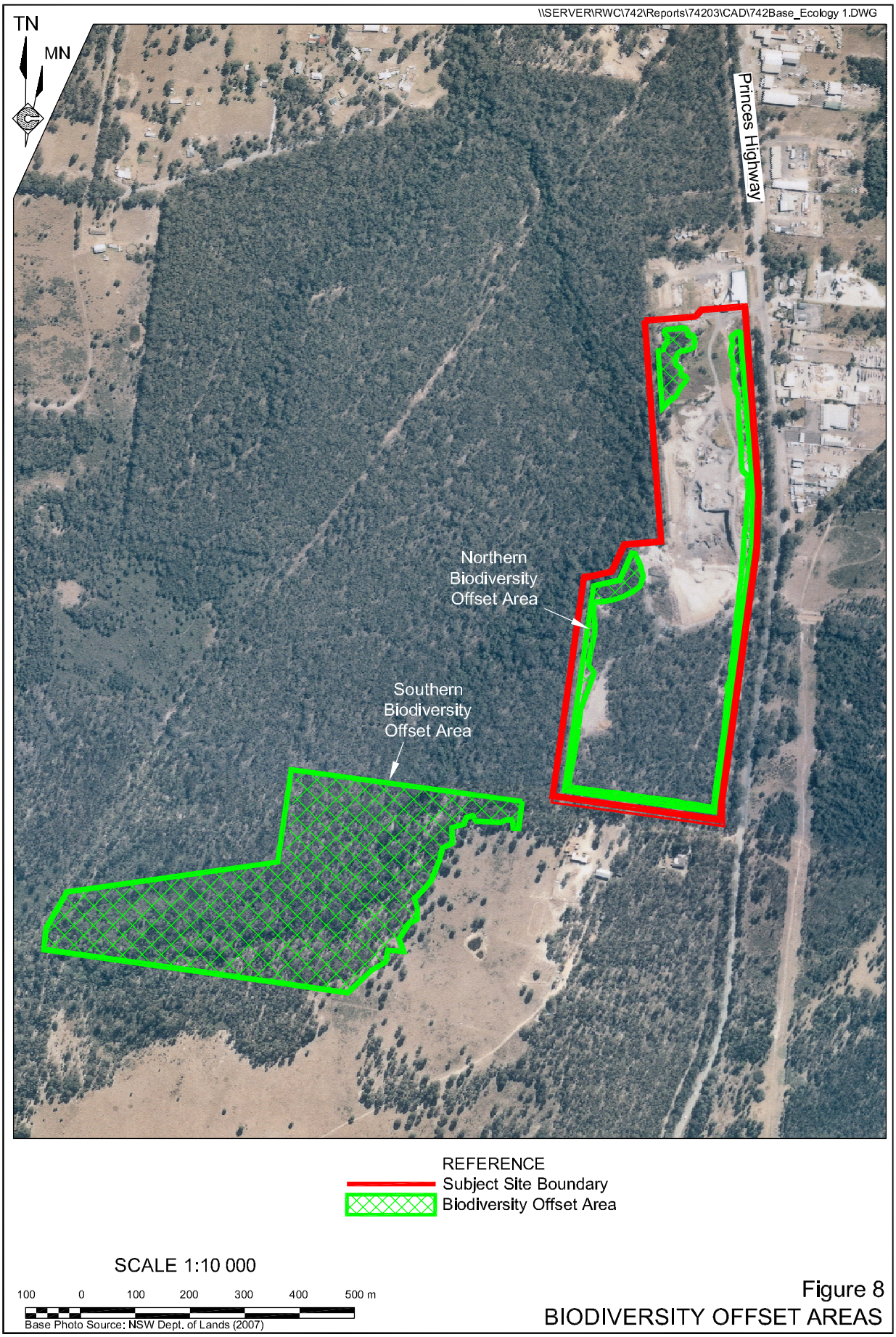

Figure 8
BIODIVERSITY OFFSET AREAS

Note: A Colour Version of this figure is available on the project CD

In addition, the proposed offset area is contiguous with retained riparian bushland adjacent to Nowra Creek within the South Coast Correctional Facility site located to the north of the offset area and west of the Subject Site, as well as riparian vegetation within the Northern Biodiversity Offset Area. Downstream (to the north) of the Subject Site, the Nowra Creek riparian zone provides a riparian corridor bounded on both sides by industrial development. Given this constraint, the riparian zone, including land within the biodiversity offset areas and land to be protected as part of the South Coast Correctional Facility site, will form the main linkage from areas of native vegetation in the vicinity and to the south of the Subject Site and larger portions of bushland, such as Shoalhaven State Forests and Depot farm council reserve beside Shoalhaven River to the north of the Subject Site.

Diurnal searches within the Southern Biodiversity Offset Area indicate that it supports a similar suite of species to the Subject site. Based on the habitat utilised by Bush Stone Curlew (DEC, 2006) the Southern Biodiversity Offset Area includes potential habitat for this species. This species is mentioned in particular because birds were detected approximately one kilometre to the north of the Subject site in 2003 (P. Craven pers. comm.). The Bush Stone Curlew is one of the rarest threatened species in the Shoalhaven, with only two confirmed records in the last decade.

6.4 Management of the Biodiversity Offset Areas

The following management measures would be implemented within the biodiversity offset areas to ensure the continued biodiversity value of the areas.

- The offset areas would be managed for the purposes of nature conservation. Any land use that is not consistent with nature conservation would not be permitted within the offset areas.
- The Southern Biodiversity Offset Area would be fenced to exclude cattle, horses and or other domestic grazing animals.
- The offset areas would not be logged or timber extracted for other purposes such as firewood.
- Unless instructed by a relevant authority, the Proponent would not conduct controlled burning in order to retain the habitat complexity.
- The weed management program prepared for the Subject site (Gaia Research 2007b) would be implemented within the Southern Biodiversity Offset Area also.

6.5 Term of the Biodiversity Offset Strategy

The proponent or its successors would continue to manage the Biodiversity Offset Areas for the life of the anticipated impacts of the Project. The Proponent anticipates that the biodiversity impacts of the Project would continue until such time as the rehabilitated final landform has biodiversity values that are similar or better than the biodiversity values of the existing landform. As rehabilitation operations within sections of the Project Site would not commence until extraction operations are complete and it is anticipated that hollows in trees generally take between 50 and 90 years to form, the Proponent anticipates that the life of the Biodiversity Offset Strategy will be between 80 and 100 years.

In the event that the Mining Leases are relinquished or cancelled, the Proponent would provide sufficient resources for the on-going management of the Northern Biodiversity Offset Area for the life of the offset strategy.

In the event that the Proponent ceases to retail control of the Southern Biodiversity Offset Area, the Proponent would ensure that its successors in title are bound by the same land management requirements for the life of the offset strategy.

6.6 Assessment of the Biodiversity Offset Strategy

DECC has established thirteen principles that are used as a guide to ascertain if proposed biodiversity offsets will achieve the desired conservation outcomes. These principals are presented in Appendix 2 of the document *Guidelines for Biodiversity Certification of Environmental Planning Instruments* published by the DECC. Each of these principles are addressed below.

1. **Impacts must be avoided first by using prevention and mitigation measures.**

   The Project has been designed to ensure that the minimum area is disturbed. Measures that have been implements include the following.

   - Maximising the use of disturbed sections of the Subject Site.
   - Ensuring, as far as practicable, that areas of high quality vegetation within the Subject Site, including areas adjacent to Nowra Creek are preserved.
   - Ensuring that areas of vegetation that would be disturbed by the Project are preserved for as long as possible.

2. **All regulatory requirements must be met.**

   The Proponent states that all regulatory requirements for the Project would be complied with. In addition, the offset strategy is not proposed to satisfy approvals or assessment requirements under other legislation such as the protection of Aboriginal heritage sites, pollution or other environmental impacts. However, the strategy will complement existing approvals for the operation of the quarry and protect water quality.

3. **Offsets must never reward ongoing poor performance.**

   The Proponent contends that the environmental performance of the existing Nowra Brickworks Quarry has been acceptable. For example, the perimeter bunds around the Subject were required to have a rehabilitation plan as part of Shoalhaven City Council development consent (DA07/1322). The plan was prepared by Gaia Research (2007a) and to date actions against this plan include the following.

   - Removal of earthen material from the root zones of two hollow-bearing Spotted Gum trees and one Grey Ironbark tree.
   - Spot spraying of weeds with Glyphosate.

- Revegetation of the bunds with endemic species of ground cover and shrubs (direct planting and broadcasting of endemic seed).
- Compilation of regular reports to Shoalhaven City Council as per the schedule of works detailed in the rehabilitation plan (Gaia Research 2007a).

4. Offsets will complement other government programs.

The offset strategy would complement existing NSW Government conservation objectives as the offset areas would protect water quality within the upper catchment of Nowra Creek. In addition, the areas are located in the vicinity of and provide linkages between the existing reserves of Triplarina Nature Reserve (158 ha) and Worrigee Nature Reserve (232 ha). Triplarina Nature Reserve is located four kilometres to the northwest of the Subject Site and Worrigee Nature Reserve is located three kilometres to the northeast. The offset areas are also contiguous with a riparian corridor that will be retained beside South Coast Correctional Centre.

5. Offsets must be underpinned by sound ecological principles.

The proposed biodiversity offset strategy:

- takes into account the structure, function and compositional elements of the Subject Site, including threatened species habitat, and to the greatest extent possible, attempts to replicate those components within the offset areas;
- enhances biodiversity at a range of scales;
- considers the conservation status of ecological communities; and
- ensures the long-term viability and functionality of biodiversity.

In addition, enhancement of existing habitat within the Subject site would be ongoing. Finally, the proposal would secure and manage the biodiversity offset areas for the sole purpose of conservation of biodiversity until such time as areas of rehabilitation within the Subject Site have achieved biodiversity values similar to greater than the biodiversity values of the existing landform.

6. Offsets should aim to result in a net improvement in biodiversity over time.

The offset strategy aims to improve the biodiversity over time by conservation of approximately 20 ha of Spotted Gum Forest in order to compensate for the disturbance of approximately 7.4ha of the same vegetation type. It is noted that vegetation within both the Subject Site and the proposed offset areas has been previously logged. The protection of the biodiversity offset areas would allow the forest within these areas to mature. In the long-term, the offset areas would support a greater number of hollow-bearing trees and, consequently, would have a greater biodiversity value than the 7.4ha of native vegetation that would be lost as a consequence of the Project.

The Southern Biodiversity Offset Area would be secured by a covenant or restriction on the use of the land for the term of the lease, namely for a period of 90 to 120 years, under Section 88B of the Conveyancing Act 1919, a conservation agreement under Part 4, Division 12 of the National Parks and Wildlife Act 1974 or a similar arrangement, to the satisfaction of the Department of Environment and Climate Change.

The purpose of such a covenant or conservation agreement would be to restrict the use of the Southern Biodiversity Offset Area for the purposes of native vegetation conservation.

The Northern Biodiversity Offset Area comprises Crown land within the mining leases held by the Proponent. On surrender or cancellation of those leases, the Proponent, or its successor in title, would provide sufficient resources for the ongoing management of the offset area for the life of the offset.

7. Offsets must be enduring and they must offset the impact of the development for the period that the impact occurs.

The Proponent anticipates that the impacts associated with the Project would occur for a period of approximately 90 to 120 years. In establishing this time frame the Proponent notes that hollows of the size and type that currently occur within the Subject Site are generally believed to take between 90 and 120 years to develop. Taking into account the 30 year life of the Project, the Proponent anticipates that the term of the offset strategy would be between 120 to 150 years.

During that period, the Proponent would allocate adequate resources to manage the biodiversity offset areas, including for fencing and weed and feral animal control.

8. Offsets should be agreed prior to the impact occurring.

As part of this proposal the proponent would provide legal commitments to the offset actions prior to the commencement of works under approval.

9. Offsets must be quantifiable and the impacts and benefits must be reliably estimated.

The following comments are made in relation to the areas of proposed disturbance and the proposed offset areas.

- The area of native vegetation to be disturbed would be approximately 7.4ha. The area of native vegetation that would be preserved within the offset areas would be approximately 20 ha.
- The ecological community within both the area to be disturbed and the proposed biodiversity offset areas is Spotted Gum forest: Forest Ecosystem 9: Coastal Lowlands Cycad Dry Shrub Dry Forest - Corymbia maculata / Macrozamia communis (Thomas *et al.*2000).
- The proposed areas to be disturbed and the offset areas are contiguous with bushland to be retained beside Nowra Creek for the South Coast Correctional Facility.
- The habitat of the offset area have been described previously and information in relation to their floristic species diversity and structure is presented in **Appendix 3** and **Appendix 4** respectively. The habitat within the offset areas is considered similar in composition and structure to the native vegetation that is proposed to be removed.
- Forest Ecosystem 9: Coastal Lowlands Cycad Dry Shrub Dry Forest is currently not listed on the TSC Act (1995) as an endangered ecological community.

- The management actions for the biodiversity offset areas include weed control as described by Gaia Research 2007a, fencing, monitoring, feral animal control, retention of fallen and standing timber and fire control.
- The Southern Biodiversity Offset Area would be secured by a covenant or restriction on the use of the land for the term of the lease under Section 88B of the Conveyancing Act 1919, a conservation agreement under Part 4, Division 12 of the National Parks and Wildlife Act 1974 or a similar arrangement, to the satisfaction of the Department of Environment and Climate Change. The purpose of such a covenant or conservation agreement would be to restrict the use of the Southern Biodiversity Offset Area for the purposes of native vegetation conservation.

  As a result, the impacts and benefits associated with the Project and the proposed offset strategy are considered to be able to be quantified and reliably estimated and, in the authors opinion, the offset strategy adequately compensates for the proposed disturbance.

10. Offsets must be targeted.

The proposed biodiversity offset strategy is aimed at preserving and protecting similar habitat to the habitat that would be disturbed in respect to floristic diversity, age of the forest, number of hollow-bearing trees and level of disturbance. The proposed biodiversity offset strategy is considered to improve the biodiversity values in the vicinity of the Subject Site for the following reasons.

- The biodiversity offset areas are located adjacent to the areas of proposed disturbance and are very similar floristically and structurally to the area to be disturbed.
- The biodiversity offset areas are located adjacent to Nowra Creek to maximise the linkages between vegetation within the Subject Site and surrounding areas of vegetation.
- The biodiversity offset areas include a variety of soil moisture levels from the ephemeral creek to the flats, providing a greater range of habitats than the Subject Site.
- Paperbarks grow beside the creek within the offset areas, a feature that is not present within the area to be disturbed.
- The section of the Northern Biodiversity Offset Area adjacent to Nowra Creek supports mature cycads with epiphytic ferns and several species of terrestrial orchids. One large Grey Ironbark would be retained in this area that is host to Ironbark Orchids *Tropilis aemula*.

11. Offsets must be located appropriately.

Where possible the offsets are located within the Subject site. In addition, the Southern Biodiversity Offset Area is located in the vicinity of the southwest of the Subject site and consequently has similar ecological characteristics as the area affected by the development

12. Offsets must be supplementary.

The biodiversity offset areas are not protected by existing covenants or other measures and not funded by other schemes. The Southern Biodiversity Offset Area has not been subject to incentive funds or protected under previous management actions such as voluntary conservation agreements or catchment management bushland incentives schemes.

13. Offsets and their actions must be enforceable through development consent conditions, licence conditions, conservation agreements or a contract.

The Proponent anticipates that the project approval, should it be granted, would include a requirement to implement the proposed offset strategy, including securing the biodiversity offset areas to the satisfaction of the DECC. In addition, the Proponent would undertake internal audits and monitoring of the biodiversity offset strategy and areas to determine that the proposed actions are leading to positive biodiversity outcomes.

In addition, the Proponent has agreed with the landowner to acquire a lease over the Southern Biodiversity Offset Area for the period of the proposed impacts, subject to the granting of project approval. The lease would include terms that would prevent the lease from being terminated by the lessor or subsequent owners of the land. The Proponent would enter into an appropriate arrangement as described previously to ensue the above commitments are implemented.

In the event that the Mining Leases are relinquished or cancelled, the proponent would provide sufficient resources for the on-going management of the On-site Biodiversity Offset Areas for the life of the offset strategy.

7 CONCLUSIONS

No small ground dwelling mammals were trapped within the Subject Site. One common species of arboreal mammal was detected within the Subject Site, and it is expected that the Common Ringtail Possum also occurs on site as it was observed in a previous assessment in 1995. One species of bat, the Little Forest Bat, was trapped within the Subject Site. This is a common species. A minimum buffer of 50m should be provided from the centre line of Nowra Creek in accordance with the *Shoalhaven Local Environment Plan 1985*. The medium to large ground dwelling mammals observed within the Subject Site included the Swamp Wallaby, Eastern Grey Kangaroo, Wombat, Echidna, Rabbit and Red Fox. All these species are common within New South Wales or are exotic. Four species of reptile and five species of frog were detected on the site. All species of herpetofauna detected are common within the local area.

One threatened species of fauna, the Grey-headed Flying Fox was detected foraging on site. No threatened species of flora was located within the Subject Site. The Square-tailed Kite was observed adjacent to the Subject Site and may nest close by (near the creek). The Gang-gang Cockatoo would occasionally forage on the Subject Site. This species have large home ranges and is highly seasonal in its occurrence in the area. The loss of approximately 7.4 hectares is not considered to be a significant impact but part of the cumulative loss of habitat.

The offset strategy proposed is to conserve three hectare of forest on site and 17 hectares off site. The offset strategy and conditions detailed in the recommendations will maintain biodiversity in the short term and pending developments on other land in the Subject area may increase biodiversity in the long-term.

8 RECOMMENDATIONS

The broad recommendations are as follows.

1. All clearing of trees must be done during winter to reduce the impact on animals that reproduce during spring/summer. This includes species of bird and microbats. Three threatened species of bat, the Grey-headed Flying Fox, Yellow-bellied Sheathtail Bat and the Eastern Bentwing Bat are seasonal migrants to the area and would not be expected to be in the region during winter.
2. A period of three consecutive trap nights should be spent prior to clearing of native vegetation where cage traps are set on large hollow-bearing trees in order to capture any gliders, possums or goanna that may be using those trees. Any trapped animal should be kept in captivity (animal carers) for the period of clearing. They may be released adjacent to the site (within their home range) after the felling of the hollow-bearing trees.
3. The non-hollow bearing trees in the area to be cleared must be felled and used for rehabilitation-revegetation related activities.

   The remaining hollow bearing trees should be felled by excavator or bulldozer. A qualified fauna consultant should be on site during the removal of the hollow bearing trees in case animals require rescue. Any injured animals are to be taken to a local animal carer. Non-injured animals can be held in cloth bags for a short period and released adjacent to the site (within the protected riparian area beside Nowra Creek) after clearing operations have been completed. The felled hollow-bearing trees are to areas to be conserved or areas undergoing rehabilitation, or stockpiled for later use during rehabilitation.
4. After clearing the vegetation, topsoil and subsoil should be stripped, stockpiled or used immediately for progressive rehabilitation operations.
5. The weed management program prepared for the site (Gaia Research 2007) should be implemented. This report specifies actions to be undertaken during the life of the Project and for several years after the site has been decommissioned. The weed management program prepared for the site (Gaia Research 2007) should also be implemented over the Off-site Biodiversity Offset Area.
6. A minimum buffer of 50m should be provided from the centre line of Nowra Creek in accordance with the Shoalhaven Local Environment Plan 1985.
7. The boundaries of the extraction area should be 6m from the base of the existing visual and acoustic bunds adjacent to the perimeter of the Project Site.
8. The extraction of shale should proceed in a staged fashion progressing from north to south. Where extraction and processing-related activities have been completed and final quarry faces have been achieved, virgin excavated natural material would be progressively placed and compacted.

These areas will be revegetated progressively as outlined by Gaia Research (2007). The final landform and vegetation community will mimic that existing prior to quarrying. The rehabilitation process will take at least five years to complete once the quarry is decommissioned. If possible ephemeral ponds may be constructed for the Green and Golden Bell Frog and large rocks placed in piles as refuge habitat for reptiles and amphibians.

9. Implement the Biodiversity Offset Strategy described in Section 6. An area of 3 hectares will be retained on site and another 15.9 hectares conserved off site. The Proponent would secure the Off-site Biodiversity Offset Areas through a covenant or restriction on the use of the land for the term of the lease under Section 88B of the *Conveyancing Act 1919*, a conservation agreement under Part 4, Division 12 of the *National Parks and Wildlife Act 1974* or a similar arrangement, to the satisfaction of the Department of Environment and Climate Change. The purpose of such a covenant or conservation agreement would be to restrict the use of the Off-site Biodiversity Offset Area for the purposes of native vegetation conservation in perpetuity.

10. The Proponent would undertake to manage the Off-site Biodiversity Offset Areas for the purpose of native vegetation / wildlife conservation during the life of the Project until such time until the areas of rehabilitation within the Project Site have similar biodiversity values as the Off-site Biodiversity Offset Area. The management actions associated with conservation include weed management (point 4) and control of exotic feral animals such as the Red Fox.

11. The Proponent would undertake to manage the Off-site Biodiversity Offset Area by excluding stock from the site. If additional fences need to be erected then the use of barb wire is prohibited and fencing should be wildlife friendly, see web site http://www.wildlifefriendlyfencing.com/

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APPENDICES

(No. of pages excluding this page = 18)

Appendix 1 Director-General's Requirements for proposal

Appendix 2 Fauna detected on the site

Appendix 3 Native flora located on the site

Appendix 4 Hollow-bearing trees located on the Subject site and the offset site

Appendix 5 Plot data for vegetation quadrats

Appendix 6 Curriculum vitae of participating consultants

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Appendix 1

Director-General's Requirements for the Proposal

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Director-General's Requirements for Proposal
Coverage of *Environmental Assessment* Requirements and Environmental Issues in the Weed Management and Rehabilitation Strategy

ENVIRONMENTAL REQUIREMENTS RAISED BY THE DIRECTOR-GENERAL RELATING TO ECOLOGY (20/09/2007)		
		Relevant Section(s)
Key Assessment Requirements, namely: • *Ecology:* - Determine impacts on threatened species, populations or endangered ecological communities or their habitats. - Include details of vegetation offsets to ensure that there is no net loss to the flora and fauna values of the area. **References:** • Draft Guidelines for Threatened Species Assessment – Available from Department of Planning.		Sections 4.1 and 4.2 Section 6.0
ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO ECOLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Environment and Climate Change (7/9/07)	The proposal should be consistent with the principle pertaining to the potential bio-certification of the Nowra / Bomaderry Structure Plan.	
	Not all areas of the proposed site may be suitable for development and any development will need to avoid Endangered Ecological Communities and provide an appropriate buffer and asset protection zone. Threatened species that could potentially occur onsite and should be considered include: • Bush Stone-curlew; • Gang-gang Cockatoo; • Large forest owls; • Glossy Black cockatoo; • Yellow-bellied Glider • All Microchripterean bats; • Square Tailed Kite; • Grey headed Flying Fox; • Green and Golden Bell Frog; • *Cryptostylis hunteriana*; • Illawarra Greenhood; and • *Genoplesium baurei*.	Table 1 and Section 4.1
	All survey work for these species should be undertaken at the appropriate time of year for each species to maximise the survey results.	Section 3.0

Director-General's Requirements for Proposal
Coverage of *Environmental Assessment* Requirements and Environmental Issues in the Weed Management and Rehabilitation Strategy

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO ECOLOGY		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Environment and Climate Change (7/9/07) (Cont'd)	All hollow bearing trees on site should be identified and marked on a map to be supplied within the *Environmental Assessment*. These hollow bearing trees should also be targeted for stag watches to indicate the presence or absence of hollow dependent fauna in particular micro bats, yellow bellied glider, squirrel gliders, Glossy black and Gang Gang cockatoos. All of these species will require an assessment of the use of the hollow bearing trees during the breeding period for each species.	Section 3.0 Figure 5
	The *Environmental Assessment* must describe what actions will be undertaken to avoid or mitigate impacts caused by the development on all threatened species described at the site.	Section 6.0
Department of Lands (7/9/07)	The likely presence of threatened flora and fauna should be assessed for all threatened species, including the Bush Stone Curlew and Illawarra Greenhood Orchid.	Section 4.0 Section 4.1
	The survey should take account of the time of year when threatened species are likely to be present.	Section 2.0
	Details of the methods used should be included in the *Environmental Assessment*.	Section 3.0
	SEPP 44 – Koala Habitat should be addressed in the assessment.	Section 4.3
Department of Water and Energy (6/9/07)	Existing vegetation within a width of 40m either side of Nowra Creek should be retained and protected as a *core riparian zone* (CRZ). The CRZ is to remain or become fully vegetated with local provenance native vegetation (including aquatic groundcovers, shrubs and other species) to a minimum width from the banks of the river.	Section 7.0
	A *vegetated buffer* (VB) of 10m either side of the CRZ should be provided.	Section 7.0
	The identified Riparian Corridor Objective Setting objectives be applied to this site and that the Brickworks Quarry Project be therefore developed in a manner which is consistent with maintaining / achieving these objectives.	Section 7.0
	The EAR should outline an appropriate management regime for the riparian areas to ensure that the riparian lands continue to meet the recommended objectives. In this regard the preparation of a Vegetation Management Plan (VMP) for the Nowra Creek Riparian Corridor continued within the Subject Site would be appropriate.	Gaia Research 2007
Shoalhaven City Council (7/9/07)	A detailed flora and fauna survey(s) of the site should be prepared in accordance with "Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities" Working Draft November 2004 by the NSW Department of Environment and Conservation, or any subsequent approved versions by the NSW Department of Environment and Climate Change (DECC).	Section 2.0
	An ecological study of the receiving water is to be carried out in accordance with DECC requirements.	N/A
	It is noted that an Endangered Ecological Community (Swamp sclerophyll forest on coastal floodplains) is mapped as occurring on the site.	Section 3.2

Appendix 2

Fauna Detected on the Site

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Fauna Detected on the Site

Nomenclature is based on Cogger (2000), Strahan (1995) and Christides and Boles (1994).

Key

Record	h	heard call
	o	observed during survey
	p	previous recorded by Daly (1995)
	s	scats
	t	trapped
	l	tadpoles
	*	introduced species

Mammals

Family	Species	Common Name	Records
Tachyglossidae	*Tachyglossus aculeatus*	Echidna	o
Vombatidae	*Vombatus ursinus*	Common Wombat	s
Pseudocheiridae	*Pseudocheirus peregrinus*	Common Ringtail Possum	p
Phalangeridae	Trichosurus vulpecula	Common Brushtail Possum	o
Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	o, p
	Wallabia bicolor	Swamp Wallaby	o, p
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying Fox	o
Molossidae	*Tararida australis*	White-striped Mastiff Bat	h, p
Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat	t
Leporidae	*Oryctolagus cuniculus*	Rabbit*	s
Canidae	*Vulpes vulpes*	Red Fox*	s

Birds

Family	Species	Common Name	
Anatidae	Chenonetta jubata	Australian Wood Duck	o
	Anus superciliosa	Black Duck	o
Accipitridae	*Accipiter fasciatus*	Brown Goshawk	o
	Lophoictinia isura	Square-tailed Kite	p
Charadriidae	*Vanellus miles*	Masked Lapwing	p
Columbidae	*Phaps chalcoptera*	Common Bronzewing	o
Cacatuidae	*Calyptorhynchus funereus*	Yellow-tailed Black-cockatoo	o
	Cacatua roseicapilla	Galah	o, p
	Cacatua galerita	Sulfur-crested Cockatoo	p
Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet	o, p
	Platycercus elegans	Crimson Rosella	p
	Cacatua roseicapilla	Galah	o
	Cacatua galerita	Sulfur-crested Cockatoo	o
Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet	o
	Platycercus eximius	Eastern Rosella	o
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra	o, p
	Todiramphus sancta	Sacred Kingfisher	o
Coraciidae	Eurystomus orientalis	Dollarbird	o
Climacteridae	*Climacteris leucophaea*	White-throated Treecreeper	o
Maluridae	*Malurus cyaneus*	Superb Fairy-wren	o, p
Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	o
	Acanthiza lineata	Striated Thornbill	h

Birds

Family	***Species***	**Common Name**	
Meliphagidae	*Acanthiza nana*	Yellow Thornbill	o, p
	Anthochaera carunculata	Red Wattlebird	o
	Anthochaera chrysoptera	Little Wattlebird	h
	Philemon corniculatus	Noisy Friarbird	o
	Meliphaga lewinii	Lewin's Honeyeater	p
	Lichenostomus chrysops	Yellow-faced Honeyeater	o
	Acanthorhynchus tenuirostris	Eastern Spinebill	h
Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	h
Cinclosomatidae	Cinclosoma punctatum	Spotted Quail-thrush	o
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	o
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	h
	Pachycephala rufiventris	Rufous Whistler	h
	Colluricincla harmonica	Grey Shrike-thrush	o
Dicruridae	*Rhipidura fuliginosa*	Grey Fantail	o, p
	Rhipidura leucophrys	Willie Wagtail	o
	Grallina cyanoleuca	Magpie Lark	o
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike	o
Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	h
Corvidae	*Corvus coronoides*	Australian Raven	o
Passeridae	*Neochmia temporalis*	Red-browed Firetail	p
Zosteropidae	*Zosterops lateralis*	Silvereye	h, p
Sturnidae	*Acridotheres tristis*	Common Myna*	h

Reptiles

Family	**Species**	**Common Name**	
Varanidae	*Varanus varius*	Lace Monitor	t
Scincidae	*Eulamprus quoyii*	Eastern Water Skink	o
	Lampropholis delicata	Grass Skink	o
Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake	m

Amphibians

Family	**Species**	**Common Name**	
Hylidae	*Litoria dentata*	Bleating Tree Frog	o, l
	Litoria peroni	Peron's Tree Frog	o, l
Myobatrachidae	*Crinia signifera*	Common Eastern Froglet	h, l
	Limnodynastes peroni	Striped Marsh Frog	l
	Pseudophryne bibronii	Bibron's Toadlet	l

Appendix 3

Native Flora located on the Subject Site and offsite offset

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Native Flora Located on the Subject Site and offsite offset

Family	Species	Common Name	On Site	Off set
FILICOPSIDA				
Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair Fern	x	x
Aspleniaceae	*Asplenium australasicum*	Birds Nest Fern	x	
	Asplenium flabellifolium	Necklace Fern	x	
Davalliaceae	*Davallia pyxidata*	Hare's Foot Fern	x	
Lindsaeaceae	*Lindsaea microphylla*	Lacy wedge Fern		x
Polypodiaceae	*Platycerium bifurcatum* subsp *bifurcatum*	Elk Horn	x	
CYCADOPSIDA				
Zamiaceae	*Macrozamia communis*	Burrawang	x	
MAGNOLIOPSIDA	**DICOTYLEDONS**			
Acanthaceae	*Pseuderanthemum variabile*	Pastel Flower	x	
Amaranthaceae	*Parsonsia straminea*	Common Silkpod	x	x
Asclepiadaceae	*Tylophora barbata*			x
Asteraceae	*Cassinia aculeata*	Common Cassinia	x	x
	Cassinia longifolia	Long-leaved Cassinia	x	
	Lagenifera stipitata		x	x
	Olearia microphylla	Bridal Daisy Bush	x	x
	Ozothamnus diosmifolium	Paper daisy	x	
Casuarinaceae	*Allocasuarina littoralis*	Black She-Oak	x	x
Campanulaceae	*Wahlenbergia sp*	Bluebells	x	x
Chenopodiaceae	*Einadia hastata*		x	
Epacridaceae	*Leucopogon juniperinus*	Bearded Heath	x	x
	Lissanthe strigosa	Native Cranberry	x	x
Fabaceae: Faboideae	*Daviesia ulicifolia*		x	x
	Glycine clandestina	Love Creeper	x	x
	Hardenbergia violacea	False sarsaparilla	x	x
	Kennedia rubicunda		x	x
	Pultenaea polifolia		x	
	Pultenaea villosa		x	x
Fabaceae: Mimosoideae	*Acacia elongata*		x	
	Acacia falcata		x	x
	Acacia longifolia	Sydney Golden Wattle	x	x
	Acacia myrtifolia	Myrtle Wattle	x	
	Acacia ulicifolia	Prickly Moses	x	x
Goodeniaceae	*Goodenia heterophylla subsp heterophylla*	Violet-leaved Goodenia	x	x
	Goodenia ovata	Hop Goodenia	x	x
Lobeliaceae	*Pratia purpurascens*	White Root	x	x
Myrtaceae	*Corymbia maculata*	Spotted Gum	x	x
	Eucalyptus globoidea	White Stringy Bark	x	x
	Eucalyptus gummifera	Red Bloodwood	x	
	Eucalyptus longifolia	Woollybutt	x	x
	Eucalyptus paniculata	Grey Iron Bark	x	x
	Kunzea ambigua	Tick Bush	x	x
	Melaleuca lineariifolia	Snow-in-summer		x
	Melaleuca styphelioides	Prickly-leaved Paperbark	x	x
	Syncarpia glomulifera	Turpentine	x	x
Pittosporaceae	*Bursaria spinosa*	Blackthorn	x	x

Family	Species	Common Name	On Site	Off set
	Rhytidosporum procumbens		x	x
Polygalaceae	*Comesperma ericinum*	Matchheads	x	
Proteaceae	*Hakea sericea*	Bushy Needlebush	x	x
Ranunculaceae	*Clematis aristata*	Old Man's Beard	x	x
MAGNOLIOPSIDA	**DICOTYLEDONS**			
Rubiaceae	*Galium binifolium*	Bedstraws		x
	Pomax umbellata			x
Rutaceae	*Boronia sp*			x
	Zieria smithii	Sandfly Zieria	x	
Santalaceae	*Exocarpus cupressiformis*	Cherry Ballart	x	x
Solonaceae	*Solunum prinophyllum*	Forest Nightshade	x	
Stylidiaceae	*Stylidium graminifolium*	Trigger Plant	x	x
Thymeliaceae	*Pimelia linifolia spp. linifolia*	Rice Flower	x	x
MAGNOLIOPSIDA -	**MONOCOTYLEDONS**			
Cyperaceae	*Baumea articulata*	Jointed twig Rush		x
	Eleocharis sp			x
	Lepidosperma laterale		x	x
	Lepidosperma urophorum		x	
	Ptilothrix deusta		x	x
Iridaceae	*Patersonia sericea*	Silky Purple Flag	x	x
Juncaceae	*Juncus bufonius*		x	
	Juncus continuus			x
Liliaceae	*Hypoxis hygrometrica*	Yellow Stars	x	x
Lomandraceae	*Lomandra gracilis*		x	
	Lomandra longifolia	Mat Rush	x	x
	Lomandra multiflora		x	x
Orchidaceae	*Acianthus fornicatus*		x	
	Calochilus robertsonii		x	
	Corybas sp.		x	
	Cyanicula caerulea		x	
	Cymbidium suave	Snake Flower	x	
	Eriochilus cucullatus		x	
	Glossodia major		x	
	Myrmechila sp.		x	
	Prasophyllum brevilabre		x	
	Pterostylis acuminata	Sharp Greenhood	x	
	Pterostylis curta		x	
	Pterostylis nutans	Nodding greenhood	x	
	Thelymitra spp.		x	
	Tropilis aemula	Ironbark Orchid	x	
Phormiaceae	*Dianella revoluta var revoluta*	Mauve Flax Lily	x	x
Poaceae	*Aristida vagans*	Three-awn Speargrass	x	x
	Entolasia stricta		x	x
	Panicum simile	Two Colour Panicum	x	x
	Phragmites australis	Native Reed	x	x
	Themeda australis	Kangaroo Grass	x	x
Xanthorrhoeaceae	*Xanthorrhoea sp.*	Grass Tree	x	x

Appendix 4

Hollow-bearing Trees located on the Subject site and the Southern Biodiversity Offset Area

(No of pages excluding this page = 3)

Hollow-bearing Trees Located on the Site

- indicates tree used by Lace Monitor *Varanus varius* as refuge site. Trees in bold represent those within the bunds areas, riparian zone and the road corridor to the south of the Subject Site (denoted by the prefix R) or other conservation areas to be retained.

Number	Species	Northing	Easting	Hollows
1	*Eucalyptus longifolia*	280904	6132306	1l
2	Stag	280876	6132298	1l
3	Stag	280807	6132270	1m
4	***Corymbia maculata***	**280806**	**6132238**	**1m**
5	*Eucalyptus longifolia*	280868	6132256	1s
6	*Eucalyptus punctata*	280925	6132377	1l
7	*Corymbia maculata*	280940	6132236	1l, 1m
8	*Corymbia maculata*	280954	6132231	4m
9	*Eucalyptus longifolia*	280964	6132249	1s
10	*Corymbia maculata*	280955	6132183	2l
11	*Corymbia maculata*	280939	6132143	1s
12	*Corymbia maculata*	280913	6132127	1l
13	***Eucalyptus longifolia***	**280955**	**6132139**	**1m, 1s**
14	Stag	280895	6132192	1l
15	*Corymbia maculata*	280846	6132210	2l, 3m
16	*Eucalyptus globoidea*	280841	6132181	1s
17	*Eucalyptus globoidea*	280893	6132181	2s
18	***Corymbia maculata***	**280963**	**6132121**	**1l, 1m**
19	*Corymbia maculata*	280935	6132108	1m
20	Stag	280931	6132103	2s
21	*Corymbia maculata*	280852	6132069	1l, 3m
22	*Eucalyptus globoidea*	280860	6132062	1m
23	*Corymbia maculata*	280803	6132127	1l, 1m
24	*Eucalyptus punctata*	280775	6132170	1m
25	*Corymbia maculata**	280749	6132130	1l
26	*Corymbia maculata*	280733	6132120	1m
27	*Corymbia maculata*	280706	6132133	3s
28	*Corymbia maculata*	280702	6132138	1m, 2s
29	***Corymbia maculata***	**280672**	**6132098**	**6m, 5s**
30	***Corymbia maculata***	**280682**	**6132043**	**3l**
31	***Corymbia maculata***	**280753**	**6132033**	**1l, 1m**
32	***Corymbia maculata***	**280769**	**6132028**	**1l, 1m**
33	***Corymbia maculata***	**280797**	**6132028**	**1l**
34	*Corymbia maculata*	280826	6132019	1m
35	*Corymbia maculata*	280876	6132028	1m
36	*Corymbia maculata*	280813	6132326	2s
37	*Corymbia maculata*	280832	6132319	1s
38	*Eucalyptus longifolia*	280779	6132296	1m
39	***Corymbia maculata***	**280702**	**6132280**	**1m**
40	*Eucalyptus globoidea*	280718	6132316	1m
41	*Corymbia maculata*	280763	6132365	1l
42	*Corymbia maculata*	280770	6132357	1m, 1s
43	*Eucalyptus paniculata*	280802	6132371	1m
44	*Eucalyptus longifolia*	280769	6132395	1l
45	***Corymbia maculata***	**280779**	**6132453**	**1l**
46	***Corymbia maculata***	**280777**	**6132486**	**1m**
47	***Eucalyptus longifolia***	**280707**	**6132400**	**2s**
R1	***Corymbia maculata***	**280851**	**6132858**	**1l**
R2	***Corymbia maculata***	**280861**	**6132800**	**1s**
R3	***Corymbia maculata***	**281008**	**6132695**	**3s**

R4	***Corymbia maculata***	**281015**	**6132620**	**1m**
R5	***Corymbia maculata***	**281015**	**6132567**	**1m**
R6	***Corymbia maculata***	**281010**	**6132505**	**1s**
R7	***Corymbia maculata***	**280993**	**6132400**	**1l**
R8	***Corymbia maculata***	**280764**	**6132002**	**1s**
R9	***Corymbia maculata***	**280778**	**6132000**	**1s**
R10	***Corymbia maculata***	**280835**	**6131995**	**1l, 2s**
R11	***Eucalyptus globoidea***	**280849**	**6131990**	**2s**
R12	***Eucalyptus globoidea*** **(stag)**	**280869**	**6131988**	**1s**
R13	***Eucalyptus longifolia***	**280871**	**6131988**	**1m**
R14	***Corymbia maculata***	**280910**	**6131990**	**1m**
R15	***Corymbia maculata***	**280727**	**6132013**	**1s**
R16	***Corymbia maculata***	**280741**	**6132031**	**1m,1s**
R17	***Eucalyptus globoidea***	**280710**	**6132017**	**1s**
R18	***Eucalyptus globoidea***	**280706**	**6132013**	**3m**
R19	***Eucalyptus globoidea*** **(stag)**	**280637**	**6132015**	**1m**
R20	***Corymbia maculata***	**280730**	**6132475**	**1l**

Hollow-bearing Trees Located within the Southern Biodiversity Offset Area

* indicates tree used by Lace Monitor *Varanus varius* as refuge site. The first 26 trees were located in Lot 229 and the remaining trees on Lot 228.

Number	Species	Northing	Easting	Hollows
1	*Eucalyptus longifolia*	280383	6132032	1m
2	*Corymbia maculata*	280332	6131972	1l
3	*Corymbia maculata*	280333	6131961	1s
4	*Corymbia maculata*	280246	6131830	1m
5	Stag	280240	6131839	4s
6	*Eucalyptus globoidea* (stag)	280254	6131856	1s
7	*Corymbia maculata*	280269	6131853	1m
8	*Eucalyptus globoidea* (stag)	280273	6131883	1s
9	*Corymbia maculata*	280321	6131911	1s
10	*Syncarpia glomulifera*	280297	6131943	1l
11	*Corymbia maculata*	280280	6131928	1l,1m
12	*Eucalyptus globoidea*	280280	6131961	2s
13	*Eucalyptus globoidea*	280278	6131962	1s
14	*Corymbia maculata*	280342	6131995	1l
15	*Eucalyptus longifolia*	280340	6131200	1s
16	*Eucalyptus globoidea*	280168	6132045	1s
17	Stag	280208	6131959	1s
18	*Eucalyptus globoidea*	280333	6131995	1s
19	*Eucalyptus longifolia*	280191	6131939	1s
20	*Eucalyptus paniculata*	280201	6131929	1s
21	*Eucalyptus longifolia*	280213	6131911	1s
22	*Eucalyptus longifolia*	280207	6131887	1m
23	*Eucalyptus globoidea*	280201	6131881	1s
24	*Eucalyptus paniculata*	280139	6131933	2s
25	Stag	280144	6131706	2m
26	*Eucalyptus globoidea*	280181	6131835	1s
27	*Eucalyptus globoidea*	280039	6131744	3M
28	*Eucalyptus globoidea*	280116	6131732	1L
29	*Eucalyptus longifolia*	280122	6131725	1M
30	*Corymbia maculata*	280147	6131651	1M
31	*Eucalyptus paniculata*	280137	6131635	1L
32	*Eucalyptus longifolia*	280127	6131624	1M
33	Stag	280143	6131588	1M
34	Stag	280053	6131894	2S
35	*Eucalyptus paniculata*	280144	6131937	1S
36	*Eucalyptus paniculata*	280140	6131944	1S
37	Stag	280063	6131955	1S
38	*Eucalyptus punctata*	280055	6131966	1S
Note 1 – AMG 66 Datum Note 2 – symbols for hollows: s=small (<300mm dia.), m=medium (300-500mm dia.) and l=large (>500mm dia.)				

Appendix 5

Plot Data for Vegetation Quadrats

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Plot Data for Vegetation Quadrats

Quadrat 1

Site ID	South Nowra Quarry, Quadrat 1			Date	24/9/07
Location	Tree Number H15 located on the NE corner				
Slope	<10%	Aspect	East South East	Elevation	80m
Coordinates AMGS 66 datum	280846		6132210		

Substrate

Wandrawandian siltstone

Vegetation community

Coastal Lowlands Spotted Gum Open Forest – Corymbia maculata

Vegetation Structure

Growth Form	Height (m)	Cover %	Dominant Species
Tree	25	20	*Corymbia maculata*
Shrub	2	40	*Hakea sericea, Acacia longifolia*
Ground cover	.5	30	*Entolasia stricta*

Fire History

Unknown – no evidence of fire in the last 5 years

Notes

Quadrat shows no recent disturbance but is likely to have been logged

Species located with quadrat

HT = height in metres, CO = projective cover

Family	Species	Common Name	HT	CO
FILICOPSIDA				
MAGNOLIOPSIDA -	**DICOTYLEDONS**			
Asteraceae	*Cassinia aculeata*	Common Cassinia	1.5	1
	Lagenifera stipitata		.1	1
Epacridaceae	*Leucopogon juniperinus*	Bearded Heath	1	1
	Lissanthe strigosa	Native Cranberry	1	1
Fabaceae: Faboideae	*Daviesia ulicifolia*		.1	1
Lobeliaceae	*Pratia purpurascens*	White Root	.1	1
Mimosaceae	*Acacia longifolia*	Sydney Golden Wattle	2	1
	Acacia ulicifolia	Prickly Moses	.5	1
Myrtaceae	*Eucalyptus maculata*	Spotty Gum	20	3
	Eucalyptus globoidea	Stringy Bark	10	1
	Kunzea ambigua	Tick Bush	1.5	1
Pittosporaceae	*Rhytidosporum procumbens*		.1	1
Proteaceae	*Hakea sericea*	Needle-leaved Hakea	.1	2
Rubiaceae	*Galium sp*		.2	1
	Opercularia sp	Stink Weed	.5	1
MAGNOLIOPSIDA -	**MONOCOTYLEDONS**			
Cyperaceae	*Lepidosperma laterale*		.5	1
Lomandraceae	*Lomandra gracilis*		.3	1
	Lomandra longifolia		.5	1
	Lomandra multiflora		.3	1
Orchidaceae	*Pterostylis nutans*		.1	1
Poaceae	*Aristida vagans*	Three Awned Speargrass	.5	2
	Entolasia stricta		.5	3
Xanthorrhoeaceae	*Xanthorrhoea sp.*	Grass tree	1.0	1

Quadrat 2

Site ID	South Nowra Quarry Quadrat 2			Date	24/10/07
Location	Tree Number H48 located on the SE corner				
Slope	<20%	Aspect	East South East	Elevation	80m
Coordinates AMGS	280734		6132423		

Substrate

Wandrawandian siltstone

Vegetation community

Coastal Lowlands Spotted Gum Open Forest – Corymbia maculata

Vegetation Structure

Growth Form	Height (m)	Cover %	Dominant Species
Tree	25	70	*Corymbia maculata, Eucalyptus paniculata*
Shrub	1.3	10	*Hakea sericea*
Ground cover	.5	65	*Lomandra longifolia, Macrozamia communis*

Fire History

Unknown – no evidence of fire in the last 5 years

Notes

Quadrat shows no recent disturbance but is likely to have been logged

Species List

Family	Species	Common Name	HT	CO
FILICOPSIDA				
Adiantaceae	*Adiantum aethiopicum*	Maidenhair	.2	1
Aspleniaceae	*Asplenium flabellifolium*	Necklace Fern	.3	1
Davalliaceae	*Davallia pyxidata*	Hare's Foot Fern	.3	1
Polypodiaceae	*Pyrrosia rupestris*	Rock Felt Fern	.1	1
Schizaeaceae	*Cheilanthes sieberi*	Mulga Fern	.2	1
CYCADOPSIDA				
Zamiaceae	*Macrozamia communis*	Burrawang	1	2
MAGNOLIOPSIDA -	**DICOTYLEDONS**			
Apocynaceae	*Parsonsia straminea*		.2	1
Asclepiadaceae	*Tylophora barbata*		.1	1
Dilleniaceae	*Hibbertia diffusa*		.2	1
Epacridaceae	*Leucopogon lanceolatus*	Lance Beard Heath	.5	1
	Lissanthe strigosa	Native Cranberry	.5	1
Fabaceae: Faboideae	*Glycine clandestina*	Love Creeper	.5	1
	Hardenbergia violaceae	False Sarsaparilla	.1	1
Fabaceae: Mimosaceae	*Acacia mearnsii*	Black Wattle	.5	1
	Acacia ulicifolia	Prickly Moses	.5	1
Lobeliaceae	*Pratia purpurascens*	White Root	.1	1
Myrtaceae	*Eucalyptus maculata*	Spotty Gum	20	3
	Eucalyptus paniculata	Iron Bark	25	3
	Melaleuca styphelioides	Prickly-leaved Paperbark	10	2
Pittosporaceae	*Billardiera scandens*	Apple-berry	.1	1
	Bursaria spinosa	Blackthorn	3.0	2
	Citriobatus pauciflorus	Orange Thorn	.7	1
Proteaceae	*Hakea sericea*	Needle-leaved Hakea	1	1
Ranunculaceae	*Clematis aristata*	Old Man's Beard	.1	1
Rutaceae	*Zieria smithii*	Sandfly Zieria	.5	1
Thymelaeaceae	*Pimelea linifolia*	Rice Flower	.5	1
MAGNOLIOPSIDA -	**MONOCOTYLEDONS**			
Cyperaceae	*Lepidosperma laterale*		.5	1
Liliaceae	*Caesia parviflora*	Pale Grass Lily	.4	1
	Dianella caerulea	Blue Flax Lily	.4	2
Lomandraceae	*Lomandra longifolia*		.5	3
	Lomandra multiflora		.3	1
Poaceae	*Entolasia stricta*		.5	2
	Themeda australis	Kangaroo Grass	.5	1

Appendix 6

Curriculum Vitae of Participating Consultants

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Curriculum Vitae of Surveyors/Authors

NAME **Garry John DALY**

DIRECTOR Gaia Research Pty. Ltd. ABN 21 073 711 421

D.O.B. 19 August 1957

ADDRESS PO Box 3109 North Nowra P.O. 2541

TELEPHONE 0244 460 384

E mail gaiaresearch@shoalhaven.net.au

QUALIFICATIONS

1980 B.Sc. majoring in zoology. The University of New South Wales.
1982 Graduate Diploma of Education, University of Wollongong.

SOCIETY MEMBERSHIP

1990-present	Society for Growing Australian Native Plants. Rainforest Study Group.
1992-present	Australasian Affiliation of Herpetological Societies.
1996-present	Royal Zoological Society of New South Wales.

EMPLOYMENT

1983-5	Science Teacher at Leumeah High School, Sydney.
1985-9	Casual teaching.
1991-2	Casual teaching, freelance fauna surveys.
1992-present	Fauna and flora surveys/assessments/impact statements/review of environmental factors.
1995-present	Director Gaia Research Pty Ltd.

COMMITTEES

1993-98	Lower Shoalhaven Catchment Management Committee
1993-2002	Bundanon Trust Community Advisory and Environment Committee
1997-present	Green and Golden Bell Frog Recovery Team (DECC)
2006-present	Giant Burrowing Frog Advisory committee / Recovery Team (DECC SF NSW)
2006-present	Broad-headed Snake Advisory committee / Recovery Team (DECC)
2006-present	NSW Threatened frog working committee (DECC)

LICENCES AND APPROVALS

Scientific Investigation Licence No. S10470.
Animal Research Authority Issued by the Director General of NSW Agriculture No. 05/2371 to conduct fauna surveys utilising a variety of techniques.

SUCCESSFUL NOMINATIONS TO TSC ACT (1995)

The listing of Stuttering Frog *Mixophyes balbus* from Vulnerable to Endangered (Schedule 1).
The listing of Heath Frog *Litoria littlejohni* as Vulnerable (Schedule2).
Brush-tailed Rock Wallaby *Petrogale penicillata* part evidence taken to list species as Endangered (Schedule 1).
Advice to species associations and distribution of Swamp sclerophyll forest on Coastal Floodplain of the NSW North Coast.
Listing of Coastal Forest Red Gum/Grass Forest as Endangered Ecological Community within the Eurobodalla local government area.
Listing of Great Glider *Petauroides volans* as endangered population on Schedule 1, Part 2.

SCIENTIFIC PUBLICATIONS

Daly, G. (1992). Aggressive territorial behaviour of free range water dragons *(Physignathus lesueurii lesueurii) Herpetofauna.* **22 (1)**: 37.

Daly, G. (1992). Destruction of cycad seed by the bush rat *(Rattus fuscipes). Palms and Cycads.* **36:** 2-5.

Daly, G. (1993). Reproductive biology of the scaly foot *(Pygopus lepidopodus). Herpetofauna*. **22(2):** 40-42.

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Daly, G. (1993). Unusual behaviour of grass skinks *(Lampropholis delicata). Herpetofauna.* **23(2):** 41.

Daly, G. (1995). Observations on the green and golden bell frog *Litoria aurea* (Anuran: Hylidae). *Herpetofauna* **25 (1):** 2-9.

Daly, G. (1995). Observations on the tusked frog *Adelotus brevis* (Anuran: Myobatrachidae). *Herpetofauna.* **25 (2)**: 32-35.

Daly, G. (1996). Some problems in the management of the green and golden bell frog *Litoria aurea* (Anura: Hylidae) at Coomonderry Swamp on the south coast of New South Wales. In *The Green and Golden Bell Frog* Litoria aurea *Biology and Conservation* (Editors G. H. Pyke and W. S. Osborne). *Aust. Zool.* **30 (2):** 233-36.

Daly, G. (1996). Observations on the eastern owl frog *Heleioporus australiacus* (Anuran: Myobatrachidae) in south eastern New South Wales. *Herpetofauna* **26(1):** 33-42.

Daly, G. (1997). Behaviour of the bearded dragon lizards *Pogona barbata* and *P. vittaceps* in captivity. *Herpetofauna.* **27(2):** 28-33.

Daly, G. (1998). Review of the status and assessment of the habitat of the stuttering frog *Mixophyes balbus* (Anuran: Myobatrachidae) on the south coast of New South Wales. *Herpetofauna* **28(1):** 2-11.

Daly, G. (2000). Island populations: Survey of the reptiles and amphibians of the Jervis Bay region on the south coast of NSW. *Herpetofauna* **30(1):** 11-17.

Daly, G. (2000). Fauna of the Jervis Bay region: corridors, dead ends and isolated populations. Pp 177-88. In *Conservation through Cooperation: integrated management for the Jervis Bay region.* Janet Mackay and Associates (Ed). Proceedings from Integrated management conference NSW NPWS.

Daly, G. (2004). Surveys of reptiles and amphibians on the south-west slopes of NSW. *Herpetofauna.* **34(1):** 2-16.

Daly, G. (2006). Mapping glider songlines: development of a landscape management policy for the yellow-bellied glider *Petaurus australis* (Shaw 1791) in the Eurobodalla Shire on the south coast of New South Wales. *Australian Zoologist* **33(2):** 180-187.

Daly, G. (2006). Reptiles and frogs in the region of Morton National Park on the south coast of NSW. *Herpetofauna.* **36(1):** 5-24.

Daly, G. (2007). Reptiles and frogs in the region of Wadbilliga National Park on the south coast of NSW. *Herpetofauna* **37:** 45-62.

Daly, G. and Evison, S. (1996). Observations of the Square-tailed Kite *(Lophoictinia isura)* at Nowra on the south coast of New South Wales. *Australian Birds* ***29*****(3):** 42-43.

Evison, S. and Daly, G. (1995). Do White-throated Nightjars *(Eurostopodus mystacalis)* (Caprimulgidae) Make Scrapes for their Egg Sites? *Australian Birds*.

Goldingay, R. Daly, G & Lemckert, F. (1996). Assessing the impacts of logging on reptile and frogs in the montane forests of southern NSW. *Wild. Res.* **23:** 495-510.

Goldingay, R. and Daly, G. (1997). Surveys of arboreal mammals in the montane forests of Queanbeyan, New South Wales. *Aust. Mamm*. **20:** 9-19.

Murphy, M. and Daly, G. (1997) Records of the marsh snake *Hemiaspis signata* near Nowra, NSW: A southern range extension for the species. *Herpetofauna* 27**(2):** 33-34.

Murphy, M. and Daly, G. (1998) Survey of the reptiles and amphibians of the escarpment and riverine forests north west of Nowra NSW. *Herpetofauna 28***(2):** 16-21.

Daly, G, Pennay, P. and Gosper, C. (2001). Reptiles and amphibians at Razorback Nature Reserve, Keverstone State Forest and the Abercrombie Caves region of New South Wales. *Herpetofauna.***31 (2):** 82-92.

Daly, G, Pennay, P. and Coombes, D. (2002). Surveys for the stuttering frog *Mixophyes balbus* on the south coast of New South Wales. *Herpetofauna.***32 (2):** 110-130.

Daly, G. and Senior, C. (2003). Surveys for and habitat assessment of the Green and Golden Bell Frog *Litoria aurea* on the far south coast of New South Wales. *Herpetofauna***33 (2):** 86-102.

Daly, G. and Coombes, D. (2005). *Limnodynastes tasmaniensis,* an addition to the herpetofauna of the Jervis Bay region of south-eastern NSW. *Herpetofauna***35 (2):** 85-6.

Daly, G. and Craven, P. (2007). Monitoring populations of Heath Frog *Litoria littlejohni* in the Shoalhaven region on the south coast of NSW. *Australian Zoologist* **34(2):** 165-172.

Daly, G. Virtue, B. and Stone, G. (2008). Results of a survey for the striped legless lizard *Delma impar* near Goulburn, New South Wales. *Herpetofauna* **38(1):** 51-58.

Daly, G. Johnson, P.; Malolakis, G.; Hyatt, A. and Peitsch, R. (2008). Reintroduction of Green and Golden Bell Frog Litoria aurea to Pambula on the south coast of New South Wales. *Australian Zoologist* **34(3):** 261-270.

Daly, G. and Craven, P. and Hyatt, A. (2008). Surveys for the Green and Golden Bell Frog *Litoria aurea* at Meroo National Park on the south coast of New South Wales. *Australian Zoologist* **34(3):** 303 -313.

BOOK

Daly, G.; Dawson, J. Schwarz, E.; Pietsch, R.; Saxson, M.; Claridge, A. and Oliver, L. (2000). *Threatened Fauna of the Shoalhaven.* Shoalhaven Catchment Management Committee and NSW National Parks and Wildlife Service, Queanbeyan.

NAME Rebecca Jane Rudd

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St. Georges Basin N.S.W. 2540

TELEPHONE 44 434899

Email rebecca.rudd@bigpond.com

EDUCATION and TRAINING

2002	Safe Pesticide Handling, Nowra Tafe
2002	Workplace Assessment, Nowra Tafe
1999, 2001	GIS Management, Environment Australia
1998	Microsoft Access Data management
1995	Snake Biology and Handling Course, Jeff Coombs
1994, 2000	Crew Leaders Course, NSW Bushfire Brigade
1995	Interpretation Course, ANCA
1994	Weed Management Training, ANCA
1994	Cross Cultural Workshop, DEST
1994	Conflict Resolution, ANCA
1993	Rainforest Plant Identification, James Cook University,
1993	Supervisors Training, TAFE,
1992, 2001	Wardens Training, A.N.P.W.S.
1991	Occupational Health and Safety Certificate, TLC OHS Training Centre,
1989	Efficient Writing Certificate, DASETT,
1989	Certificate of Horticulture, Woden TAFE,
1988	ACT Forests Chainsaw Operator's Certificate ,
1988	Rainforest Plant Identification, UNE Summer School
1987	Native Plant Identification, ANU Summer School,
1987	First Aid Certificate, St. Johns Ambulance, updated 1993, 1996, 1999
1976	Higher School Certificate, Canberra,

Currently on the NSW weeds management board

EMPLOYMENT

May 2002 – present

- Flora surveys and assessments including the application of transect and quadrat techniques, noting rare or endangered flora species and defining vegetation communities for Gaia Research.

June 1997 – May 2002 Senior Project Officer Booderee National Park

Develop and implement strategies to protect the natural resource in Booderee National Park. Projects included:

Weed management
Feral animal management
Fire management

Catchment management
Native vegetation management
Threatened species management

Jan 1995 – June 1997 Ranger Grade 2 Jervis Bay National Park

- Assist in the development and implementation of strategies to effect efficient management of the park in accordance with the Plan of Management.
- Provide technical assistance to management as required.
- Enforce regulations under the Parks and Wildlife Act, 1975.
- Assist visiting researchers, volunteers.
- Provide on the job training to trainee staff.
- Plan and deliver school holiday and other interpretation programs.
- Produce interpretive material including signage, pamphlets and Park Notes as required.
- Routine ranger duties.

May 1996 to September 1996 Exchange Ranger Kakadu National Park

- Assist in the development and implementation of strategies to effect efficient management of the park in accordance with the Plan of Management.
- Provide technical assistance to management as required.
- Enforce regulations under the Parks and Wildlife Act, 1975.
- Routine ranger duties.
- Assist in fire management program and wildfire control as required.
- Special:
- Developed weed awareness program for Jabiru.
- Participated in wildlife management programs.

July 1994 to January 1995 A/g Ranger Grade 2 Beecroft Peninsula

- Duties as for R2 JBNP plus:
- Carry on liaison with Department of Defence.

December 1993 Coral Sea Patrol

- Set up vegetation survey system for monitoring purposes.
- Collect bird and vegetation data.
- Take part in turtle monitoring program.
- Carry out routine maintenance tasks.

August 1993 to December 1993 A/g Professional Officer (Project Officer)
Environmental Resources Information Network (ERIN)

- Project: Pilot project to set up a Geographic Information System (vegetation layer) for Beecroft Peninsula.
- Assist in developing specifications for consultant ecologist to use.
- Contract and liaise with consultant, ensuring compliance with specifications and provide field assistance as required.

- Assist in data analysis.
- Produce draft report.

March 1990 to August 1993 GSO 8/ Gardening Manager Jervis Bay Botanic Gardens

- Oversee carrying out of day to day operations and developmental projects.
- Supervise eight staff including two trainees.
- Provide on the job and task specific training to staff.
- Manage living collection: nursery facilities; plant propagation; field collection; Rare and Endangered species; maintain records for IBIS database.
- Provide interpretation to the general public and to special interest groups.
- Develop interpretive material.
- Provide technical advice on Gardens' development and POM.
- Special: Established Public Access Herbarium; designed and constructed system of walking tracks.

September 1991 to December 1991; August 1989 to April 1990 A/g Manager JBBG

- Operate as part of the ANBG management team.
- Develop briefs for and oversee construction of new works.
- Forecast and monitor budget allocations.
- Develop works programs.
- Instigate recruitment procedures as required.

October 1986 to March 1989 A/g Gardening Overseer, Glasshouses ANBG

- Supervise three staff.
- Maintain living collections in five glasshouses (inc. R&E, orchids).
- Develop and implement pest control, field collection and propagation programs.
- Maintain plant and equipment associated with glasshouse operation.
- Maintain IBIS records

June to October 1986 Gardener Grade 3, Plant Production ANBG

- Undertake plant propagation.
- Maintain living collections.
- Maintain IBIS records.
- Supervise disabled volunteers.

March to June 1986 Gardener Grade 3, Plant Records ANBG

- Carry out regular tasks involved in stocktaking, mapping and registration of living collection.

NAME **Alan William Stephenson**

ADDRESS 43 McKay Street, NOWRA NSW 2541

TELEPHONE 44217773 **MOBILE** 0401195321

Email astephenson@vtown.com.au

QUALIFICATIONS Member of NSW NPWS *Prasophyllum affine* recovery team. 2001-present.

RECENT ORCHID SURVEYS

Vincentia 2001: Gaia Research, (Eight Part Test), discovered *Rhizanthella slateri* (Eastern Underground Orchid) *in situ*.

Huskisson 2002: Gaia Research, site for Marine Services Building. Target species *Arachnorchis tessellata* (syn. *Caladenia tessellata*).

Vincentia 2002: The Bay Consultancy (Jervis Bay Baptist Church). Target species *Arachnorchis tessellata* (syn. *Caladenia tessellata).*

Batemans Bay 2002: Gaia Research (Canberra Investment Corporation). Target species *Genoplesium vernale* (syn. *Corunastylis vernalis*), *Cryptostylis hunteriana*.

Shoalhaven City Council 2003: Vincentia and Maddens Plains as required by NSW Scientific Committee, target species *Prasophyllum affine*.

Jervis Bay Baptist Church 2003: Target species *Prasophyllum affine* and *Cryptostylis hunteriana.*

Booderee National Park 2004. Booderee National Park Committee of Management. Target species *Corybas undulatus, Prasophyllum affine* and *Cryptostylis hunteriana.*

Bamarang 2005. Target species *Oligochaetochilus gibbosus* (syn. *Pterostylis gibbosa*).

Shoalhaven City Council 2006. Assessment of damage to site of *Corunastylis superba* (syn. *Genoplesium superbum*)

Department of Environment and Climate Change (DECC) 2006: independent assessment of above site.

Old Nowra Brickworks 2007: Gaia Research, Target species *Oligochaetochilus gibbosus, Cryptostylis hunteriana*.

Appendix 7

Offset in principle agreement

(No of pages excluding this page = 1)

09/10/2008 10:48 44217988 PAGE 02/02

Your ref:
Our ref: TWE:SOU7582:TL
Reply to: Wollongong Office

8 October 2008

Chris Outtersides
Director
City Plan Services
Level 1, 364 Kent Street
SYDNEY NSW 2000

Dear Chris

RE: SOUTH COAST CONCRETE CRUSHING & RECYCLING PTY LTD
PROPOSED LEASE OVER LOT 228 IN DP 755952

We refer to our discussions in relation to the above matter confirm we have advanced negotiations with Mrs Goodsell who is the owner of the above property.

Our client has an "in principle" agreement with Mrs Goodsell to lease the above property on terms that will satisfy the Offset Strategy in our client's Part 3A Application to the Department of Planning. The "in principle" agreement will be subject to formal documents being entered into between the parties which will satisfy the Department of Planning. In acknowledgement, Mrs Goodsell has endorsed this letter with consent for the documentation to progress.

The arrangement with Mrs Goodsell is not binding until such time as formal documents have been submitted and approved by Mrs Goodsell and the Department of Planning.

If you have any further queries, please feel free to contact our office.

Yours faithfully

Valda M Goodsell
Mrs V Goodsell

ACCESS BUSINESS LAWYERS

Reply Attention To: David Swan

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations at the

Nowra Brickworks Quarry, South Nowra

Weed Management and Rehabilitation Strategy

Prepared by

Gaia Research Pty Ltd

December, 2007

Specialist Consultant Studies Compendium: Part 2B

Weed Management and Rehabilitation Strategy

for the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

Prepared for:

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75 Kite Street
ORANGE NSW 2800

and

City Plan Services Pty Limited
Level 1, 364 Kent Street
SYDNEY NSW 2000

On behalf of:

South Coast Concrete Crushing and Recycling Pty Ltd
PO Box 192
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December, 2007

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CONTENTS

Page

EXECUTIVE SUMMARY 2B-5

1 INTRODUCTION 2B-7
1.1 Description of Study Site 2B-7

2 PURPOSE, AIMS AND OBJECTIVES 2B-10

3 METHODS 2B-11
3.1 Flora Surveys 2B-11

4 DESCRIPTION OF THE NATIVE VEGETATION OCCURRING ON THE SITE 2B-11

5 THE INTRODUCED FLORA 2B-12
5.1 Widespread Weeds, Weeds of Disturbance 2B-12
5.2 Declared Noxious Weeds 2B-13
5.3 Weeds of National Significance 2B-13
5.4 Key Threatening Processes 2B-14

6 RESTORATION AND REVEGETATION 2B-14
6.1 Existing Storage Piles 2B-15
6.2 Future Storage Piles 2B-15
6.3 Final Site Restoration 2B-15

7 MONITORING COMPLIANCE AND SUCCESS 2B-16

8 ACTION PLAN 2B-16

9 REFERENCES 2B-20

10 BIBLIOGRAPHY OF WEB SITES 2B-20

APPENDICES

Appendix 1 Species of Weed Located on Site 2B-23
Appendix 2 Specific Prescriptions for Weed Species 2B-25
Appendix 3 Noxious Weeds of the Shoalhaven LGA 2B-43
Appendix 4 Species Suitable for Revegetation 2B-45
Appendix 5 Native Species Found on Site 2B-47
Appendix 6 Curriculum Vitae of Author 2B-51

FIGURES

Figure 1 Location of Study Site and Surrounding Land Uses 2B-8
Figure 2 Detail of Mining Leases 2B-9
Figure 3 Staged Development and Rehabilitaiton of Subject Site 2B-17

TABLES

Table 1 Objectives for Weed Control 2B-11
Table 2 Noxious Weeds Identified on Site 2B-14
Table 3 Annual Works Program 2B-16
Table 4 Annual Works Program 2B-19

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EXECUTIVE SUMMARY

The Subject Site is located within Lot 464 DP 1058778, Princes Highway, South Nowra. The purpose of this plan is to set out the strategic framework for the effective and integrated management of weeds within the Subject Site and to document the restoration and revegetation activities that would be implemented following completion of landform reconstruction operations.

The nature of the quarry's operations result in a highly disturbed landscape. Weeds colonise disturbed landscapes and currently thirty species have been located within the Subject Site. This report details the weeds present and provides a program of works to control these weeds. Control work has commenced and will be ongoing.

The Project would require the removal of the majority of the natural vegetation within the Subject Site. It is therefore necessary that an ongoing program of progressive rehabilitation of native vegetation be part of the quarry's operating procedures. This report provides a description of the native vegetation on site and identifies those species that would be utilised for progressive rehabilitation. The revegetation and rehabilitation program would be documented and regular monitoring and compliance reporting provided to the relevant government agencies. An annual budget would be allocated for these activities during the life of the Project and for a period after the decommissioning of the quarry.

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1 INTRODUCTION

This report was commissioned by South Coast Concrete Crushing Pty Ltd to document a weed management strategy for part Lot 464 DP 10568778, Princes Highway, South Nowra (the "Subject Site") (**Figures 1** and **2**). The Subject Site has two mining leases (ML5087 and ML6322). ML5087 is approximately 7.4 hectares and is currently operational. ML6322 is approximately 14.7 hectares and requires development consent. The area is currently zoned partly 1(b) Main Arterial Road Protection and (a small portion) 1(f) (forest zone) zone under the Shoalhaven Local Environmental Plan 1985. The land is currently used as a quarry for the extraction of shale. The western perimeter of ML5087 and a large portion of ML6322 supports native vegetation. Bunds of earth have been created around the perimeter of the Subject Site and weeds are common within the bund areas and other disturbed sites within the Subject Site.

The history of the existing mine lease is detailed by City Plan Services and R.W. Corkery and Co. Pty Ltd (2007). In summary the quarrying of ML5087 has lawful consent but quarrying within ML6322 requires consent. As a result of changes to the *Mining Act 1992*, the existing operations on ML5087 will require approval under the *Environmental Planning & Assessment Act 1979* (EP&A Act) by December 2007. Therefore, the following revegetation plan forms a component of the development application for the continuation and expansion of extractive operations from within ML5087 and ML6322 under Part 3A of the EP&A Act.

A previous report (Gaia Research 2007a), detailed a schedule of works to eradicate weeds within the area of the bunding areas and revegetate this land with endemic species. In order to address the problem with weeds further degrading the site we detail an inventory of weed species and provide specific management programmes to control these species. This report is complementary with the previous report but is broader in scope addressing the weeds over the entire property and the life of the quarry. The previous report provides specific milestones for remediation activities and this report covers everything in the previous report.

This report was prepared by Ms Rebecca Rudd. Ms Rudd's Curriculum Vitae is presented in **Appendix 6**.

1.1 Description of Study Site

The Subject site occupies part of Lot 464 DP 1058778, Princes Highway, South Nowra (Huskisson 1: 25,000 topographic map Lat 34^{o} 55' 30", Long 150^{o} 36' AMG 281000 6132700, altitude 40 m AHD) and is situated on the south coast of NSW, six kilometres south of the Shoalhaven River **(Figure 1).** The Subject site has, thin poorly drained clayey soils derived from Nowra Sandstone (Hazelton, 1993). Rock outcrops are absent.

The bunding area occurs around the perimeter of ML6322. Clay and soil have been deposited in a linear manner around the edge of the property. The material has been positioned about 5 m from the edge of the boundaries (except for the southern boundary, which is wider). The height of the bunds is approximately 4 m and their width approximately 10 m.

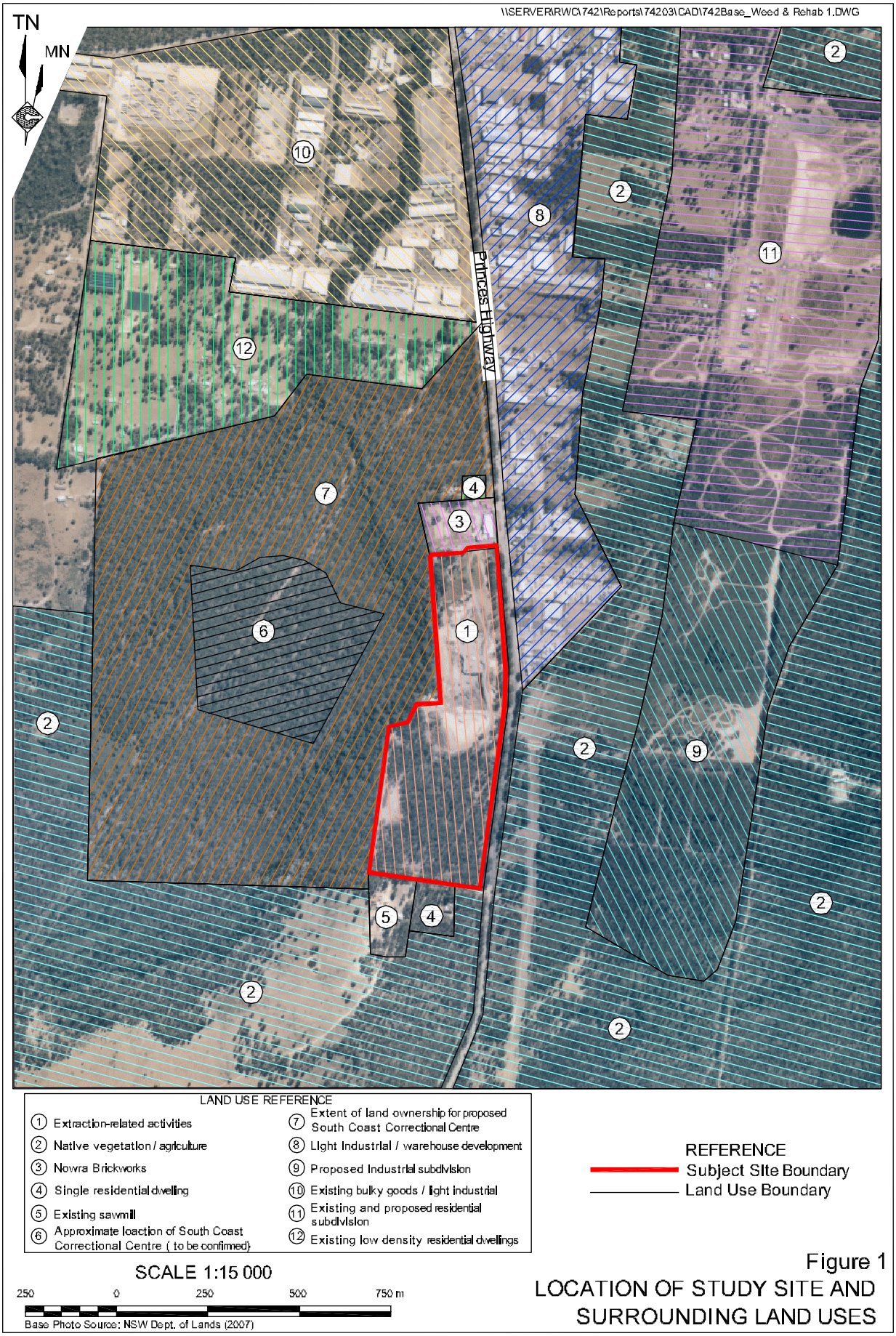

Figure 1
LOCATION OF STUDY SITE AND SURROUNDING LAND USES

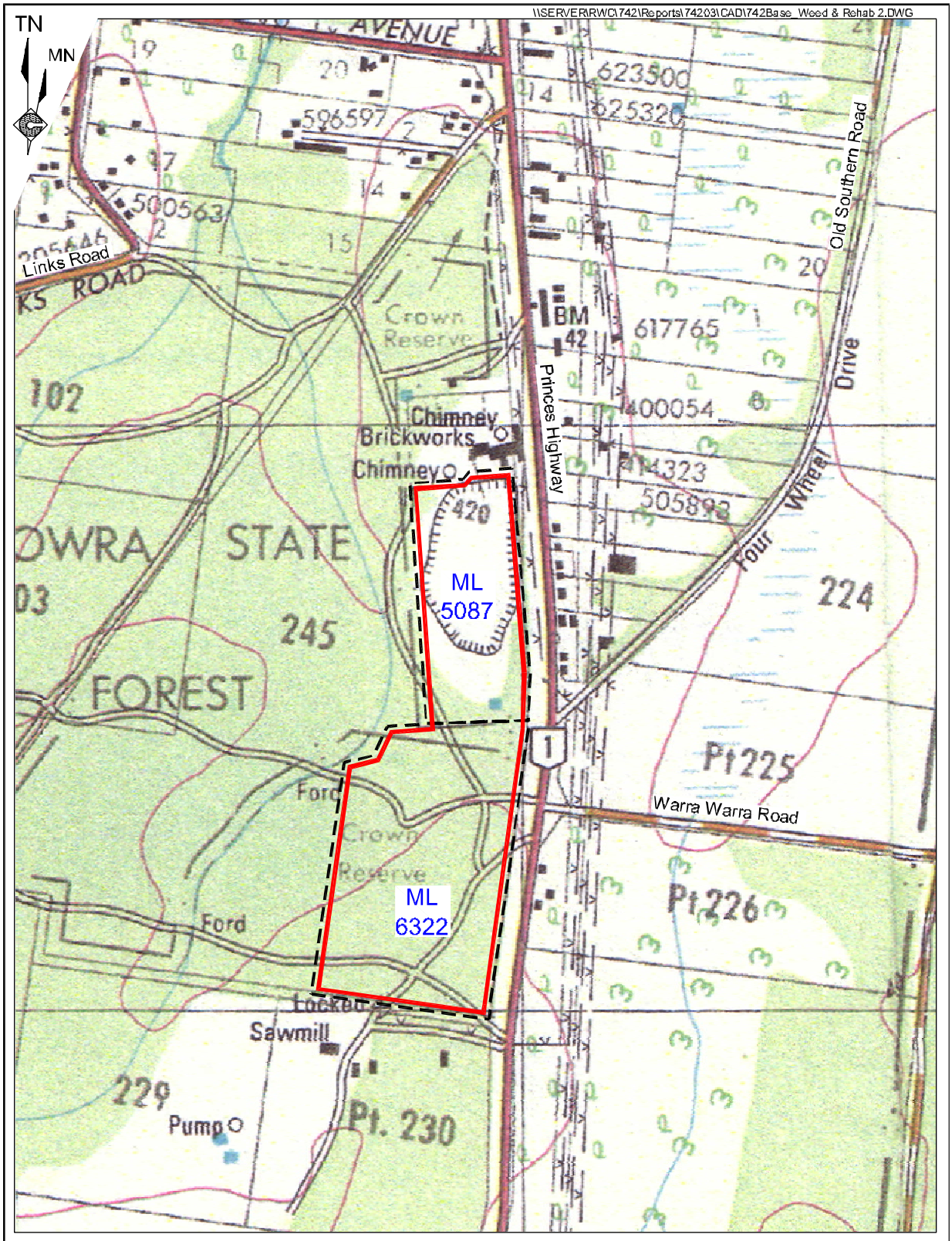

Figure 2
DETAIL OF MINING LEASES

Note: A Colour Version of this figure is available on the project CD

The vegetation on these bunds consists of kikuyu, other weeds and some regenerating local native species. The indigenous vegetation has been cleared prior to the placement of the earth and remnant trees persist. Some are partially buried by the deposited material.

At the southern end of ML5087 is a stockpile area. Piles of material within this area have been colonised by native species, indicating that natural regeneration is occurring on the site. However, in other disturbed areas there are patches of weeds and the nature of the operation means that there will be continual disturbance for many years. Hence there is a need to provide a short and long term strategy for dealing with the weeds that currently exist on the site but also those that may colonise areas in the future and mechanisms to remediate the site.

2 PURPOSE, AIMS AND OBJECTIVES

The purpose of this plan is to set out the strategic framework for the effective and integrated management of weeds on the Subject Site and to facilitate suitable restoration during and after mining operations.

The aims of the plan are to:

- avoid new problems by preventing the establishment of new and emerging weeds;
- reduce the impact of existing weeds;
- prioritise weed control programs and operations to protect the surrounding natural environment;
- control and maintain control of those weed species that pose the greatest threat to the surrounding natural environment;
- eradicate isolated infestations of high priority weeds and prevent their spread into areas currently not infested;
- rehabilitate areas that have been disturbed; and
- restore areas once the mining operation is completed.

The objectives of the plan are set out in **Table 1**.

This report forms a companion report to the "*Ecological Assessment Report*" for the Project prepared by Gaia Research Pty Ltd. That report is presented as Part 3a of the *Specialist Consultant Studies Compendium and* is referred to hereafter as the "Part 3a Report". The conclusions reached in the Part 3a Report assure full implementation of the recommendations of this report.

Table 1
Objectives for Weed Control

Objective	Performance indicator
No infestation of noxious weeds (see Section 5.2) is allowed to establish on site.	Annual weed inspection and control program ensures that no noxious weeds establish on site.
Reduce the impact of existing weed problems.	Implement an ongoing weed control program within 12 months.
Prevent weeds from invading any natural areas retained onsite or neighbouring properties.	No weeds found in the natural areas or along fence-lines during annual inspections. Treat all weeds found during inspection visits.
Balance the management of kikuyu as a dust suppressor and its potential as a weed.	Gradually reduce the area covered by kikuyu and replace it with native shrubs and ground covers.
Restoration and revegetation of areas that have been disturbed.	Regular collection and redistribution of seed on the site. Annual planting of local native tube stock in autumn.
Reduce levels of annual weeds.	Implement annual control programs before seed set.
Weed control operators comply with all legislative requirements.	No breaches of the relevant requirements are recorded by the authorities.
All weed control operations consider waterways.	All weed control operators are able to competently work in creek-lines and water bodies. All weed operators are provided with recommended practices for weed control over waterways.

3 METHODS

3.1 Flora Surveys

The flora surveys were conducted on 3 April 2007 and between July-August 2007. Plant identifications were made according to nomenclature used in Harden (1990, 1991, 1992 and 1993). Recent name changes outlined in issues of *Cunninghamia* and *Telopea* were used where applicable. The conservation significance of species was established with reference to Briggs and Leigh (1999) and the *Threatened Species Conservation Act, 1995* (TSC Act).

The vegetation was searched using a general botanic survey method, as outlined by York, Binns and Shields (1991), in order to establish an inventory of most plant species occurring in the study area and to determine the location and extent of vegetation types. All vegetation stands in the study area were surveyed using the general botanic survey method. Specific searches for plant species of conservation significance were then carried out in potential habitat using the "Random Meander Technique" (Cropper 1993). The native species located are detailed in **Appendix 5**.

4 DESCRIPTION OF THE NATIVE VEGETATION OCCURRING ON THE SITE

The endemic vegetation community is Coastal Lowlands Cycad Dry Shrub Dry Forest - *Corymbia maculata / Macrozamia communis,* Forest Ecosystem 9 as described by Thomas *et al.* (2000). The forest has been disturbed by previous clearing and logging. Much of the sub-canopy is regrowth and, based on diameter at breast height the trees were in the order of forty years old. During the survey 111 species were located this included 81 native (**Appendix 5)** and thirty species (27%) of weeds (**Appendix 1**).

The forest is defined as Forest Ecosystem 9: Coastal Lowlands Cycad Dry Shrub Dry Forest - *Corymbia maculata / Macrozamia communis* (Thomas *et al.*2000). The forest type is closely aligned with Spotted Gum Open Forest (MU 25) as defined by NPWS (2002) for the northern Illawarra.

Spotted Gum *Corymbia maculata* was the tallest and most abundant species, with grey ironbark *Eucalyptus paniculata,* woollybutt *Eucalyptus longifolia* and white stringybark *Eucalyptus globoidea* occurring as isolated trees. The canopy attained 25 metres in height and many trees contained hollows (Gaia Research 2007b). This forest has been heavily logged and most trees were regeneration from this previous disturbance.

The midcanopy and shrub layer was sparse. A full species list is presented in **Appendix 5**.

5 THE INTRODUCED FLORA

Environmental weeds are plants that invade natural ecosystems. Thirty species of weed were identified within the Subject site (**Appendix 1**). The distribution of these weeds is highly associated with material introduced to the site. Weeds have established where there has been disturbance. As the Subject Site is a working mine, disturbance is inevitable.

Introduced plant species are of concern because they have detrimental effects on the ecological values of native bushland. There is a risk that they may spread to and from neighbouring land. There is also the risk that they may spread via the movement of material to and from the site.

5.1 Widespread Weeds, Weeds of Disturbance

Weed invasion is most likely after disturbance of the ground and they are spread by vectors such as humans, birds and animals such as the red fox and by processes such as wind and water. Weeds may be spread on tools, machinery, clothing and shoes. Foxes and birds can carry seeds in their gut, fur or feathers.

In general the greater the disturbance the greater the potential for weeds to invade an area. Weeds infestation is most likely to occur where there is bare soft soil, high nutrient availability, moist conditions and high light intensity. The Subject Site has a large diversity of weeds as a result of the high level of disturbance. The maintenance of a healthy forest canopy, dense shrub layer and ground cover is therefore a priority in reducing the potential for weeds to establish and spread into the undisturbed areas.

Weeds of disturbance such as kikuyu *Pennisetum clandestine*, cobblers pegs *Bidens pilosa*, fleabane *Conyza albida*, inkweed *Phytolacca octandra*, Paspalum *Paspalum dilatatum* couch *Cynodon dactylon* and capeweed *Arctotheca calendula* are widespread in areas that have been subjected to past or current disturbances in the Study area. These weeds and are best controlled by regular hand removal, restricted use of herbicides and through maintaining native perennial ground and mid-storey cover.

5.2 Declared Noxious Weeds

Some weeds have been declared noxious under the *Noxious Weeds Act, 1993* (NW Act). These are distinct from other weeds in that they have been deemed to have a greater ability to impact on ecosystems than other species of weed. The various categories of noxious weeds are defined below.

In New South Wales, the control of noxious weeds is governed by the NW Act. The Minister for Agriculture has the power pursuant to s.7 and s.8 of the Act to make orders declaring the plants listed in Schedule 1 of the Act to be noxious weeds for the purpose of the Act and specifying the control category or categories which will apply to each weed. The five categories of noxious weeds under the Act are described below:

- **W1**: State Prohibited Weeds – the control objective for W1 is to prevent the introduction and establishment of those plants in NSW. These plants must be eradicated from the land and the land must be kept free of the plant.
- **W2**: Regionally Prohibited Weeds – the control objective for W2 weeds is to prevent the introduction and establishment of those plants in parts of NSW. These plants must be eradicated from the land and the land must be kept free of the plant.
- **W3**: Regionally Controlled Weeds – the control objective for W3 weeds is to reduce the area and the impact of those plants in parts of NSW. These plants must be fully and continuously suppressed and destroyed.
- **W4**: Locally Controlled Weeds – the control objective for W4 weeds is to minimise the negative impact of those plants on the economy, community or environment of NSW. The growth and spread of these plants must be controlled according to the measures specified in a management plan published by the local control authority.
- **W5**: Restricted Plants – the control objective for W5 weeds is to prevent the introduction of those plants into NSW, the spread of those plants within NSW or from NSW to another jurisdiction. The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with.

The site occurs within the Shoalhaven City Council Local Government Area and declared noxious plants for the Shoalhaven City Council area are listed in **Appendix 3**. The declared noxious plants occurring on the site and their designated categories are listed in **Table 2**.

5.3 Weeds of National Significance

In 1997 the National Weeds Strategy was launched by the Federal Government. A central component of the strategy is the identification of Weeds of National Significance (WONS) and the resultant co-ordinated actions across all States and Territories. Nominated weeds were assessed against four major criteria: invasiveness, impacts, potential spread and socio-economic and environmental values. After considerable analysis twenty WONS were identified. Two WONS are found on the site (**Table 2**). These are bitou bush and blackberry, these species are also listed under the NW Act.

Table 2
Noxious Weeds Identified on Site

Common name	Scientific name	Category
Bitou Bush	*Chrysanthemoides monilifera*	W4 Key threatening process WONS
Blackberry	*Rubus fruticosus*	W4 Key threatening process WONS
Crofton Weed	*Ageratina adenophora*	W4
Fireweed	*Senecio madagascariensis*	W4
Honey Suckle	*Lonicera japonica*	Key threatening process
Madeira Vine	*Anredera cordifolia*	Key threatening process
Moth Vine	*Araujia sericifera*	Key threatening process
Turkey Rhubarb	*Acetosa sagittata*	Key threatening process

Note 1: W4 – the growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority. These weed management plans are available on the web site http://www.shoalhaven.nsw.gov.au/Environment/weeds. Key threatening process is listing under the *Threatened Species Conservation Act, 1995*.
Note 2: Under the *Threatened Species Conservation Act 1995*.
Note 3: Weed of National Significance.

5.4 Key Threatening Processes

Schedule 3 of the *Threatened Species Conservation Act 1995* lists key threatening processes. The NSW Scientific Committee has made a final determination to list invasion and establishment of exotic vines and scramblers as a Key Threatening Process of the Act. Bitou bush is also listed as a key threatening process.

A large number of vines and scramblers have become established in NSW. These types of plants occurring on the site have been listed in **Table 2**. The majority of these species were introduced for horticultural purposes and have escaped cultivation. Exotic vines and scramblers may act as 'transformer species' altering the nature of the environment where they become dominant. They reproduce prolifically and are well adapted to spread both from asexually-produced propagules and by seed. They are easily spread when material is moved from site to site. Within the Subject Site madeira vine *Andredera cordifolia,* honeysuckle *Lonicera japonica*, mothvine *Araujia sericifera* and turkey rhubarb *Acetosa sagittata* were found.

6 RESTORATION AND REVEGETATION

The nature of the activities on the site will result in extensive modification to the natural vegetation that is currently present. It is therefore vital that there is a comprehensive and ongoing program of rehabilitation. An annual budget must be allocated for these activities.

The long-term objective of the restoration and revegetation program is to establish a final landform that mimics the pre-extraction landform and to establish vegetation communities similar to those present in undisturbed areas adjacent to the Study Site. However, in the interim there will be substantial disturbance, movement and storage of material. This needs to be managed in a way that minimises any long term damage and protects as much habitat as possible.

6.1 Existing Storage Piles

These areas largely consist of the perimeter bund with some storage of material abutting the existing operation. These piles need to be stabilised quickly. The best approach is to use fast growing native ground covers and small shrubs that will stabilise the mounds and limit the opportunity for weeds to establish. This can be achieved by the distribution of seed collected from the site opportunistically and an annual planting of local native tube stock. A comprehensive list of species suitable for revegetation is included in **Appendix 4.** The focus for revegetation operations should be on fast growing species such as *Hardenbergia violaceae, Kennedia rubicunda, Acacia sp* and local grasses such as *Themeda australis*.

An important component of the restoration and revegetation program is to suppress the potential for the creation of dust. Kikuyu is well established on some sections of the bund and it does serve to suppress a potential dust problem. Kikuyu needs to be carefully managed and only gradually removed when native species are available for immediate planting after the kikuyu is treated.

6.2 Future Storage Piles

As material from the site is retained in piles for storage and in the longer term restoration, a native vegetation cover that will diminish the dust problem and retain some of the genetic integrity of the existing vegetation needs to be established. Piles should be seeded and tube stock planted in the autumn. Kikuyu should not be used to stabilise new piles. Any mulch resulting from the clearing of native vegetation on the site should be used on these piles.

6.3 Final Site Restoration

As landform reconstruction operations are completed in sections of the quarry area, a program of permanent restoration will commence. This will be undertaken progressively, with soil material removed during land preparation activities placed immediately on areas undergoing permanent restoration (**Figure 3**). The process would require material to be deposited within the section to mimic the original contour of the land. Any native vegetation cleared from the section being developed would be used to provide cover and habitat in the restoration area. Once the major earthworks are completed a program to re-establishing the native cover shall be commenced. A combination of direct seeding and planting of local native species would be required.

Within the areas undergoing permanent restoration, a cover of lower, mid and upper storey species would be established as quickly as possible. It should include planting of endemic tree species grown from seed of local provenance. To achieve this, the seed needs to be collected opportunistically from the site and stored in an appropriate manner for later use. When the non-hollow bearing trees are cleared they should be placed within the area to be rehabilitated to provide a source of seed and habitat for fauna. The hollow-bearing trees will be felled and placed into the riparian protection area near Nowra Creek to provide habitat for fauna. There must be an ongoing program of seed collection, propagation and planting. The restoration program will take at least 5 years of successive planting weed control and monitoring.

7 MONITORING COMPLIANCE AND SUCCESS

The monitoring program must be simple, time and cost effective. There is a requirement to assess the site on a regular basis to identify issues requiring management, set future rehabilitation priorities and determine the effectiveness of control methods. A set photographic reference points would be established through the site to monitor rehabilitation progress. Taking before and after photos of particular tasks and activities will also be a useful reporting tool for compliance reporting.

Records that need to be maintained include:

- the species of weeds treated and the method of control and timing of control;
- the species of seed collected and when it is collected;
- the species planted, the quantities and when and where they are planted;
- a measure of the effectiveness of weed control techniques;
- dates when a new weed species is observed or an existing species is observed to become more abundant; and
- a qualitative measure of the level of weed infestation.

8 ACTION PLAN

Table 3
Annual Works Program

Page 1 of 2

Action	Timing	Comment
Control of Declared Noxious weeds.	As per weed prescriptions. On going all year and as required (**Appendix 2**)	High priority task requiring immediate action. Use of herbicides is generally best when the weed is actively growing. Hand removal can be opportunistic and best before the weed has a chance to set seed. There is a legislative requirement to do this work.
Control of all other weeds.	As per weed prescriptions. On going all year and as required (**Appendix 2**)	Regular control measures need to be taken to meet the objectives in **Table 1**.
Seed collection	Generally summer and autumn	Seed collected opportunistically when ripe. Site visit every 3 months will be sufficient to determine the availability of seed for collection. Seed can also be collected when vegetation is being cleared or there are wind falls. This applies to the collection of *Eucalyptus* seed.
Direct seeding	Autumn	Seed should be broadcast when there is a high likelihood of rain. Autumn is the most reliable time in this region. Any weeds in areas to be direct seeded need to be treated prior to the broadcasting of seed.
Storage of cleared native vegetation	When native vegetation is being cleared	Native vegetation that is removed in the quarrying operation must be used to stabilise areas that are being restored.

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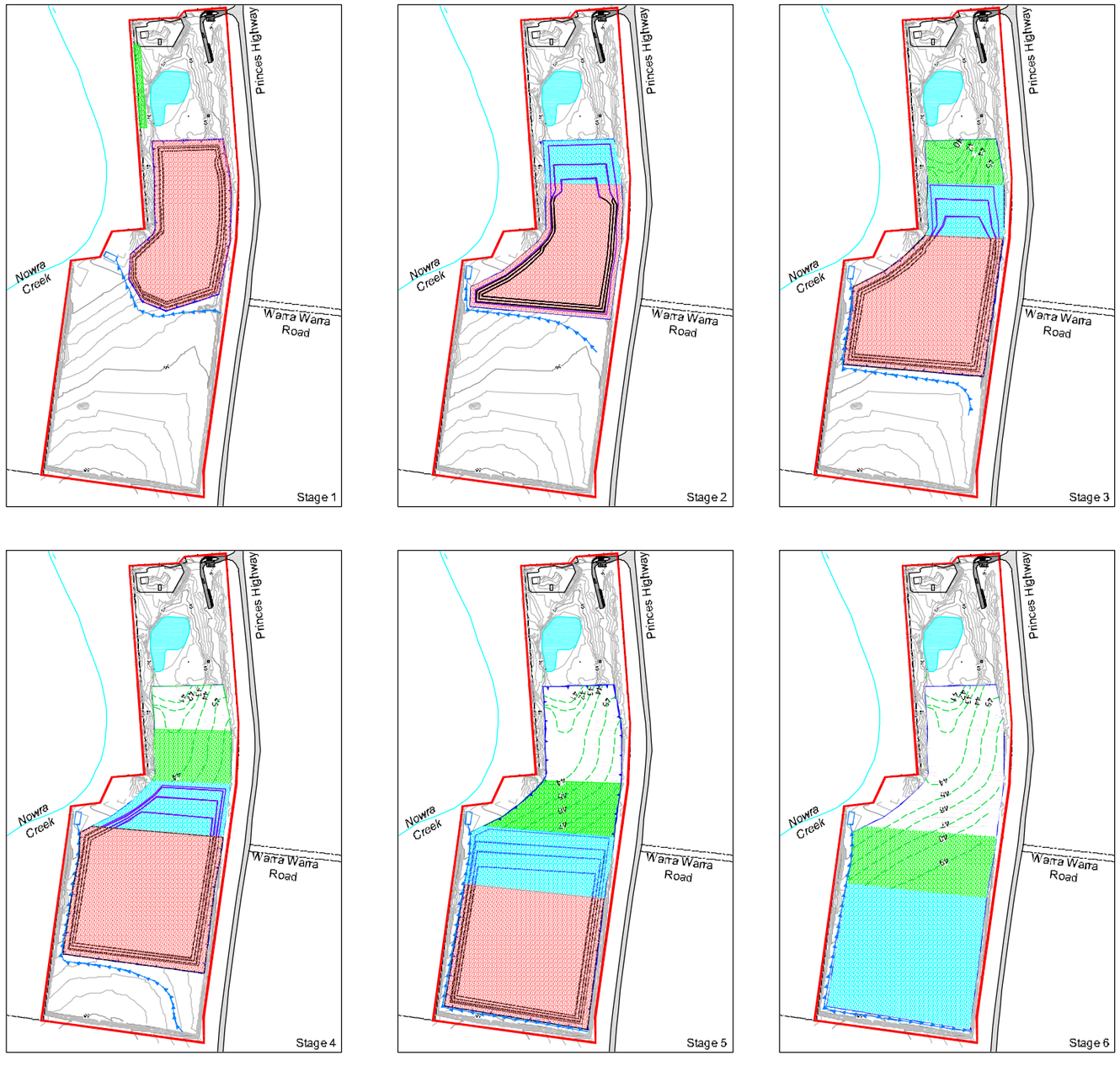
TN
MN



REFERENCE
- Project Site Boundary
- Proposed Limit of Extraction
- Proposed Extraction / Placement Bench
- Existing Contour (m AHD)(Interval = 1m)
- Final Contour (m AHD)(Interval = 1m)
- Sealed Road
- Unsealed Road / Track
- Fence
- Clean Water Diversion
- Sediment Containment Structure
- Extraction and Processing - related Operations
- Placement and Processing - related Operations
- Rehabilitation and Processing - related Operations

SCALE 1:10 000

100 0 100 200 300 400 500 m

Contour Survey Source: Ian Wady (2007)

Figure 3
STAGED DEVELOPMENT AND REHABILITATION OF THE SUBJECT SITE

Table 4
Annual Works Program

Action	Timing	Comment
Tube stock planting	Autumn	Tubes must be ordered well in advance to ensure that stock is available for autumn planting.
Monitoring	Every 3 months	Spring and Autumn are when it is most likely to detect weed incursions and control works can be undertaken. However the site needs to closely monitored for the availability of seed and any potential problems and quarterly site inspections will facilitate early detection.
Photo points	Every 3 months	Set photo monitoring sites and take the same photo every 6 months. Also opportunistically when activities are being undertaken every 3 months.
Reporting	Reporting of weed management would be incorporated into the Annual Environmental Management Report to the Department of Primary Industries – Mineral Resources.	See Section 7 for details of what is required in the report.

Acknowledgements

We thank R.W. Corkery & Co. Pty. Limited for providing **Figures 1, 2** and **3**.

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Australian Pesticides and Veterinary Medicines Authority: www.apvma.gov.au
Department of Environment and Climate Change: www.epa.nsw.gov.au
Shoalhaven City Council: www.Shoalhaven.nsw.gov.au
CRA Weed Management, University of Adelaide: www.weeds.crc.org.au

APPENDICES

(No. of pages excluding this page = 28)

Appendix 1 **Species of weeds located on site**

Appendix 2 **Specific prescriptions for weed species**

Appendix 3 **Noxious weeds of the Shoalhaven LGA**

Appendix 4 **Species suitable for revegetation**

Appendix 5 **Native species found on site**

Appendix 6 **Curriculum vitae of author**

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Appendix 1

Species of Weed Located on Site

(No. of pages excluding this page = 1)

Appendix 1 Species of weed located on site

Please note that only those weeds that pose a significant threat to the Subject Site are described in **Appendix 2**.

Common name	Scientific name	Category
Bitou Bush	*Chrysanthemoides monilifera ssp.*	WONS[3], W4[1]
Blackberry	*Rubus fruticosus species aggregate*	WONS[3], W4
Black Thistle	*Cirsium vulgare*	
Capeweed	*Arctotheca calendula*	
Castor oil plant	*Ricinus communis*	
Cleavers	*Galium aparine*	
Cobblers Pegs	*Bidens pilosa*	
Couch	*Cynodon dactylon*	
Crofton Weed	*Ageratina adenophora*	W4[1]
Dock	*Rumex sp*	
Fireweed	*Senecio madagascariensis*	W4[1]
Fleabane	*Conyza sp*	
Honey Suckle	*Lonicera japonica*	Key threatening process[2]
Inkweed	*Phytolacca octandra*	
Kikuyu	*Pennisetum clandestinum*	
Madeira Vine	*Anredera cordifolia*	Key threatening process[2]
Mistflower	*Ageratina riparia*	W4[1]
Mother of Millions	*Bryophyllum delagoense*	
Moth Vine	*Araujia sericifera*	Key threatening process[2]
Mustard	*Sisymbrium orientale*	
Paddy's Lucerne	*Sida rhombifolia*	
Paspalum	*Paspalum dilatatum*	
Purple Top	*Verbena bonariensis*	
Rhodes Grass	*Chloris gayana*	
Ribgrass	*Plantago lanceolatus*	
Scarlet pimpernel	*Anagallis arvensis*	
Senna	*Senna pendula*	
Smoke Weed	*Fumaria muralis*	
Soursob	*Oxalis pes-caprae*	
Turkey Rhubarb	*Acetosa sagittata*	Key threatening process[2]

Note 1: W4 – the growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority. These weed management plans are available on the web site http://www.shoalhaven.nsw.gov.au/Environment/weeds. Key threatening process is listing under the *Threatened Species Conservation Act, (1995)*.
Note 2: Under the *Threatened Species Conservation Act 1995*.
Note 3: Weed of National Significance.

Appendix 2

Specific Prescriptions for Weed Species

(No. of pages excluding this page = 17)

Note: A colour version of this Appendix is presented on the Project CD

Appendix 2 Specific prescriptions for weed species

Bitou Bush (*Chrysanthemoides monilifera ssp rotundata*)

Legal status

Declared Noxious Weed (Class W4) in the Shoalhaven LGA.

Distribution

Isolated seedlings only on eastern and western bunds.

Control strategy

Remove isolated plants by hand or use of herbicide and monitor annually. Eradication achievable.

Problem

The huge seed production by this species and distribution by birds makes it very invasive. Seed remains viable for up to 10 years.

Specifications for control

- Current infestation levels allow for hand-removal or spot spraying.
- Annual monitoring of whole site for any occurrences. Treat immediately.
- Cut and paint, in younger plants, or spray foliage for larger plants.
- Undiluted Glyphosate 360g/L for stem-scrape application.
- The following herbicide prescriptions should be used:
  - For foliar use Glyphosate 360g/L at 5 or 10 ml per litre of water. Handgun or knapsack. Spray to wet all foliage. Apply at peak flowering to actively growing bushes during winter. Do not apply during periods of drought stress. Use higher rate for plants over 1.5m.

Timing

Best in autumn/winter before seed set and while native vegetation is dormant. Cut and paint when plants are actively growing.

Blackberry (*Rubus fruticosus aggregate*)

Legal status
Declared Noxious Weed (Class W4) in the Shoalhaven LGA.

Distribution
Two small plants found on western side of the site.

Control strategy
Treat with herbicide. Eradication from the site is easy to achieve within 12 months.

Problem

- Blackberry is one of the most significant weeds in temperate Australia because of its invasiveness in both natural and agricultural ecosystems.
- Blackberry thickets also provide harbour for pest animals such as rabbits and foxes, which further impact on the native flora and fauna.
- Dead plants and large infestations may become a fire hazard, which may impact the area through fire regime changes.

Specifications for control

- Use of foliar herbicides is recommended, as results are usually superior. However, if use of herbicides is not favoured, small plants may be hand-pulled; grubbed out with a mattock (or similar); or canes can be cut and painted with undiluted Glyphosate360g/L. Apply when bushes are actively growing.

Timing

- Apply herbicide when bushes are actively growing, preferably at the commencement of flowering (October to January). Spray operations should be completed prior to the formation of fruit. For further information on control techniques contact Shoalhaven City Council's Noxious Weed Officer.

Crofton Weed (*Ageratina adenophora*)

Legal status
Declared Noxious Weed (Class W4) in the Shoalhaven LGA.
Distribution
Localised infestation on western side of the site.
Control strategy
Hand removal and spot spraying.

Problem

- Broken off pieces may take root.

Specifications for control

- Hand pull or dig. Spray with herbicide when the plant is actively growing but before flowering occurs. Monitor and control any regrowth. Current infestation is confined and small. Eradication is a likely outcome if control action is taken.

Fireweed (*Senecio madagascariensis*)

Legal status
Declared Noxious Weed (Class W4) in the Shoalhaven LGA.
Distribution
Sporadic in all disturbed areas on the site.
Control strategy
Hand removal and spot spraying.

Problem

- From germination to flowering can take as little as 6 weeks.
- Seed is wind blown and spread in soil and on vehicles and machinery.

Specifications for control

- Hand pull as soon as the plants become visible when they begin to flower. Bag the whole plant for burning or deep burial. Do not leave seed heads in situ. Spot spraying if infestation becomes larger at the first sign of flowering. The site is likely to be regularly infested with this weed.

Madeira Vine (*Anredera cordifolia*)

Legal status
Not declared in the Shoalhaven. Listed as a Key Threatening process under the TSC Act.
Distribution
Single plant only on eastern bund.
Control strategy
Remove carefully by hand.

Problem

- Spread by tubers in contaminated soil.
- Aerial tubers will be shed from stems if the vine is cut and remain viable in the soil for at least 5 years.

Specifications for control

- Plants can be dug up but large tubers may break in the process. Collection and disposal of aerial tubers will be needed if pulling vines down. Scrape and paint method can be used on mature plants. This will kill aerial tubers slowly. Results need to be monitored for regrowth. Respraying needs to be done frequently to prevent enough foliage recovering to support the development of new tubers.

Moth Vine (*Araujia sericifera*)

Legal status

Not declared in the Shoalhaven. Listed as a Key Threatening Process under the TSC Act.

Distribution

Occasional young plant found on the bund. No fruit had set.

Control strategy

Remove carefully by hand.

Problem

- Milky sap is an irritant to the skin and eyes.
- Climbs over shrubs and trees, smothering and breaking them down.
- Spread by wind

Specifications for control

- Young plants can be hand pulled or dug out. Large plants can be treated by the scrape and paint method. Gloves need to be worn when handling this plant to avoid getting the sap in the mouth or eyes. If the plant reaches fruiting stage all fruit must be collected burnt or buried. At this time there are no plants established sufficiently to produce fruit Eradication possible if treated quickly.

Turkey Rhubarb (*Acetosa sagittata*)

Legal status

Not declared in the Shoalhaven. Listed as a Key Threatening process under the TSC Act (1995).

Distribution

Establish plants found in stockpile area.

Control strategy

Tubers removed and burnt or deep buried. Use of herbicide prior to seeding.

Problem

- Spread from seed and tubers in contaminated soil.
- Seed spread by wind and water
- Constant resprouting from tubers make this plant difficult to control.

Specifications for control

- Plants can be dug up but every tuber needs to be removed and burnt or deep buried. Spraying with herbicide prior to seeding can be effective in late autumn or winter. Any control method will require repeated effort and monitoring. Likely to be an ongoing problem.

Black Thistle (*Cirsium vulgare*)

Legal status
Not declared in the Shoalhaven.
Distribution
Frequent in bund area.
Control strategy
Annual spot spraying at the rosette stage.

Problem

- Seed is wind blown.
- Seed is moved around in soil and on vehicles and machinery.

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Specifications for control

- Thistles can be chipped out with a mattock. Spot spraying can be used for larger infestation. Chemical control measures are most effective when the plant is at rosette stage before seed is set. Winter and spring are the best times. Control for this weed will be ongoing at this site.

Capeweed *(Arctotheca calendula)*

Legal status
Not declared in the Shoalhaven.
Distribution
Frequent in bund area.
Control strategy
Annual spot spraying at the rosette stage when actively growing.

Problem

- Seed is wind blown.
- Seed is moved around in soil and on vehicles and machinery.

Specifications for control

- Capeweed can be chipped out with a mattock being careful to sever the root well below ground level to prevent resprouting. Spot spraying can be used for larger infestation. Chemical control measures are most effective when the plant is at rosette stage before seed is set. Control for this weed will be ongoing at this site.

Castor oil plant (*Ricinus communis*)

Legal status
Not declared in the Shoalhaven.
Distribution
Occasional single plant in bund area.
Control strategy
Cut and paint mature plants. Hand removal of seedlings. Monitor for several years. Eradication easily achieved on this site.
Problem

- Seed is ejected explosively and can be spread in contaminated soil.
- The leaves are poisonous and the seed very poisonous if swallowed.

Specifications for control

- Mature plants need to be treated before they set seed in spring and summer. Cut and paint larger plants and remove seedlings by hand. Follow up control will be needed for several years.

Cobbler's Pegs *(Bidens pilosa)*

Legal status
Not declared in the Shoalhaven.
Distribution
Frequent and widespread on site.
Control strategy
Annual spot spraying and hand removal.

Problem

- Seed is barbed and adheres to clothing.
- Seed is spread on animals, clothing, mud and soil.

Specifications for control

- Hand pull prior to burrs forming and spot spraying prior to seed setting. Avoid walking through seeding plants to limit the spread. If removing seeding plants bag them for burning or deep burial. Control for this weed will be ongoing at this site and can take place all year.

Inkweed (*Phytolacca octandra*)

Legal status
Not declared in the Shoalhaven.
Distribution
Sporadic in all disturbed areas on the site.
Control strategy
Spot spraying.

Problem

- Often appears after disturbance. Clumps often come up around windrows of felled timber.
- The plant is poisonous.
- The rampant growth will suppress any other plants growing beneath it.

Specifications for control

- Hand-pulling is ineffective even on small plants, as the plant invariably snaps off and leaves the root behind to regrow. Spot spray when other weeds are being treated.

Kikuyu (*Pennisetum clandestinum*)

Legal status
Not declared in the Shoalhaven.
Distribution
Frequent on bunds and other areas where there has been soil movement.
Control strategy
Gradually remove from bunds and replace with local native species.

Problem

- Provides an effective dust suppression action on the site.
- It can smother shrubs and young trees.
- It can invade remnant native vegetation.

Specifications for control

- Control needs to be well managed to avoid creating a dust problem on the site. Kikuyu should be gradually treated with herbicide and treated areas must be replanted with local native species soon after herbicide treatment. Kikuyu should be treated in all remnant native vegetation areas left on the site.

Mother of Millions (*Bryophyllum delagoense*)

Legal status
Not declared in the Shoalhaven.
Distribution
Single infestation near the centre of the site.
Control strategy
Remove carefully by hand. Eradication easily achieved.

Problem

- Spreads prolifically by small plantlets produced vegetatively at the leaf tips.
- Highly tolerant of dry conditions and shallow infertile soils.
- Leaves have a waxy coating making it difficult to control with herbicide.

Specifications for control

- Plants can be dug up but will need to be burnt or deeply buried to prevent the plants from taking root again. Eradication is likely. There is currently only one small patch on site and this can easily be removed.

Paspalum (*Paspalum dilatatum*)

Legal status
Not declared in the Shoalhaven.
Distribution
Sporadic along road edges or where moisture level is higher.
Control strategy
Could be treated with herbicide or dug out.

Problem

- Seed is spread by sticking to clothing, machinery and vehicles.

Specifications for control

- Young individual plants can be hand pulled or dug out. Large infestations can be treated with herbicide but dead plants need to be replaced with local growing natives. This is likely to be an ongoing problem particularly when there are higher moisture levels.

Purpletop (*Verbena bonariensis*)

Legal status

Not declared in the Shoalhaven.

Distribution

Sporadic in disturbed areas and areas used for storage of materials.

Control strategy

Can be hand pulled in the early stages of infestation but herbicide is needed for more extensive infestations.

Problem

- Responds to disturbance.
- Tolerates dry infertile soils.
- Seed attaches to clothing and animals and is transported in contaminated soil.

Specifications for control

- Young small infestations plants can be hand pulled or dug out and the plants bagged for burning or deep burial. Large infestations can be treated with herbicide.

Senna (*Senna pendula*)

Legal status

Not declared in the Shoalhaven.

Distribution

Seedlings only on western bund.

Control strategy

Can be hand pulled in the early stages of infestation but herbicide is needed for more extensive infestations.

Problem

- Can become invasive in the understorey of coastal forest.

Specifications for control

- Hand pull seedlings when found. The whole root system needs to be removed to avoid resprouting. For larger plants use the cut and paste technic using herbicide. This is often best in summer autumn when the plants are easily recognised by their showy yellow flowers. All plants must be prevented from seeding. Eradication is a likely outcome for this site considering the current level of infestation.

Appendix 3

Noxious Weeds of the Shoalhaven LGA

(No. of pages excluding this page = 1)

Appendix 3 Noxious Weeds of the Shoalhaven LGA

The category numbers listed in the table below refer to the noxious weed control categories specified in the *Noxious Weed Act, 1993*. Refer to Section 3.3 in this document for details of the controls that apply to each category.

Common Name	Scientific name	Class
African Boxthorn	*Lycium ferocissimum*	4
African Lovegrass	*Eragrostis curvula*	4
Alligator Weed	*Alternanthera philoxeroides*	2
Bathurst and Noogoora Burrs	*Xanthium spp.*	4
Bitou Bush, Boneseed	*Chrysanthemoides monilifera*	4
Black Knapweed	*Centaurea nigra*	1
Blackberry	*Rubus fruticosus*	4
Bridal Veil Creeper	*Myrsiphyllum asparagoides*	5
Broom Rape	*Orobanche spp*	1
Cabomba	*Cabomba spp*	5
Crofton Weed	*Ageratina adenophora*	4
Dodder	*Cuscuta spp.*	5
Fireweed	*Senecio madagascariensis*	4
Giant Parramatta Grass	*Sporobolus fertilis*	3
Gorse	*Ulex europaeus*	4
Green Cestrum	*Cestrum parqui*	3
Harrisia Cactus	*Harrisia spp*	4
Hawkweed	*Hieracium spp.*	1
Horsetail	*Equisetum arvense*	1
Indian Hemp	*Equisetum spp.*	1
Karroo Thorn	*Acacia karoo*	1
Kochia	*Kochia scoparia*	1
Lagarosiphon	*Lagarosiphon major*	1
Lantana	*Lantana camara*	4 and 5
Mexican Feather Grass	*Nassella tenuissima syn Stipa tenuissima*	1
Miconia	*Miconia spp*	1
Mist Flower	*Ageratina riparia*	4
Nodding Thistle	*Carduus nutans*	4
Pampas Grass	*Cortaderia spp.*	4
Parthenium Weed	*Parthenium hysterophorus*	1
Prickly Pears	*Opuntia spp.*	4
Privet - broadleaf	*Ligustrum lucidum*	4
Privet - narrowleaf	*Ligustrum sinense*	4
Rhus Tree	*Toxicodendron succendaneum*	4
Salvinia	*Salvinia molesta*	2
Scotch/English Broom	*Cytisus scorparius*	4
Senegal Tea Plant	*Gymnocoronis spilantoides*	1
Serrated Tussock	*Nassella trichotoma*	4
Siam Weed	*Chlorolaena odorata*	1
Spotted Knapweed	*Centaurea maculosa*	1
St Johns Wort	*Hypericum perforatum*	3
Water Hyacinth	*Eichhornia crassipes*	3
Water Lettuce	*Pistia stratiotes*	1
Willows	*Salix spp.*	5

Appendix 4

Species Suitable for Revegetation

(No. of pages excluding this page = 1)

Appendix 4 Species suitable for revegetation program

Family	Species	Common Name
Zamiaceae	*Macrozamia communis*	Burrawang
MAGNOLIOPSIDA -	**DICOTYLEDONS**	
Epacridaceae	*Lissanthe strigosa*	Native Cranberry
Fabaceae: Faboideae	*Daviesia ulicifolia*	
	Glycine clandestina	Love Creeper
	Hardenbergia violacea	False sarsaparilla
	Kennedia rubicunda	
	Pultenaea polifolia	
	Pultenaea villosa	
Fabaceae: Mimosoideae	*Acacia elongata*	
	Acacia falcata	
	Acacia longifolia	
	Acacia myrtifolia	
	Acacia ulicifolia	Prickly Moses
Goodeniaceae	*Goodenia ovata*	Hop Goodenia
Myrtaceae	*Corymbia maculata*	Spotty Gum
	Eucalyptus globoidea	White Stringy Bark
	Eucalyptus longifolia	Woollybutt
	Eucalyptus paniculata	Grey Iron Bark
	Kunzea ambigua	
	Melaleuca decora	White Feather Honeymyrtle
	Melaleuca styphelioides	Prickly-leaved Paperbark
Proteaceae	*Hakea sericea*	Bushy Needlebush
MAGNOLIOPSIDA -	**MONOCOTYLEDONS**	
Iridaceae	*Patersonia sericea*	Silky Purple Flag
Lomandraceae	*Lomandra longifolia*	
	Lomandra multiflora	
Phormiaceae	*Dianella revoluta* var *revoluta*	Mauve Flax Lily
Poaceae	*Themeda australis*	Kangaroo Grass

Appendix 5

Native Species Found on Site

(No. of pages excluding this page = 2)

Appendix 5 Native species found on site

Family	Species	Common Name
FILICOPSIDA		
Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair Fern
Aspleniaceae	*Asplenium australasicum*	Birds Nest Fern
	Asplenium flabellifolium	Necklace Fern
Davalliaceae	*Davallia pyxidata*	Hare's Foot Fern
Polypodiaceae	*Platycerium bifurcatum* subsp *bifurcatum*	Elk Horn
CYCADOPSIDA		
Zamiaceae	*Macrozamia communis*	Burrawang
MAGNOLIOPSIDA -	**DICOTYLEDONS**	
Acanthaceae	*Pseuderanthemum variabile*	Pastel Flower
Amaranthaceae	*Parsonsia straminea*	Common Silkpod
Asteraceae	*Cassinia aculeata*	Common Cassinia
	Cassinia longifolia	Long-leaved Cassinia
	Lagenifera stipitata	
	Olearia microphylla	Bridal Daisy Bush
	Ozothamnus diosmifolium	Paper daisy
Casuarinaceae	*Allocasuarina littoralis*	Black She-Oak
Campanulaceae	*Wahlenbergia sp*	Bluebells
Chenopodiaceae	*Einadia hastata*	
Epacridaceae	*Leucopogon juniperinus*	Bearded Heath
	Lissanthe strigosa	Native Cranberry
Fabaceae: Faboideae	*Daviesia ulicifolia*	
	Glycine clandestina	Love Creeper
	Hardenbergia violacea	False sarsaparilla
	Kennedia rubicunda	
	Pultenaea polifolia	
	Pultenaea villosa	
Fabaceae: Mimosoideae	*Acacia elongata*	
	Acacia falcata	
	Acacia longifolia	Sydney Golden Wattle
	Acacia myrtifolia	Myrtle Wattle
	Acacia ulicifolia	Prickly Moses
Goodeniaceae	*Goodenia heterophylla subsp heterophylla*	Violet-leaved Goodenia
	Goodenia ovata	Hop Goodenia
Lobeliaceae	*Pratia purpurascens*	White Root
Myrtaceae	*Corymbia maculata*	Spotted Gum
	Eucalyptus globoidea	White Stringy Bark
	Eucalyptus gummifera	Red Bloodwood
	Eucalyptus longifolia	Woollybutt
	Eucalyptus paniculata	Grey Iron Bark
	Kunzea ambigua	Tick Bush
	Melaleuca decora	White Feather Honeymyrtle
	Melaleuca styphelioides	Prickly-leaved Paperbark
	Syncarpia glomulifera	Turpentine
Pittosporaceae	*Bursaria spinosa*	Blackthorn
	Rhytidosporum procumbens	
Polygalaceae	*Comesperma ericinum*	Matchheads
Proteaceae	*Hakea sericea*	Bushy Needlebush

Family	Species	Common Name
MAGNOLIOPSIDA -	**DICOTYLEDONS**	
Ranunculaceae	*Clematis aristata*	Old Man's Beard
Magnoliopsida -	*Dicotyledons*	
Rutaceae	*Zieria smithii*	Sandfly Zieria
Santalaceae	*Exocarpus cupressiformis*	Cherry Ballart
Solonaceae	*Solunum prinophyllum*	Forest Nightshade
Stylidiaceae	*Stylidium graminifolium*	Trigger Plant
Thymeliaceae	*Pimelia linifolia spp. linifolia*	Rice Flower
Magnoliopsida -	*Monocotyledons*	
Cyperaceae	*Lepidosperma laterale*	
	Lepidosperma urophorum	
	Ptilothrix deusta	
Iridaceae	*Patersonia sericea*	Silky Purple Flag
Juncaceae	*Juncus bufonius*	
Liliaceae	*Hypoxis hygrometrica*	Yellow Stars
Lomandraceae	*Lomandra gracilis*	
	Lomandra longifolia	Mat Rush
	Lomandra multiflora	
Orchidaceae	*Acianthus fornicatus*	
	Calochilus robertsonii	
	Corybas sp.	
	Cyanicula caerulea	
	Cymbidium suave	Snake Flower
	Eriochilus cucullatus	
	Glossodia major	
	Myrmechila sp.	
	Prasophyllum brevilabre	
	Pterostylis acuminata	Sharp Greenhood
	Pterostylis curta	
	Pterostylis nutans	Nodding greenhood
	Thelymitra spp.	
	Tropilis aemula	Ironbark Orchid
Phormiaceae	*Dianella revoluta var revoluta*	Mauve Flax Lily
Poaceae	*Aristida vagans*	Three-awn Speargrass
	Entolasia stricta	
	Panicum simile	Two Colour Panicum
	Phragmites australis	Native Reed
	Themeda australis	Kangaroo Grass
Xanthorrhoeaceae	*Xanthorrhoea sp.*	Grass Tree

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Appendix 6

Curriculum Vitae of Author

(No. of pages excluding this page = 3)

Appendix 6 Curriculum vitae of author

NAME Rebecca Jane Rudd

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EDUCATION and TRAINING

2002 Safe Pesticide Handling, Nowra Tafe
2002 Workplace Assessment, Nowra Tafe
1999, 2001 GIS Management, Environment Australia
1998 Microsoft Access Data management
1995 Snake Biology and Handling Course, Jeff Coombs
1994, 2000 Crew Leaders Course, NSW Bushfire Brigade
1995 Interpretation Course, ANCA
1994 Weed Management Training, ANCA
1994 Cross Cultural Workshop, DEST
1994 Conflict Resolution, ANCA
1993 Rainforest Plant Identification, James Cook University,
1993 Supervisors Training, TAFE,
1992, 2001 Wardens Training, A.N.P.W.S.
1991 Occupational Health and Safety Certificate, TLC OHS Training Centre,
1989 Efficient Writing Certificate, DASETT
1989 Certificate of Horticulture, Woden TAFE,
1988 ACT Forests Chainsaw Operator's Certificate
1988 Rainforest Plant Identification, UNE Summer School
1987 Native Plant Identification, ANU Summer School
1987 First Aid Certificate, St. Johns Ambulance, updated 1990, 1993, 1996, and1999
1976 Higher School Certificate, Canberra,

EMPLOYMENT

May 2002 – present

- Flora surveys and assessments including the application of transect and quadrat techniques, noting rare or endangered flora species and defining vegetation communities.

June 1997 – May 2002 Senior Project Officer Booderee National Park

Develop and implement strategies to protect the natural resource in Booderee National Park. Projects included:

Weed management
Feral animal management
Fire management
Catchment management

Native vegetation management
Threatened species management

Jan 1995 – June 1997 Ranger Grade 2 Jervis Bay National Park

- Assist in the development and implementation of strategies to effect efficient management of the park in accordance with the Plan of Management.
- Provide technical assistance to management as required.
- Enforce regulations under the Parks and Wildlife Act, 1975.
- Assist visiting researchers, volunteers.
- Provide on the job training to trainee staff.
- Plan and deliver school holiday and other interpretation programs.
- Produce interpretive material including signage, pamphlets and Park Notes as required.
- Routine ranger duties.

May 1996 to September 1996 Exchange Ranger Kakadu National Park

- Assist in the development and implementation of strategies to effect efficient management of the park in accordance with the Plan of Management.
- Provide technical assistance to management as required.
- Enforce regulations under the Parks and Wildlife Act, 1975.
- Routine ranger duties.
- Assist in fire management program and wildfire control as required.
- Special:
- Developed weed awareness program for Jabiru.
- Participated in wildlife management programs.

July 1994 to January 1995 A/g Ranger Grade 2 Beecroft Peninsula

- Duties as for R2 JBNP plus:
- Carry on liaison with Department of Defence.

December 1993 Coral Sea Patrol

- Set up vegetation survey system for monitoring purposes.
- Collect bird and vegetation data.
- Take part in turtle monitoring program.
- Carry out routine maintenance tasks.

August 1993 to December 1993 A/g Professional Officer (Project Officer)
Environmental Resources Information Network (ERIN)

- Project: Pilot project to set up a Geographic Information System (vegetation layer) for Beecroft Peninsula.
- Assist in developing specifications for consultant ecologist to use.
- Contract and liaise with consultant, ensuring compliance with specifications and provide field assistance as required.
- Assist in data analysis.
- Produce draft report.

March 1990 to August 1993 GSO 8/ Gardening Manager Jervis Bay Botanic Gardens

- Oversee carrying out of day to day operations and developmental projects.
- Supervise eight staff including two trainees.
- Provide on the job and task specific training to staff.
- Manage living collection: nursery facilities; plant propagation; field collection; Rare and Endangered species; maintain records for IBIS database.
- Provide interpretation to the general public and to special interest groups.
- Develop interpretive material.
- Provide technical advice on Gardens' development and POM.
- Special: Established Public Access Herbarium; designed and constructed system of walking tracks.

September 1991 to December 1991; August 1989 to April 1990 A/g Manager JBBG

- Operate as part of the ANBG management team.
- Develop briefs for and oversee construction of new works.
- Forecast and monitor budget allocations.
- Develop works programs.
- Instigate recruitment procedures as required.

October 1986 to March 1989 A/g Gardening Overseer, Glasshouses ANBG

- Supervise three staff.
- Maintain living collections in five glasshouses (inc. R&E, orchids).
- Develop and implement pest control, field collection and propagation programs.
- Maintain plant and equipment associated with glasshouse operation.
- Maintain IBIS records

June to October 1986 Gardener Grade 3, Plant Production ANBG

- Undertake plant propagation.
- Maintain living collections.
- Maintain IBIS records.
- Supervise disabled volunteers.

March to June 1986 Gardener Grade 3, Plant Records ANBG

- Carry out regular tasks involved in stocktaking, mapping and registration of living collection

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Traffic and Transportation Assessment

Prepared by

John Coady Consulting Pty Ltd

December, 2007

Specialist Consultant Studies Compendium:
Part 3

Traffic and Transportation Assessment

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

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December, 2007

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CONTENTS

Page

EXECUTIVE SUMMARY 3-5

1 INTRODUCTION 3-7

2 PROJECT OVERVIEW 3-9

3 OPERATIONAL CHARACTERISTICS OF NOWRA BRICKWORKS QUARRY 3-10

3.1 Existing Operational Characteristics 3-10
3.2 Post-Expansion Operational Characteristics 3-14
3.3 Truck Routes 3-17

4 PROPOSED ACCESS ARRANGEMENTS 3-17

5 ROAD NETWORK AND TRAFFIC CONDITIONS 3-17

5.1 Existing Road Network 3-17
5.2 Existing Traffic Conditions 3-18
5.3 Future Road Network 3-19
5.4 Projected Future Traffic Conditions 3-20

6 TRAFFIC ASSESSMENT 3-20

APPENDICES

Appendix 1 Results of Survey of Traffic Generation Characteristics of Existing Quarry .. 3-27
Appendix 2 Princes Highway, South Nowra Traffic Growth and Projections 3-35
Appendix 3 Traffic Count Data 3-37
Appendix 4 Criteria for Interpreting Results of Intanal Analysis 3-39

TABLES

Table 1 Truck Movements and Tonnage July 06 to June 07 3-10
Table 2 Existing Heavy Vehicle Traffic Generation Calculation 3-12
Table 3 Surveyed Traffic Generation of Existing Quarry (vehicle trips – IN + OUT) .. 3-13
Table 4 Traffic Generation of Existing Quarry Under 85th Percentile Operation Condition (vehicle trips – IN + OUT) 3-14
Table 5 Existing Workforce 3-14
Table 6 Projected Traffic Generation 3-15
Table 7 Proposed Workforce 3-16

CONTENTS

Page

TABLES (Con'td)

Table 8 Traffic Generation Potential of Quarry with Expanded Extractive Operations (vehicle trips – IN + OUT) 3-16
Table 9 RTA Daily Traffic Volumes – Browns Creek Station 3-18
Table 10 Peak Period Traffic Flows on Princes Highway 3-19
Table 11 Additional Traffic Generation Potential of Quarry with Expanded Extraction Operations (vehicle trips – IN + OUT) 3-20
Table 12 Intanal Analysis – Scenario 1 3-22
Table 13 Intanal Analysis – Scenario 2 3-22
Table 14 Intanal Analysis – Scenario 3 3-23
Table 15 Intanal Analysis – Scenario 4 3-23

FIGURES

Figure 1 Locality Plan 3-8
Figure 2 Project Site Layout 3-11
Figure 3 Proposed Project Site Entrance 3-18

EXECUTIVE SUMMARY

1. Currently, approximately 30% of production from the Nowra Brickworks Quarry comprises imported construction and concrete waste material and waste bitumen and/or imported quarry products. The remaining 70% of production comprises material extracted from within the quarry site. The average products despatched from the Project Site is in the order of 125 000t per year with approximately 125 000t per year of material imported to the Project Site for recycling and blending to produce quarry products.
2. Materials imported or despatched from the Project Site are transported using large rigid trucks, truck and dog trailers, semi-trailers and B-Doubles. Few deliveries are made by light rigid trucks, trailers and utility vehicles. The Proponent advises that all heavy vehicles departing the Project Site are loaded with material. Approximately 50% of trucks returning to the Project Site are loaded with materials to be recycled and are weighed in when entering the Project Site. The remaining trucks returning to the Project Site are unladen and proceed directly to the loading area. It follows that the number of trucks entering the Project Site should therefore equal the number of trucks departing the Project Site. As there will always be more material exported from the Project Site than imported, the controlling factor that determines the truck generation is the tonnage per *despatched* vehicle.
3. The average tonnage per loaded vehicle during the 85th percentile period is 20t per vehicle.
4. The Proponent has indicated that the proposed truck delivery areas will be similar to the existing areas, with 80% to/from the north of the Project Site and 20% to/from the south of the Project Site as follows.
    - 25% to/from the Nowra area.
    - 25% to/from the Bomaderry – Cambewarra – Kangaroo Valley area.
    - 30% to/from the area north of Bomaderry (such as Berry).
    - 20% to/from the south (such as Huskisson and St Georges Basin).
5. Current 2007 traffic flows on the Princes Highway are estimated to be in the order 30,247 vehicles per day (vpd), while projected 2017 traffic flows on the highway are in the order of 42,667 vpd.
6. The RTA anticipates that the section of Princes Highway along the frontage of the Project Site will be upgraded to a four-lane roadway including a wire rope safety barrier within a median strip separating opposing lanes of traffic. A two-lane roundabout at the intersection of Princes Highway with Warra Warra Rd, south of the Project Site entrance serving the quarry is also proposed. The Authority however has no fixed timetable for these work.
7. The traffic generation potential of the existing quarry under the 85th percentile operating condition is 139 vehicles per day, 23 vehicles per hour (vph) during the midday quarry peak period, 10 vph during the morning peak and 4 vph during the evening peak.

8. The traffic generation potential of the proposed quarry under the 85th percentile operating condition is 419 vehicles per day, 78 vehicles per hour (vph) during the midday quarry peak period, 21 vph during the morning peak and 6 vph during the evening peak.
9. The results of the INTANAL analysis of the Project Site entrance reveal that satisfactory intersection performance is indicated for existing (2007) traffic conditions on Princes Highway with the 85th percentile operating condition at the existing quarry, and the 85th percentile operating condition with the expanded extractive operations.
10. Satisfactory intersection performance is also indicated for projected 2017 traffic conditions on Princes Highway and with the expanded quarry operation, although Level of Service "C" is indicated for the AM peak period. However, it can reasonably be anticipated that this section of Princes Highway will be amplified by 2017 in which case Princes Highway will be a four-lane divided road and quarry access will be restricted to left-turn/In/out only. The results of the INTANAL analysis of the intersection of Princes Highway and quarry access driveway under this road configuration and the expanded extractive operations reveal satisfactory intersection performance.

It can be concluded that the continuation and expansion of extractive operations at the Nowra Brickworks Quarry will have no unacceptable traffic implications.

1 INTRODUCTION

This report has been prepared to support a major projects application for planning approval to the Department of Planning for the proposed continuation and expansion of extractive operations at the Nowra Brickwork Quarry located at Lot 464, DP 1058778, South Nowra (**Figure 1**).

The Project Site is located at South Nowra, approximately 5km south of Nowra CBD, on the western side of the Princes Highway, and within the administrative area of Shoalhaven City Council. The Project Site incorporates two Mining Leases, ML5087 which occupies approximately 7 hectares, and ML6322 which occupies approximately 14 hectares. The existing vehicular access for the Project Site is off Princes Highway via a 7.7m wide access gate located adjacent to the northern site boundary.

Plate 1 Photograph of existing site access

ML5087 was granted around 8 January 1948, while ML6322 was granted around 8 March 1972. Both leases have been subsequently renewed and have expiry dates of 8 January 2019 and 8 March 2020 respectively. South Coast Concrete Crushing and Recycling Pty Ltd (the "Proponent") has operated extractive operations within both ML5087 and ML6322 since the Mineral Leases were acquired from the previous operator in 2002. The subject application is for the continuation and expansion of extractive operations within ML5087 and ML6322.

The Proponent estimates that the average production level for the quarry is currently in the order of 125 000t per year, while the maximum production level likely to be achieved as a consequence of the proposed expansion of extractive operations at the quarry is in the order of 500 000t per year.

The purpose of this report is to assess the traffic implications of the application for continuation and expansion of extractive operations at the Nowra Brickworks Quarry site.

\\SERVER\RWC\74203\CAD\742Base_Traffic 1.DWG

REFERENCE
Project Site Boundary

SCALE 1:150 000

2.5 0 2.5 5.0 7.5 km

Base Map Source: Kiama and Jervis Bay 1: 100 000 Topographic Maps (1983)

Note: A colour version of this figure is available on the Project CD

Figure 1
LOCALITY PLAN

2 PROJECT OVERVIEW

The proposed continuation and expansion of extractive operations at the Nowra Brickworks Quarry would include the following.

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark before the amount of quarry products despatched from the Project Site exceeds 250 000t per year.
- Staged extraction of up to 7000t per year of weathered shale material using an excavator from a proposed extraction area of approximately 15ha, incorporating an existing extraction area of approximately 2ha for direct sale to the Proponent's customers.
- Staged extraction of up to 350 000t per year of unweathered shale material ("extracted material") using drill and blast methods from the above extraction area for processing and blending to produce quarry products.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted and recycling materials to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and despatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A proportion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

Figure 2 presents the proposed Project Site Layout.

3 OPERATIONAL CHARACTERISTICS OF NOWRA BRICKWORKS QUARRY

3.1 Existing Operational Characteristics

Currently, approximately 30% of production from the Nowra Brickworks Quarry comprises imported construction and concrete waste material and waste bitumen and/or imported quarry products. The remaining 70% of production comprises material extracted from within the Project Site. The average production level of the existing quarry operation is in the order of 125 000t per year, with approximately 55 000t per year of material imported to the Project Site for recycling, blending and incorporation into quarry products.

The Proponent has provided the following recorded information on the operational characteristics of the existing quarry for each month over the 12 month period between July 2006 and June 2007.

Table 1
Truck Movements and Tonnage July 06 to June 07

Month	Loaded Truck Movements (In & Out)			Net Tonnage		
	Rigid Truck Movements	Truck/Trailer Movements	Total Loaded Movements	Net Tonne In	Net Tonne Out	Total Net Tonnage
July	644	371	1015	4439.62	9735.37	14174.99
August	854	619	1473	6223.18	13646.42	19869.60
September	525	396	921	4079.11	8944.82	13023.93
October	409	610	1019	6382.17	13995.08	20377.25
November	396	499	895	3926.17	8609.46	12535.63
December	458	451	909	4423.99	9701.11	14125.10
January	299	268	567	2681.75	5880.66	8562.41
February	289	259	548	2588.94	5677.13	8266.07
March	324	291	615	2907.96	6376.67	9284.63
April	477	428	905	4279.81	9384.93	13664.74
May	761	682	1443	6827.17	14967.38	21794.55
June	745	668	1413	6682.49	14653.63	21336.12
Totals	**6181**	**5542**	**11723**	**55442.36**	**121572.66**	**177015.02**

Note 1: The 85th percentile month for the year is October (based on monthly tonnage).
Note 2: The October Total Tonnage (20,377T) represents 11.5% of the Yearly Total Tonnage (121 572T).
Note 3: During October, 40% of truck movements were rigid trucks, 60% were articulated vehicles.

Table 2.1 indicates that as the tonnage of transported material increases, the number of truck departures do not increase in direct proportion. This is because when the tonnage of transported material increases, a higher proportion of articulated vehicles are used, and those articulated vehicles have a significantly higher carrying capacity than the rigid trucks.

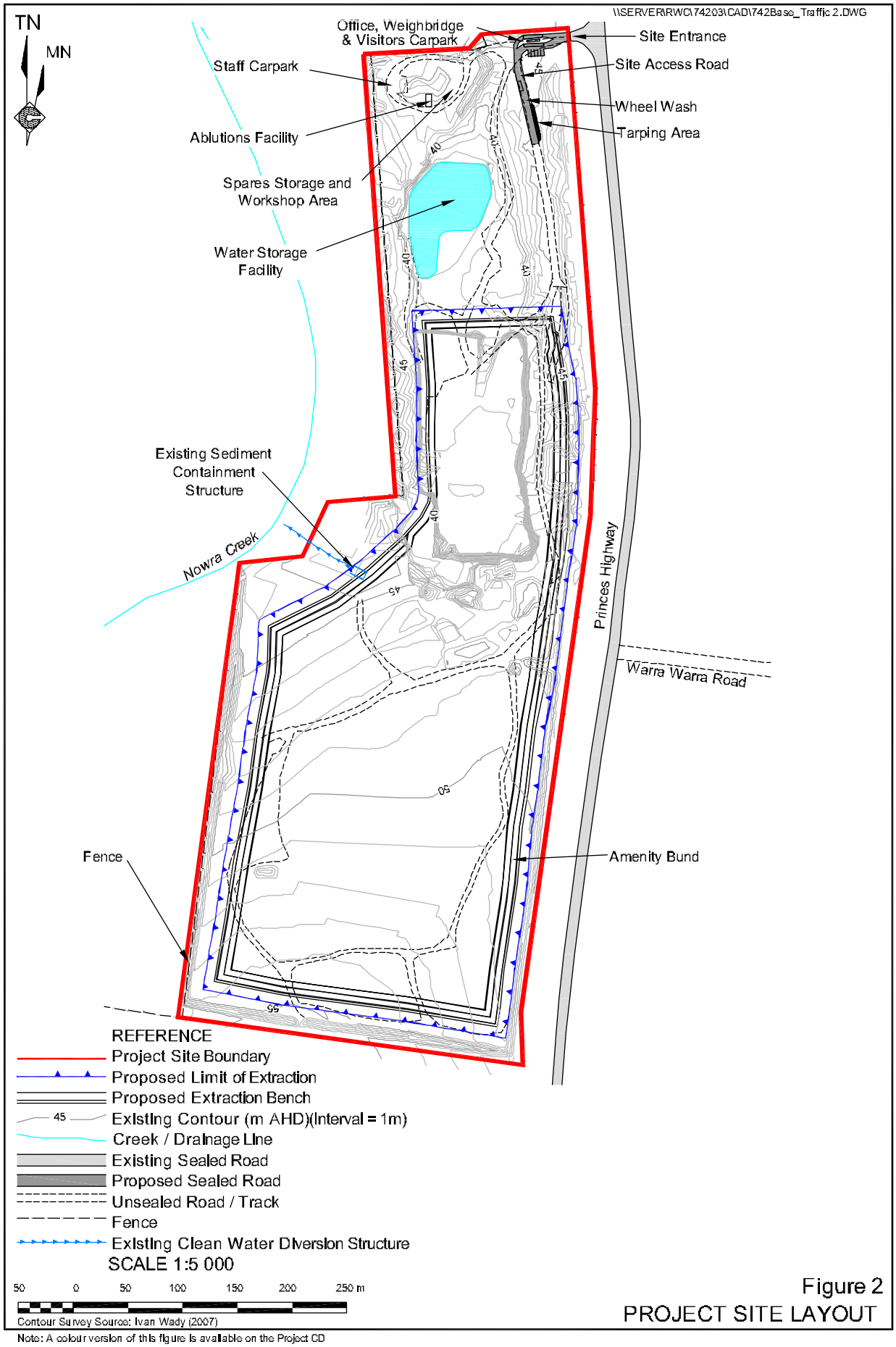

Figure 2
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

Materials imported or despatched from the Project Site are transported using large rigid trucks, truck and dog trailers, semi-trailers and B-Doubles. Few deliveries are made by light rigid trucks, trailers and utility vehicles. The Proponent advises that all heavy vehicles departing the Project Site are loaded with material. Approximately 50% of trucks returning to the Project Site are loaded with materials to be recycled or blended and are weighed in when entering the Project Site. The remaining trucks returning to the Project Site are unladen and proceed directly to the loading area.

For the purposes of this assessment, the overall monthly net tonnage has been used to determine the 85th percentile month for the year. Based on the yearly data supplied by the Proponent, October 2006 has been adopted as the 85th percentile month with, 20 377t transported to and from the Project Site. It should also be noted that October 2006 was the 85th percentile month for tonnage despatched from the Project Site.

Based on the supplied data, the following monthly and daily operational characteristics of the existing quarry have been adopted for the 85th percentile period:

Table 2
Existing Heavy Vehicle Traffic Generation Calculation

Existing Monthly 85th%ile Traffic Generation

Monthly Total Tonnage	**20,377**	**(13995 outbound / 6382 inbound)**	
Monthly Loaded Movements	**1,019**		
Average Tonne per Loaded Movement	**20.00**		
Monthly Outbound Loaded Movements	**700**	***(13,995T @ 20T per Loaded Movement)***	***Note: Loaded inbound plus loaded outbound = 1,019 Movements***
Monthly Inbound Loaded Movements	**319**	***(6,382T @ 20T per Loaded Movement)***	
Monthly Inbound Unladen Movements	**381**	**There must be as many inbound as outbound vehicles (ie. 381 + 319 = 700)**	
Monthly Total Truck Movements	**1,400**		

Average Daily Traffic Generation for 85th%ile Month (Assuming 25 days per month)

Daily Total Tonnage	**815**	**(600 outbound / 215 inbound)**	
Daily Loaded Movements	**41**		
Daily Outbound Loaded Movements	**30**	***(600T @20T per Loaded Movement)***	***Note: Loaded inbound plus loaded outbound = 41 Movements per day***
Daily Inbound Loaded Movements	**11**	***(215T @20T per Loaded Movement)***	
Daily Inbound Unladen Movements	**19**	**There must be as many inbound as outbound vehicles (ie. 19 + 11 = 30)**	
Daily Total Truck Movements	**60**		

Table 2 indicates that the average tonnage per loaded vehicle during the 85th percentile period is 20t per vehicle.

As noted in the foregoing, the Proponent advises that all heavy vehicles departing the Project Site are loaded with material, while trucks returning to the Project Site are either laden with waste material or unladen. It follows that the number of trucks entering the Project Site should therefore equal the number of trucks departing the Project Site. As there will always be more material exported from the Project Site than imported, the controlling factor that determines the truck generation is the tonnage per *despatched* vehicle, for example:

- 600T despatched @ 20T per truck 30 outbound / 30 inbound = 60 truck trips.

- 700T despatched @ 20T per truck 35 outbound / 35 inbound = 70 truck trips.
- 800T despatched @ 20T per truck 40 outbound / 40 inbound = 80 truck trips.
- 1,000T despatched @ 20T per truck 50 outbound / 50 inbound = 100 truck trips.

To check the validity of the abovementioned theory, an observation survey of the traffic generation of the existing quarry operation was conducted between 7.00am - 7.00pm on Monday 29 October 2007, and the detailed results of that traffic survey are included as **Appendix 1** to this report. That survey revealed the following traffic generation characteristics.

Table 3
Surveyed Traffic Generation of Existing Quarry
(vehicle trips – IN + OUT)

	Daily	Quarry peak (1.00-2.00pm)	AM Peak (8.15-9.15am)	PM Peak (4.30-5.30pm)
Cars	31	1	6	4
Light Rigid Trucks (2 axle)	32	4	0	0
Heavy Rigid Trucks (3+ axles)	42	10	4	0
Articulated vehicles	30	7	0	0
TOTAL	135	22	10	4

The observation survey revealed that the Project Site generated 72 heavy vehicle trips (36 in / 36 out) comprising 42 rigid and 30 articulated trucks.

The Proponent has advised that the daily tonnage of transported material for Monday 29 October 2007 was 717t comprising 712.48t despatched and only 4.52t of imported material. The despatched materials were transported using 36 trucks comprising 21 rigid and 15 articulated trucks, while the small amount of imported waste material was transported using 1 rigid truck. This data supplied by the Proponent correlates with the data recorded during the traffic survey.

The average load despatched from the Project Site on the day of the observation survey was in the order of 20t per despatched vehicle calculated as follows:

712.48t / 36 trucks = 19.8t per vehicle

In the circumstances, the recorded tonnage per loaded vehicle for Monday 29 October 2007 (19.8t per vehicle) compares with the 85th percentile tonnage per loaded vehicle (20t per vehicle) calculated in the foregoing.

As noted in Table 2, the average daily total tonnage for the 85th percentile month (October) is 815t comprising 600t despatched and 215t imported. This tonnage equates to approximately 60 heavy vehicle movements comprising 30 inbound and 30 outbound movements. On the day of the observation survey, the Project Site generated less overall tonnage (717t) but generated 72 heavy vehicle movements (36 in / 36 out) due the higher than predicted despatched volume (712.48t).

In addition, the daily tonnage for the 85th percentile month (815t) is 13.7% higher than the overall tonnage transported to/from the Project Site on the day of the observation survey (717t).

An indication of the current traffic generation characteristics of the existing quarry under the 85th percentile operating condition is provided by:

- adopting the car traffic generation of the survey;
- increasing the light rigid truck generation characteristics by 13.7%, and deriving the proportion of light truck traffic generation during the quarry peak period and during the AM and PM peak periods on the basis of the proportions indicated by the results of the traffic survey; and
- adopting the heavy truck generation of the traffic survey.

That calculation yields the following traffic generation potential of the existing quarry under the 85th percentile operating condition:

Table 4
Traffic Generation of Existing Quarry Under 85th Percentile Operation Condition
(vehicle trips – IN + OUT)

	Daily	Quarry peak (1.00-2.00pm)	AM Peak (8.15-9.15am)	PM Peak (4.30-5.30pm)
Cars	31	1	6	4
Light Rigid Trucks (2 axle)	36	5	0	0
Heavy Rigid Trucks (3+ axles)	42	10	4	0
Articulated vehicles	30	7	0	0
TOTAL	**139**	**23**	**10**	**4**

The Proponent advises that the existing workforce of the Nowra Brickworks Quarry is as follows.

Table 5
Existing Workforce

Extraction	12 people
Transportation	4 people
Total	**16 people**

3.2 Post-Expansion Operational Characteristics

At the anticipated, maximum product despatch rate of approximately 500 000t per year, it is expected that approximately 325 000t per year of shale material would be extracted from the Project Site. The remaining 175 000t of material would be recycled imported material. The Proponent would also import approximately 200 000t of Virgin Excavated Natural Material (VENM) to the Project Site that would be used to backfill areas of the quarry that are no longer required for extraction-related operations.

As noted in the foregoing, the Project Site currently exports approximately 125 000t of quarry products per year. The maximum production level of 500 000t per year represents an overall increase in despatched material of 400%. While the Proponent has indicated that the average tonnage of vehicles departing the Project Site will be in the order of 30t per loaded vehicle, this assessment will adopt a conservative approach and utilise the 85th percentile tonnage calculated in the foregoing of 20t per vehicle.

Based on the proposed tonnages, the following yearly, monthly and daily heavy vehicle traffic generation characteristics have been adopted for the proposed development:

Table 6
Projected Traffic Generation

Projected Yearly Traffic Generation		
Yearly Total Tonnage Out	**500,000**	
Yearly Total Tonnage In	**375,000**	
Yearly Total Tonnage	**875,000**	
Yearly Outbound Loaded Movements	**25,000**	***(500,000T @ 20T per Loaded Movement)***
Yearly Inbound Loaded Movements	**18,750**	***(375,000T @ 20T per Loaded Movement)***
Yearly Inbound Unladen Movements	**6,250**	**There must be as many inbound as outbound vehicles (ie. 6,250 + 18,750 = 25,000)**
Yearly Total Truck Movements	**50,000**	**(25,000 inbound / 25,000 outbound)**
Projected Monthly 85th%ile Traffic Generation (Based on 11.5% of Total Yearly Tonnage)		
85th%ile Monthly Total Tonnage Out	**57,500**	
85th%ile Monthly Total Tonnage In	**43,125**	
85th%ile Monthly Total Tonnage	**100,625**	**(875,000T x 11.5%)**
Monthly Outbound Loaded Movements	**2,875**	***(57,500T @ 20T per Loaded Movement)***
Monthly Inbound Loaded Movements	**2,156**	***(43,125T @ 20T per Loaded Movement)***
Monthly Inbound Unladen Movements	**719**	**There must be as many inbound as outbound vehicles (ie. 719 + 2,156 = 2,875)**
Monthly Total Truck Movements	**5,750**	
Projected Daily Traffic Generation (Assuming 25 days per month)		
85th%ile Daily Total Tonnage Out	**2,300**	
85th%ile Daily Total Tonnage In	**1,725**	
85th%ile Daily Total Tonnage	**4,025**	
Daily Outbound Loaded Movements	**115**	***(2,300T @ 20T per Loaded Movement)***
Daily Inbound Loaded Movements	**86**	***(1,725T @ 20T per Loaded Movement)***
Daily Inbound Unladen Movements	**29**	**There must be as many inbound as outbound vehicles (ie. 29 + 86 = 115)**
Daily Total Truck Movements	**230**	

The Proponent has advised that following the proposed expansion of extractive operations at the quarry, the workforce will be as follows.

Table 7
Proposed Workforce

Extraction	17 people
Transportation	6 people
Total	**23 people**

Accordingly, the workforce required to operate the quarry following expansion of the extractive operations is 44% greater than the existing workforce.

For the purposes of this assessment, the typical traffic generation characteristics of the quarry following expansion of extractive operations have been calculated by:

- increasing the car traffic generation recorded by approximately 44%;
- increasing the light truck traffic generation by approximately 400%; and
- adopting the projected traffic generation calculated above and deriving the proportion of heavy truck traffic generation during the quarry peak period and during the AM and PM peak periods on the basis of the proportions indicated by the results of the traffic survey.

That calculation yields the following traffic generation potential for the quarry following expansion of extractive operations:

Table 8
Traffic Generation Potential of Quarry with Expanded Extractive Operations
(vehicle trips – IN + OUT)

	Daily	**Quarry peak (1.00-2.00pm)**	**AM Peak (8.15-9.15am)**	**PM Peak (4.30-5.30pm)**
Cars	45	2	9	6
Light Rigid Trucks (2 axle)	144	20	0	0
Heavy Rigid Trucks (3+ axles)	134	34	12	0
Articulated vehicles	96	22	0	0
TOTAL	**419**	**78**	**21**	**6**

In fact, the projected traffic generation potential of the Nowra Brickworks Quarry following expansion of extractive operations set out in the table above is likely to overstate the actual truck generation characteristics as it can be reasonably expected that a higher proportion of articulated vehicles (including B-Double trucks) would be involved in transporting the higher tonnage of transported materials generated by the proposed expansion of extractive operations. As noted above, the Proponent has indicated that the average load for vehicles departing the Project Site would be 30t per vehicle.

3.3 Truck Routes

The Proponent has indicated that the proposed truck delivery areas will be similar to the existing areas, with 80% of materials despatched to the north of the Project Site and 20% despatched to the south of the Project Site as follows.

- 25% to/from the Nowra area.
- 25% to/from the Bomaderry – Cambewarra – Kangaroo Valley area.
- 30% to/from the area north of Bomaderry (such as Berry).
- 20% to/from the south (such as Huskisson and St Georges Basin).

4 PROPOSED ACCESS ARRANGEMENTS

It is proposed to provide an access driveway to serve the Nowra Brickworks Quarry with expanded extractive operation in the same location as the existing access driveway that is adjacent to the northern site boundary. However, given the relatively high proportion of articulated vehicles, including B double trucks, involved in transporting material to and from the Project Site, an amplified access driveway will be required.

The driveway required to serve the quarry with the expanded extractive operation has been designed using the turning path templates of B-Double trucks entering and departing the Project Site concurrently. The driveway design takes into account the proposed amplification of this section of Princes Highway to provide a four-lane divided carriageway with a wire rope safety barrier installed along a central median (see Chapter 5.3). That design, which is illustrated on **Figure 3** requires an access driveway 11m wide at the Project Site boundary splaying to 40m wide at the edge of bitumen.

The existing Project Site entrance includes a sealed access road approximately 11m wide at the Project Site boundary. This increases to approximately 52m wide where the Project Site access road joins the Princes Highway. The Proponent has indicated that the Roads and Traffic Authority has indicated that the Princes Highway, is proposed to be widened to 4 lanes, with a wire rope safety barrier. **Figure 3** presents a conceptual Project Site Entrance that may be constructed in consultation with the RTA, should the proposed road works be implemented.

5 ROAD NETWORK AND TRAFFIC CONDITIONS

5.1 Existing Road Network

The classifications assigned to the road network serving the Project Site by the RTA identify the Princes Highway as a classified State Road.

The section of Princes Highway along the frontage of the Project Site is constructed as a two-lane undivided road (one lane in each direction), 6.2 metres wide between edgelines, with a variable width bitumen shoulder on either side. Adjacent to the existing Project Site entrance, the bitumen shoulder is approximately 2.8m wide on the western side of the road, and 4.5m wide on the eastern side of the road. The intersection of Princes Highway with Central Ave to the north of the quarry site operates under the control of a two-lane roundabout.

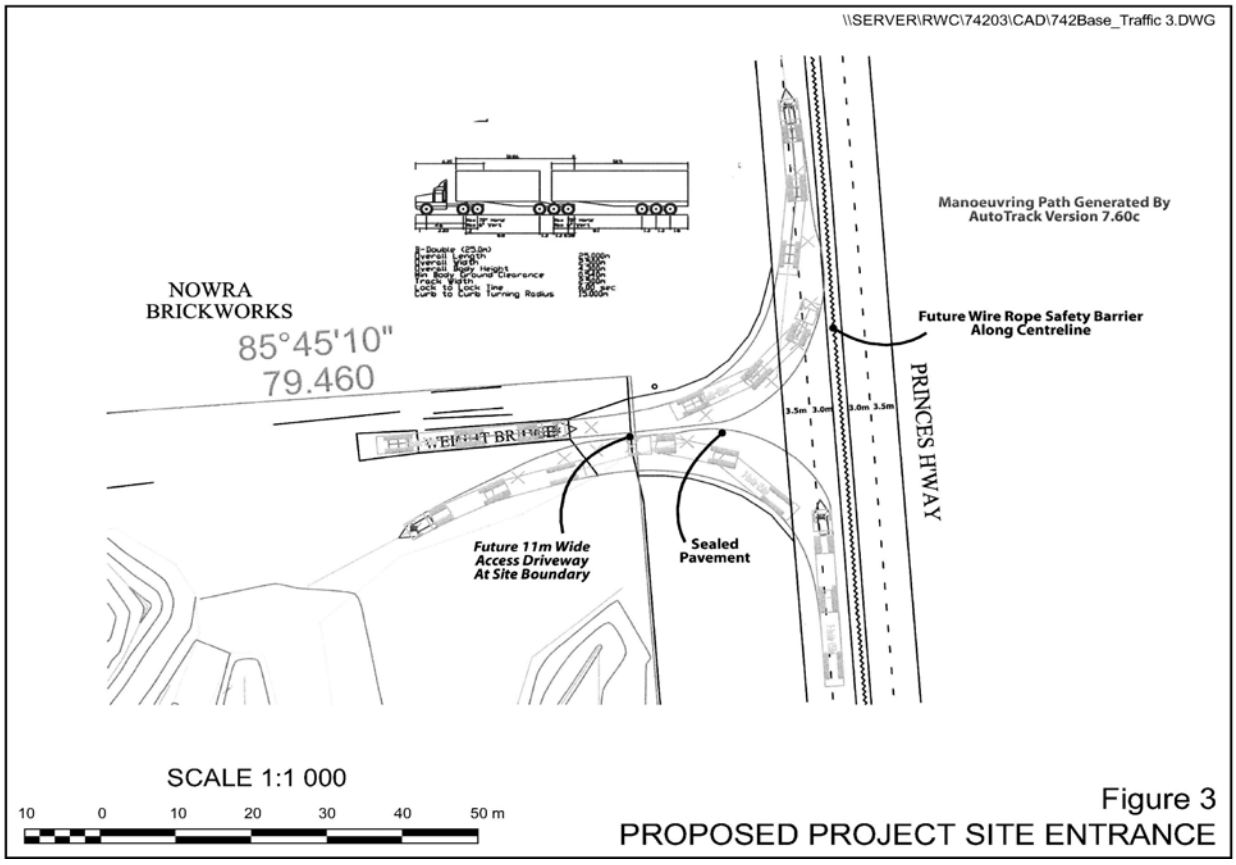

Figure 3
PROPOSED PROJECT SITE ENTRANCE

The speed limit on the section of Princes Highway along the frontage of the Project Site is 80km/h.

5.2 Existing Traffic Conditions

An indication of existing traffic conditions on this section of Princes Highway is provided by the RTA Daily Traffic Volume Data[1] which identifies the following average annual daily traffic volumes at the Browns Creek Survey Station approximately 2.5km to the north of the Project Site.

Table 9
RTA Daily Traffic Volumes – Browns Creek Station

Year	Vehicles per day
1997	21 443
2000	23 144
2003	26 366

That traffic count data indicates a growth rate in the order of 3.5% per annum in the level of traffic activity on this section of Princes Highway. That growth rate has been applied to the AADT traffic data compiled by the RTA to project current (2007) daily traffic flows on this section of Princes Highway (30 247 vehicles per day) and daily traffic flows on this section of Pacific Highway in 2017 (42 667 vehicles per day). Those projected traffic flows on Princes Highway are tabled in **Appendix 2**.

[1] *RTA "Traffic Volume Data for Southern Region" 2003*

To provide information on the distribution of daily traffic flows on this section of Princes Highway, a count of traffic activity at the intersection of Princes Highway with Central Ave (**Figure 2**) was conducted between 7.00am - 7.00pm on Monday 29 October, 2007, and the results of that traffic count are included as **Appendix 3**, revealing the following peak period traffic flows on this section of Princes Highway:

Table 10
Peak Period Traffic Flows on Princes Highway

	Total	Northbound	Southbound
Quarry peak (1.00 - 2.00pm)	1331	741	590
AM peak (8.15 - 9.15am)	1585	1089	496
PM peak (4.30 - 5.30pm)	1549	1043	506

5.3 Future Road Network

The main future changes to the road network serving the Project Site involve the ongoing upgrading of the Princes Highway by the RTA. The Authority is currently involved in upgrading the section of Princes Highway between Forest Rd at South Nowra and Falls Rd at Falls Creek, just south of the Project Site. That work, which is being carried out under the AusLink Strategic Regional Program funded by the Commonwealth and State Governments involves the following.

- Widening the highway to a four lane divided carriageway from just south of Forest Rd to Falls Rd.
- Duplication of the two-lane bridge over Currambene Creek.
- Installing a wire rope safety barrier in the median strip between opposing lanes of traffic.
- Upgrading highway intersections at Comberton Grange Rd, Parma Rd and Falls Rd including U-turn facilities at Forest Rd, Comberton Grange Rd and Parma Rd to allow landowners directly fronting the highway to have safe access in all directions (**Figure 2**).
- Repaving the road surface of bus bays at existing stopping areas opposite Parma Rd and on each side of the highway near Falls Rd (**Figure 2**).

The RTA anticipates that the section of Princes Highway along the frontage of the Nowra Brickworks Quarry site will be similarly upgraded, including construction of a two-lane roundabout at the intersection of Princes Highway with Warra Warra Rd, just south of the access driveway serving the quarry. However, the Authority has no fixed timetable for that work.

5.4 Projected Future Traffic Conditions

Projected future traffic conditions on this section of Princes Highway, calculated by extrapolating the AADT volumes recorded for the highway by the RTA on the basis of historical growth trends, are set out on the table in **Appendix 2**. As can be observed, current 2007 traffic flows on the highway are estimated to be in the order 30 247 vehicles per day, while projected 2017 traffic flows on the highway are in the order of 42 667 vehicles per day. The directional split of those two-way traffic flows at different times of the day can be calculated by reference to the results of the count of traffic activity at the Princes Highway/Central Ave intersection (**Appendix 3**).

6 TRAFFIC ASSESSMENT

An indication of the traffic generation characteristics of the existing quarry under the 85th percentile operating condition is set out in **Table 4**, while the projected traffic generation potential of the quarry with expanded extractive operations, also under 85th percentile operating conditions, is set out on **Table 8**. The additional traffic generation potential of the quarry with expanded extractive operations is therefore presented in **Table 11**.

Table 11
Additional Traffic Generation Potential of Quarry with Expanded Extraction Operations
(vehicle trips – IN + OUT)

	Daily	Quarry peak (1.00-2.00pm)	AM Peak (8.15-9.15am)	PM Peak (4.30-5.30pm)
Cars	14	1	3	2
Light Rigid Trucks (2 axle)	108	15	0	0
Heavy Rigid Trucks (3+ axles)	92	24	8	0
Articulated vehicles	66	15	0	0
TOTAL	**280**	**55**	**11**	**2**

In numerical terms, the additional traffic demand on the road network serving the Project Site as a consequence of the expansion of extractive operations at Nowra Brickworks Quarry is relatively minor. At current estimated traffic levels of 30 247 vehicles per day additional project-related traffic would increase the estimated traffic levels by approximately, 0.1%.the estimated 2017 traffic level of 42 667 vehicles per day, additional project-related traffic would increase the estimated traffic levels by 0.06%. These increases are not of a level which is likely to result in unacceptable traffic conditions at key intersections along Princes Highway.

In these circumstances, the main traffic issue associated with the proposed expansion of extractive operations at the quarry concerns the ability of vehicles to enter/depart the Project Site via the Project Site entrance. As noted in the foregoing, should the proposed upgrade of the Princes Highway occur, the Project Site entrance would be amplified in accordance with **Figure 4**. However the following analysis assumes that the proposed upgrade of the Princes Highway has not been undertaken and traffic entering and exiting the Project Site continue to use the existing Project Site entrance and 2-lane Princes Highway.

The ability of the Project Site entrance to accommodate projected demand, and the effect of the additional demand on traffic conditions on Princes Highway, has been assessed using the INTANAL traffic model, and criteria for assessing the results of INTANAL analysis are set out in **Appendix 4**. In this case, the intersection of Princes Highway with the Project Site entrance has been modelled under the following conditions.

- Scenario 1 - Existing (2007) traffic flows on Princes Highway (2-lane), and the traffic generation of the existing quarry under the 85th percentile operating condition (**Table 12**).
- Scenario 2 - Existing (2007) traffic flows on Princes Highway (2-lane), and the projected traffic generation potential of the quarry with expanded extractive operations (**Table 13**).
- Scenario 3 - Projected (2017) traffic flows on Princes Highway (2-lane), and the projected traffic generation potential of the quarry with expanded extractive operations (**Table 14**).
- Scenario 4 – Projected (2017) Traffic flows and Princes Highway (4 lane) and the project traffic generation potential of the quarry with expanded extractive operations (**Table 15**).

The results of the INTANAL analysis are set out in **Tables 12**, **13**, **14** and **15**. The results of that analysis may be summarised as follows.

- Satisfactory intersection performance is indicated for existing (2007) traffic conditions on Princes Highway with the 85th percentile operating condition at the existing quarry, and the 85th percentile operating condition with the expanded extractive operations.
- Satisfactory intersection performance is also indicated for projected 2017 traffic conditions on Princes Highway and with the expanded quarry operation, although Level of Service “C” is indicated for the AM peak period. However, it can reasonably be anticipated that this section of Princes Highway will be amplified by 2017 in which case Princes Highway will be a four-lane divided road and quarry access will be restricted to left-turn/In/out only. The results of the INTANAL analysis of the intersection of Princes Highway and quarry access driveway under this road configuration and the expanded extractive operations are set out in **Table 15** revealing satisfactory intersection performance.

In the circumstances, it can be concluded that the continuation and expansion of extractive operations at the Nowra Brickworks Quarry will have no unacceptable traffic implications.

Table 12
Intanal Analysis – Scenario 1

Key Indicators		**AM**	**MIDDAY**	**PM**
Level of Service		B	A	A
Degree of Saturation		0.05	0.06	0.01
Average Vehicle Delay (secs/veh)				
Princes Highway (north)	T	0	0	0
	R	6.4	4.9	4.7
Site Access (west)	L	17.5	8.1	7.1
	R	0	12.4	12.3
Princes Highway (south)	L	2.9	2.9	0
	T	0	0	0
TOTAL AVERAGE VEHICLE DELAY		**12.7**	**7.1**	**8.1**

Note: See **Appendix 4** for criteria for interpreting the results of INTANAL analysis.

Table 13
Intanal Analysis – Scenario 2

Key Indicators		**AM**	**MIDDAY**	**PM**
Level of Service		B	A	A
Degree of Saturation		0.10	0.20	0.02
Average Vehicle Delay (secs/veh)				
Princes Highway (north)	T	0	0	0
	R	6.5	5.0	0
Site Access (west)	L	18.3	9.3	7.1
	R	0	13.4	12.4
Princes Highway (south)	L	2.9	2.9	0
	T	0	0	0
TOTAL AVERAGE VEHICLE DELAY		**12.7**	**8.0**	**8.9**

Note: See **Appendix 4** for criteria for interpreting the results of INTANAL analysis.

Table 14
Intanal Analysis – Scenario 3

Key Indicators		**AM**	**MIDDAY**	**PM**
Level of Service		C	B	B
Degree of Saturation		0.20	0.28	0.02
Average Vehicle Delay (secs/veh)				
Princes Highway (north)	T	0	0	0
	R	8.4	5.6	0
Site Access (west)	L	38.6	14.4	9.9
	R	0	20.9	18.6
Princes Highway (south)	L	2.9	2.9	0
	T	0	0	0
TOTAL AVERAGE VEHICLE DELAY		**24.9**	**11.7**	**12.8**

Note: See **Appendix 4** for criteria for interpreting the results of INTANAL analysis.

Table 15
Intanal Analysis – Scenario 4

Key Indicators		**AM**	**MIDDAY**	**PM**
Level of Service		A	A	A
Degree of Saturation		0.05	0.14	0.02
Average Vehicle Delay (secs/veh)				
Princes Highway (north)	T	0	0	0
Site Access (west)	L	10.9	6.7	5.6
Princes Highway (south)	L	2.9	2.9	0
	T	0	0	0
TOTAL AVERAGE VEHICLE DELAY		**7.4**	**5.5**	**5.6**

Note: See **Appendix 4** for criteria for interpreting the results of INTANAL analysis.

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APPENDICES

(No. of pages excluding this page = 8)

Appendix 1	**Results of Survey of Traffic Generation Characteristics of Existing Quarry**
Appendix 2	**Princes Highway, South Nowra – Traffic Growth and Projections**
Appendix 3	**Traffic Count Data**
Appendix 4	**Criteria for Interpreting Results of Intanal Analysis**

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Appendix 1

Results of Survey of Traffic Generation Characteristics of Existing Quarry

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R.O.A.R. DATA

Reliable, Original & Authentic Results

Ph.88196847, Fax 88196849, Mob.0418-239019

Client :John Coady Consulting
Job No/Name :2012 Nowra Princess Hwy
Day/Date :Monday 29th Oct 07

Cars / Vans

Time Per	NORTH Princess T	NORTH Princess R	WEST Quarry L	WEST Quarry R	SOUTH Princess L	SOUTH Princess T	TOT
0700 - 0715		1	0	0	0		1
0715 - 0730		0	0	0	0		0
0730 - 0745		0	1	0	0		1
0745 - 0800		1	0	0	0		1
0800 - 0815		0	2	0	0		2
0815 - 0830		1	0	0	0		1
0830 - 0845		2	2	0	0		4
0845 - 0900		0	1	0	0		1
0900 - 0915		0	0	0	0		0
0915 - 0930		1	0	0	0		1
0930 - 0945		0	0	0	0		0
0945 - 1000		1	1	0	0		2
1000 - 1015		0	0	0	0		0
1015 - 1030		0	0	0	0		0
1030 - 1045		0	1	0	0		1
1045 - 1100		0	0	0	1		1
1100 - 1115		0	0	0	0		0
1115 - 1130		0	0	0	0		0
1130 - 1145		1	0	0	1		2
1145 - 1200		0	0	0	0		0
1200 - 1215		0	1	0	0		1
1215 - 1230		0	0	0	0		0
1230 - 1245		0	1	0	0		1
1245 - 1300		0	0	0	0		0
1300 - 1315		0	0	0	0		0
1315 - 1330		0	0	0	0		0
1330 - 1345		0	0	0	1		1
1345 - 1400		0	0	0	0		0
1400 - 1415		0	0	0	0		0
1415 - 1430		1	1	0	0		2
1430 - 1445		1	0	0	0		1
1445 - 1500		2	1	0	0		3
1500 - 1515		0	0	0	0		0
1515 - 1530		0	0	0	0		0
1530 - 1545		0	0	0	0		0
1545 - 1600		0	0	0	0		0
1600 - 1615		0	0	0	0		0
1615 - 1630		0	0	0	0		0
1630 - 1645		0	0	0	0		0
1645 - 1700		0	2	1	0		3
1700 - 1715		0	0	0	0		0
1715 - 1730		0	1	0	0		1
1730 - 1745		0	0	0	0		0
1745 - 1800		0	0	0	0		0
1800 - 1815		0	0	0	0		0
1815 - 1830		0	0	0	0		0
1830 - 1845		0	0	0	0		0
1845 - 1900		0	0	0	0		0
Per End	0	12	15	1	3	0	31

2 Axle Trucks

Time Per	NORTH Princess T	NORTH Princess R	WEST Quarry L	WEST Quarry R	SOUTH Princess L	SOUTH Princess T	TOT
0700 - 0715		0	2	0	0		2
0715 - 0730		0	0	0	0		0
0730 - 0745		1	0	0	0		1
0745 - 0800		0	1	0	0		1
0800 - 0815		0	0	0	0		0
0815 - 0830		0	0	0	0		0
0830 - 0845		0	0	0	0		0
0845 - 0900		0	0	0	0		0
0900 - 0915		0	0	0	0		0
0915 - 0930		0	0	0	0		0
0930 - 0945		0	0	0	0		0
0945 - 1000		0	0	0	0		0
1000 - 1015		0	0	0	1		1
1015 - 1030		0	1	0	0		1
1030 - 1045		0	0	0	0		0
1045 - 1100		1	1	0	1		3
1100 - 1115		0	0	0	0		0
1115 - 1130		1	0	0	0		1
1130 - 1145		0	1	0	0		1
1145 - 1200		0	0	0	0		0
1200 - 1215		0	1	0	1		2
1215 - 1230		0	0	0	0		0
1230 - 1245		1	0	2	1		4
1245 - 1300		0	0	0	1		1
1300 - 1315		1	0	0	0		1
1315 - 1330		0	0	1	0		1
1330 - 1345		1	0	0	0		1
1345 - 1400		0	1	0	0		1
1400 - 1415		1	1	0	0		2
1415 - 1430		0	1	0	1		2
1430 - 1445		1	3	0	0		4
1445 - 1500		1	1	0	0		2
1500 - 1515		0	0	0	0		0
1515 - 1530		0	0	0	0		0
1530 - 1545		0	0	0	0		0
1545 - 1600		0	0	0	0		0
1600 - 1615		0	0	0	0		0
1615 - 1630		0	0	0	0		0
1630 - 1645		0	0	0	0		0
1645 - 1700		0	0	0	0		0
1700 - 1715		0	0	0	0		0
1715 - 1730		0	0	0	0		0
1730 - 1745		0	0	0	0		0
1745 - 1800		0	0	0	0		0
1800 - 1815		0	0	0	0		0
1815 - 1830		0	0	0	0		0
1830 - 1845		0	0	0	0		0
1845 - 1900		0	0	0	0		0
Per End	0	9	14	3	6	0	32

3+ Axle Trucks

Time Per	NORTH Princess Hwy T	NORTH Princess Hwy R	WEST Quarry L	WEST Quarry R	SOUTH Princess Hwy L	SOUTH Princess Hwy T	TOT
0700 - 0715		1	1	0	0		2
0715 - 0730		0	0	0	0		0
0730 - 0745		1	1	0	1		3
0745 - 0800		0	1	0	0		1
0800 - 0815		1	0	0	0		1
0815 - 0830		0	2	0	1		3
0830 - 0845		0	0	0	0		0
0845 - 0900		0	0	0	0		0
0900 - 0915		0	0	0	1		1
0915 - 0930		1	2	0	0		3
0930 - 0945		0	1	0	1		2
0945 - 1000		0	0	0	0		0
1000 - 1015		1	1	0	1		3
1015 - 1030		0	0	1	0		1
1030 - 1045		0	0	0	1		1
1045 - 1100		0	0	0	0		0
1100 - 1115		0	1	0	2		3
1115 - 1130		0	0	0	0		0
1130 - 1145		0	0	0	0		0
1145 - 1200		0	0	0	0		0
1200 - 1215		0	0	0	1		1
1215 - 1230		0	0	0	1		1
1230 - 1245		1	2	0	1		4
1245 - 1300		1	0	0	0		1
1300 - 1315		0	1	0	0		1
1315 - 1330		1	0	0	0		1
1330 - 1345		0	3	0	0		3
1345 - 1400		2	3	0	0		5
1400 - 1415		0	0	0	0		0
1415 - 1430		0	0	0	0		0
1430 - 1445		0	1	0	0		1
1445 - 1500		0	0	0	0		0
1500 - 1515		0	0	0	0		0
1515 - 1530		0	0	0	0		0
1530 - 1545		0	0	0	0		0
1545 - 1600		0	0	0	0		0
1600 - 1615		0	0	0	0		0
1615 - 1630		0	0	0	0		0
1630 - 1645		0	0	0	0		0
1645 - 1700		0	0	0	0		0
1700 - 1715		0	0	0	0		0
1715 - 1730		0	0	0	0		0
1730 - 1745		0	0	0	0		0
1745 - 1800		0	0	0	0		0
1800 - 1815		0	0	0	0		0
1815 - 1830		0	0	0	0		0
1830 - 1845		0	0	0	0		0
1845 - 1900		0	0	0	0		0
Per End	0	10	20	1	11	0	42

R.O.A.R. DATA

Reliable, Original & Authentic Results

Ph.88196847, Fax 88196849, Mob.0418-239019

Client :John Coady Consulting
Job No/Name :2012 Nowra Princess Hwy
Day/Date :Monday 29th Oct 07

Cars / Vans

	NORTH		WEST		SOUTH		
	Princess		*Quarry*		*Princess*		
Peak Per	T	R	L	R	L	T	TOT
0700 - 0800		2	1	0	0		3
0715 - 0815		1	3	0	0		4
0730 - 0830		2	3	0	0		5
0745 - 0845		4	4	0	0		8
0800 - 0900		3	5	0	0		8
0815 - 0915		3	3	0	0		6
0830 - 0930		3	3	0	0		6
0845 - 0945		1	1	0	0		2
0900 - 1000		2	1	0	0		3
0915 - 1015		2	1	0	0		3
0930 - 1030		1	1	0	0		2
0945 - 1045		1	2	0	0		3
1000 - 1100		0	1	0	1		2
1015 - 1115		0	1	0	1		2
1030 - 1130		0	1	0	1		2
1045 - 1145		1	0	0	2		3
1100 - 1200		1	0	0	1		2
1115 - 1215		1	1	0	1		3
1130 - 1230		1	1	0	1		3
1145 - 1245		0	2	0	0		2
1200 - 1300		0	2	0	0		2
1215 - 1315		0	1	0	0		1
1230 - 1330		0	1	0	0		1
1245 - 1345		0	0	0	1		1
1300 - 1400		0	0	0	1		1
1315 - 1415		0	0	0	1		1
1330 - 1430		1	1	0	1		3
1345 - 1445		2	1	0	0		3
1400 - 1500		4	2	0	0		6
1415 - 1515		4	2	0	0		6
1430 - 1530		3	1	0	0		4
1445 - 1545		2	1	0	0		3
1500 - 1600		0	0	0	0		0
1515 - 1615		0	0	0	0		0
1530 - 1630		0	0	0	0		0
1545 - 1645		0	0	0	0		0
1600 - 1700		0	2	1	0		3
1615 - 1715		0	2	1	0		3
1630 - 1730		0	3	1	0		4
1645 - 1745		0	3	1	0		4
1700 - 1800		0	1	0	0		1
1715 - 1815		0	1	0	0		1
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		0	0	0	1		1

2 Axle Trucks

	NORTH		WEST		SOUTH		
	Princess		*Quarry*		*Princess*		
Peak Per	T	R	L	R	L	T	TOT
0700 - 0800		1	3	0	0		4
0715 - 0815		1	1	0	0		2
0730 - 0830		1	1	0	0		2
0745 - 0845		0	1	0	0		1
0800 - 0900		0	0	0	0		0
0815 - 0915		0	0	0	0		0
0830 - 0930		0	0	0	0		0
0845 - 0945		0	0	0	0		0
0900 - 1000		0	0	0	0		0
0915 - 1015		0	0	0	1		1
0930 - 1030		0	1	0	1		2
0945 - 1045		0	1	0	1		2
1000 - 1100		1	2	0	2		5
1015 - 1115		1	2	0	1		4
1030 - 1130		2	1	0	1		4
1045 - 1145		2	2	0	1		5
1100 - 1200		1	1	0	0		2
1115 - 1215		1	2	0	1		4
1130 - 1230		0	2	0	1		3
1145 - 1245		1	1	2	2		6
1200 - 1300		1	1	2	3		7
1215 - 1315		2	0	2	2		6
1230 - 1330		2	0	3	2		7
1245 - 1345		2	0	1	1		4
1300 - 1400		2	1	1	0		4
1315 - 1415		2	2	1	0		5
1330 - 1430		2	3	0	1		6
1345 - 1445		2	6	0	1		9
1400 - 1500		3	6	0	1		10
1415 - 1515		2	5	0	1		8
1430 - 1530		2	4	0	0		6
1445 - 1545		1	1	0	0		2
1500 - 1600		0	0	0	0		0
1515 - 1615		0	0	0	0		0
1530 - 1630		0	0	0	0		0
1545 - 1645		0	0	0	0		0
1600 - 1700		0	0	0	0		0
1615 - 1715		0	0	0	0		0
1630 - 1730		0	0	0	0		0
1645 - 1745		0	0	0	0		0
1700 - 1800		0	0	0	0		0
1715 - 1815		0	0	0	0		0
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		2	1	1	0		4

3+ Axle Trucks

	NORTH		WEST		SOUTH		
	Princess Hwy		*Quarry*		*Princess Hwy*		
Peak Per	T	R	L	R	L	T	TOT
0700 - 0800		2	3	0	1		6
0715 - 0815		2	2	0	1		5
0730 - 0830		2	4	0	2		8
0745 - 0845		1	3	0	1		5
0800 - 0900		1	2	0	1		4
0815 - 0915		0	2	0	2		4
0830 - 0930		1	2	0	1		4
0845 - 0945		1	3	0	2		6
0900 - 1000		1	3	0	2		6
0915 - 1015		2	4	0	2		8
0930 - 1030		1	2	1	2		6
0945 - 1045		1	1	1	2		5
1000 - 1100		1	1	1	2		5
1015 - 1115		0	1	1	3		5
1030 - 1130		0	1	0	3		4
1045 - 1145		0	1	0	2		3
1100 - 1200		0	1	0	2		3
1115 - 1215		0	0	0	1		1
1130 - 1230		0	0	0	2		2
1145 - 1245		1	2	0	3		6
1200 - 1300		2	2	0	3		7
1215 - 1315		2	3	0	2		7
1230 - 1330		3	3	0	1		7
1245 - 1345		2	4	0	0		6
1300 - 1400		3	7	0	0		10
1315 - 1415		3	6	0	0		9
1330 - 1430		2	6	0	0		8
1345 - 1445		2	4	0	0		6
1400 - 1500		0	1	0	0		1
1415 - 1515		0	1	0	0		1
1430 - 1530		0	1	0	0		1
1445 - 1545		0	0	0	0		0
1500 - 1600		0	0	0	0		0
1515 - 1615		0	0	0	0		0
1530 - 1630		0	0	0	0		0
1545 - 1645		0	0	0	0		0
1600 - 1700		0	0	0	0		0
1615 - 1715		0	0	0	0		0
1630 - 1730		0	0	0	0		0
1645 - 1745		0	0	0	0		0
1700 - 1800		0	0	0	0		0
1715 - 1815		0	0	0	0		0
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		3	7	0	0		10

R.O.A.R. DATA

Reliable, Original & Authentic Results

Ph.88196847, Fax 88196849, Mob.0418-239019

Client :John Coady Consulting
Job No/Name :2012 Nowra Princess Hwy
Day/Date :Monday 29th Oct 07

Articulated

	NORTH		WEST		SOUTH		
	Princess		*Quarry*		*Princess*		
Time Per	T	R	L	R	L	T	TOT
0700 - 0715		0	0	0	0		**0**
0715 - 0730		0	0	0	0		**0**
0730 - 0745		0	0	0	0		**0**
0745 - 0800		0	0	0	0		**0**
0800 - 0815		0	0	0	0		**0**
0815 - 0830		0	0	0	0		**0**
0830 - 0845		0	0	0	0		**0**
0845 - 0900		0	0	0	0		**0**
0900 - 0915		0	0	0	0		**0**
0915 - 0930		1	0	0	0		**1**
0930 - 0945		0	0	0	0		**0**
0945 - 1000		0	0	0	1		**1**
1000 - 1015		0	1	0	0		**1**
1015 - 1030		0	0	0	0		**0**
1030 - 1045		1	0	0	0		**1**
1045 - 1100		0	0	0	0		**0**
1100 - 1115		0	0	0	1		**1**
1115 - 1130		0	2	0	0		**2**
1130 - 1145		0	0	0	0		**0**
1145 - 1200		1	0	0	0		**1**
1200 - 1215		0	1	0	0		**1**
1215 - 1230		0	0	0	0		**0**
1230 - 1245		0	1	0	0		**1**
1245 - 1300		1	0	0	0		**1**
1300 - 1315		0	1	0	1		**2**
1315 - 1330		1	1	0	0		**2**
1330 - 1345		1	1	0	0		**2**
1345 - 1400		0	1	0	0		**1**
1400 - 1415		1	0	0	0		**1**
1415 - 1430		0	0	0	1		**1**
1430 - 1445		1	0	0	0		**1**
1445 - 1500		0	1	0	0		**1**
1500 - 1515		1	1	0	0		**2**
1515 - 1530		0	1	0	0		**1**
1530 - 1545		1	0	0	0		**1**
1545 - 1600		1	0	0	0		**1**
1600 - 1615		0	2	0	0		**2**
1615 - 1630		0	0	1	0		**1**
1630 - 1645		0	0	0	0		**0**
1645 - 1700		0	0	0	0		**0**
1700 - 1715		0	0	0	0		**0**
1715 - 1730		0	0	0	0		**0**
1730 - 1745		0	0	0	0		**0**
1745 - 1800		0	0	0	0		**0**
1800 - 1815		0	0	0	0		**0**
1815 - 1830		0	0	0	0		**0**
1830 - 1845		0	0	0	0		**0**
1845 - 1900		0	0	0	0		**0**
Per End		**11**	**14**	**1**	**4**		**30**

B-Double

	NORTH		WEST		SOUTH		
	Princess		*Quarry*		*Princess*		
Time Per	T	R	L	R	L	T	TOT
0700 - 0715		0	0	0	0		**0**
0715 - 0730		0	0	0	0		**0**
0730 - 0745		0	0	0	0		**0**
0745 - 0800		0	0	0	0		**0**
0800 - 0815		0	0	0	0		**0**
0815 - 0830		0	0	0	0		**0**
0830 - 0845		0	0	0	0		**0**
0845 - 0900		0	0	0	0		**0**
0900 - 0915		0	0	0	0		**0**
0915 - 0930		0	0	0	0		**0**
0930 - 0945		0	0	0	0		**0**
0945 - 1000		0	0	0	0		**0**
1000 - 1015		0	0	0	0		**0**
1015 - 1030		0	0	0	0		**0**
1030 - 1045		0	0	0	0		**0**
1045 - 1100		0	0	0	0		**0**
1100 - 1115		0	0	0	0		**0**
1115 - 1130		0	0	0	0		**0**
1130 - 1145		0	0	0	0		**0**
1145 - 1200		0	0	0	0		**0**
1200 - 1215		0	0	0	0		**0**
1215 - 1230		0	0	0	0		**0**
1230 - 1245		0	0	0	0		**0**
1245 - 1300		0	0	0	0		**0**
1300 - 1315		0	0	0	0		**0**
1315 - 1330		0	0	0	0		**0**
1330 - 1345		0	0	0	0		**0**
1345 - 1400		0	0	0	0		**0**
1400 - 1415		0	0	0	0		**0**
1415 - 1430		0	0	0	0		**0**
1430 - 1445		0	0	0	0		**0**
1445 - 1500		0	0	0	0		**0**
1500 - 1515		0	0	0	0		**0**
1515 - 1530		0	0	0	0		**0**
1530 - 1545		0	0	0	0		**0**
1545 - 1600		0	0	0	0		**0**
1600 - 1615		0	0	0	0		**0**
1615 - 1630		0	0	0	0		**0**
1630 - 1645		0	0	0	0		**0**
1645 - 1700		0	0	0	0		**0**
1700 - 1715		0	0	0	0		**0**
1715 - 1730		0	0	0	0		**0**
1730 - 1745		0	0	0	0		**0**
1745 - 1800		0	0	0	0		**0**
1800 - 1815		0	0	0	0		**0**
1815 - 1830		0	0	0	0		**0**
1830 - 1845		0	0	0	0		**0**
1845 - 1900		0	0	0	0		**0**
Per End		**0**	**0**	**0**	**0**		**0**

Combined

	NORTH		WEST		SOUTH		
	Princess Hwy		*Quarry*		*Princess Hwy*		
Time Per	T	R	L	R	L	T	TOT
0700 - 0715		2	3	0	0		**5**
0715 - 0730		0	0	0	0		**0**
0730 - 0745		2	2	0	1		**5**
0745 - 0800		1	2	0	0		**3**
0800 - 0815		1	2	0	0		**3**
0815 - 0830		1	2	0	1		**4**
0830 - 0845		2	2	0	0		**4**
0845 - 0900		0	1	0	0		**1**
0900 - 0915		0	0	0	1		**1**
0915 - 0930		3	2	0	0		**5**
0930 - 0945		0	1	0	1		**2**
0945 - 1000		1	1	0	1		**3**
1000 - 1015		1	2	0	2		**5**
1015 - 1030		0	1	1	0		**2**
1030 - 1045		1	1	0	1		**3**
1045 - 1100		1	1	0	2		**4**
1100 - 1115		0	1	0	3		**4**
1115 - 1130		1	2	0	0		**3**
1130 - 1145		1	1	0	1		**3**
1145 - 1200		1	0	0	0		**1**
1200 - 1215		0	3	0	2		**5**
1215 - 1230		0	0	0	1		**1**
1230 - 1245		2	4	2	2		**10**
1245 - 1300		2	0	0	1		**3**
1300 - 1315		1	2	0	1		**4**
1315 - 1330		2	1	1	0		**4**
1330 - 1345		2	4	0	1		**7**
1345 - 1400		2	5	0	0		**7**
1400 - 1415		2	1	0	0		**3**
1415 - 1430		1	2	0	2		**5**
1430 - 1445		3	4	0	0		**7**
1445 - 1500		3	3	0	0		**6**
1500 - 1515		1	1	0	0		**2**
1515 - 1530		0	1	0	0		**1**
1530 - 1545		1	0	0	0		**1**
1545 - 1600		1	0	0	0		**1**
1600 - 1615		0	2	0	0		**2**
1615 - 1630		0	0	1	0		**1**
1630 - 1645		0	0	0	0		**0**
1645 - 1700		0	2	1	0		**3**
1700 - 1715		0	0	0	0		**0**
1715 - 1730		0	1	0	0		**1**
1730 - 1745		0	0	0	0		**0**
1745 - 1800		0	0	0	0		**0**
1800 - 1815		0	0	0	0		**0**
1815 - 1830		0	0	0	0		**0**
1830 - 1845		0	0	0	0		**0**
1845 - 1900		0	0	0	0		**0**
Per End		**42**	**63**	**6**	**24**		**135**

R.O.A.R. DATA

Reliable, Original & Authentic Results

Ph.88196847, Fax 88196849, Mob.0418-239019

Client :John Coady Consulting
Job No/Name :2012 Nowra Princess Hwy
Day/Date :Monday 29th Oct 07

Articulated

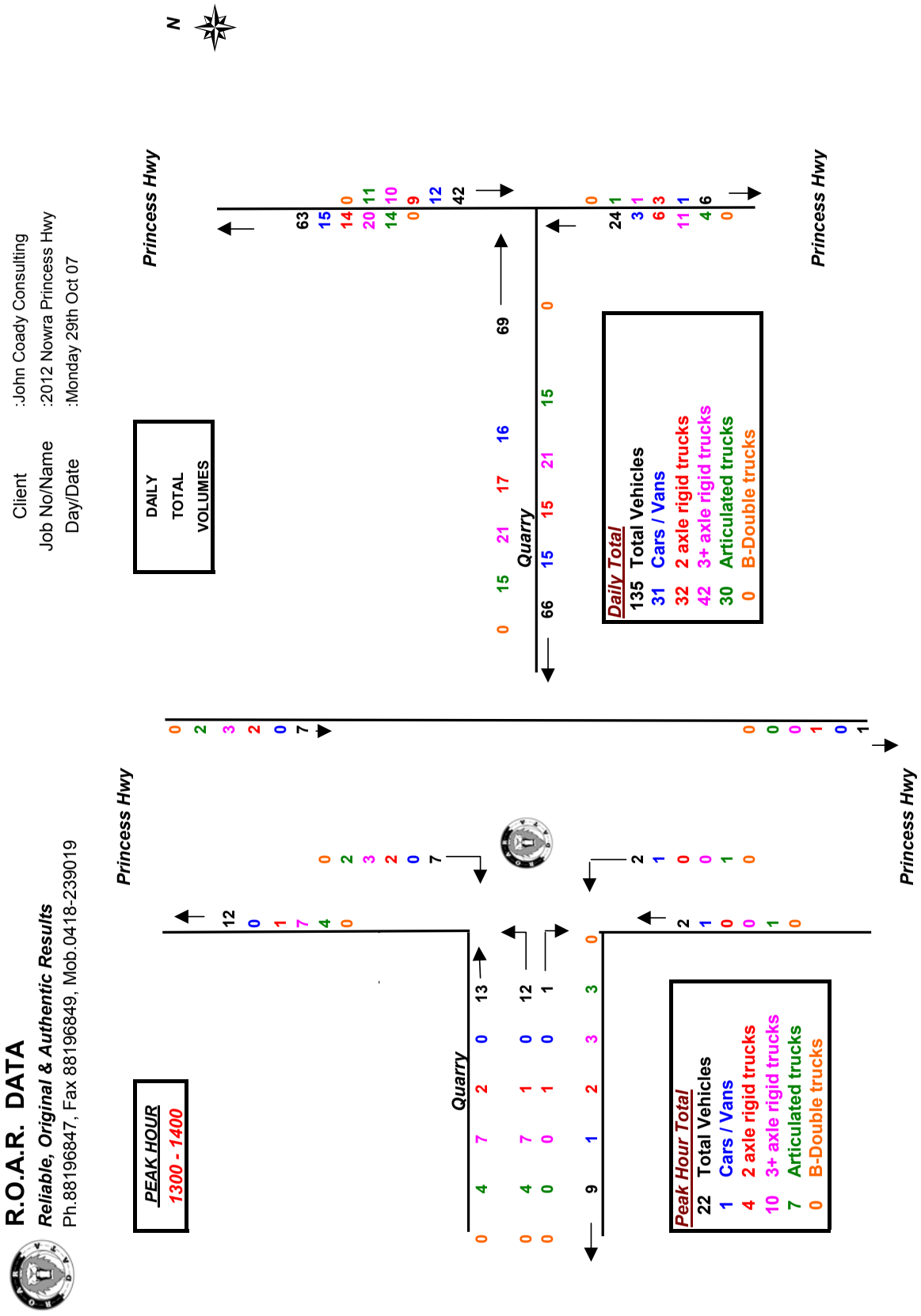
Peak Per	NORTH Princess T	NORTH Princess R	WEST Quarry L	WEST Quarry R	SOUTH Princess L	SOUTH Princess T	TOT
0700 - 0800		0	0	0	0		0
0715 - 0815		0	0	0	0		0
0730 - 0830		0	0	0	0		0
0745 - 0845		0	0	0	0		0
0800 - 0900		0	0	0	0		0
0815 - 0915		0	0	0	0		0
0830 - 0930		1	0	0	0		1
0845 - 0945		1	0	0	0		1
0900 - 1000		1	0	0	1		2
0915 - 1015		1	1	0	1		3
0930 - 1030		0	1	0	1		2
0945 - 1045		1	1	0	1		3
1000 - 1100		1	1	0	0		2
1015 - 1115		1	0	0	1		2
1030 - 1130		1	2	0	1		4
1045 - 1145		0	2	0	1		3
1100 - 1200		1	2	0	1		4
1115 - 1215		1	3	0	0		4
1130 - 1230		1	1	0	0		2
1145 - 1245		1	2	0	0		3
1200 - 1300		1	2	0	0		3
1215 - 1315		1	2	0	1		4
1230 - 1330		2	3	0	1		6
1245 - 1345		3	3	0	1		7
1300 - 1400		2	4	0	1		7
1315 - 1415		3	3	0	0		6
1330 - 1430		2	2	0	1		5
1345 - 1445		2	1	0	1		4
1400 - 1500		2	1	0	1		4
1415 - 1515		2	2	0	1		5
1430 - 1530		2	3	0	0		5
1445 - 1545		2	3	0	0		5
1500 - 1600		3	2	0	0		5
1515 - 1615		2	3	0	0		5
1530 - 1630		2	2	1	0		5
1545 - 1645		1	2	1	0		4
1600 - 1700		0	2	1	0		3
1615 - 1715		0	0	1	0		1
1630 - 1730		0	0	0	0		0
1645 - 1745		0	0	0	0		0
1700 - 1800		0	0	0	0		0
1715 - 1815		0	0	0	0		0
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		**2**	**4**	**0**	**1**		**7**

B-Double

Peak Per	NORTH Princess T	NORTH Princess R	WEST Quarry L	WEST Quarry R	SOUTH Princess L	SOUTH Princess T	TOT
0700 - 0800		0	0	0	0		0
0715 - 0815		0	0	0	0		0
0730 - 0830		0	0	0	0		0
0745 - 0845		0	0	0	0		0
0800 - 0900		0	0	0	0		0
0815 - 0915		0	0	0	0		0
0830 - 0930		0	0	0	0		0
0845 - 0945		0	0	0	0		0
0900 - 1000		0	0	0	0		0
0915 - 1015		0	0	0	0		0
0930 - 1030		0	0	0	0		0
0945 - 1045		0	0	0	0		0
1000 - 1100		0	0	0	0		0
1015 - 1115		0	0	0	0		0
1030 - 1130		0	0	0	0		0
1045 - 1145		0	0	0	0		0
1100 - 1200		0	0	0	0		0
1115 - 1215		0	0	0	0		0
1130 - 1230		0	0	0	0		0
1145 - 1245		0	0	0	0		0
1200 - 1300		0	0	0	0		0
1215 - 1315		0	0	0	0		0
1230 - 1330		0	0	0	0		0
1245 - 1345		0	0	0	0		0
1300 - 1400		0	0	0	0		0
1315 - 1415		0	0	0	0		0
1330 - 1430		0	0	0	0		0
1345 - 1445		0	0	0	0		0
1400 - 1500		0	0	0	0		0
1415 - 1515		0	0	0	0		0
1430 - 1530		0	0	0	0		0
1445 - 1545		0	0	0	0		0
1500 - 1600		0	0	0	0		0
1515 - 1615		0	0	0	0		0
1530 - 1630		0	0	0	0		0
1545 - 1645		0	0	0	0		0
1600 - 1700		0	0	0	0		0
1615 - 1715		0	0	0	0		0
1630 - 1730		0	0	0	0		0
1645 - 1745		0	0	0	0		0
1700 - 1800		0	0	0	0		0
1715 - 1815		0	0	0	0		0
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		**0**	**0**	**0**	**0**		**0**

Combined

Peak Per	NORTH Princess Hwy T	NORTH Princess Hwy R	WEST Quarry L	WEST Quarry R	SOUTH Princess Hwy L	SOUTH Princess Hwy T	TOT
0700 - 0800		5	7	0	1		13
0715 - 0815		4	6	0	1		11
0730 - 0830		5	8	0	2		15
0745 - 0845		5	8	0	1		14
0800 - 0900		4	7	0	1		12
0815 - 0915		3	5	0	2		10
0830 - 0930		5	5	0	1		11
0845 - 0945		3	4	0	2		9
0900 - 1000		4	4	0	3		11
0915 - 1015		5	6	0	4		15
0930 - 1030		2	5	1	4		12
0945 - 1045		3	5	1	4		13
1000 - 1100		3	5	1	5		14
1015 - 1115		2	4	1	6		13
1030 - 1130		3	5	0	6		14
1045 - 1145		3	5	0	6		14
1100 - 1200		3	4	0	4		11
1115 - 1215		3	6	0	3		12
1130 - 1230		2	4	0	4		10
1145 - 1245		3	7	2	5		17
1200 - 1300		4	7	2	6		19
1215 - 1315		5	6	2	5		18
1230 - 1330		7	7	3	4		21
1245 - 1345		7	7	1	3		18
1300 - 1400		7	12	1	2		22
1315 - 1415		8	11	1	1		21
1330 - 1430		7	12	0	3		22
1345 - 1445		8	12	0	2		22
1400 - 1500		9	10	0	2		21
1415 - 1515		8	10	0	2		20
1430 - 1530		7	9	0	0		16
1445 - 1545		5	5	0	0		10
1500 - 1600		3	2	0	0		5
1515 - 1615		2	3	0	0		5
1530 - 1630		2	2	1	0		5
1545 - 1645		1	2	1	0		4
1600 - 1700		0	4	2	0		6
1615 - 1715		0	2	2	0		4
1630 - 1730		0	3	1	0		4
1645 - 1745		0	3	1	0		4
1700 - 1800		0	1	0	0		1
1715 - 1815		0	1	0	0		1
1730 - 1830		0	0	0	0		0
1745 - 1845		0	0	0	0		0
1800 - 1900		0	0	0	0		0
PEAK HR		**7**	**12**	**1**	**2**		**22**


R.O.A.R. DATA
Reliable, Original & Authentic Results
Ph.88196847, Fax 88196849, Mob.0418-239019
Client :John Coady Consulting
Job No/Name :2012 Nowra Princess Hwy
Day/Date :Monday 29th Oct 07
DAILY TOTAL VOLUMES
PEAK HOUR 1300 - 1400
Princess Hwy
Quarry
Daily Total
135 Total Vehicles
31 Cars / Vans
32 2 axle rigid trucks
42 3+ axle rigid trucks
30 Articulated trucks
0 B-Double trucks
Peak Hour Total
22 Total Vehicles
1 Cars / Vans
4 2 axle rigid trucks
10 3+ axle rigid trucks
7 Articulated trucks
0 B-Double trucks

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Appendix 2

Princes Highway, South Nowra Traffic Growth and Projections

(No of pages excluding this page = 1)

Princes Highway, South Nowra

Traffic Growth and 10 Year Projections

Station 07.707 - At Browns Creek Bridge (3.5% increase per annum)

Year	Recorded AADT	Projected AADT
1997	21443	21443
1998		22194
1999		22970
2000	23144	23774
2001		24606
2002		25468
2003	26366	26359
2004		27281
2005		28236
2006		29225
2007		30247
2008		31306
2009		32402
2010		33536
2011		34710
2012		35925
2013		37182
2014		38483
2015		39830
2016		41224
2017		42667

Appendix 3

Traffic Count Data

(No of pages excluding this page = 1)

R.O.A.R. DATA
Reliable, Original & Authentic Results
Ph.88196847, Fax 88196849, Mob.0418-239019

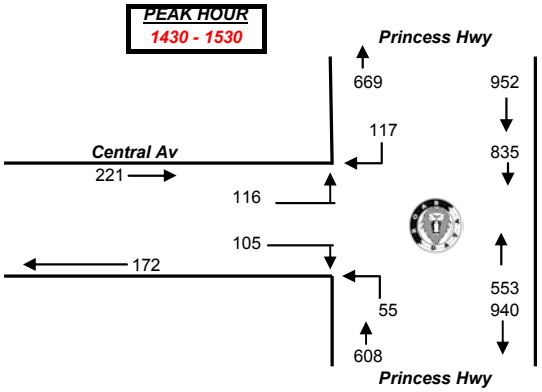
Client : John Coady Consulting
Job No/Name : 2012 Nowra Princess Hwy
Day/Date : Monday 29th October 2007

All Vehicles

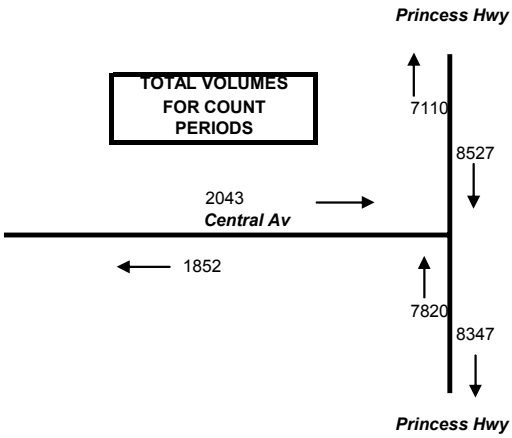
	WEST		NORTH		SOUTH		
	Central Av		*Princess Hwy*		*Princess Hwy*		
Time Per	**L**	**R**	**R**	**T**	**L**	**T**	**TOTAL**
0700 - 0715	12	17	9	102	6	151	**297**
0715 - 0730	13	16	14	84	16	180	**323**
0730 - 0745	9	12	9	94	11	197	**332**
0745 - 0800	8	12	6	96	15	258	**395**
0800 - 0815	7	5	25	99	17	276	**429**
0815 - 0830	12	14	19	114	13	289	**461**
0830 - 0845	10	14	18	119	21	261	**443**
0845 - 0900	9	10	30	105	7	230	**391**
0900 - 0915	15	6	36	114	25	243	**439**
0915 - 0930	29	12	43	115	22	200	**421**
0930 - 0945	21	15	28	116	12	186	**378**
0945 - 1000	17	14	23	184	43	137	**418**
1000 - 1015	30	17	22	114	15	136	**334**
1015 - 1030	26	13	17	137	16	158	**367**
1030 - 1045	19	15	27	131	21	162	**375**
1045 - 1100	23	12	34	133	24	184	**410**
1100 - 1115	25	9	35	118	21	147	**355**
1115 - 1130	51	10	38	141	19	170	**429**
1130 - 1145	34	20	42	131	13	124	**364**
1145 - 1200	39	18	18	134	20	169	**398**
1200 - 1215	23	22	35	152	14	150	**396**
1215 - 1230	26	17	27	127	24	140	**361**
1230 - 1245	26	15	24	143	17	120	**345**
1245 - 1300	36	24	42	169	12	110	**393**
1300 - 1315	36	28	40	202	13	157	**476**
1315 - 1330	35	21	32	154	14	121	**377**
1330 - 1345	11	14	14	160	30	100	**329**
1345 - 1400	30	22	37	140	18	137	**384**
1400 - 1415	25	25	29	177	13	131	**400**
1415 - 1430	27	26	27	177	21	143	**421**
1430 - 1445	36	32	31	210	13	126	**448**
1445 - 1500	26	24	27	190	13	154	**434**
1500 - 1515	36	23	25	220	14	133	**451**
1515 - 1530	18	26	34	215	15	140	**448**
1530 - 1545	20	31	30	208	15	130	**434**
1545 - 1600	13	15	23	220	16	120	**407**
1600 - 1615	25	35	25	198	14	138	**435**
1615 - 1630	27	28	28	200	11	115	**409**
1630 - 1645	29	35	36	204	11	104	**419**
1645 - 1700	33	38	28	224	13	112	**448**
1700 - 1715	32	42	21	246	18	115	**474**
1715 - 1730	28	35	10	219	8	125	**425**
1730 - 1745	32	48	10	201	3	74	**368**
1745 - 1800	23	27	5	186	4	99	**344**
1800 - 1815	12	24	1	174	2	67	**280**
1815 - 1830	4	11	1	129	1	75	**221**
1830 - 1845	2	7	4	97	3	68	**181**
1845 - 1900	1	6	3	62	3	48	**123**
Period End	**1081**	**962**	**1142**	**7385**	**710**	**7110**	**18390**

	WEST		NORTH		SOUTH		
	Central Av		*Princess Hwy*		*Princess Hwy*		
Peak Per	**L**	**R**	**R**	**T**	**L**	**T**	**TOTAL**
0700 - 0800	42	57	38	376	48	786	**1347**
0715 - 0815	37	45	54	373	59	911	**1479**
0730 - 0830	36	43	59	403	56	1020	**1617**
0745 - 0845	37	45	68	428	66	1084	**1728**
0800 - 0900	38	43	92	437	58	1056	**1724**
0815 - 0915	46	44	103	452	66	1023	**1734**
0830 - 0930	63	42	127	453	75	934	**1694**
0845 - 0945	74	43	137	450	66	859	**1629**
0900 - 1000	82	47	130	529	102	766	**1656**
0915 - 1015	97	58	116	529	92	659	**1551**
0930 - 1030	94	59	90	551	86	617	**1497**
0945 - 1045	92	59	89	566	95	593	**1494**
1000 - 1100	98	57	100	515	76	640	**1486**
1015 - 1115	93	49	113	519	82	651	**1507**
1030 - 1130	118	46	134	523	85	663	**1569**
1045 - 1145	133	51	149	523	77	625	**1558**
1100 - 1200	149	57	133	524	73	610	**1546**
1115 - 1215	147	70	133	558	66	613	**1587**
1130 - 1230	122	77	122	544	71	583	**1519**
1145 - 1245	114	72	104	556	75	579	**1500**
1200 - 1300	111	78	128	591	67	520	**1495**
1215 - 1315	124	84	133	641	66	527	**1575**
1230 - 1330	133	88	138	668	56	508	**1591**
1245 - 1345	118	87	128	685	69	488	**1575**
1300 - 1400	112	85	123	656	75	515	**1566**
1315 - 1415	101	82	112	631	75	489	**1490**
1330 - 1430	93	87	107	654	82	511	**1534**
1345 - 1445	118	105	124	704	65	537	**1653**
1400 - 1500	114	107	114	754	60	554	**1703**
1415 - 1515	125	105	110	797	61	556	**1754**
1430 - 1530	116	105	117	835	55	553	**1781**
1445 - 1545	100	104	116	833	57	557	**1767**
1500 - 1600	87	95	112	863	60	523	**1740**
1515 - 1615	76	107	112	841	60	528	**1724**
1530 - 1630	85	109	106	826	56	503	**1685**
1545 - 1645	94	113	112	822	52	477	**1670**
1600 - 1700	114	136	117	826	49	469	**1711**
1615 - 1715	121	143	113	874	53	446	**1750**
1630 - 1730	122	150	95	893	50	456	**1766**
1645 - 1745	125	163	69	890	42	426	**1715**
1700 - 1800	115	152	46	852	33	413	**1611**
1715 - 1815	95	134	26	780	17	365	**1417**
1730 - 1830	71	110	17	690	10	315	**1213**
1745 - 1845	41	69	11	586	10	309	**1026**
1800 - 1900	19	48	9	462	9	258	**805**
PEAK HR	**116**	**105**	**117**	**835**	**55**	**553**	**1781**

PEAK HOUR
1430 - 1530



TOTAL VOLUMES FOR COUNT PERIODS



Appendix 4

Criteria for Interpreting Results of Intanal Analysis

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Criteria for Interpreting Results of Intanal Analysis

1. Level of Service (LOS)

LOS	Traffic Signals and Roundabouts	Give Way and Stop Signs
'A'	Good operation.	Good operation.
'B'	Good with acceptable delays and spare capacity.	Acceptable delays and spare capacity.
'C'	Satisfactory.	Satisfactory but accident study required.
'D'	Operating near capacity.	Near capacity and accident study required.
'E'	At capacity; at signals incidents will cause excessive delays. Roundabouts require other control mode.	At capacity and requires other control mode.
'F'	Unsatisfactory and requires additional capacity.	Unsatisfactory and requires other control mode.

2. Average Vehicle Delay (AVD)

The AVD provides a measure of the operational performance of an intersection as indicated on the table below which relates AVD to LOS. The AVD=s listed in the table should be taken as a guide only as longer delays could be tolerated in some locations (ie inner city conditions) and on some roads (ie minor side street intersecting with a major arterial route).

Level of Service	Average Delay per Vehicle (secs/veh)	Traffic Signals, Roundabout	Give Way and Stop Signs
A	less than 14	Good operation.	Good operation.
B	15 to 28	Good with acceptable delays and spare capacity.	Acceptable delays and spare capacity.
C	29 to 42	Satisfactory.	Satisfactory but accident study required.
D	43 to 56	Operating near capacity.	Near capacity and accident study required.
E	57 to 70	At capacity; at signals incidents will cause excessive delays. Roundabouts require other control mode.	At capacity and requires other control mode.

3. Degree of Saturation (DS)

The DS is another measure of the operational performance of individual intersections.

For intersections controlled by traffic signals[2] both queue length and delay increase rapidly as DS approaches 1, and it is usual to attempt to keep DS to less than 0.9. Values of DS in the order of 0.7 generally represent satisfactory intersection operation. When DS exceeds 0.9 queues can be anticipated.

For intersections controlled by a roundabout or GIVE WAY or STOP signs, satisfactory intersection operation is indicated by a DS of 0.8 or less.

---

[2] *The values of DS for intersections under traffic signal control are only valid for cycle length of 120 secs.*

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Air Quality Assessment

Prepared by

Heggies Pty Ltd

December, 2007

Specialist Consultant Studies Compendium:
Part 4

Air Quality Assessment

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

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CONTENTS

Page

EXECUTIVE SUMMARY 4-7
1 INTRODUCTION 4-11
1.1 Background 4-11
1.2 Phase 1 Air Quality Assessment 4-11
1.3 Air Quality Assessment 4-12
1.4 Project Location and Sensitive Receptors 4-12
2 RECEIVING ENVIRONMENT 4-14
2.1 Air Quality Criteria 4-14
2.1.1 Introduction 4-14
2.1.2 Suspended Particulate Concentrations 4-15
2.1.3 Dust Deposition Criteria 4-17
2.1.4 Project Specific Air Quality Criteria 4-17
2.2 Climatology and Meteorology 4-18
2.2.1 Introduction 4-18
2.2.2 Ambient Temperature and Sunshine Incidence 4-18
2.2.3 Rainfall, Relative Humidity and Evaporation 4-19
2.2.4 Prevailing Wind Regime 4-20
2.2.5 TAPM Simulation of Atmospheric Stability and Mixing Layer Depth 4-23
2.3 Existing Sources of Atmospheric Emissions 4-25
2.3.1 Current SCCCR Operations 4-25
2.3.2 Sources of Atmospheric Emissions unrelated to SCCCR Operations 4-30
2.4 Monitored Ambient Air Quality 4-34
2.4.1 Introduction 4-34
2.4.2 Airborne PM10 Concentrations 4-34
2.4.3 PM2.5 Concentrations 4-37
2.4.4 Dust Deposition Monitoring 4-37
2.5 Background Air Quality for Cumulative Assessment Purposes 4-39
3 EMISSIONS INVENTORY FOR QUARRY OPERATIONS 4-39
3.1 Introduction 4-39
3.2 Emissions from Current Quarry Operations 4-39
3.3 Proposed Quarry Expansion 4-41
3.3.1 Introduction 4-41
3.3.2 Quarry Expansion Overview 4-41
3.3.3 Scenarios Selected for Emissions Inventory and Modelling 4-42
3.3.4 Emissions from Proposed Quarry Operations 4-45
4 DISPERSION MODELLING METHODOLOGY AND RESULTS 4-46
4.1 Dispersion Model Selection and Application 4-46
4.1.1 Meteorological Data Inputs 4-46
4.1.2 Modelling Domain and Receptor Grid 4-49
4.2 Model Results 4-49
5 AIR QUALITY ASSESSMENT 4-56
5.1 Introduction 4-56
5.2 Compliance with Ambient Air Quality Criteria 4-56
5.2.1 Current Quarry Operations 4-56
5.2.2 Future Quarry Operations – Scenario 1, Current Dust Controls 4-56
5.2.3 Future Quarry Operations – Scenario 2, Additional Dust Controls 4-57
5.3 Potential for Dust Impacts on Vegetation and Livestock 4-57

CONTENTS

Page

6 CONCLUSIONS AND RECOMMENDATIONS 4-58
6.1 Main Study Findings 4-58
6.1.1 Baseline Environment and Current Quarry Operations 4-58
6.1.2 Proposed Future Quarry Operations (Maximum Production) 4-59
6.2 Recommendations 4-60
7 REFERENCES 4-62

FIGURES

Figure 1 SCCCR Site and Surrounding Landuses 4-13
Figure 2 Butchery situated directly across the Princes Highway, opposite the SCCCR's main gate 4-15
Figure 3 Commercial activity situated across the road from the SCCCR site 4-15
Figure 4 Long-term (1942-2000) average monthly variations in rainfall 4-19
Figure 5 Long-term (1942-2000) average rainfall, evaporation and moisture deficits 4-20
Figure 6 Annual Average Wind Roses 4-21
Figure 7 2006 Seasonal Average Wind Roses 4-22
Figure 8 2006 Diurnal Wind Roses 4-23
Figure 9 Annual stability class distribution for the study site, as simulated by TAPM 4-25
Figure 10 Seasonal stability class distribution for the study site as simulated by TAPM 4-25
Figure 11 Average annual diurnal variation in mixing layer height for the study site, as simulated by TAPM 4-26
Figure 12 In-pit operations at the SCCCR site (photograph taken looking northwards towards the Nowra Brickworks) 4-28
Figure 13 Secondary crushing and stockpiling operations within the extraction area, with dozer activity evident in the foreground 4-28
Figure 14 Weathered shale extraction area situated near the eastern boundary of the site (bund evident in the background 4-28
Figure 15 Unpaved on-site haul roads (photograph taken looking southwards, from SCCCR office towards the extraction area) 4-28
Figure 16 Sealed on-site road section which crosses the weighbridge and adjoins the Pacific Highway 4-29
Figure 17 Evidence of track-on along the Princes Highway in front of the main gate of SCCCR 4-29
Figure 18 Extraction related operations in foreground with partially vegetated bund wall and tree line along western boundary 4-29
Figure 19 Non Project-related Dust Emission Sources 4-33
Figure 20 Concrete batching operation to the east of the Princes Highway, opposite the SCCCR's main gate 4-35
Figure 21 Operations at the Nowra Brickworks situated immediately north of the SCCCR site 4-35
Figure 22 Location of off-road vehicle activity to the east of the SCCCR site, within the area of the proposed industrial subdivision 4-35
Figure 23 Monthly Variations in Maximum Daily and Monthly average PM10 concentrations recorded 4-36
Figure 24 Location of dust deposition monitoring sites 4-38
Figure 25 Proposed Development Stages 4-43
Figure 26 Location of Assumed Emission Sources 4-44
Figure 27 Location of Modelled Receptors 4-50
Figure 28 Predicted Cumulative Daily PM10 Exceedance Contour 4-54
Figure 29 Predicted Incremental Dust Deposition Exceedance Contour 4-55

CONTENTS

Page

TABLES

Table 1 NSW DECC PM10 Impact Assessment Criteria 4-16
Table 2 PM2.5 advisory reporting criteria published by the NEPC 4-17
Table 3 Dust deposition criteria published by the NSW DECC 4-17
Table 4 Project Air Quality Criteria 4-17
Table 5 Long-term (1955-2000) Monthly Average Climate Statistics 4-18
Table 6 Description of atmospheric stability classes 4-24
Table 7 Volumes and characteristics of raw materials handled and products generated 4-27
Table 8 Potential sources of atmospheric emissions associated with existing quarry operations 4-31
Table 9 Maximum Daily and Annual Average PM10 Concentrations Recorded 4-36
Table 10 Dust deposition measured (as total insoluble matter) at the SCCCR Operation 4-39
Table 11 Estimated emissions for current quarry operations 4-40
Table 12 Estimated emissions for future quarry operations – Scenario 1 comprising proposed dust control measures 4-47
Table 13 Estimated emissions for future quarry operations – Scenario 2 comprising additional dust control measures 4-48
Table 14 Predicted PM10 concentrations and dust deposition rates for Current Quarry Operations 4-51
Table 15 Predicted PM10 concentrations and dust deposition rates for Future Quarry Operations – Scenario 1 4-52
Table 16 Predicted PM10 and PM2.5 concentrations and dust deposition rates for Future Quarry Operations – Scenario 2 4-53

APPENDICES

Appendix 1 Technical Overview of TAPM 4-67
Appendix 2 Emissions Inventory Results 4-71
Appendix 3 Dispersion Simulation Results 4-79

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EXECUTIVE SUMMARY

Introduction

South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) has historically operated the Nowra Brickworks Quarry located adjacent to the Princes Highway, South Nowra, in the Shoalhaven City Council Local Government Area. The quarry is located within two Mining Leases (ML), namely ML 5087 and ML 6322. Extractive operations on ML6322 are currently on hold pending an application under Part 3A of the *Environmental Planning and Assessment Act 1979*, while operations on ML5087 continue. City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited were appointed to prepare the *Environmental Assessment* in respect of a "Project Site" comprising ML5087 and ML6322 for works involving the continuation of extractive operations within ML5087 and the recommencement and expansion of extractive operations within ML6322 (the "Project").

Heggies Pty Ltd (Heggies) in turn was commissioned by City Plan Services to undertake the air quality assessment for the "Project". The air quality assessment for SCCCR comprised two main phases:

- **Phase 1** – Qualitative air quality assessment for the existing operations on ML5087, primarily comprising collation of project information and a site investigation.
- **Phase 2** - Quantitative air quality assessment conducted as part of the Environmental Assessment phase for the Project, including operations on both ML5087 and ML6322.

Methodological Overview

Baseline air quality was characterised based on dust deposition monitoring undertaken at the existing quarry and on PM10 concentrations recorded historically at the Nowra Sewage Treatment Works by the Department of Environment and Climate Change (DECC). Meteorological data from the Bureau of Meteorology's Nowra RAN Automatic Weather Station was used in the characterisation of the prevailing dust generation and dispersion potential and as input in the air dispersion modelling undertaken.

The contribution of current SCCCR Quarry operations to suspended fine particulate concentrations and dust deposition rates were predicted and changes in such levels due to proposed future quarry operations projected. This was achieved through the establishment of emission inventories for current and future quarry operations and the prediction of resultant concentrations and deposition through air dispersion modelling. Emissions were estimated based on appropriate methods, including Australian National Pollutant Inventory (NPI) Emission Estimation Techniques and US-EPA AP42 predictive emission factor equations. Air dispersion modelling was undertaken using Ausplume, the dispersion model developed by EPA Victoria and recommended for regulatory modelling by the NSW DECC.

Baseline Environment and Current Quarry Operations

The main findings of the baseline environment study, which comprised an assessment of the legislative context, proximity of sensitive receptors, potential for cumulative impacts given neighbouring sources and review of the atmospheric dispersion potential of the area and dust generation related to existing SCCCR operations, were as follows:

There are a number of sources of atmospheric emission in proximity to the SCCCR operation which contribute to ambient particulate concentrations including certain industrial operations (e.g. neighbouring brickworks, concrete batching operation and saw mill) and diffuse sources such as vehicle entrainment from public (paved and unpaved) roads and off-track vehicle activity.

- Based on historical data (1996-2001) it was found that elevated airborne concentrations of fine particulates occur in the region but that such concentrations are within air quality criteria with a decreasing trend in concentrations. No more recent data are available on which to determine more recent compliance and trends.
- Rainfall occurs on approximately 18% of days during the year, increasing moisture contents and reducing dust generation potentials during and immediately following rainfall events.
- Strong wind prevails frequently in the area increasing the potential for dust generation on no-rain days. The wind sheltering of quarry activities through in-pit operations, use of bund walls and retention of tree lines is considered to significantly reduce the potential for quarry emissions and impacts.
- The wind field is dominated by two main wind components, namely northwesterly to westerly wind and southerly to south-southwesterly airflow. This indicates that receptors situated to the east, southeast and north of the SCCCR site are more likely to be impacted should significant emissions occur at the site.
- Developments to the north include Nowra brickworks and a single residential dwelling. The South Nowra commercial area is located further to the north (>1km) beyond the likely impact area of the quarry.
- Potential receptors to the east comprise light industrial and commercial developments. Although the bund walls and tree line on the eastern boundary of the site serve to reduce the potential for impacts on such receptors, it is noted that these operations are located in close proximity to quarry operations and therefore that impacts could occur if dust controls are not consistently applied at the quarry.
- Crushing operations and vehicle entrainment from unpaved road sections represent the largest sources of routine emissions, with blasting operations comprising a significant but intermittent source. Materials handling and wind entrainment were estimated to be more minor sources. The potential for re-entrainment of material tracked onto the Princes Highway (mainly from the road shoulders) was identified as being potentially significant due to the extent of vehicle activity along this road and the fact that these sources occurs off-site, in relative proximity to potential receptors.

- Wet suppression represents the main type of dust mitigation measure implemented at the quarry. Given the frequency and intensity of watering evident at the SCCCR site, control efficiencies are expected to be in excess of 70% for roads and greater than 60% for crushing operations.
- Current routine quarry operations are not predicted to result in exceedances of PM_{10} guidelines at any neighbouring sensitive receptor sites, taking background concentrations into account.
- At nearby residential sites dust deposition rates attributable to the current operation are predicted to be below 1.5 g/m²/month and therefore within the incremental dust deposition threshold of 2g/m²/month.

Proposed Future Quarry Operations (Maximum Production)

Emissions were estimated and dispersion simulations undertaken for two dust control scenarios, namely:

- **Scenario 1 – Current Dust Controls**

  Continuation of current dust mitigation practices which mainly comprise the use of wet suppression for unpaved roads (water truck) and crushing and screening operations (water sprays). Maximum dust control efficiencies of 75% for the unpaved haul road and 60% for crushing and screening operations were assumed to be achievable through the application of these measures.

- **Scenario 2 – Additional Dust Controls**

  The control efficiency for vehicle entrainment from unpaved haul roads was assumed to increase from 75% to 90%. The control efficiencies for crushing operations were assumed to increase from 60% to 80%. These increases in efficiencies could realistically be achieved through the use of chemical dust suppression products and, in the case of crushing operations, the application of either wind sheltering and misting sprays or enclosure and venting to an abatement device such as a baghouse.

Scenario 1 emissions were predicted to result in exceedances of the PM_{10} daily criterion and dust deposition rates in excess of permissible cumulative dust deposition thresholds at various of the nearby sensitive receptor sites. Additional dust controls were therefore concluded to be required to bring airborne particulate concentrations and dust deposition rates due to maximum production future quarry operations into compliance within NSW DECC air quality criteria.

With additional dust controls implemented (Scenario 2), future routine quarry operations are predicted to be in compliance with PM_{10} criteria at nearby sensitive receptor sites, taking into account background concentrations. Advisory criteria for $PM_{2.5}$ are also projected to be met at all receptor sites with the exception of the residences to the south of the quarry where the advisory daily limit of 25µg/m³ is predicted to be marginally exceeded (26µg/m³) on one day during the year modelled. Dust deposition rates were generally within the permissible incremental threshold of 2g/m²/day, with minor exceedances at the brickworks and proposed Warra Warra Road traffic circle. *Such dust deposition was however lower than the dust deposition rates predicted to occur at these sites due to current quarry operations*.

Documented dose response thresholds given for potential impacts on vegetation, including sensitive natural vegetation and crops, and livestock are orders of magnitude higher than are predicted to occur as a result of the proposed quarry operation. Controlled emissions from the quarry are therefore not expected to be associated with any significant impacts on neighbouring vegetation and potential livestock.

Recommendations

Air quality modelling indicates dust generation and the impact of the current SCCCR operations are currently being adequately managed by the dust mitigation measures being applied and the effect of in-pit operations and the use of bund walls and tree lines.

The proposed operations would however necessitate the application of improved and/or additional dust control measures to ensure compliance with air quality criteria. Recommended measures are as follows:

- Further reduce vehicle entrainment along unpaved haul roads and unpaved working areas to increase dust control efficiencies from 75% to 90%. This is most practically achieved in the case of unsealed roads through the effective use of chemical suppression. The effectiveness of the measure would be dependent on:
  - successful selection and application of a suitable chemical suppression system;
  - avoidance of material being deposited or tracked onto the road (e.g. through stabilisation of road shoulders); and
  - the timely clean up of material deposited on the treated road.
- Reductions in vehicle speed along unpaved haul roads and the minimisation of truck activity rates (where possible) represent further measures implementable to ensure high dust control efficiencies are achieved. Speed limits of 40 kph or lower are recommended for on-site haul roads.
- Increase dust control efficiencies for crushing operations from 60% to 80%. This is achievable through the use of wind sheltering in combination with efficient mist sprays or through the enclosure of operations and venting of dust loaden air to abatement technologies (e.g. baghouse) prior to being released to the atmosphere. Operations should be ceased in the event that dust suppression systems are not operational.
- Installation of a wheel wash at the main gate to reduce material being tracked onto the Princes Highway from the site.
- Consider paving or stabilising road shoulder areas in the immediate vicinity of the main gate to further reduce the potential for track on. (It is noted that this occurs as a result of both quarry-related and other vehicle activity.)
- On-site dust deposition monitoring should be carried out to track the success of dust control measures. It is recommended that two of the existing dust deposition gauges be retained for use on-site in this manner with the third gauge relocated to the residential dwelling south of the quarry as operations expand in this direction.

1 INTRODUCTION

1.1 Background

South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) has historically operated the Nowra Brickworks Quarry located adjacent to the Princes Highway, South Nowra, in the Shoalhaven City Council Local Government Area. The quarry is located within two Mining Leases (ML), namely ML 5087 and ML 6322. Extractive operations on ML6322 are currently on hold pending an application under Part 3A of the *Environmental Planning and Assessment Act 1979*, while operations on ML5087 continue. City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited were appointed to prepare the *Environmental Assessment* in respect of a "Project Site" comprising ML5087 and ML6322 for works involving the continuation of extractive operations within ML5087 and the recommencement and expansion of extractive operations within ML6322 (the "Project").

Heggies Pty Ltd (Heggies) in turn was commissioned by City Plan Services to undertake the air quality assessment for the "Project". The air quality assessment for SCCCR comprised two main phases:

- **Phase 1** – Qualitative air quality assessment for the existing operations on ML5087, primarily comprising collation of project information and a site investigation.
- **Phase 2** - Quantitative air quality assessment conducted as part of the Environmental Assessment phase for the Project, including operations on both ML5087 and ML6322.

1.2 Phase 1 Air Quality Assessment

Phase 1 of the air quality assessment aimed at determining whether existing quarry operations satisfies the relevant air quality standards and if any interim measures were required prior to submission of the Major Projects Application. The Phase 1 assessment also aimed at identifying environmental factors, pertaining to air quality, which will need to be taken into account as part of the air quality assessment to be compiled based on the Director General's Requirements. Key components of the Phase 1 assessment comprised the following:

- Characterisation of baseline air quality based on the review of existing, available air quality monitoring information and the identification and qualitative evaluation of existing sources of atmospheric emission including current SCCCR operations and other sources.
- Assessment of the prevailing wind field based on data from the Bureau of Meteorology's Nowra RAN Air Station.
- Qualitative assessment of dust generation and impact potential of current SCCCR operations taking into account the nature and scale of operations, the prevailing wind field, proximity of sensitive receptors and dust management and mitigation measures currently in place.
- Establishment of three dust deposition monitoring sites to measure existing deposition rates at the SCCCR site.

Phase 1 has been completed, with the main findings documented within this report for the purpose of characterising baseline air quality.

1.3 Air Quality Assessment

The scope of study for the Phase 2 Quantitative Assessment is as follows.

- Collate project information for proposed ML5087 and ML6322 operations
- Determine air quality criteria to be used in the compliance assessment based on Federal and State regulations
- Characterise the prevailing dispersion meteorology of the project site based on available monitoring data and formatting of data for input into air dispersion modelling.
- Baseline air quality characterisation based on information compiled for the Phase 1 Report and any available results for the dust deposition monitoring sites established.
- Compilation of an emissions inventory for planned ML5087 and ML6322 operations using National Pollutant Inventory documented *Emission Estimation Techniques* produced by Environment Australia and, where required, United States Environmental Protection Agency (US-EPA) AP-42 emission factors and methods.
- Identify dust control measures proposed or recommended for implementation and estimated dust control efficiencies for such measures.
- Prepare baseline dust deposition and suspended fine particulate (PM_{10}, particular matter with an aerodynamic diameter of <10µm) concentration data sets excluding current ML5087 operations, for use in simulating cumulative concentrations/deposition rates due to future ML5087 and ML6322 operations.
- Conduct atmospheric dispersion modelling to predict incremental and cumulative PM_{10} concentrations and dust deposition rates occurring due to proposed future ML5087 and ML6322 operations.
- Undertake a compliance analysis and air quality impact assessment, in which predicted incremental and cumulative particulate concentrations and dust deposition rates are evaluated against air quality criteria and dust deposition criteria.
- Make recommendations regarding necessary mitigation and management measures to be implemented to ensure that the proposed quarry activities operate in compliance with relevant air quality criteria.

1.4 Project Location and Sensitive Receptors

The SCCCR site is located in South Nowra within the administrative area of Shoalhaven City Council. Situated about 5km south of the Norwa CBD, the site is adjacent to the Princes Highway. The site comprises two mining lease areas, ML5087 to the north and ML6322 to the south. The majority of the area of ML5087 has been disturbed, whereas only the northernmost part of the ML6322 has been disturbed with the remainder still being under trees and grass (**Figure 1**).

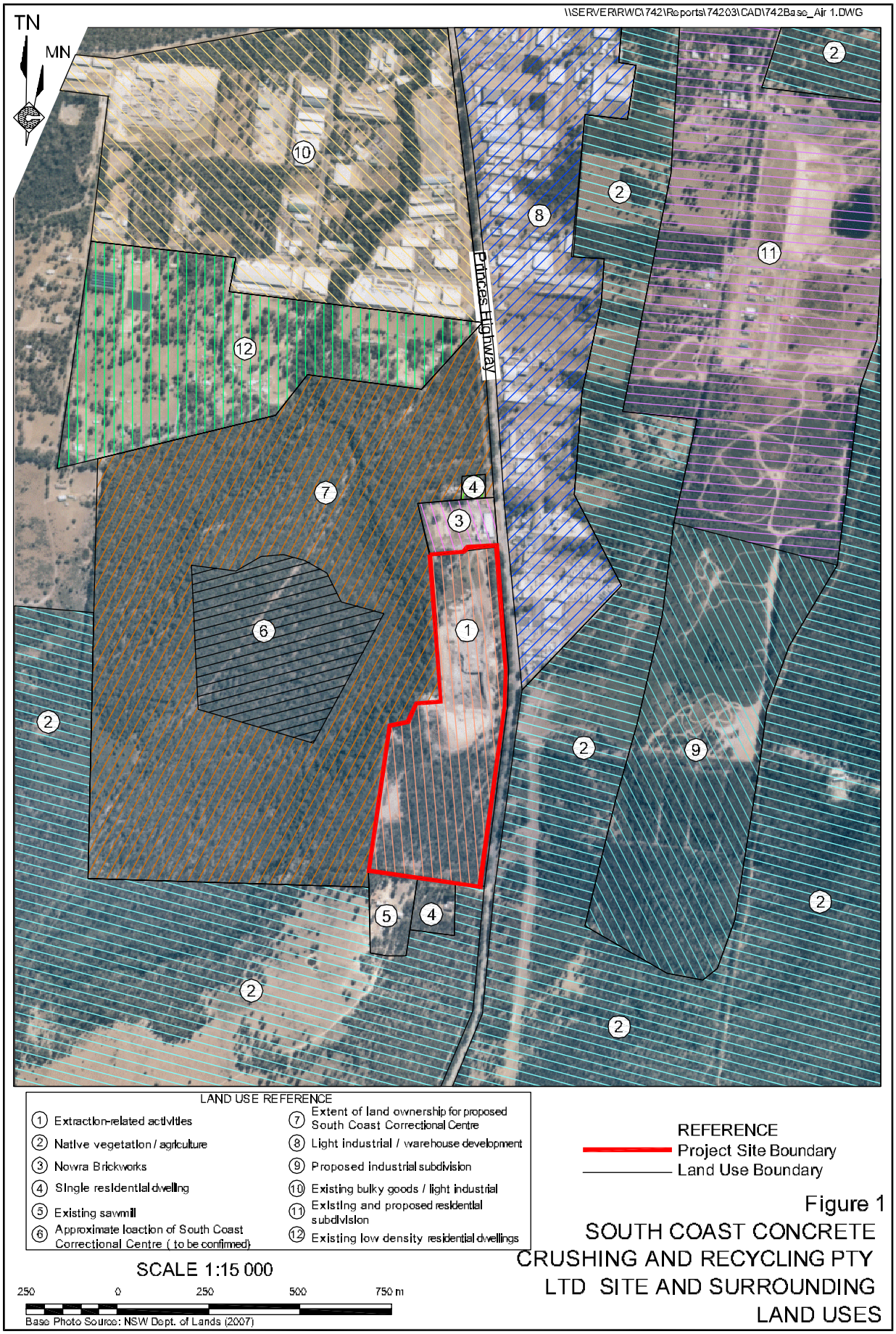

Figure 1
SOUTH COAST CONCRETE CRUSHING AND RECYCLING PTY LTD SITE AND SURROUNDING LAND USES

Figure 1 presents an aerial photograph of the SCCCR site and surrounds. The Nowra Brickworks is situated to the north of the site, beyond which is situated a single residential dwelling. Further north of this dwelling, as well as to the west of the site is Crown Land comprising land intended for the location of the proposed South Coast Correctional Centre. This land is largely undisturbed. Bulk goods and light industrial areas are situated further to the north of the site within South Nowra. A second single residential is situated to the south of the ML6322 area, together with a saw mill.

To the east of the site, across the Princes Highway, there is low density commercial/industrial development. Enterprises situated directly opposite the main gate of the Nowra Brickworks Quarry include a butchery (**Figure 2**) and concrete batching operation with various other commercial operations situated along the highway (**Figure 3**).

2 RECEIVING ENVIRONMENT

Air quality assessment criteria selected for application in the compliance assessment are documented in **Section 2.1**. Criteria are given for air pollutants which are expected to occur as a result of current and proposed quarry operations and which were quantified and simulated during the study, specifically suspended particulates and dust deposition. In the selection of air quality assessment criteria attention was paid to Federal and NSW State requirements.

The prevailing climatic conditions, particularly wind field and rainfall incidence, is of interest due to its impact on fugitive dust generation potentials and rates of atmospheric dispersion and deposition. An overview of the prevailing climatic conditions of relevance to the Project location is given in **Section 2.2**.

Other sources of atmospheric emissions situated in the vicinity of the Project site, which could contribute to local ambient air pollutant concentrations, are discussed in **Section 2.3** and previously measured air pollutant concentrations and dust deposition rates presented in **Sections 2.4** and **2.5** respectively.

2.1 Air Quality Criteria

2.1.1 Introduction

In June 1998, the National Environment Protection Council (NEPC) of Environment Ministers agreed to set uniform health standards for ambient air quality to apply to all States and Territories. These standards are contained in the National Environment Protection Measure (NEPM) for ambient air quality. The NEPM air quality criteria (termed goals) were developed by the NEPC to be achieved within 10 years of commencement. It is noted that the NEPM goals have been developed with the intention of assessing regional air quality and accordingly are not intended as impact assessment criteria.

The NSW DECC has established ground level air quality criteria for key air pollutants to achieve appropriate environmental outcomes and to minimise associated risks to human health. The criteria specified by DECC are documented in the document "*Approved Methods and Guidance for Modelling and Assessment of Air Pollutants in New South Wales*" 2005 (the "Approved Methods").

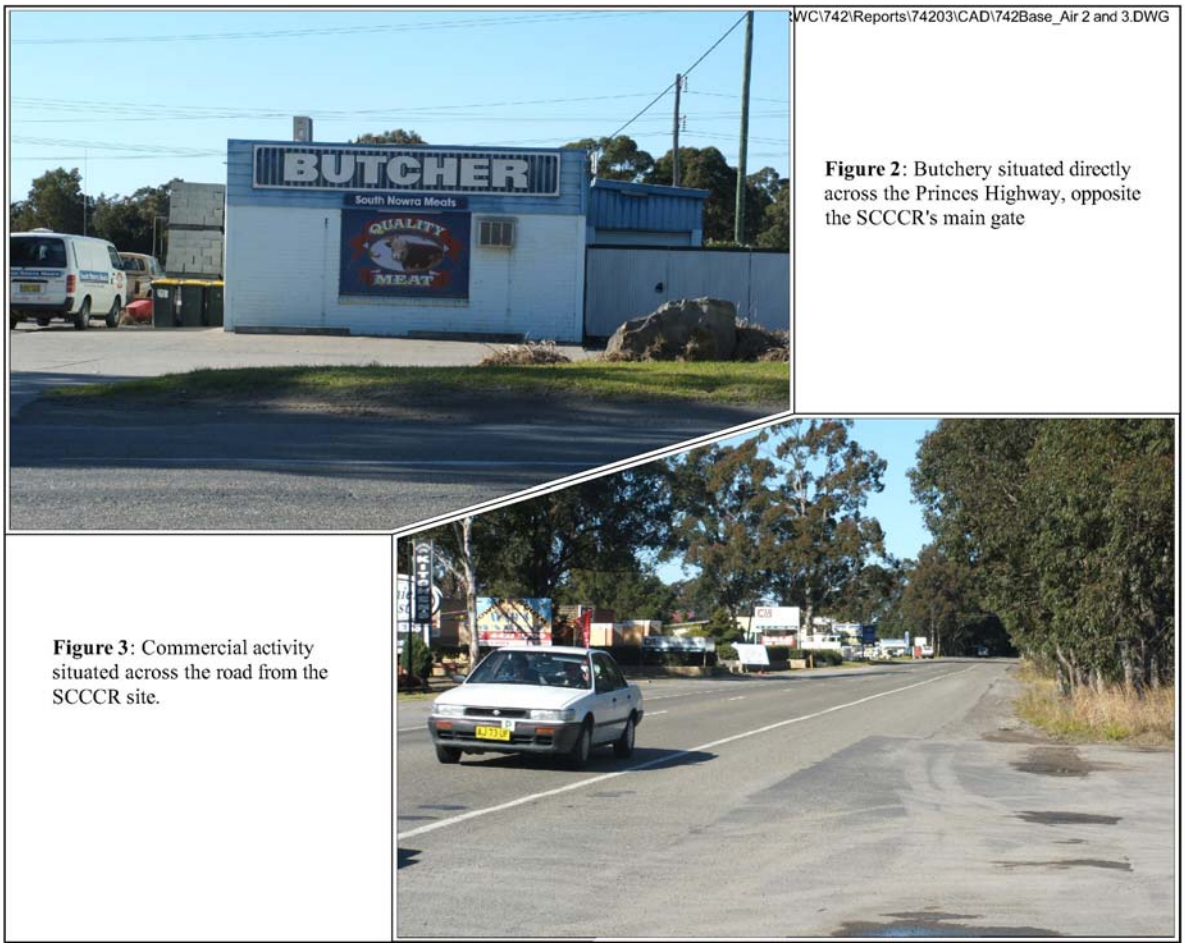

Figure 2: Butchery situated directly across the Princes Highway, opposite the SCCCR's main gate

Figure 3: Commercial activity situated across the road from the SCCCR site.

2.1.2 Suspended Particulate Concentrations

Air quality criteria for particulates are typically given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM_{10} (i.e. particulates with an aerodynamic diameter of less than 10µm) and respirable particulates of $PM_{2.5}$ (i.e. particulates with an aerodynamic diameter of less than 2.5µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100µm, effective upper limit of 30µm aerodynamic diameter is frequently assigned. PM_{10} and $PM_{2.5}$ are of concern due to their health impact potentials. Such fine particles are able to be deposited in, and cause damage to, the lower airways and gas-exchanging portions of the lung. Potential adverse health impacts associate with exposure to PM_{10} and $PM_{2.5}$ include increased mortality from respiratory and cardiovascular diseases, chronic obstructive pulmonary disease, heart disease and reduced lung capacity in asthmatic children.

2.1.2.1 Air Quality Criteria for Inhalable Particulates (PM_{10})

Despite the international medical community not having been able to establish a threshold value for PM_{10} below which there are no adverse health impacts, air quality criteria are routinely issued for these pollutants, including by federal and state governments in Australia for management and compliance assessment purposes.

The NSW Department of Environment and Climate Change PM_{10} impact assessment criteria, as expressed in their document *Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005) are given in **Table 1**.

Table 1
NSW DECC PM_{10} Impact Assessment Criteria

Pollutant	Averaging Period	Concentration (µg/m³)
PM_{10}	24 hours	50
	Annual	30
Source: DEC, 2005 Approved Methods for the Modelling and Assessment of Air Pollutants in NSW.		

The DECC's daily threshold for PM_{10} was based on the NEPM reporting goal developed by the NEPC in 1998 for achievement within 10 years of commencement (NEPC, 2003). Although the threshold value of the DECC's 24-hour PM_{10} reporting criterion is equivalent to that of the NEPM reporting goal (i.e. 50µg/m³), the NEPM reporting goal permits five exceedances per year whereas no provision is made for permissible frequencies within the DECC's impact assessment criteria.

The impact assessment criterion given by the DECC for annual PM_{10} concentrations derives from the NSW Environmental Protection Agency (1998) publication *Action for Air: The NSW Government's 25-year Air Quality Management Plan.*

2.1.2.2 Air Quality Criteria for Total Suspended Particulates (TSP)

Air quality criteria for Total Suspended Particulates (TSP) were typically set prior to the development of an improved understanding of the relationship between health impacts and exposure to fine particulate concentrations, and have subsequently either been discarded or given reduced importance by countries internationally.

The NSW DECC TSP impact assessment criterion is given as 90µm/m³ for an annual averaging period and is based on the goal recommended by the National Health and Medical Research Council (NHMRC) (DEC, 2005; NHMRC, 1996).

The PM_{10} component of TSP has been found to be typically in the range of 40% to 90%. The PM_{10} fraction typically comprises 50% of TSP in areas not dominated by road traffic sources. In urban areas, where traffic emissions are a significant source of particulate matter, the PM_{10} fraction has been found to represent a more significant proportion of TSP (60% to 90%).

Taking the ranges and typical ratio of PM_{10} to TSP into account it is evident that an annual TSP air quality criterion of 90µg/m³ implies a PM_{10} criterion in the range of 35µg/m³ to 80µg/m³ (typically 45µg/m³). This range is less stringent than the DECC's annual PM_{10} criterion of 30µg/m³. It is therefore evident that the TSP annual criterion can be expected to be achieved if the annual PM_{10} criterion is complied with. The current study will therefore focus on assessing compliance with PM_{10} criteria.

2.1.2.3 Air Quality Criteria for Respirable Particulates ($PM_{2.5}$)

The NSW DECC has not published ambient air quality criteria for $PM_{2.5}$. Reference may however be made to the $PM_{2.5}$ advisory reporting criteria issued by the NEPC (NEPC, 2003).

The NEPC initiated a review in December 2000 to determine whether a new ambient air quality standard is needed in Australia for $PM_{2.5}$ and the feasibility of developing such a standard. The review concluded that health effects are associated with exposures to fine particles, with the health effects observed by overseas studies being supported by Australian studies. Furthermore it was noted that $PM_{2.5}$ criteria have been adopted or proposed for adoption in countries such as Canada, the USA and New Zealand. The review concluded that there is sufficient community concern regarding $PM_{2.5}$ to consider it an entity separate from PM_{10}. Based on this review, a variation to the Ambient Air Quality NEPM was implemented in July 2003 with advisory reporting criteria being set for $PM_{2.5}$ and presented in **Table 2** (NEPC, 2003).

Table 2
$PM_{2.5}$ advisory reporting criteria published by the NEPC

Pollutant	Averaging Period	Concentration (µg/m³)
$PM_{2.5}$	24 hours	25
	annual	8
Source: NEPC, 2003, National Environment Protection (Ambient Air Quality) Measure, as amended.		

2.1.3 Dust Deposition Criteria

Nuisance dust deposition is regulated through the stipulation of maximum permissible dust deposition rates. The NSW DECC impact assessment criteria for dust deposition are given in **Table 3** illustrating the allowable increment in dust deposition rates above ambient (background) dust deposition rates which would be acceptable to ensure dust nuisance is avoided.

Table 3
Dust deposition criteria published by the NSW DECC

Pollutant	Maximum Increase in Dust Deposition	Maximum Total Dust Deposited Level
Deposited dust (assessed as insoluble solids)	2g/m^2/month	4g/m^2/month
Source: DEC, 2005 *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW.*		

2.1.4 Project Specific Air Quality Criteria

The project specific criteria which are applicable to the current study to assess the acceptability of baseline and potential future air pollution concentrations, selected on the basis of Federal and State air quality criteria, are given in **Table 4**.

Table 4
Project Air Quality Criteria

Pollutant	Averaging Time	Maximum Concentration	Reference
Inhalable particulates (PM_{10})	24 hours Annual	50 µg/m^3 30 µg/m^3	DEC (2005).
Respirable particulates ($PM_{2.5}$)[(a)]	24 hours Annual	25 µg/m^3 8 µg/m^3	NEPC (2003).
Dust Deposition	Annual	2g/m²/month[(b)] 4g/m²/month[(c)]	DEC (2005).

Notes:
(a) Advisory limit.
(b) Dust deposition limit for incremental dust deposition.
(c) Limit for cumulative dust deposition.

2.2 Climatology and Meteorology

2.2.1 Introduction

The climate and meteorology of the study site was characterised based on climate statistics obtained from the Bureau of Meteorology's long-term weather station at the Nowra RAN Air Station (Station number 068076) and hourly meteorological data obtained from the Nowra RAN Air Automatic Weather Station (Station no. 068072) opened in November 2000. Climate statistics were available for the period 1955 until 2000. Hourly average meteorological data were received from the automatic weather station for the period 2001 to 2007. This station is situated approximately 6.5km west-southwest of SCCCR and is expected to be representative of the meteorology of the project site taking the terrain into account. The CSIRO's prognostic TAPM model was used to derive information on the atmospheric stability and mixing depth of the study region.

Long-term (1955-2000) monthly average temperature, rainfall, relative humidity and wind speed data for the Bureau of Meteorology's long-term Norwa RAN Air Station are presented in **Table 5** and discussed in subsequent subsections.

Table 5
Long-term (1955-2000) Monthly Average Climate Statistics

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Mean maximum temperature (°C)	25.8	25.8	24.5	22.1	19	16.4	15.8	17.1	19.3	21.5	23.1	25.1	21.3
Mean minimum temperature (°C)	16.1	16.3	14.8	12.1	9.7	7.6	6.2	6.7	8.3	10.7	12.6	14.6	11.3
Rainfall and Cloud Cover													
Mean rainfall (mm)	91.3	119.7	124.4	97.1	90.5	107	57	75.8	65.6	107.5	98.1	73.1	1110.1
Decile 5 (median) rainfall (mm)	73.2	70.9	76.6	51.6	72.2	62.1	40.5	35.2	47.7	68.8	64.4	63.1	1092.8
Mean number of days of rain ≥ 1 mm	6.4	6.2	6.3	4.9	5.3	5.2	3.9	4.3	4.8	6.3	6.8	5.4	65.8
Relative Humidity													
Mean 9am relative humidity (%)	72	76	74	71	74	75	72	68	63	64	66	68	70
Mean 3pm relative humidity (%)	62	63	63	59	59	59	54	52	52	57	58	59	58
Wind Speed													
Mean 9am wind speed (km/h)	8.2	7.8	8.5	10.8	12.9	14.9	15.5	15.4	14.6	12.1	10.5	9.2	11.7
Mean 3pm wind speed (km/h)	17.7	17.3	15.8	14.9	14.2	15	16.9	19	20.5	19.7	19.7	19.2	17.5
Source: Bureau of Meteorology's Nowra RAN Air Station (No. 068076) (as obtained from the BoM, July 2007)													

2.2.2 Ambient Temperature and Sunshine Incidence

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

Situated in proximity to the coast Nowra experiences less extreme temperature variations when compared with areas located further inland. Mean minimum temperatures are given as being in the range 6°C to 16°C, based on the long-term record, with average minimum temperatures of the order of 11°C. Mean maximum temperatures have been recorded to be in the range of 16° to 26°C. Peaks occur during summer months with the highest temperatures typically being recorded in January-February. The lowest temperatures are usually experienced during July.

The average number of hours per day receiving sunshine is of the order of 6 to 8 hours, with the mean number of clear days per year being approximately 100 based on the long-term record (1965 to 1997).

2.2.3 Rainfall, Relative Humidity and Evaporation

Precipitation is important to air pollution studies since it reduces the potential for fugitive dust emissions and represents an effective removal mechanism of atmospheric pollutants. The long-term (1942 – 2000) monthly average rainfall and number of rain days recorded at the BoM Nowra RAN Air Station is depicted in **Figure 4**. The long-term average annual rainfall is in the order of 1100mm with a total of 66 days per year experiencing rainfall in excess of 1mm.

Higher rainfall occurs during spring and late summer. The number of rain days per month ranges from approximately 4 days in July to approximately 7 days in November.

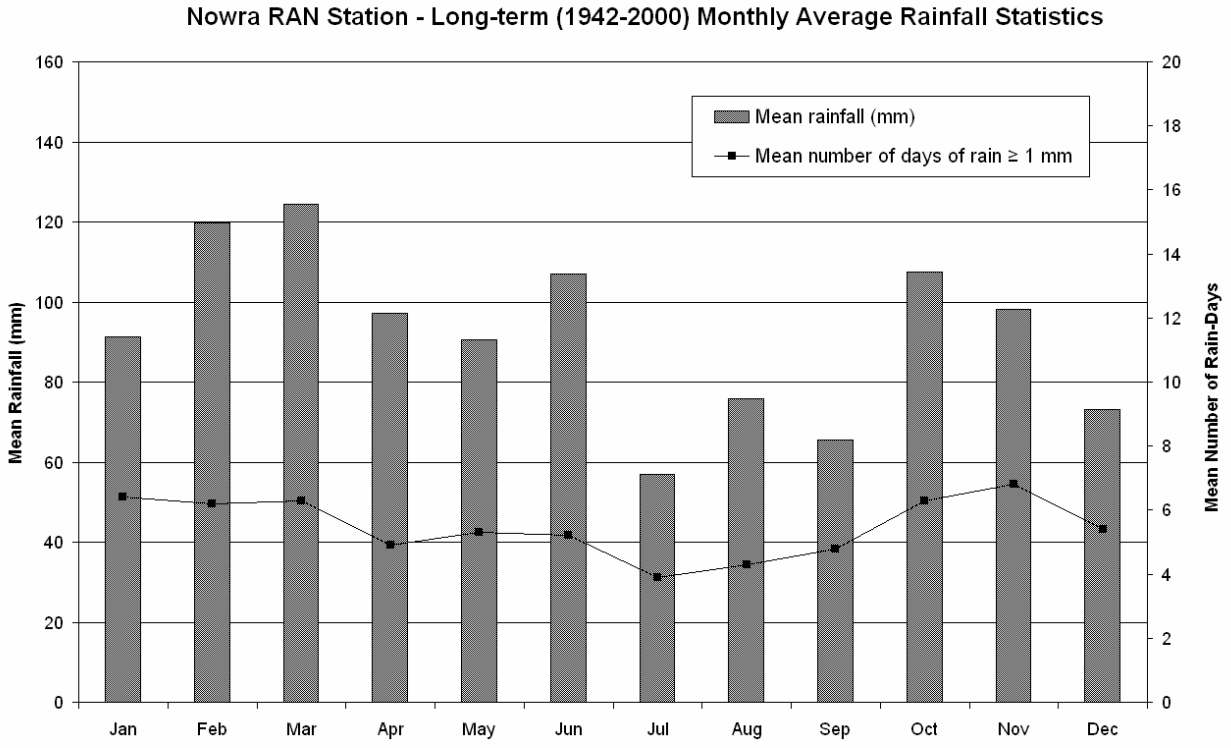

Figure 4
Long-term (1942-2000) average monthly variations in rainfall

Moderately higher relative humidity occurs during the morning when compared to the afternoon as may be expected, with monthly average values in the range of 63% to 76% (average of 70%) having been recorded at 09h00. During the afternoon, relative humidity ranges from 52% to 63% (typically 58%). The small intra-annual variation in relative humidity is characteristic of coastal sites.

Evaporation is a function of ambient temperature, wind and the saturation deficit of the air. Generally Nowra experiences a water deficit with evaporation exceeding rainfall for all months of the year except July (**Figure 5**). Calculated monthly moisture surplus/deficits are in the range of 37 mm (July) to -136mm (December), with average annual deficits estimated to be approximately -660 mm. This would need to be accounted for in the dust control programme of the proposed quarry operations given that such operations are associated with fugitive emissions for which wet suppression is to be implemented.

2.2.4 Prevailing Wind Regime

Annual wind roses for the period 2001 to 2006 are presented in **Figure 6** with seasonal and diurnal variations in airflow illustrated for the year 2006 in **Figures 7** and **8** respectively.

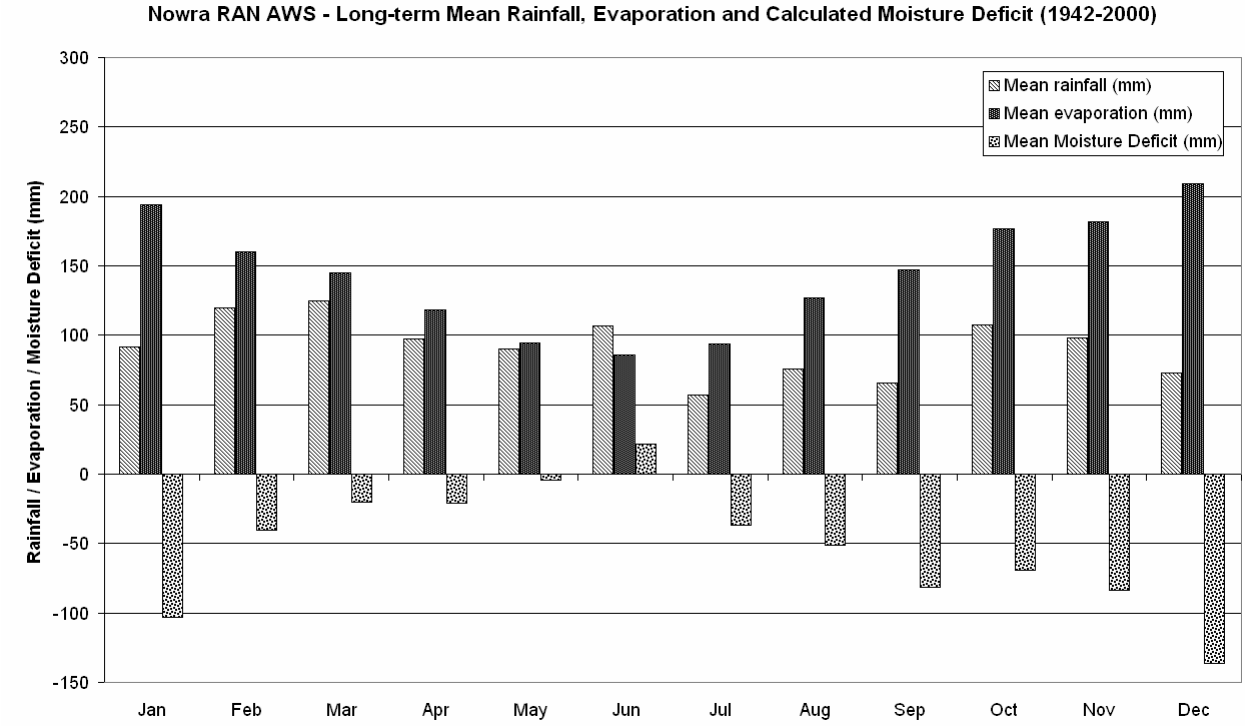

Figure 5
Long-term (1942-2000) average rainfall, evaporation and moisture deficits

Note 1: Mean monthly rainfall and evaporation are measured averages. Mean monthly moisture deficit is calculated.

Source: Bureau of Meteorology Nowra RAN Air Station (Station Number 068076)

Strong, frequent west-northwesterly and westerly airflow prevails with airflow with a southerly flow component evident but less prominent and characterised by weaker wind. Little inter-annual variation in the wind field pattern it is evident that westerly winds were stronger and more frequent during certain years (2001 and 2002) compared to others (2005 and 2006). The year 2001/2002 also experienced a lower frequency of calm periods (1.1% and 1.6% respectively) compared to the 2003-2006 period during which time the percentage of calms ranged between 4.9% and 6.6%. Average annual wind speeds were observed to be in the range of 3.7m/s to 4.0m/s during the 2001 to 2006 period, which compares well with the long-term (1955 – 2000) average recorded wind speed of 4.1m/s (represents an average across wind speeds recorded at 9 am and 3 pm).

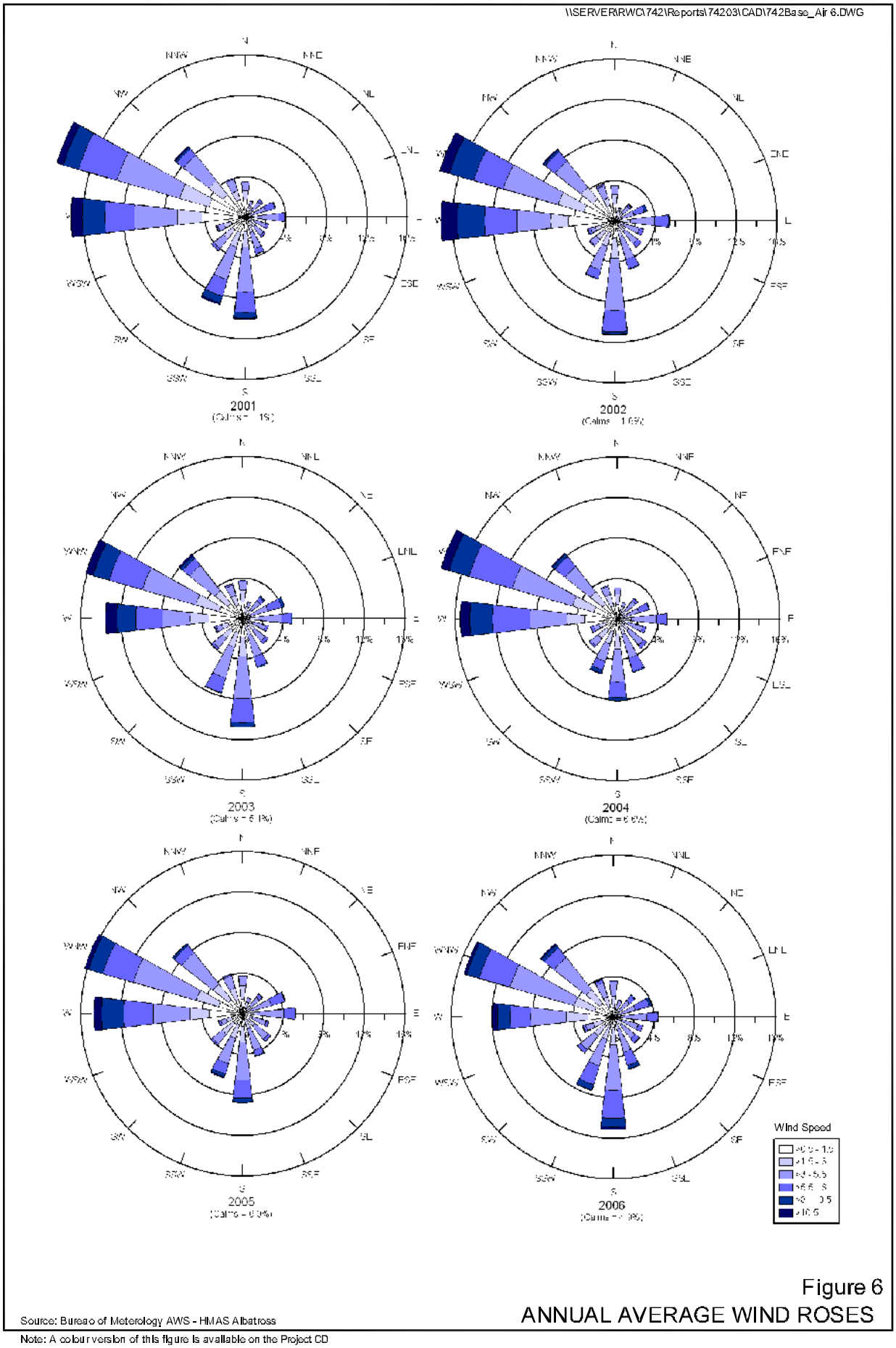

Figure 6
ANNUAL AVERAGE WIND ROSES

Source: Bureau of Meterology AWS - HMAS Albatross

Note: A colour version of this figure is available on the Project CD

Distinct seasonal and diurnal variations in airflow patterns are apparent (**Figure 7** and **Figure 8**). North-westerly to north-northwesterly winds prevail during winter months with relatively frequent south-southwesterly airflow also apparent. With the onset of spring, the incidence of northerly and west-northwesterly airflow is reduced and there is an increase in the frequency of southerly wind. During summer months, there is a further increase in the frequency of occurrence of southerly airflow with further reductions in northwesterly flow. Easterly and east-northeasterly winds are also apparent during the summer. Southerly and easterly flow components reduce and the incidence of westerly and west-northwesterly wind again increases during the autumn.

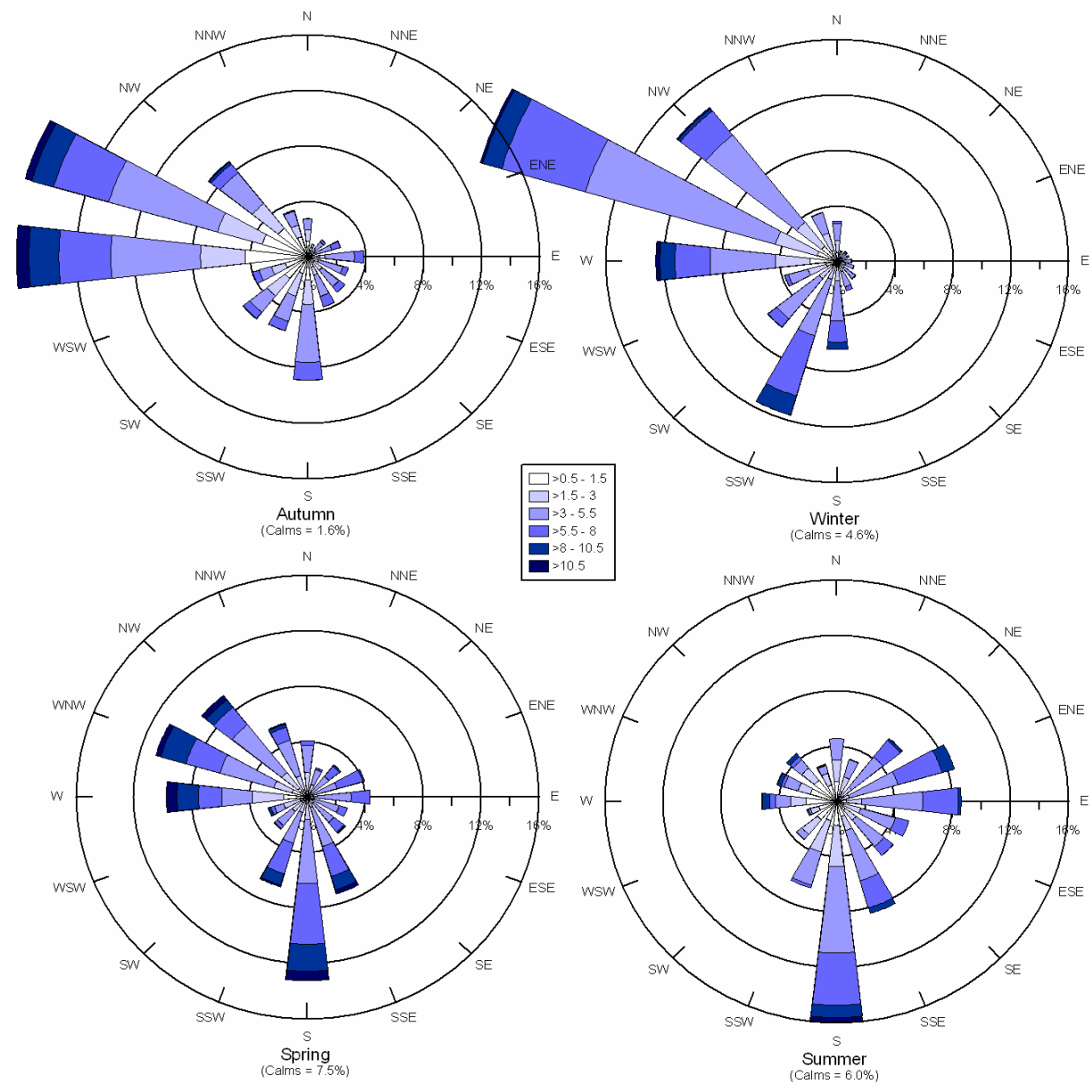

Figure 7
2006 Seasonal Average Wind Roses

Weak, off-shore wind prevails during the night-time as is characteristic of coastal environments where land-sea breeze circulation systems occur. During the daytime, the wind shifts with an increase in southerly and easterly (on-shore) airflow despite frequent north-northwesterly and westerly winds still apparent. Average wind speeds of 3.1m/s and frequent calm periods (6.2%) occur during the night-time compared to stronger winds (average of 4.7m/s) and lower calms (1.1%) during the daytime.

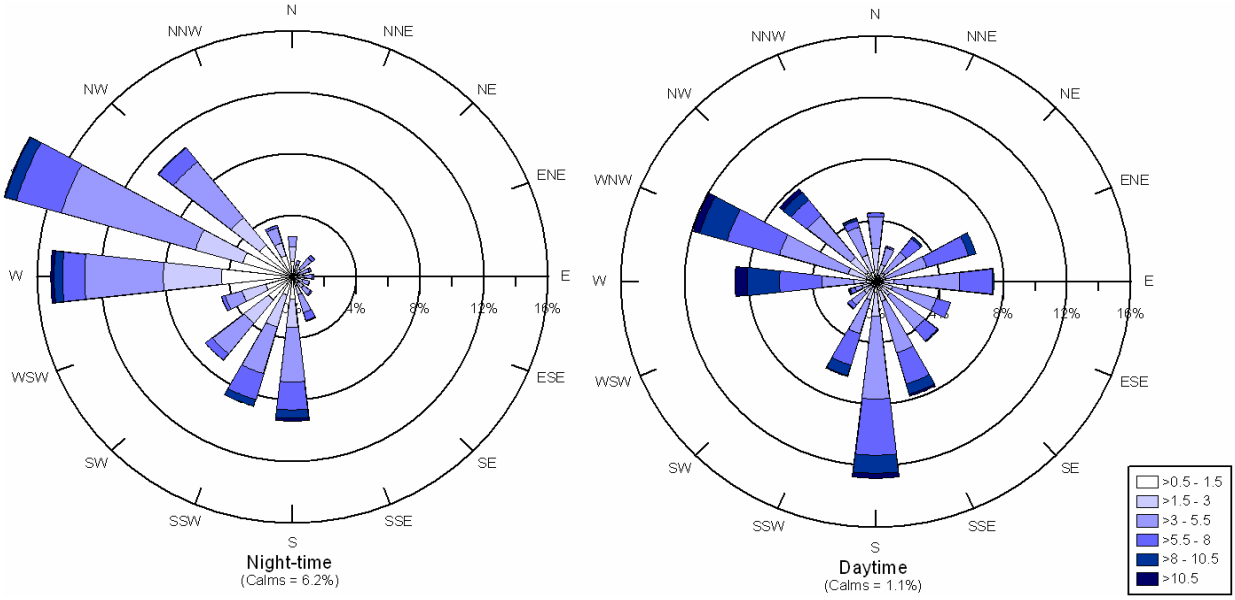

Figure 8
2006 Diurnal Wind Roses

2.2.5 TAPM Simulation of Atmospheric Stability and Mixing Layer Depth

2.2.5.1 Introduction

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface (Stull, 1997; Oke, 2003). During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated subsidence inversion. Elevated inversions may occur for a variety of reasons including anticyclonic subsidence and the passage of frontal systems.

Radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. Nighttimes are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential. The mixed layer thus ranges in depth from a few metres (i.e. stable or neutral layers) during nighttimes to the base of the lowest-level elevated subsidence inversion during unstable, daytime conditions.

For elevated releases, the highest ground level concentrations frequently occur during unstable, daytime conditions when the plume is 'brought to ground'. In contrast, the highest concentrations for ground level non-wind dependent releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

Meteorological parameters such as atmospheric stability class and mixing height are not routinely recorded and must therefore be derived or simulated. The Air Pollution Model (TAPM) was used during the course of this study to generate these parameters in order to support the description of the meso-scale atmospheric dispersion potential and to provide the necessary input to the atmospheric dispersion simulations undertaken for the proposed development.

2.2.5.2 TAPM Simulations

TAPM is a prognostic model which may be used to predict three-dimensional meteorological data, with no local data inputs required. The model predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases, including terrain, vegetation and soil type, temperature and synoptic scale meteorological analysis, which are subsequently used in the model input to generate site-specific hourly meteorological observations.

Additionally, the TAPM model may assimilate wind observations so that they can optionally be included in a model solution. The wind speed and direction observations are used to realign the predicted solution towards the observation values. This function of accounting for actual meteorological observations within the region of interest is referred to as “data assimilation”.

TAPM was applied using the data assimilation option to incorporate wind field observations from the Bureau of Meteorology’s (BoM) Nowra RAN AWS. The data set selected for the modelling was 2001 given it was the most recent complete data set concurrent with the continuous PM_{10} monitoring data that was available during the preparation of the report.

Further background on the TAPM model, including details of validation exercises, is presented in **Appendix 1**.

2.2.5.3 Atmospheric Stability and Mixing Depth

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Turner assignment scheme identifies six Stability Classes, “A” to “F”, to categorise the degree of atmospheric stability. These classes indicate the characteristics of the prevailing meteorological conditions and are used as input into various air dispersion models (**Table 6**).

Table 6
Description of atmospheric stability classes

Atmospheric Stability Class	Category	Description
A	Very unstable	Low wind, clear skies, hot daytime conditions
B	Unstable	Clear skies, daytime conditions
C	Moderately unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions
Source: Stull, (1997)		

The frequency of occurrence of predicted stability class at the study site, as modelled by TAPM based on meteorological data from the Nowra RAN AWS site for 2001, is presented in **Figure 9** and **Figure 10** for annual and seasonal periods. TAPM results indicate a high frequency of neutral conditions which are characterised by moderate dispersion potentials. Relatively small variations in the incidence of various stability classes were forecast to occur across seasons.

Diurnal variations in maximum and average mixing depths forecast by TAPM for the study site are illustrated in **Figure 11**. An increase in the mixing depth during the morning arising due to the onset of vertical mixing following sunrise, is apparent with maximum mixing heights occurring in the mid to late afternoon due to the dissipation of ground-based temperature inversions and the growth of convective mixing layer.

2.3 Existing Sources of Atmospheric Emissions

2.3.1 Current SCCCR Operations

Information on existing operations, and sources of emission identified and qualitatively assessed during a site visit conducted on 26 July 2007. A brief synopsis of existing operations is given below. Potential sources of atmospheric emissions identified are listed, with the nature and possible control efficiency of the management and mitigation measures currently in place described. The atmospheric dispersion potential of emissions is discussed, taking into account the prevailing wind field, the location of emission sources within the extraction area and the presence of bunding on the perimeter of the quarry site.

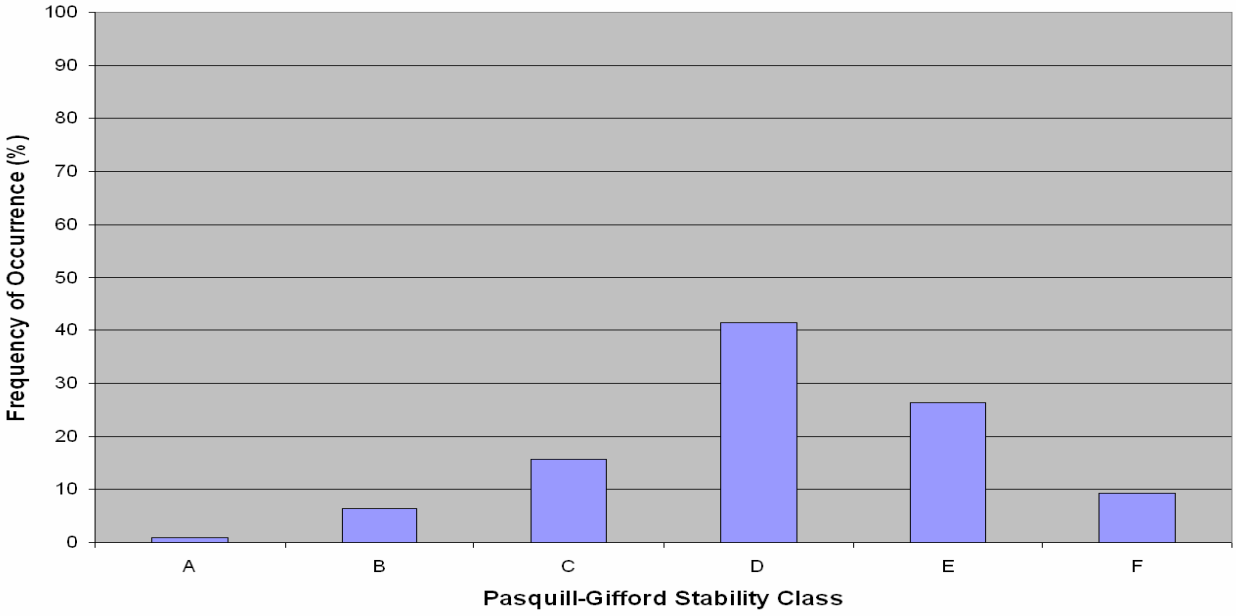

Figure 9
Annual stability class distribution for the study site, as simulated by TAPM

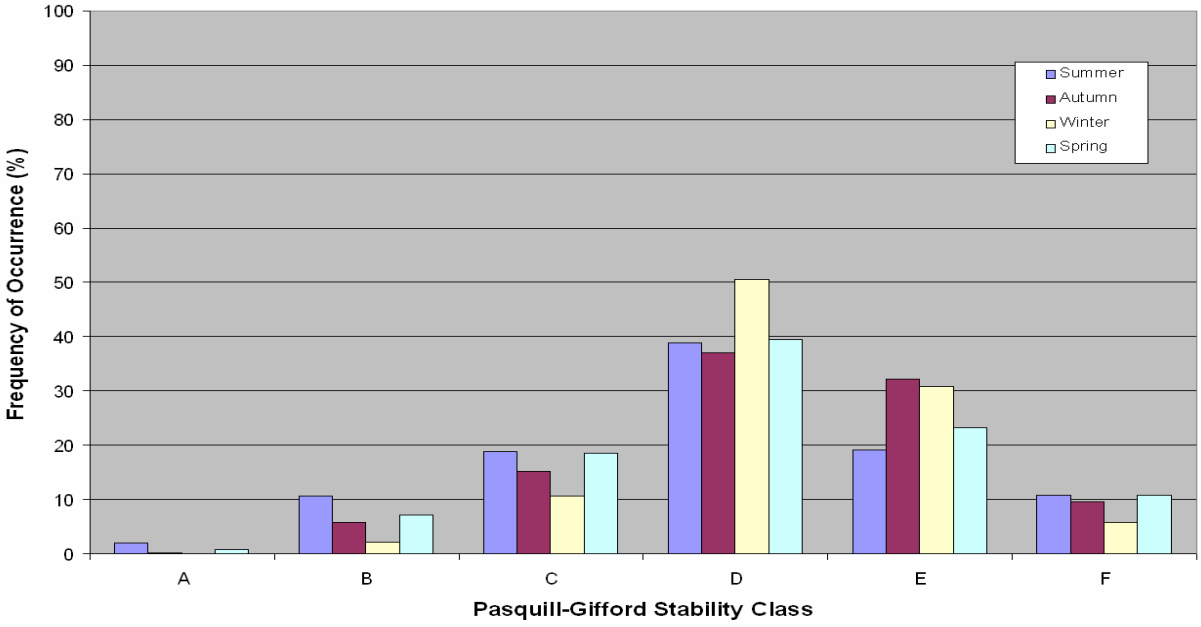

Figure 10
Seasonal stability class distribution for the study site as simulated by TAPM

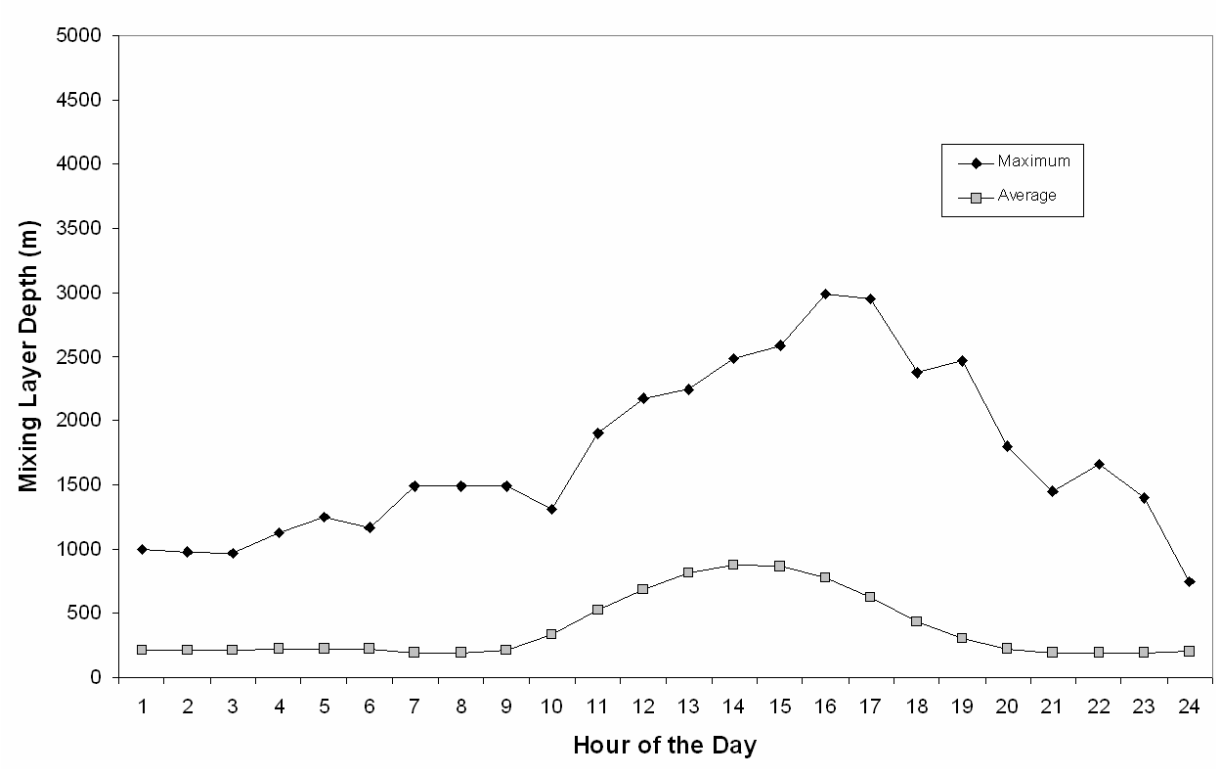

Figure 11
Average annual diurnal variation in mixing layer height for the study site, as simulated by TAPM

2.3.1.1 Existing Operations

The existing extractive operation comprises the extraction of weathered and unweathered shale from the extraction area. The unweathered shale is crushed and blended with imported raw materials (blue metal, concrete, bitumen) to produce various products (90% of which comprises 20mm, 40mm and unsealed pavement material or UPM). The weathered shale is sold for general control filling and local farm use.

The quarry operates from 07h00 to 16h00 Monday to Thursday, 07h00 to 15h30 on Fridays and from 07h00 to 12h00 on Saturdays. There are three mobile crushing plants (two primary and one secondary) and two mobile screening plants at the site. One of the primary crushers is a standby crusher with typical operations comprising the use of two screening, one primary crushing and one secondary crushing plants.

The unweathered shale is intermittently blasted with approximately 4 to 5 blasts per year. This blast rock is transferred using excavators to mobile, mechanised screens, conveyed to primary and secondary crushers and subsequently stockpiled and trucked off-site. Water sprays are used to suppress dust during crushing operations (**Figure 13**).

The weathered shale is currently extracted from a location close to the eastern boundary of the site and loaded to trucks on demand (**Figure 14**). There is an approximately 3m bund wall and a line of tall trees around the perimeter of the quarry site.

On-site roads are primarily unpaved, with dust suppression comprising wet suppression using water spraying from two dedicated water trucks (**Figure 15**). There is an approximately 50m section of sealed road in the vicinity of the weighbridge and adjoining the Princes Highway (**Figure 16**). The silt loading on this section of roadway was observed to be relatively limited, however, material does appear to be "tracked onto" the Princes Highway in front of the SCCCR operation's main gates (**Figure 17**) which could result in re-entrainment by vehicles travelling along the highway. Although it is proposed to install a wheelwash at the main gate to reduce the potential for "track-on", this measure was not yet installed at the time of the site visit. It was noted that much of the material being tracked onto the main road comes from the shoulder of the road and not necessarily from the site itself. This material is tracked onto the main road by haul vehicles in addition to other vehicles unrelated to SCCCR operations which use the site entrance area to stop off or turn around.

Bund walls of 3m to 4m in height are situated on the eastern, southern and western boundaries of the mine lease area (**Figure 18**). These walls are generally covered in vegetation.

Volumes and characteristics of raw materials extracted, imported and handled at the site and products generated are given in **Table 7**.

Table 7
Volumes and characteristics of raw materials handled and products generated

	Material Type	**Volumes (tpa)**	**Moisture Content**	**% <75µm (specification)**	**% <13µm**
Raw materials (extracted)	Rip Shale ("weathered shale")	11,500	9%	ND	ND
	Blue Shale ("unweathered shale")	164,000	ND	ND	ND
Raw materials (imported)	Includes Blue metal ("dust"), concrete and bitumen	55,000	ND	ND	ND
Main Products[(a)]	20mm	65,500	9%	10% (7-30%)	5%
	40mm	65,500	11.8%	10% (7-20%)	ND
	Unsealed Pavement Material (UPM)	65,500	8.1%	8%	3%
	Rip Shale ("brown shale")	11,500	9%	ND	ND

ND – no data
(a) Products comprising approximately 90% of total products from blue shale crushing and blending, with the 20mm, 40mm and UPM products given as accounting for a third each of this volume.
Source: SCCCR

2.3.1.2 Atmospheric Emission Sources associated with Current Quarry Operations

A synopsis of the main potential sources of atmospheric emissions associated with current operations is given in **Table 8** and existing dust management and mitigation measures which are applied listed. Particular matter represents the main pollutant released at the site. Gaseous emissions such as oxides of nitrogen (NO_x), carbon monoxide (CO) and sulphur dioxide (SO_2) are also released due to on-site vehicle exhaust emissions and intermittently as a result of blasting operations. Particulate emissions represent however the most significant pollutant in terms of the extent of emissions and the likelihood of resulting in impacts.

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Figure 12 : In-pit operations at the SCCCR site (photograph taken looking northwards towards the Nowra Brickworks)

Figure 13 : Secondary crushing and stockpiling operations within the extraction area, with dozer activity evident in the foreground.

Figure 14 : Weathered shale extraction area situated near the eastern boundary of the site (bund evident in the background)

Figure 15 : Unpaved on-site haul roads (photograph taken looking southwards, from SCCCR office towards the extraction area)

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Figure 16: Sealed on-site road section which crosses the weigh bridge and adjoins the Pacific Highway

Figure 17: Evidence of track-on along the Princes Highway in front of the main gate of SCCCR.

Figure 18: Extraction-related Operations in foreground with partially vegetated bund wall and tree line along western boundary.

Emissions were estimated for materials handling, vehicle entrainment, crushing and screening operations and wind entrainment based on Australian National Pollutant Inventory (NPI) Emission Estimation Techniques and United States Environmental Protection Agency AP42 Emission Factors. The purpose being to assess the relative magnitude of sources in relation to each other and determine the likely dust control efficiency achieved by the dust control measures which are currently implemented. The emission estimates are presented in **Section 3**.

Crushing operations and vehicle entrainment from unpaved road sections represent significant sources of routine emissions, with blasting operations comprising a significant but intermittent source. Materials handling and wind entrainment were estimated to be less significant sources. The potential for re-entrainment of material tracked onto the main road (mainly from the road shoulders) was identified as being potentially significant due to the extent of vehicle activity along the Princes Highway and the fact that this sources occurs off-site, in relative proximity to potential receptors.

Wet suppression represents the main type of dust mitigation measure implemented at the site, being used for crushing operations (water sprays), roads (water trucks) and dust suppression on open areas and prior to stockpile recovery. The dust control efficiency of watering is given to be in the order of 60% to 75% (US-EPA, 2003). Given the frequency and intensity of watering evident at the SCCCR site, control efficiencies are expected to be in approximately 75% for roads and approximately 60% for crushing operations. Control efficiencies of greater than 90% are generally only achievable for crushing when crushers are enclosed with emissions vented to a cleaning devise (e.g. bag filter). Higher control efficiencies for unpaved roads (>90%) could be achieved through the addition of a chemical surfactant.

2.3.2 Sources of Atmospheric Emissions unrelated to SCCCR Operations

Other activities operating in the Shoalhaven area which have licences regulating air emissions issued by the NSW DECC include: agricultural produce industries, sewage treatment systems, concrete works, paper production, extractive industries, electricity generation, bitumen pre-mix or hot mix industries, crushing/grinding/separation industries, composing and related reprocessing and livestock processing / slaughter. Industries situated in the vicinity of the SCCCR site are listed in **Table 9** and their locations in relation to the SCCCR site described. The locations of the closest industries are illustrated in **Figure 19**.

C & M Brick, Nowra Chemicals, Nowra Concrete, South Coast Liquid Treatment and Boral Asphalt are all located within South Nowra north of the SCCCR site. Pioneer Construction Materials, a concrete batching facility, is situated directly across the Princes Highway (**Figure 20**) with the Allen Taylor & Co saw mill situated to the south of SCCCR ML6322. The Nowra Brickworks, located immediately north of the SCCCR site, no longer undertakes kiln operations with potential dust emissions primarily associated with materials handling operations (**Figure 21**). Soilco and Boral Resources are situated in western Nowra. Other industries situated further away in Bomaderry (to the north) which emit particulates include Shoalhaven Starches Pty Ltd and Australian Paper Pty Ltd.

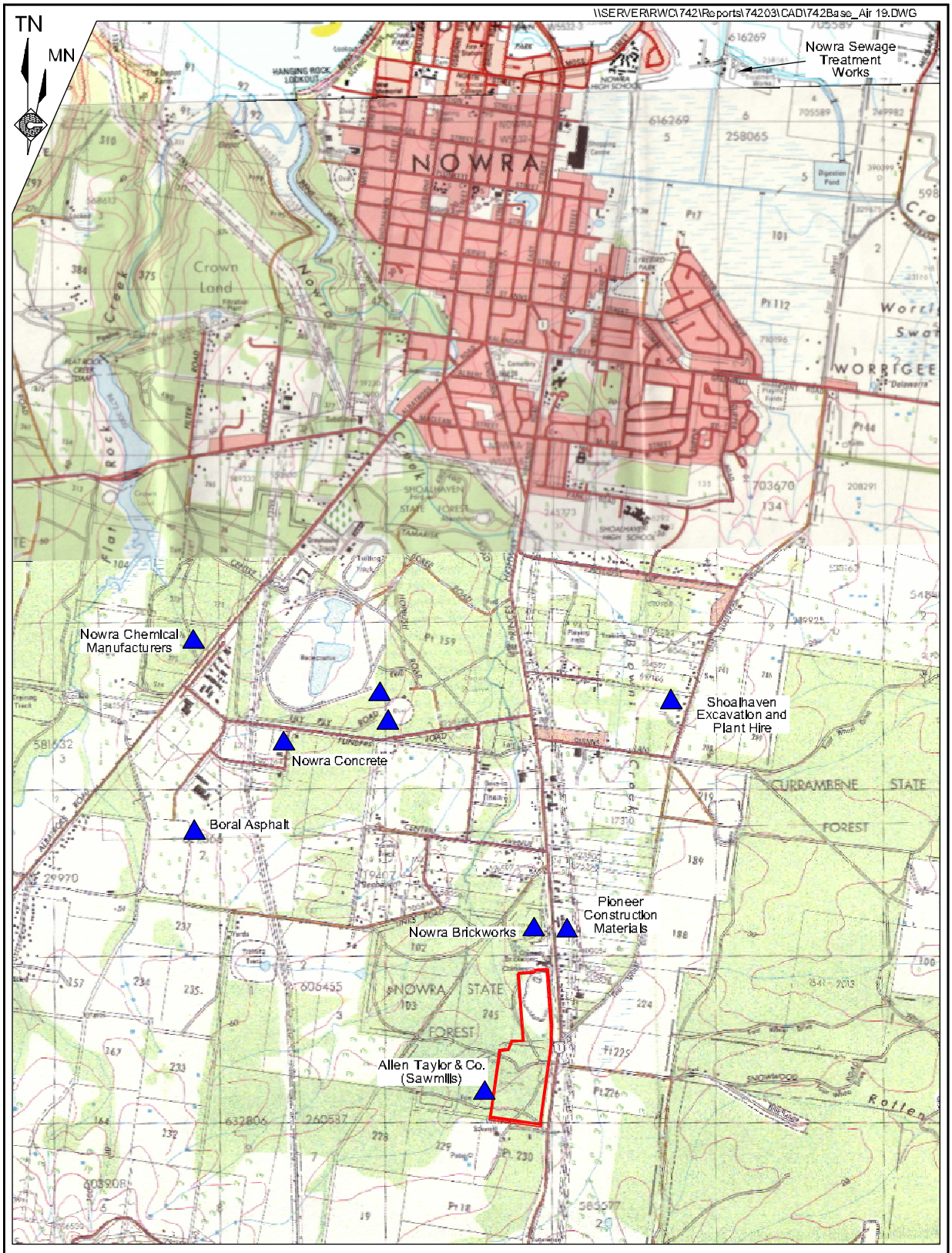
Table 8
Potential sources of atmospheric emissions associated with existing quarry operations

Potential Dust Generating Activities	Nature and Extent of Activity	Factors Affecting Extent of Emissions	Management and Mitigation Measures
ROUTINE OPERATIONS			
Extraction and loading of weathered shale	11.5ktpa handled (currently outside of pit and along the eastern boundary of the site)	• Moisture content of material • Ambient wind speed • Particle size of materials • Volume of material handled	• Moisture content of material is relatively high (9%) • Face is wetted during extraction process to suppress dust potential • Extraction within 3m high bund wall (wind sheltering)
Handling of unweathered shale	164ktpa transferred to screens	• Moisture content of material • Ambient wind speed • Particle size of materials • Volume of material handled	• Within pit (wind sheltering; partial dust containment) • Wetting prior to recovery as required
Screening	Mobile mechanised screening of blue shale (164kpta)	• Volume of material screened • Moisture content of material • Dust controls implemented	• Within pit (wind sheltering; partial dust containment) • Wet suppression (water sprays)
Primary and secondary crushing	Crushing of blue shale (164ktpa)	• Volume of material crushed • Moisture content of material • Dust controls implemented	• Within pit (wind sheltering; partial dust containment) • Wet suppression (water sprays)
Stockpiling of materials	Temporary stockpiling of raw materials and product (200ktpa throughput)	• Moisture content of material • Ambient wind speed • Particle size of materials • Volume of material stored • Mitigation measures in place	• Within pit (wind sheltering; partial dust containment) • Wetting as required
Loading of trucks	Production of 200ktpa	• Moisture content of material • Ambient wind speed • Volume of material handled	• Within pit (wind sheltering; partial dust containment) • Wetting as required
Vehicle entrainment from unpaved (gravel) roads	Approximately 200ktpa material trucked from site	• % Silt content of road surface material • Number of vehicle kilometres travelled • Mean vehicle weight • Dust controls implemented	• Watering of roads (2 water carts)
Vehicle entrainment from on-site, paved road section	Approximately 200ktpa material trucked from site	• Silt loading (g/m²) on road • Number of vehicle kilometres travelled • Dust controls implemented	• Watering of roads (2 water carts)
Wind entrainment from on-site open areas		• Extent of open areas (ha) • Wind speeds including frequency of wind speeds above thresholds associated with mobilisation of material • Particle size of materials • Dust controls	• Retain/encourage vegetation cover • Wetting as required

Table 8 (Cont'd)
Potential sources of atmospheric emissions associated with existing quarry operations

Potential Dust Generating Activities	Nature and Extent of Activity	Factors Affecting Extent of Emissions	Management and Mitigation Measures
ROUTINE OPERATIONS			
Vehicle entrainment of material "tracked onto" and deposited onto off-site roads	Approximately 200ktpa material trucked from site	• Silt loading (g/m²) on road • Number of vehicle kilometres travelled • Dust controls implemented	• Require haul trucks to be covered prior to leaving site • Wheel wash to be installed (not currently in operation)
INTERMITTENT OPERATIONS			
Dozers	Movement of stockpiles	• Duration of dosing operations • Area affected • Dust controls implemented	• Wet suppression
Blasting of unweathered shale	Intermittent (4-5 times a year); ANFO used; area blasted is typically 25m by 25m and 10m deep; blasts typically scheduled for around 13h00 with authorities and neighbours notified	• Horizontal area of blast • Moisture content of blasted material • Depth of blast holes • Number of blasts • Dust controls implemented	• Use of blast professionals • Notification of authorities and neighbours • Blasts conducted during midday (reduce potential for fumigation effects) • Within pit (wind sheltering; partial dust containment)
Drilling for blast holes	Intermittent (as for blasting); 95 holes per blast	• Number of holes drilled • Dust controls implemented	• Within pit (wind sheltering; partial dust containment)
Bund wall repair	Intermittent repair of bund walls	• Moisture content • Duration / area of activity • Dust controls implemented	• Wet suppression

Source: SCCCR



Note: A colour version of this figure is available on the Project CD

Figure 19
NON PROJECT-RELATED
DUST EMISSION SOURCES

Non-industrial sources of emissions in the region include:

- backyard burning;
- solid fuel heaters;
- vehicle exhaust emissions;
- vehicle entrainment of road dust (paved and unpaved roads);
- bush fires;
- wind blown dust from open areas; and
- off-road entrainment by vehicles.

Vehicle entrained dust was identified as a potentially significant source of dust emissions within the immediate study area. Vehicle entrainment from various unpaved roads and from busy paved roads with high surface silt loadings (including sections of the Princes Highway) is apparent. Off-road vehicle activity was also evident to the east of the site within the proposed industrial area (**Figure 22**).

In addition to local sources of particulate emissions, long-range transport of fine particles and precursors are also expected to contribute to suspended particulate concentration in the study area.

2.4 Monitored Ambient Air Quality

2.4.1 Introduction

Given that particulate matter represents the primary emission from the SCCCR's operations, and that air quality criteria are given for suspended fine particulate concentrations and dust deposition, it is pertinent to consider any available airborne particulate and dust deposition data for the study area.

2.4.2 Airborne PM_{10} Concentrations

Although suspended fine particulate concentration data are not available in the immediate vicinity of the SCCCR's operations, ambient PM_{10} (particulate matter with an aerodynamic diameter of less than 10 microns) concentration data were obtained from the NSW DECC for a historical monitoring station situated at the Nowra Sewage Treatment Works (located on Terara Road, Nowra, approximately 6km north-northeast of the SCCCR operation). The location of the Nowra Sewage Treatment Works Monitoring Station is illustrated in **Figure 19**.

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Figure 20 : Concrete batching operation to the east of the Princes Highway, opposite the SCCCR's main gate.

Figure 21 : Operations at the Nowra Brickworks situated immediately north of the SCCR site.

Figure 22 : Location of off-road vehicle activity to the east of the SCCCR site, within the area of the proposed industrial subdivision.

The PM_{10} monitoring at Nowra Sewage Treatment Works was conducted using a Hi-volume Sampler with 24-hour average concentrations recorded on a six-daily cycle. The station was established in July 1996 and decommissioned in December 2001. Maximum daily and annual average PM_{10} concentrations recorded at the Nowra Sewage Treatment Works Station during the period July 1996 to December 2001 are given in **Table 10**.

Maximum daily average PM_{10} concentrations were recorded to be in the range of 24µg/m³ to 44µg/m³ (i.e. 48% to 88% of the maximum PM_{10} daily limit of 50µg/m³), with annual averages of the order of 8µg/m³ to 14µg/m³ (28% to 48% of the annual PM10 limit of 30µg/m³).

Table 9
Maximum Daily and Annual Average PM_{10} Concentrations Recorded

Year	Highest Daily Average PM_{10} Concentrations (µg/m³)	Annual Average PM_{10} Concentrations (µg/m³)
1996 (Jul – Dec)	42.1	14.4
1997	39.0	13.9
1998	29.5	10.6
1999	44.0	8.4
2000	23.6	10.0
2001	25.4	10.0
1997 - 2001	**44.0**	**10.8**
Source: NSW DECC Nowra Sewage Treatment Works Air Quality Station during the period July 1996 to December 2001		

Elevated PM_{10} concentrations tended to occur during summer and spring months with lower concentrations evident during the winter (**Figure 23**), possibly due to above average wind speeds which occur during summer and spring which may have resulted in increased dust entrainment. It is also possible that the higher PM_{10} concentrations may be due to increased contributions of sources situated to the south of the monitoring station during these months as a result of the increased incidence of southerly airflow.

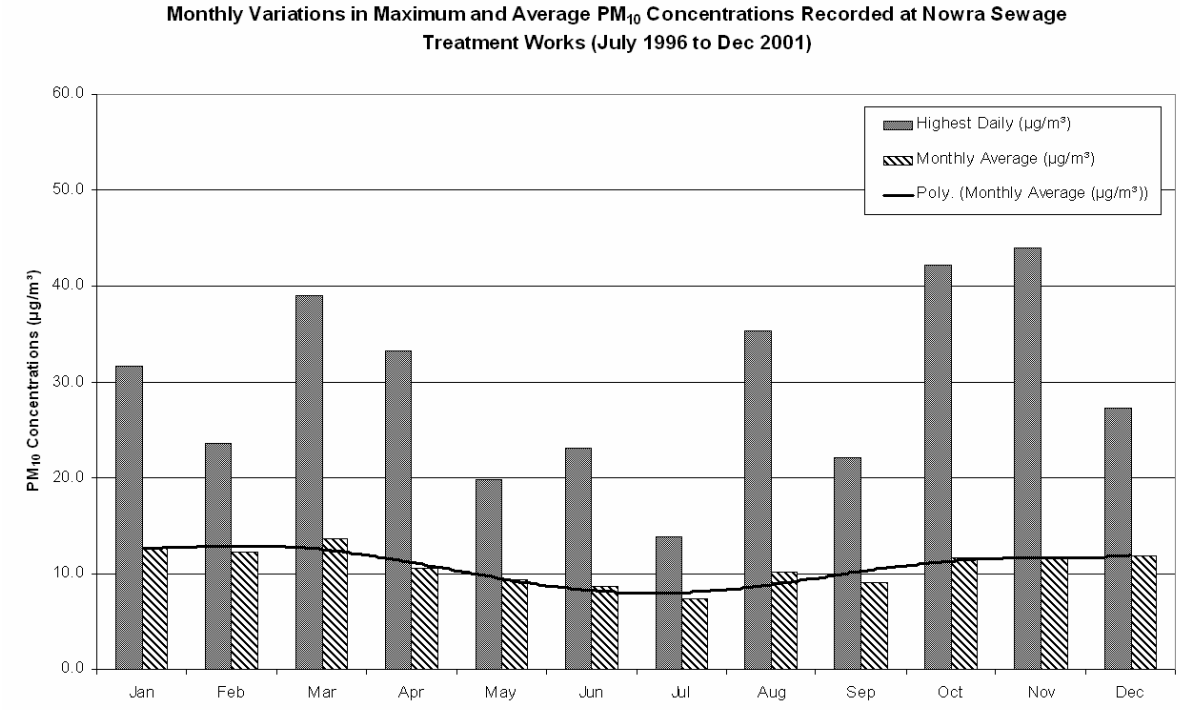


Figure 23
Monthly Variations in Maximum Daily and Monthly average PM_{10} concentrations recorded
Source: Nowra Sewage Treatment Works by NSW DECC during the period July 1996 to December 2001

Given the location of the SCCCR operation relative to the Nowra Sewage Treatment Works it is expected that the greatest contribution of this operation to ambient PM_{10} concentrations recorded at the works, if such a contribution was evident, would occur during winter months when frequent south-southwesterly airflow occurs.

A decreasing trend in ambient PM_{10} concentrations is apparent from the July 1996 to December 2001 dataset. More recent data are not available to determine whether this trend has persisted, nor whether current PM_{10} concentrations are of the same order of magnitude as previously recorded.

2.4.3 $PM_{2.5}$ Concentrations

$PM_{2.5}$ concentration monitoring data are not available for the study area on which to estimate background concentration levels. Reference is therefore made to the $PM_{2.5}$ concentrations measured elsewhere in NSW to provide an indication of the likely order of magnitude of such concentrations.

$PM_{2.5}$ concentrations are recorded by the NSW DECC at various stations in Sydney (Chullora, Earlwood, Liverpool, Richmond), the Illawarra (Warrawong, Wollongong) and the Lower Hunter (Beresfield, Wallsend). $PM_{2.5}$ levels in NSW infrequently exceed the Air NEPM advisory reporting standard of 25µg/m³ for a 24-hour level (with highest 24-hour average concentrations having ranged from 22µg/m³ to 35µg/m³ across the various monitoring stations in 2005). Annual average $PM_{2.5}$ concentrations were recorded to be in the range 7µg/m³ to 12µg/m³, exceeding the annual reporting level of 8µg/m³ at most stations. $PM_{2.5}$ concentrations within the Lower Hunter and Illawarra regions were generally lower than those recorded in Sydney. At the NSW DECC's Wollongong station, maximum daily and annual average $PM_{2.5}$ concentrations of 25.2µg/m³ and 8.7µg/m³ were recorded during 2005, thus marginally exceeding the NEPM advisory standards. The $PM_{2.5}/PM_{10}$ ratios for the maximum and mean were noted to be 0.46 and 0.52 respectively (NSW DEC 2006).

2.4.4 Dust Deposition Monitoring

No dust deposition measurements are available for the study area. Three dust deposition monitors were installed on 23 August 2007 to monitor dust deposition rates associated with quarry operations. Given the existence of other sources of emission in the area and the screening by trees between the quarry and the various receptor sites, these monitors were placed on-site rather than at neighbouring receptor sites.

The locations of the dust bucket monitors are illustrated in **Figure 24**. The DDG1 site is situated next along a section of the main unpaved haul road which is expected to have the highest traffic activity rates. DDG2 is located on the eastern boundary of the site in close proximity to the rip shale extraction operations. DDG3 was sited on the southeastern corner of the ML5087 area.

Taking the nature of the area into account, dust deposition recorded at neighbouring receptor sites are unlikely to accurately indicate dust deposition occurring due to quarry operations. The on-site placement of deposition monitors at the boundaries of the quarry operations serve to track deposition rates which are primarily due to quarry operations.

Dust deposition monitoring was initiated on 23 August 2007. The dust sampling is undertaken over monthly periods, with samples collected sent to ALS Laboratory Group for gravimetric analysis. A synopsis of the total insoluble matter results for each sampling site is given in **Table 11**. The highest dust deposition rates occur in the immediate vicinity of the unpaved haul road (Site DDG1), with elevated rates also evident in the vicinity of the weathered shale extraction area (DDG2). On-site deposition rates further away from quarry and haul activities are notably lower as is evident from the measurements at DDG3.

It is important to note that the NSW DECC maximum permissible dust deposition rates are not applicable within industrial sites. The on-site dust deposition data and simulated deposition rates (see **Section 4**) for current quarry operations indicates that dust fallout immediately beyond the site boundary is in the range of 1g/m²/month to 3g/m²/month, with dust deposition at nearest residences being <1.5g/m²/month.

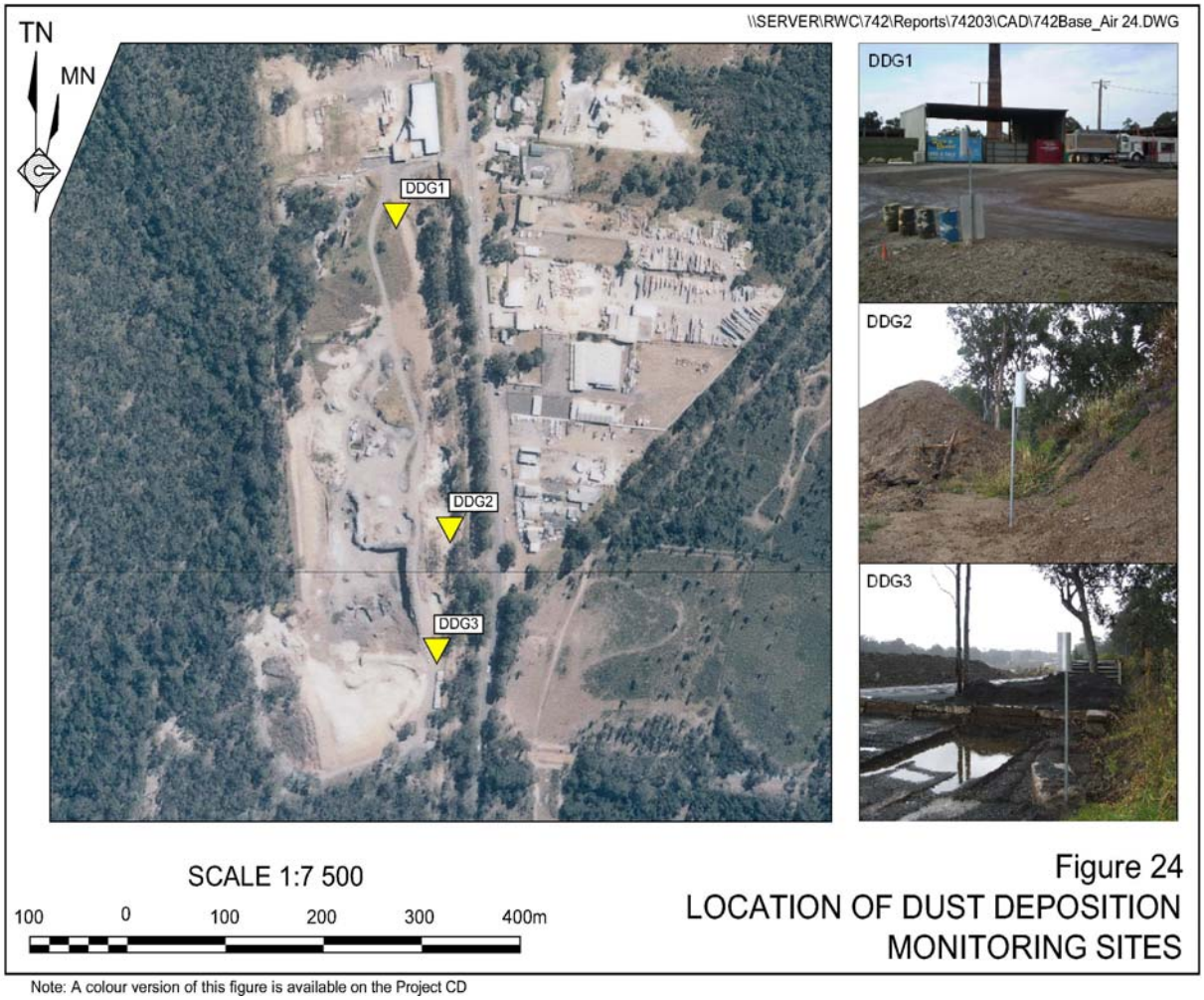


Figure 24
LOCATION OF DUST DEPOSITION MONITORING SITES

Note: A colour version of this figure is available on the Project CD

Table 10
Dust deposition measured (as total insoluble matter) at the SCCCR Operation

Sampling Period	Dust Deposition Rates (g/m²/month)		
	DDG1	DDG2	DDG3
23 Aug – 23 Sep 2007	3.5	1.6	0.7
24 Sep – 19 Oct 2007	5.3	3.2	1.1

2.5 Background Air Quality for Cumulative Assessment Purposes

Hourly PM_{10} concentrations recorded at the Nowra Sewage Treatment Works Monitoring Station during 2001 were used to provide the background concentration data set input in the dispersion simulations for the proposed quarry expansion as per the requirements of the DEC (2005) guideline, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.* Highest daily and annual average PM_{10} concentrations during 2001 were 25µg/m³ and 10µg/m³ respectively, with no exceedances of the DECC goals. Based on the average $PM_{2.5}/PM_{10}$ ratios measured at Wollongong and the PM_{10} data measured at Nowra, the $PM_{2.5}$ concentrations are likely to be low (average of approximately 5µg/m³ with peaks of approximately 15µg/m³).

Off-site dust deposition rates are estimated based on dust deposition monitoring and modelling for existing quarry operations (see **Section 4**) to be <2g/m²/month at nearest residences. Incremental dust deposition due to the proposed quarry expansion will therefore be evaluated against the NSW DECC's maximum permitted increment dust deposition goal of 2g/m²/month.

3 EMISSIONS INVENTORY FOR QUARRY OPERATIONS

3.1 Introduction

Emission sources associated with current and proposed quarry operations were quantified through the application of Australian EPA National Pollutant Inventory (NPI) emission estimation techniques and United States Environmental Protection Agency (US-EPA) AP42 predictive emission factor equations.

In establishing the emissions inventories, priority was given to the estimation of particulates given that this represents the main pollutant emitted from the proposed operations. Particulate releases were quantified for various particle size fractions, with the Total Suspended Particulate (TSP) fraction being estimated and simulated to provide an indication of nuisance dust deposition rates. Fine particulates (PM_{10} and $PM_{2.5}$) were estimated and resultant concentrations simulated for the purpose of assessing compliance with air quality criteria which are protective of human health.

3.2 Emissions from Current Quarry Operations

An overview of current quarry operations was given in **Section 2**. Emissions estimates for current quarry operations, taking existing dust mitigation measures in place, are presented in **Table 12**. Information on the emission factors applied in the quantification of sources and the inputs used in predictive emission factor equations are also provided.

Crushing and screening operations were estimated to comprise a significant source of total TSP (27%), PM_{10} (45%) and $PM_{2.5}$ (62%) emissions. Vehicle entrainment from the unpaved haul road represents the second largest source of fine particulates, estimated to 29% of PM_{10} and 13% of $PM_{2.5}$ and the largest source of total dust (accounting for 46% of TSP emissions).

Table 11
Estimated emissions for current quarry operations

Source	TSP	PM_{10}	$PM_{2.5}$	Emission Factor Applied	Calculation Inputs
	tpa	tpa	tpa		
Paved road section	0.48	0.09	0.01	US-EPA AP42 Paved Roads (Section 13.2.1) (November 2006)	Silt loading of 2.4g/m² used based on site observations and generic loadings given for concrete batching operations. Road length approximately 50m. Vehicle kilometres travelled (VKT) estimated to be approximately 730 per annum.
Unpaved haul road	13.40	3.25	0.32	US-EPA AP42 Unpaved Roads (Section 13.2.2) (November 2006)	Road length approximately 500m with an estimated 59 vehicle trips per day. The silt content of the road surface material was assumed to be 8.3%, given by the US-EPA as being characteristic of haul roads within sand quarry operations. The dust control efficiency due to watering was assumed to be 75% based on the application rate calculated.
Materials handling	2.60	1.23	0.19	US-EPA AP42 Aggregate Handling (Section 13.2.4) (November 2006)	A mean wind speed of 4m/s (based on 2001-2006 hourly measurements from Nowra RAN Air Station) was used in the calculations. Material moisture contents of 9%, 4% and 2% were used for rip shale, blue shale and products respectively.
Crushing & screening	7.87	4.99	1.52	NPI EETM for Mining Version 2.3, Dec 2001	Emission factors for high moisture (>4%) ores was applied. Dust control efficiency achieved through wet suppression of 60% was assumed.
Dozer operations	3.33	0.78	0.08	NPI EETM for Mining Version 2.3, Dec 2001	Dozer assumed to operate 3 hours/day during quarry operational hours.
Wind erosion of exposed areas	0.34	0.17	0.03	NPI EETM for Mining Version 2.3, Dec 2001	Generic emission factor of 0.3 kg/ha/hr used over an area of 1.64ha.
Blasting operations	1.18	0.61	0.31	NPI EETM for Mining Version 2.3, Dec 2001	5 blasts per year each covering an area of 600m²; with a depth of 10m. A moisture content of 4% was assumed.
TOTAL	**29.21**	**11.13**	**2.45**		

Materials handling and dozer operations were each calculated to be responsible for about 10% of the total dust emissions. Vehicle entrainment from the limited length of paved road and wind entrainment were estimated to be minor sources – each comprising <2% of total emissions.

Blasting operations were predicted to contribute only 4%, 6% and 13% pf TSP, PM_{10} and $PM_{2.5}$ respectively. Despite the limited contribution to total annual emissions, blasting is notable in that blasts represent a significant peak emission associated with infrequent quarry operations (5 blasts per year).

3.3 Proposed Quarry Expansion

3.3.1 Introduction

A brief overview of the proposed quarry expansion is given in **Section 3.2.1** and emissions estimates for the selected maximum emission scenarios presented in subsequent subsections. Information on the emission factors applied in the quantification of sources and the inputs used in predictive emission factor equations are also provided.

3.3.2 Quarry Expansion Overview

SCCCR proposes to extend its current quarry operations across both ML5087 and ML6322. Material extraction, importation and production rates given as being indicative of maximum quarry operations were given as follows (Chris Outtersides, City Plan Services, 5 September 2007):

- Approximately 350 000 tonnes of material comprising up to 35 000 tonnes of weathered rip shale and 315,000 tonnes of unweathered shale will be extracted from the quarry per annum (increased from 175 500tpa currently).
- Approximately 150 000 tonnes of construction, concrete waste material, waste bitumen and quarry products from other quarries to be imported per annum (increased from 55 000 tpa currently). In addition, up to approximately 200 000 tonnes of VENM will be imported into the site per annum.
- The final product will be comprised of a mixture of the above materials in the quantities as set out above.

Product will be transported from the processing area to the stockpiling area by one or two front-end loaders and road transport vehicles will transport the product from the stockpiling area via a haul road on the eastern margin of the extraction area.

The Hours of Operation will be as follows.

- Extraction, processing and VENM backfilling-related activities will take place 7.00am to 6.00pm, Monday to Friday and 7.00am to 4.00pm on Saturdays.
- Product dispatching will be undertaken between 7.00am and 6.00pm, Monday to Saturday. Unladen trucks would be able to arrive at the Project Site from 6.00am and may return to the Project Site until 8.00pm.
- Maintenance-related activities will take place 6.00am to 10.00pm, Monday to Friday, and 6.00am to 6.00pm on Saturdays.
- The quarry will not operate on Sundays or Public Holidays.

The number of blasting operations will increase, with up to 18 blasts per year. The average area affected by each blast will be in the range of 1 250m^2 to 1 500m^2. Blasts will continue to take place around 13h00 Monday to Friday.

It is proposed that crushing and screening operations will proceed as at present, but with increased throughput as indicated above. The mobile crushing plant will continue to be fitted with dust suppression equipment to limit the generation of airborne dust. In addition to this, any stockpiles likely to contribute to substantial dust lift-off would be watered with sprinklers or a water cart. A water cart with at least 8,000L capacity would continue to be used as required to limit the generation of airborne dust from roads and other areas.

3.3.3 Scenarios Selected for Emissions Inventory and Modelling

Extraction will be undertaken in a staged manner with operations progressing from north to south (**Figure 25**). The estimation of emissions and simulation of resultant air pollutant concentrations for each stage of quarry development is impractical. Instead, a worst case emission scenario was selected taking into account maximum quarry extraction rates and stages of development where quarry activities would be in closest proximity to neighbouring sensitive receptor sites. This emission scenario was defined as comprising the following simultaneous operations.

- Vegetation clearing, topsoil and subsoil removal and storage and initiation of weathered shale ripping and extraction within the Stage 6 area.
- Extraction of unweathered shale within the Stage 5 area, with crushing and screening operations being located and operational in this area.
- Transportation of approximately 200 000tpa VENM to the Stage 4 area for use in backfilling and rehabilitation operations.
- Importation of approximately 150 000 tpa of raw material to the site.
- Haulage of product (at maximum production rates) from the Stage 6 and Stage 5 areas along the unpaved haul road to the main site access.

This maximum production scenario, with quarry operations on the southern part of the lease area, includes maximum on-site haul distances and the greatest proximity to the residential dwelling and saw mill situated to the south of the site. Source locations assumed for the worst case future emission scenario are illustrated in **Figure 26**.

3.3.3.1 Future Scenario 1 – Proposed Dust Controls

Emissions were estimated and dispersion simulations undertaken with the existing dust control measures in. Such controls represent a continuation of current dust mitigation practices and primarily comprise the use of wet suppression for unpaved roads (water truck) and crushing and screening operations (water sprays). Maximum dust control efficiencies of 75% for the unpaved haul road and 60% for crushing and screening operations are achievable through the application of these measures.

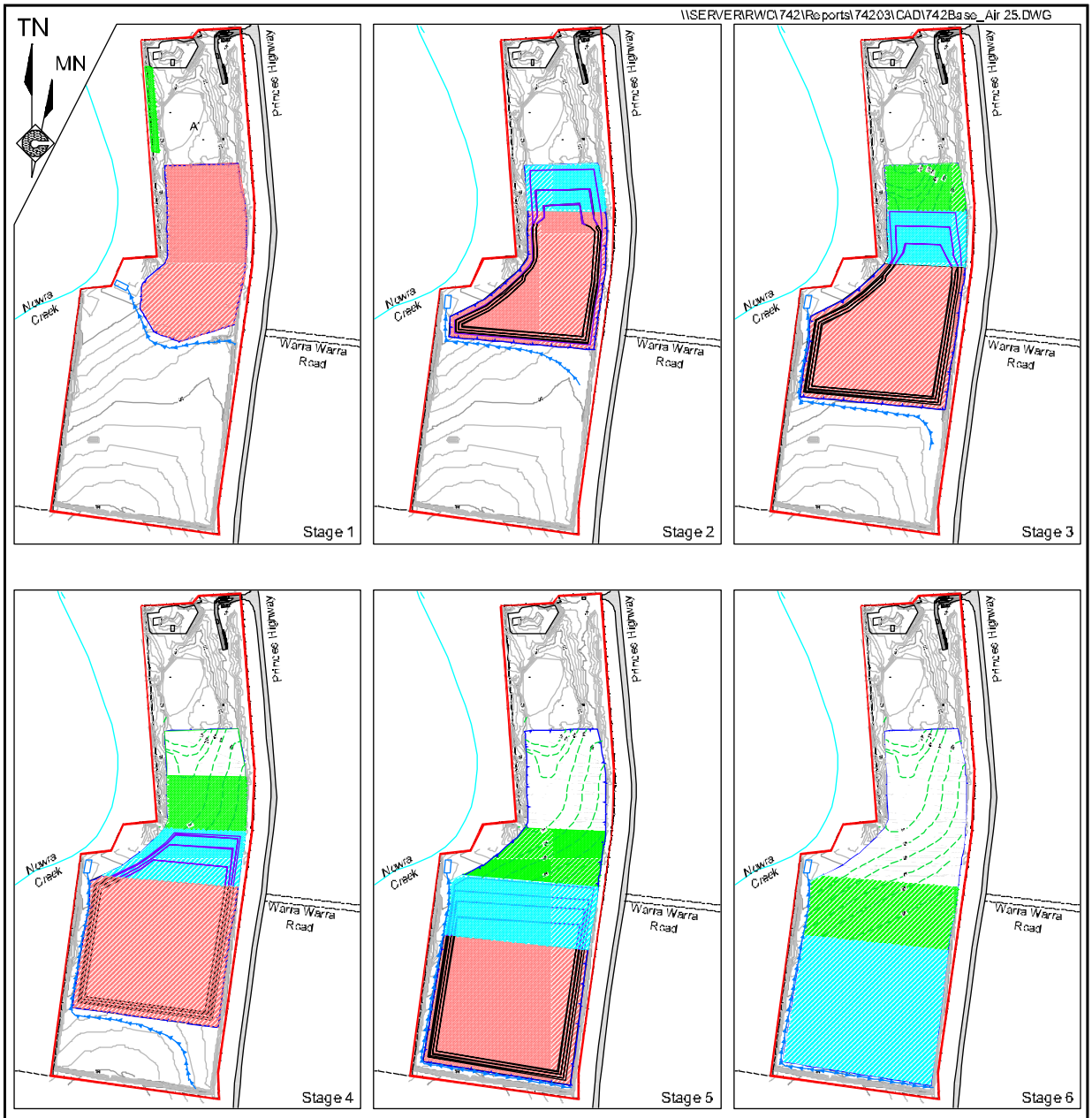


Figure 25
PROPOSED DEVELOPMENT STAGES

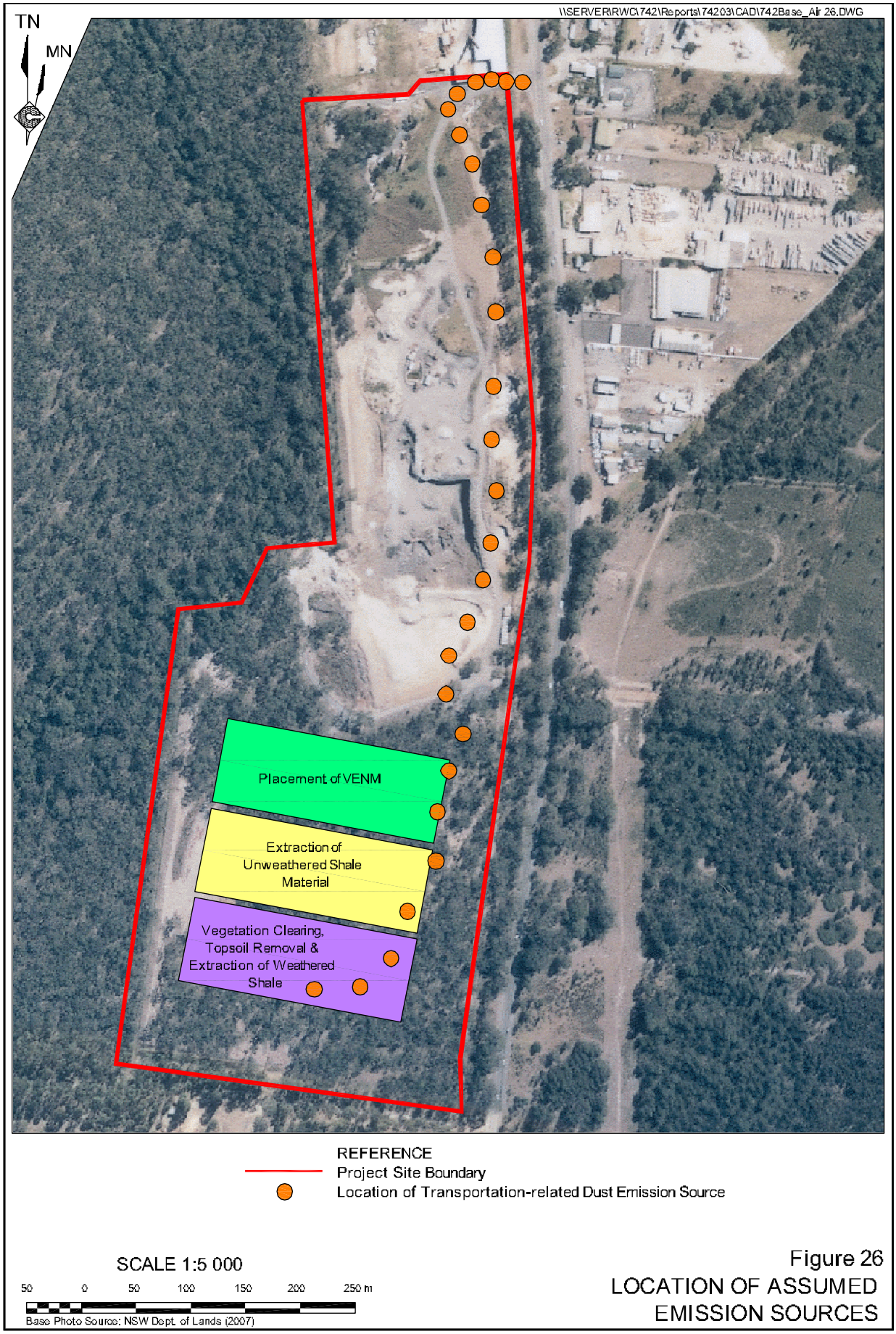


Figure 26
LOCATION OF ASSUMED EMISSION SOURCES

3.3.3.2 Future Scenario 2 – Additional Dust Controls

Uncertainties regarding the adequacy of the proposed dust controls in achieving compliance with air quality criteria, made it necessary to undertake a further simulation scenario comprising the implementation of dust controls associated with higher potential control efficiencies for the most significant sources.

The control efficiency for vehicle entrainment from unpaved haul roads was assumed to increase from 75% to 90%. This is most practically achieved in the case of temporary roads through the effective use of chemical suppression. The effectiveness of this control measure would be dependent on:

- successful selection and application of a suitable chemical suppression system;
- avoidance of material being deposited or tracked onto the road (e.g. through stabilisation of road shoulders); and
- the timely clean up of material deposited on the treated road.

Reductions in vehicle speed along unpaved haul roads and the minimisation of truck activity rates (where possible) represent further measures implementable to ensure high dust control efficiencies are achieved. The use of chemical suppression was also assumed to be implemented within the weathered shale extraction and rehabilitation areas.

The control efficiencies for crushing operations were assumed to increase from 60% to 80%. This is achievable through the use of wind sheltering in combination with efficient mist sprays or through the enclosure of operations and venting of dust loaden air to abatement technologies (e.g. baghouse) prior to being released to the atmosphere.

3.3.4 Emissions from Proposed Quarry Operations

Emissions data for Future Scenarios 1 and 2 are presented in **Table 13** and **Table 14** respectively. Information on the emission factors applied in the quantification of sources and the inputs used in predictive emission factor equations are also provided.

TSP, PM_{10} and $PM_{2.5}$ emissions were estimated to increase from current quarry operations by 69%, 64% and 57% respectively for Future Scenario 1. This is due in to the increase in extraction, importation and processing rates, increases in the vehicle trip numbers and the length of the haul route, vegetation cover removal and topsoil and subsoil stockpiling and increased rehabilitation efforts. Through the application of additional dust controls as assumed for Future Scenario 2, TSP, PM_{10} and $PM_{2.5}$ emissions due to maximum proposed quarry operations would increase by 50%, 45% and 42% respectively above current levels.

Based on Future Scenario 1, vehicle entrainment was estimated to represent a significant source of TSP, PM_{10} and $PM_{2.5}$ emissions (39%, 28% and 15% respectively), with crushing and screening operations estimated to contribute 16%, 31% and 51% of such emissions respectively. Dozer operations associated with land clearing and rehabilitation was also identified as having a significant contribution (30%, 21% and 12% respectively).

For Future Scenario 2, vehicle entrainment remains the most significant source of total dust with crushing and screening operations being a more significant source of fine particulate emissions.

4 DISPERSION MODELLING METHODOLOGY AND RESULTS

4.1 Dispersion Model Selection and Application

The atmospheric dispersion modelling carried out for this assessment utilises the Ausplume Gaussian Plume Dispersion Model software (Version 6.0) developed by the EPA, Victoria. Default operation specified in the Technical Users Manual (EPA Victoria, 2000) has been used as applicable.

Ausplume version 6.0 or later is the approved dispersion model for use in most simple, near-field applications in NSW, where coastal effects and complex terrain are of no concern (DEC, 2005). The use of the Ausplume steady-state model is considered appropriate for this assessment due to the nature of the terrain and the availability of meteorological data in close proximity to the proposed development site (i.e. Bureau of Meteorology's Nowra RAN Meteorological Station). The relatively uncomplicated terrain means that atmospheric dispersion of pollutants at the proposed site will not be strongly influenced by complex drainage flows such as katabatic drift or terrain influenced channelling effects.

Given that the sources of atmospheric emission associated with the proposed development are non-buoyant and occur near the ground it is expected that the greatest potential for air quality impacts will occur in the near field. This further supports the selection of Ausplume for application in the dispersion simulations.

Input data types required for the Ausplume model include: meteorological and terrain data, source and emissions data, and information on the nature of the receptor grid. Source and emission data inputs to the model are given in **Section 3** and **Appendix 2**. Further details of the meteorological data set input in the dispersion simulations and the modelling domain and receptor grid specified are given in subsequent subsections.

4.1.1 Meteorological Data Inputs

In terms of meteorological data inputs, Ausplume requires, as a minimum, hourly values (preferably hourly averages) of wind speed, wind direction, atmospheric stability (expressed as Pasquil classes) and mixing depth. Hourly temperatures are also required if the model is to be used to simulate stacks emitting at temperatures above ambient.

Measured wind field and temperature data from the nearby Bureau of Meteorology's Nowra RAN AWS for the year 2001 were used as input in the dispersion simulations. This year was selected due to it coinciding with the most recent year for which measured ambient PM_{10} concentrations were available for the region.

Table 12
Estimated emissions for future quarry operations – Scenario 1 comprising proposed dust control measures

Source	TSP	PM_{10}	$PM_{2.5}$	Emission Factor Applied	Calculation Inputs
	Tpa	tpa	tpa		
Paved road section	1.18	0.23	0.03	US-EPA AP42 Paved Roads (Section 13.2.1) (November 2006)	Silt loading of 2.4g/m² used based on site observations and generic loadings given for concrete batching operations. Road length approximately 50m. Vehicle kilometres travelled (VKT) given as being 120 per day.
Unpaved haul road	36.03	8.74	0.87	US-EPA AP42 Unpaved Roads (Section 13.2.2) (November 2006)	Road length of approximately 1.1km with an estimated 120 vehicle return-trips per day. The silt content of the road surface material was assumed to be 8.3%, given by the US-EPA as being characteristic of haul roads within sand quarry operations. The dust control efficiency due to watering was assumed to be 75% as for current operations.
Materials handling	7.51	3.55	0.54	US-EPA AP42 Aggregate Handling (Section 13.2.4) (November 2006)	A mean wind speed of 4m/s (based on 2001-2006 hourly measurements from Nowra RAN Air Station) was used in the calculations. Material moisture contents of 9%, 4% and 2% were used for rip shale, blue shale and products respectively to estimate emissions from the expanded volumes being handled.
Crushing & screening	15.12	9.58	2.91	NPI EETM for Mining Version 2.3, Dec 2001	Emission factors for high moisture (>4%) ores was applied. Dust control efficiency achieved through wet suppression of 60% was assumed as for current operations.
Dozer operations	28.29	6.66	0.67	NPI EETM for Mining Version 2.3, Dec 2001	Two dozer assumed to be in operation during quarry operational hours, one undertaking soil stripping operations and the other rehabilitation.
Wind erosion of exposed areas	3.15	1.58	0.24	NPI EETM for Mining Version 2.3, Dec 2001	Generic emission factor of 0.3 kg/ha/hr used over a maximum area of 15ha.
Blasting operations	1.76	0.92	0.46	NPI EETM for Mining Version 2.3, Dec 2001	18 blasts per year were given covering an area of 1250m² to 15000 m² (latte used in estimations); with a depth of 12m. A moisture content of 4% was assumed.
TOTAL	**93.05**	**31.24**	**5.72**		

Table 13
Estimated emissions for future quarry operations – Scenario 2 comprising additional dust control measures

Source	TSP	PM_{10}	$PM_{2.5}$	Emission Factor Applied	Calculation Inputs
	Tpa	tpa	tpa		
Paved road section	1.18	0.23	0.03	US-EPA AP42 Paved Roads (Section 13.2.1) (November 2006)	Silt loading of 2.4g/m² used based on site observations and generic loadings given for concrete batching operations. Road length approximately 50m. Vehicle kilometres travelled (VKT) given as being 120 per day.
Unpaved haul road	14.41	3.50	0.35	US-EPA AP42 Unpaved Roads (Section 13.2.2) (November 2006)	Road length of approximately 1.1km with an estimated 120 vehicle return-trips per day. The silt content of the road surface material was assumed to be 8.3%, given by the US-EPA as being characteristic of haul roads within sand quarry operations. **A dust control efficiency of 90% was assumed.**
Materials handling	7.51	3.55	0.54	US-EPA AP42 Aggregate Handling (Section 13.2.4) (November 2006)	A mean wind speed of 4m/s (based on 2001-2006 hourly measurements from Nowra RAN Air Station) was used in the calculations. Material moisture contents of 9%, 4% and 2% were used for rip shale, blue shale and products respectively to estimate emissions from the expanded volumes being handled.
Crushing & screening	7.56	4.79	1.46	NPI EETM for Mining Version 2.3, Dec 2001	Emission factors for high moisture (>4%) ores was applied. **A dust control efficiency of 80% was assumed.**
Dozer operations	11.32	2.66	0.27	NPI EETM for Mining Version 2.3, Dec 2001	Two dozer assumed to be in operation during quarry operational hours, one undertaking soil stripping operations and the other rehabilitation. **A dust control efficiency of 90% was assumed.**
Wind erosion of exposed areas	3.15	1.58	0.24	NPI EETM for Mining Version 2.3, Dec 2001	Generic emission factor of 0.3 kg/ha/hr used over a maximum area of 15ha.
Blasting operations	1.76	0.92	0.46	NPI EETM for Mining Version 2.3, Dec 2001	18 blasts per year were given covering an area of 1250m² to 15000 m² (latte used in estimations); with a depth of 12m. A moisture content of 4% was assumed.
TOTAL	**46.90**	**17.22**	**3.34**		

Atmospheric stability class and mixing depth are not routinely measured at weather stations. Site-specific stability and mixing depth data were generated through the application of The Air Pollution Model (TAPM) software developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), as described in **Section 2.2.5**. TAPM is frequently used to provide the required meteorological input data for the regulatory Ausplume model where insufficient on-site meteorological data are available.

4.1.2 Modelling Domain and Receptor Grid

The dispersion of pollutants was modelled for an area covering 2.8 km by 3.1 km with the proposed development site situated near the centre of the modelling domain. Receptor points were specified at intervals of 100m. The Ausplume model simulates ground-level concentrations for each of the receptor grid points. In addition to the gridded receptor points, discrete receptors were defined for selected sensitive receptor sites situated in close proximity to the quarry's operations. The extent of the air dispersion modelling domain and location of the discrete receptors used in the simulations are illustrated in **Figure 27**.

4.2 Model Results

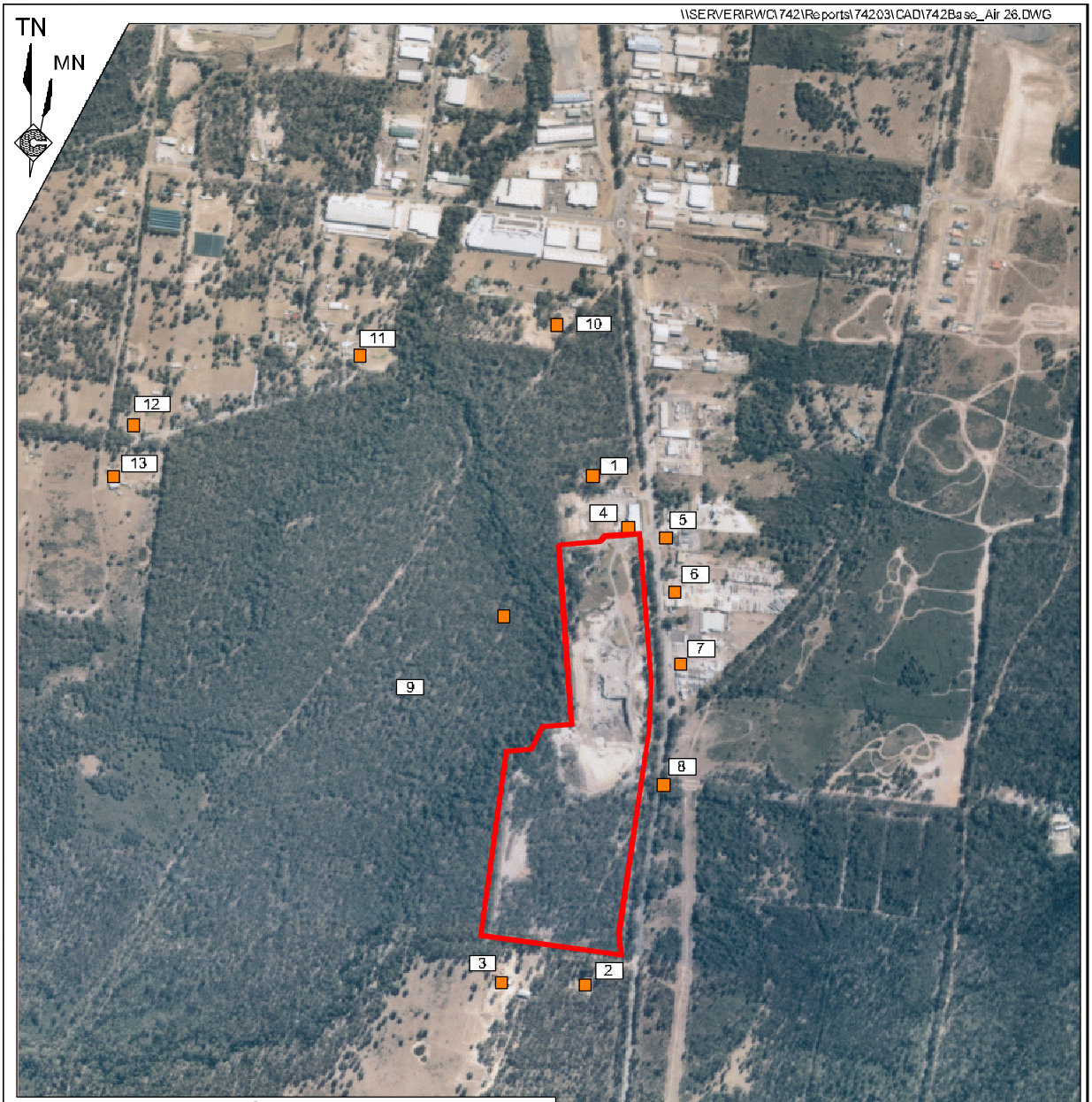
Dispersion simulations were undertaken and results analysed for highest daily and annual average PM_{10} concentrations and annual average dust deposition occurring due to the following Operational Scenarios.

- Current (basecase) Quarry Operations.
- Future Quarry Operations – Scenario 1, Current Dust Controls (as described in **Section 3**).
- Future Quarry Operations – Scenario 2, Additional Dust Controls (as described in **Section 3**).

Incremental suspended particulate concentrations and dust deposition rates occurring exclusively due to quarry and cumulative particulate concentrations, taking background levels into account, were modelled. Highest daily and annual $PM_{2.5}$ concentrations were only undertaken for Future Quarry Operations Scenario 2 given that exceedances of the PM_{10} daily criterion was predicted to occur due to Scenario 1 indicating the unacceptability of this emission scenario.

Results of particulate concentration and dust deposition rates predicted at discrete receptor points are presented for Current Quarry Operations and Scenario 1 and 2 Future Quarry Operations in **Table 15**, **Table 16** and **Table 17** respectively.

Isopleth plots illustrating the spatial extent of daily maximum PM_{10} criterion exceedances and the incremental dust deposition threshold are presented in **Figure 28** and **Figure 29** respectively.



REFERENCE
Project Site Boundary
1 Location of Modelled Receptor

Receptor No.	Description
1	Dwelling to north of quarry
2	Dwelling to south of quarry
3	Saw mill
4	Brickworks
5	Butchery
6	Light industry (to east, pt 1)
7	Light industry (to east, pt 2)
8	Warra Warra traffic circle (proposed)
9	South Coast Correctional Centre (proposed)
10	Low density residential north
11	Low density residential NNW
12	Low density residential NW
13	Low density residential WNW

SCALE 1:15 000

250 0 250 500 750 m

Base Photo Source: NSW Dept. of Lands (2007)

Note: A colour version of this figure is available on the Project CD

Figure 27
LOCATION OF Modelled RECEPTORS

Table 14
Predicted PM_{10} concentrations and dust deposition rates for Current Quarry Operations

Receptor No.	Receptor description	Scenario - Current Quarry Operations						
		Incremental PM_{10} Concentrations and Dust Deposition (excluding background concentrations / deposition rates)				Cumulative PM_{10} Concentrations (including background concentrations / deposition rates)		
		Maximum daily PM_{10} Concentrations ($\mu g/m^3$)	Annual Average PM_{10} Concentrations ($\mu g/m^3$)	Dust Deposition (g/m^2/month)	Frequencies of Exceedance of Daily PM_{10} Criterion (days/year)	Maximum daily PM_{10} Concentrations ($\mu g/m^3$)	Annual Average PM_{10} Concentrations ($\mu g/m^3$)	Frequencies of Exceedance of Daily PM_{10} Criterion (days/year)
	Assessment Criteria	50	30	4		50	30	
1	Dwelling to north of quarry	14	1.5	0.76	0	30	11.4	0
2	Dwelling to south of quarry	12	0.2	0.06	0	31	10.1	0
3	Saw mill	6	0.2	0.06	0	25	10.1	0
4	Brickworks	33	5.1	3.46	0	46	15.0	0
5	Butchery	19	5.1	3.72	0	34	15.0	0
6	Light industry (to east, pt 1)	30	5.4	3.63	0	42	15.3	0
7	Light industry (to east, pt 2)	33	6.1	2.64	0	41	16.0	0
8	Warra Warra Roundabout (proposed)	13	1.4	0.27	0	33	11.3	0
9	South Coast Correctional Centre (proposed)	14	0.6	0.16	0	27	10.5	0
10	Low density residential north	5	0.4	0.17	0	25	10.3	0
11	Low density residential NNW	4	0.2	0.06	0	25	10.1	0
12	Low density residential NW	2	0.1	0.02	0	25	10.0	0
13	Low density residential WNW	2	0.1	0.03	0	25	10.0	0

Notes:

Exceedance of guideline levels indicated in bold.

The NSW DECC criteria for incremental dust deposition rates is given for proposed developments and not specifically applicable for current operations. Reference is therefore made to the dust deposition criterion given for total dust deposition rates permissible for the purpose of assessing existing deposition rates.

Results are considered conservative since vegetation screening due to the existing tree line is not accounted for in the air dispersion simulations.

Table 15
Predicted PM_{10} concentrations and dust deposition rates for Future Quarry Operations – Scenario 1

Receptor No.	Receptor description	Future Quarry Operations – Scenario 1 – Proposed Dust Controls						
		Incremental PM_{10} Concentrations and Dust Deposition (excluding background concentrations / deposition rates)				Cumulative PM_{10} Concentrations (including background concentrations / deposition rates)		
		Maximum daily PM_{10} Concentrations (µg/m³)	Annual Average PM_{10} Concentrations (µg/m³)	Dust Deposition (g/m²/month)	Frequencies of Exceedance of Daily PM_{10} Guideline (days/year)	Maximum daily PM_{10} Concentrations (µg/m³)	Annual Average PM_{10} Concentrations (µg/m³)	Frequencies of Exceedance of Daily PM_{10} Guideline (days/year)
	Assessment Criteria	50	30	2		50	30	
1	Dwelling to north of quarry	23	2.3	1.16	0	35	12.2	0
2	Dwelling to south of quarry	**94**	3.3	0.84	1	**113**	13.2	**1**
3	Saw mill	**63**	3.9	1.06	2	**70**	13.8	**4**
4	Brickworks	**68**	8.0	**5.41**	2	**71**	17.9	8
5	Butchery	35	7.8	**5.73**	0	44	17.7	0
6	Light industry (to east, pt 1)	27	6.4	**4.27**	0	39	16.3	0
7	Light industry (to east, pt 2)	30	5.6	**2.42**	0	41	15.5	0
8	Warra Warra Roundabout (proposed)	50	9.6	1.80	0	**61**	19.5	**5**
9	South Coast Correctional Centre (proposed)	30	1.7	0.48	0	39	11.6	0
10	Low density residential north	12	0.8	0.36	0	26	10.7	0
11	Low density residential NNW	9	0.5	0.17	0	28	10.4	0
12	Low density residential NW	8	0.3	0.09	0	26	10.2	0
13	Low density residential WNW	8	0.3	0.09	0	25	10.2	0

Note: Exceedance of guideline levels indicated in bold.

Table 16
Predicted PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates for Future Quarry Operations – Scenario 2

Receptor No.	Receptor description	Future Quarry Operations – Scenario 2 – Additional Dust Controls						
		Cumulative Particulate Concentrations (including background concentrations / deposition rates)						Dust Deposition Rates (Incremental) (g/m^2/month)
		Maximum daily PM_{10} Concentrations ($\mu g/m^3$)	Annual Average PM_{10} Concentrations ($\mu g/m^3$)	Frequencies of Exceedance of Daily PM_{10} Guideline of 50$\mu g/m^3$ (days/year)	Maximum daily $PM_{2.5}$ Concentrations ($\mu g/m^3$)	Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$)	Frequencies of Exceedance of Daily $PM_{2.5}$ Criterion of 25$\mu g/m^3$ (days/year)	
	Assessment Criteria	50	30		25	8		2
1	Dwelling to north of quarry	27	11.00	0	13.20	5.36	0	0.6
2	Dwelling to south of quarry	34	11.60	0	**26.25**	5.78	1	0.6
3	Saw mill	42	12.00	0	19.23	5.90	0	0.8
4	Brickworks	39	14.20	0	14.00	5.81	0	**2.2**
5	Butchery	31	14.60	0	13.94	5.87	0	2.0
6	Light industry (to east, pt 1)	27	12.70	0	13.50	5.56	0	2.0
7	Light industry (to east, pt 2)	27	12.40	0	13.35	5.57	0	1.7
8	Warra Warra traffic circle (proposed)	36	14.50	0	14.33	6.04	0	**2.7**
9	South Coast Correctional Centre (proposed)	25	10.80	0	14.28	5.39	0	0.3
10	Low density residential north	25	10.30	0	13.20	5.24	0	0.2
11	Low density residential NNW	25	10.20	0	13.20	5.21	0	0.1
12	Low density residential NW	25	10.10	0	13.20	5.18	0	0.1
13	Low density residential WNW	25	10.10	0	13.20	5.18	0	0.1

Note: Exceedance of guideline levels indicated in bold.

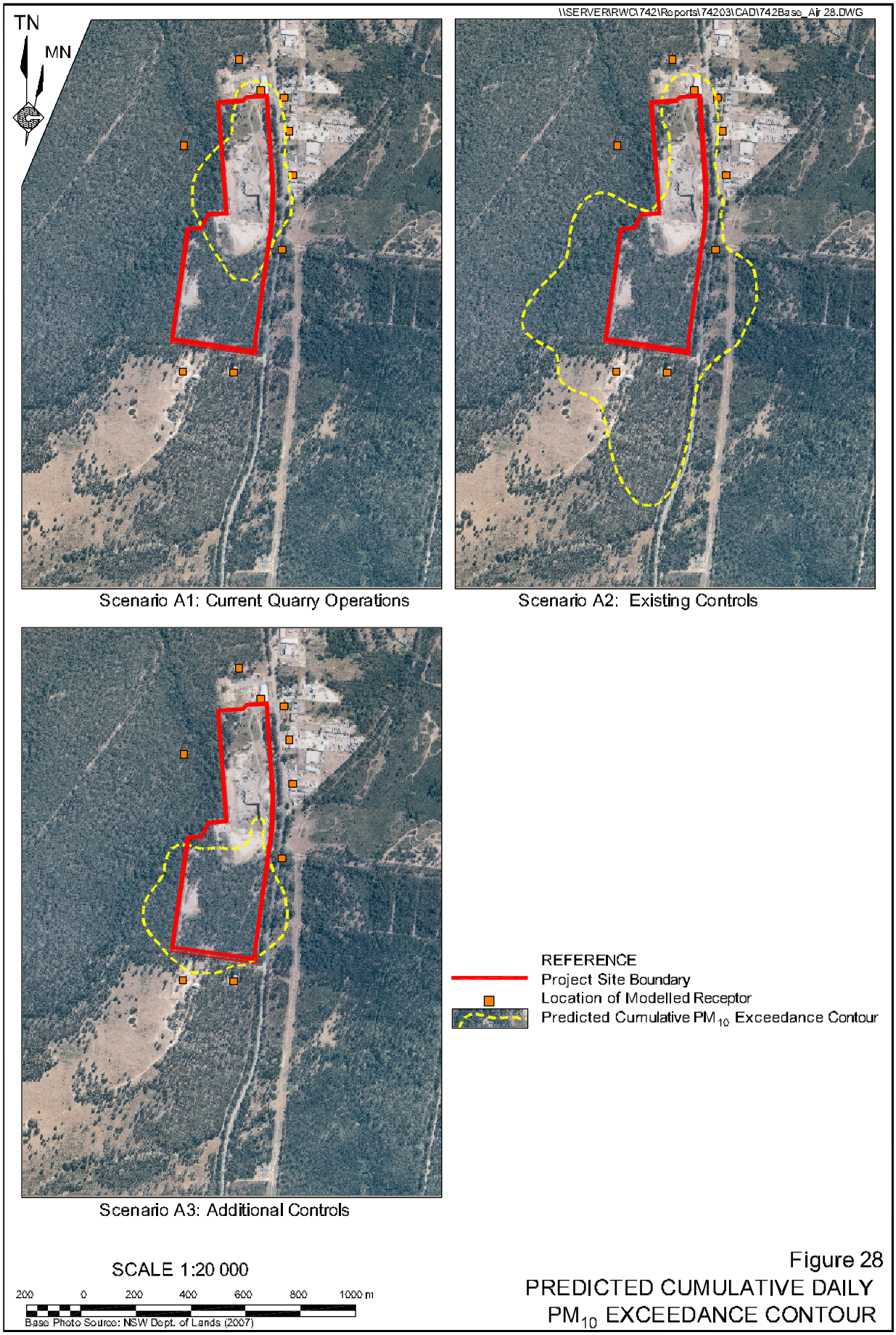
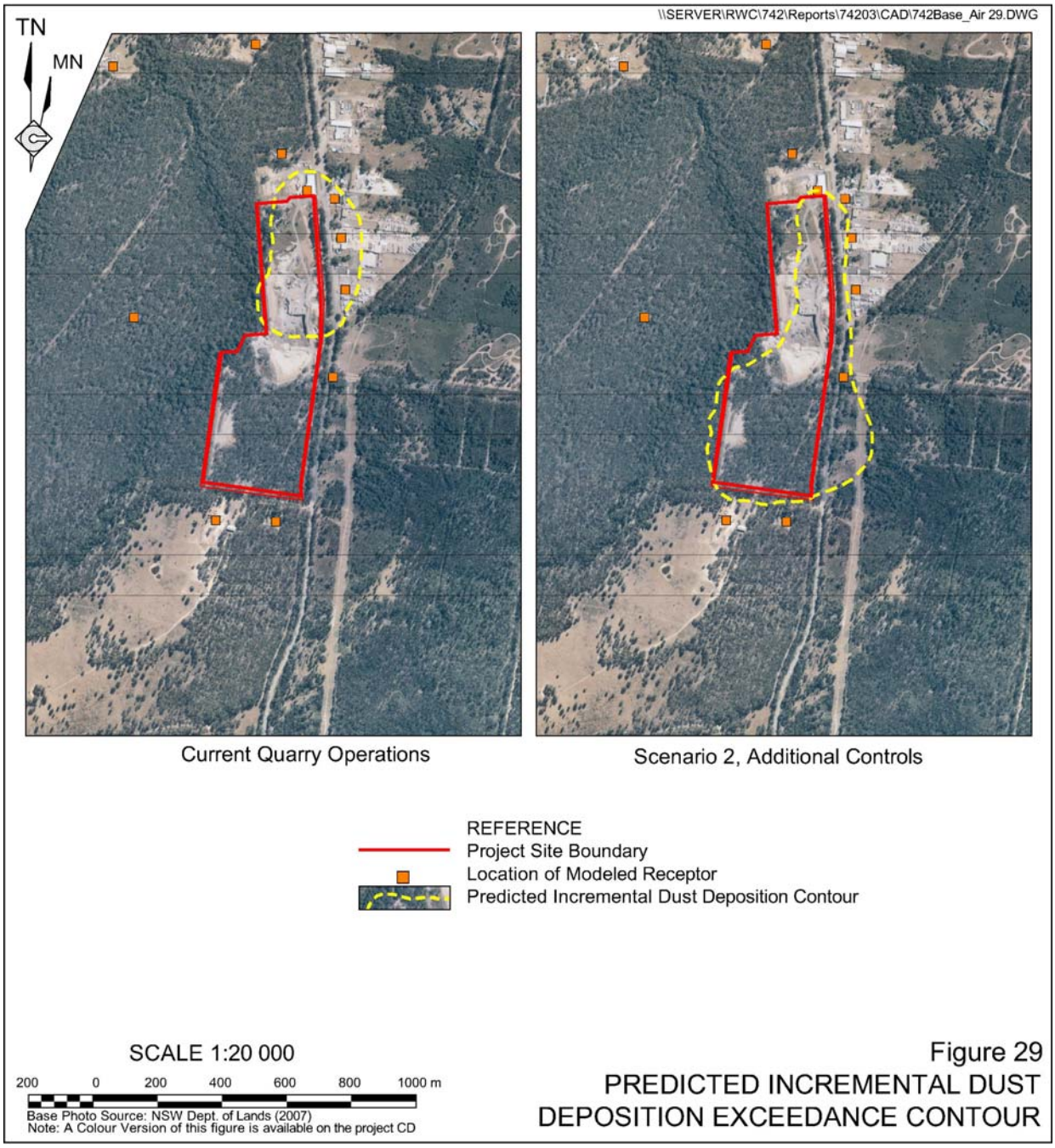


Figure 28
PREDICTED CUMULATIVE DAILY PM_{10} EXCEEDANCE CONTOUR

Note: A Colour Version of this figure is available on the project CD



Isopleth plots, illustrating spatial variations in cumulative particulate concentrations and dust deposition rates due to Current (base-case) and Future Quarry Operations (Scenario 2), are provided in **Appendix 3**. Results are not presented in full for Future Operations – Scenario 1 since this scenario does not ensure compliance with air quality criteria.) Isopleth plots of maximum daily average PM_{10} and $PM_{2.5}$ concentrations presented in **Appendix 3** do not represent the dispersion pattern on any individual day, but rather illustrate the maximum daily concentration that was simulated to be possible at each receptor point given the range of meteorological conditions occurring over the period modelled (1 year).

5 AIR QUALITY ASSESSMENT

5.1 Introduction

The air quality assessment comprises an analysis of compliance with ambient air quality criteria and the evaluation of the likelihood of impacts on human health and welfare and other aspects of the biophysical environment as a result of atmospheric emissions due to the proposed quarry expansion.

5.2 Compliance with Ambient Air Quality Criteria

5.2.1 Current Quarry Operations

Airborne particulate concentration and dust deposition predictions for current quarry operations are conservative in that vegetation screening by the tree line bordering various of the quarry boundaries were not accounted for in the atmospheric dispersion simulations.

Cumulative PM_{10} concentrations due to current routine quarry operations are not predicted to result in exceedances of PM_{10} criteria at any neighbouring sensitive receptor sites (based on 2001 data from Nowra Sewage Treatment Works monitoring station) (**Table 15, Figure 25**).

Given that the NSW DECC dust deposition criteria is primarily given for the assessment of proposed developments rather than existing operations, reference is made to the cumulative dust deposition criterion of 4g/m²/month in evaluating current dust deposition rates. Dust deposition rates due to current quarry operations were predicted to be in the range 2.6g/m²/month to 3.7g/m²/month at adjacent industrial sites, with deposition rates at nearby sensitive receptor sites below 1.5 g/m²/month (**Table 15, Figure 26)**. The predicted dust deposition rates are within the cumulative dust deposition criterion.

5.2.2 Future Quarry Operations – Scenario 1, Current Dust Controls

Cumulative PM_{10} concentrations due to future quarry operations, with current dust controls in place, are predicted to result in exceedances of the daily maximum PM_{10} criterion at the residential dwelling situated immediately south of the quarry (1 day/year) and at the nearby saw mill (4 days/year). The most frequent exceedances are predicted for the brickworks (8 days/year), with exceedances also predicted at the proposed Warra Warra Road roundabout (5 days/year). No exceedances of the annual PM_{10} criterion are projected (**Table 16, Figure 25**).

Given that the future operations are proposed, the NSW DECC incremental dust deposition criterion of 2g/m²/month applies in evaluating predicted dust deposition rates. Dust deposition rates in excess of the permissible dust deposition threshold of 2g/m²/day are predicted to occur at the brickworks and within the light industrial area to the east of the site across the Princes Highway including at the nearby butchery (**Table 16, Figure 26)**.

Additional dust controls are therefore likely to be required to ensure airborne particulate concentrations and dust deposition rates due to future quarry operations comply with NSW DECC air quality criteria.

5.2.3 Future Quarry Operations – Scenario 2, Additional Dust Controls

With the additional dust controls identified in **Section 3** implemented, cumulative PM_{10} concentrations due to proposed quarry operations are predicted to be in compliance with PM_{10} criteria at nearby sensitive receptor sites (**Table 17, Figure 25**).

Dust deposition rates were generally within the permissible incremental threshold of 2g/m²/day, with minor exceedances at the brickworks and proposed Warra Warra Road traffic circle. *Such dust deposition was however lower than the dust deposition rates predicted to occur at these sites due to current quarry operations* (**Table 17, Figure 26)**.

Due to emissions from this future quarry operation scenario being predicted to be within permissible PM_{10} concentration and dust deposition levels, the scenario was further assessed for compliance with advisory criteria given nationally for $PM_{2.5}$ concentrations. Cumulative concentrations of $PM_{2.5}$ are predicted to be below the advisory criteria at all sensitive receptors with the exception of the residence to the south of the quarry where the advisory daily criterion of 25µg/m³ is predicted to be marginally exceeded (by 1µg/m³) on one day during the year modelled (**Table 17**)[(1)].

5.3 Potential for Dust Impacts on Vegetation and Livestock

Various studies have examined the impact of dust contamination on pastures, plants and livestock (Lillie, 1970; Lodge *et al.*, 1981; Yang, 1988; Mentor Consulting, 1993; Environment Canada, 1998; Hunt, 2003).

Effects on vegetation can occur due to physical smothering of the leaf surface which results in reduced light transmissions and hence reduced photosynthesis and physical blocking of stomata through particle lodging resulting in reduced stomatal functioning. Depending on the particle composition, effects could also include direct chemical effects or indirect effects on soil pH and ionic composition. Yang (1988) noted that dust deposition levels of 0.75 to 1.5g/m²/day (i.e. 22 to 45g/m²/month) would not result in adverse effects on plant production. Decreased respiration rates were noted to occur for cereals when cement dust deposition rates exceeded 7g/m²/day (Environment Canada, 1998).

Mentor Consulting (1993), as quoted in Hunt (2003), undertook grazing trials in NSW with dairy cattle. The trails were designed to determine the impact of coal mine dust contamination of pasture on pasture intake, grazing behavior and milk production of dairy cattle. Coal dust added to a pasture equivalent to 8g/m²/day had no effect on pasture palatability or cattle production. Hunt (2003) cites a study by Marek and Hais (1970) which investigated dust inhalation and ingestion of contaminated pastures by dairy cattle. According to this study, production levels were reduced by about 10% when deposition levels reached 48 to 96g/m²/month but not detectable at lower dust deposition rates.

[1] Background $PM_{2.5}$ concentrations were projected based on 2001 PM_{10} concentrations measured at the Nowra Sewage Treatment Works monitoring station and $PM_{2.5}/PM_{10}$ ratios measured to occur at Wollongong.

Documented dose response thresholds given for potential impacts on vegetation, including sensitive natural vegetation and crops, and livestock are orders of magnitude higher than were predicted to occur in the vicinity of the quarry operation. Controlled emissions from the quarry are therefore not expected to be associated with any significant impacts on neighbouring vegetation and potential livestock.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Main Study Findings

6.1.1 Baseline Environment and Current Quarry Operations

The main findings of the baseline environment study, which comprised an assessment of the legislative context, proximity of sensitive receptors, potential for cumulative impacts given neighbouring sources and review of the atmospheric dispersion potential of the area and dust generation related to existing SCCCR operations, were as follows:

- There are a number of sources of atmospheric emission in proximity to the SCCCR operation which contribute to ambient particulate concentrations including certain industrial operations (e.g. neighbouring brickworks, concrete batching operation and saw mill) and diffuse sources such as vehicle entrainment from public (paved and unpaved) roads and off-track vehicle activity.
- Based on historical data (1996-2001) it was found that elevated airborne concentrations of fine particulates occur in the region but that such concentrations are within air quality criteria with a decreasing trend in concentrations. No more recent data are available on which to determine more recent compliance and trends.
- Rainfall occurs on approximately 18% of days during the year, increasing moisture contents and reducing dust generation potentials during and immediately following rainfall events.
- Strong wind prevails frequently in the area increasing the potential for dust generation on no-rain days. The wind sheltering of quarry activities through in-pit operations, use of bund walls and retention of tree lines is considered to significantly reduce the potential for quarry emissions and impacts.
- The wind field is dominated by two main wind components, namely northwesterly to westerly wind and southerly to south-southwesterly airflow. This indicates that receptors situated to the east, southeast and north of the SCCCR site are more likely to be impacted should significant emissions occur at the site.
- Developments to the north include Nowra brickworks and a single residential dwelling. The South Nowra commercial area is located further to the north (>1km) beyond the likely impact area of the quarry.
- Potential receptors to the east comprise light industrial and commercial developments. Although the bund walls and tree line on the eastern boundary of the site serve to reduce the potential for impacts on such receptors, it is noted that these operations are located in close proximity to quarry operations and therefore that impacts could occur if dust controls are not consistently applied at the quarry.

- Crushing operations and vehicle entrainment from unpaved road sections represent the largest sources of routine emissions, with blasting operations comprising a significant but intermittent source. Materials handling and wind entrainment were estimated to be more minor sources. The potential for re-entrainment of material tracked onto the Princes Highway (mainly from the road shoulders) was identified as being potentially significant due to the extent of vehicle activity along this road and the fact that these sources occurs off-site, in relative proximity to potential receptors.
- Wet suppression represents the main type of dust mitigation measure implemented at the quarry. Given the frequency and intensity of watering evident at the SCCCR site, control efficiencies are expected to be in excess of 70% for roads and greater than 60% for crushing operations.
- Current routine quarry operations are not predicted to result in exceedances of PM_{10} guidelines at any neighbouring sensitive receptor sites, taking background concentrations into account.
- At nearby residential sites dust deposition rates attributable to the current operation are predicted to be below 1.5 g/m²/month and therefore within the incremental dust deposition threshold of 2g/m²/month.

6.1.2 Proposed Future Quarry Operations (Maximum Production)

Emissions were estimated and dispersion simulations undertaken for two dust control scenarios, namely:

- **Scenario 1 – Current Dust Controls**

  Continuation of current dust mitigation practices which mainly comprise the use of wet suppression for unpaved roads (water truck) and crushing and screening operations (water sprays). Maximum dust control efficiencies of 75% for the unpaved haul road and 60% for crushing and screening operations were assumed to be achievable through the application of these measures.

- **Scenario 2 – Additional Dust Controls**

  The control efficiency for vehicle entrainment from unpaved haul roads was assumed to increase from 75% to 90%. The control efficiencies for crushing operations were assumed to increase from 60% to 80%. These increases in efficiencies could realistically be achieved through the use of chemical dust suppression products and, in the case of crushing operations, the application of either wind sheltering and misting sprays or enclosure and venting to an abatement device such as a baghouse.

Scenario 1 emissions were predicted to result in exceedances of the PM_{10} daily criterion and dust deposition rates in excess of permissible cumulative dust deposition thresholds at various of the nearby sensitive receptor sites. Additional dust controls were therefore concluded to be required to bring airborne particulate concentrations and dust deposition rates due to maximum production future quarry operations into compliance within NSW DECC air quality criteria.

With additional dust controls implemented (Scenario 2), future routine quarry operations are predicted to be in compliance with PM_{10} criteria at nearby sensitive receptor sites, taking into account background concentrations. Advisory criteria for $PM_{2.5}$ are also projected to be met at all receptor sites with the exception of the residences to the south of the quarry where the advisory daily limit of 25µg/m³ is predicted to be marginally exceeded (26µg/m³) on one day during the year modelled. Dust deposition rates were generally within the permissible incremental threshold of 2g/m²/day, with minor exceedances at the brickworks and proposed Warra Warra Road traffic circle. *Such dust deposition was however lower than the dust deposition rates predicted to occur at these sites due to current quarry operations*.

Documented dose response thresholds given for potential impacts on vegetation, including sensitive natural vegetation and crops, and livestock are orders of magnitude higher than are predicted to occur as a result of the proposed quarry operation. Controlled emissions from the quarry are therefore not expected to be associated with any significant impacts on neighbouring vegetation and potential livestock.

6.2 Recommendations

Air quality modelling indicates dust generation and the impact of the current SCCCR operations are currently being adequately managed by the dust mitigation measures being applied and the effect of in-pit operations and the use of bund walls and tree lines.

The proposed operations would however necessitate the application of improved and/or additional dust control measures to ensure compliance with air quality criteria. Recommended measures are as follows:

- Further reduce vehicle entrainment along unpaved haul roads and unpaved working areas to increase dust control efficiencies from 75% to 90%. This is most practically achieved in the case of unsealed roads through the effective use of chemical suppression. The effectiveness of the measure would be dependent on:
  - successful selection and application of a suitable chemical suppression system;
  - avoidance of material being deposited or tracked onto the road (e.g. through stabilisation of road shoulders); and
  - the timely clean up of material deposited on the treated road.
- Reductions in vehicle speed along unpaved haul roads and the minimisation of truck activity rates (where possible) represent further measures implementable to ensure high dust control efficiencies are achieved. Speed limits of 40 kph or lower are recommended for on-site haul roads.
- Increase dust control efficiencies for crushing operations from 60% to 80%. This is achievable through the use of wind sheltering in combination with efficient mist sprays or through the enclosure of operations and venting of dust loaden air to abatement technologies (e.g. baghouse) prior to being released to the atmosphere. Operations should be ceased in the event that dust suppression systems are not operational.

- Installation of a wheel wash at the main gate to reduce material being tracked onto the Princes Highway from the site.
- Consider paving or stabilising road shoulder areas in the immediate vicinity of the main gate to further reduce the potential for track on. (It is noted that this occurs as a result of both quarry-related and other vehicle activity.)
- On-site dust deposition monitoring should be carried out to track the success of dust control measures. It is recommended that two of the existing dust deposition gauges be retained for use on-site in this manner with the third gauge relocated to the residential dwelling south of the quarry as operations expand in this direction.

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APPENDICES

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Appendix 1 Technical Overview of TAPM

Appendix 2 Emissions Inventory Results

Appendix 3 Dispersion Simulation Results

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Appendix 1

Technical Overview of TAPM

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1 Introduction

This appendix clarifies the use of The Air Pollution Model (TAPM) in the generation of site-specific meteorological data.

2 Meteorology and Dispersion Modelling

Air pollutant dispersion models, such as the Ausplume Gaussian Plume Dispersion Model software developed by EPA Victoria, require meteorological data inputs to simulate the potential impacts of pollutants on the nearest receptors. In the past, this has been achieved using observations from the nearest meteorological monitoring station and converting these into a format suitable for dispersion modelling (Martin & Cook, 2002).

However, there are a number of problems inherent in this approach. Upper air parameters such as mixing height are often inaccurately estimated due to the small number of upper air stations in Australia (Martin & Cook, 2002). Additionally, there is often a significant geographical separation between study areas and the nearest meteorological stations, particularly in rural areas.

The Air Pollution Model (TAPM) software, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is often used simulate the meteorology of an area where insufficient on-site meteorological data is available. TAPM is a prognostic model which may be used to predict three-dimensional meteorological data, with no local data inputs required.

The model predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations. TAPM is often used to drive the regulatory Ausplume model where insufficient on-site meteorology data is available.

The TAPM model also allows for the assimilation of wind observations to be optionally included in a model simulation. The wind speed and direction observations are used to “nudge” the predicted solution towards the observation values.

3 TAPM Verification Studies

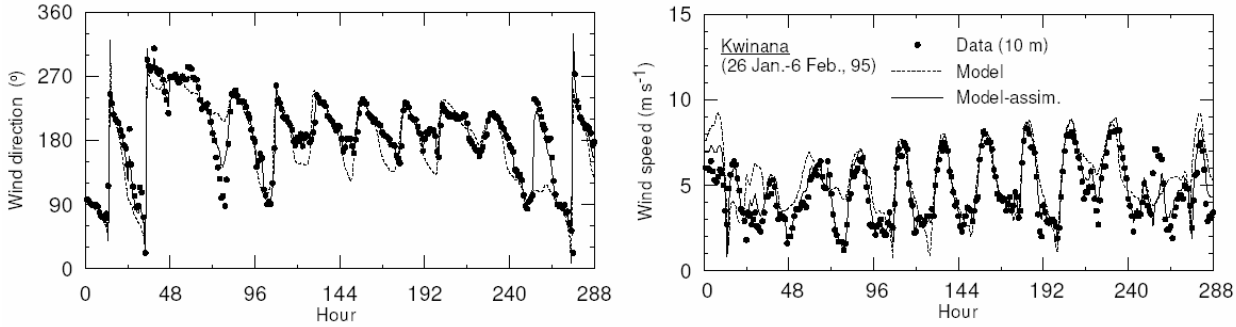
There exists a number of studies that investigate the effectiveness of the TAPM software in simulating site-specific meteorological data. These verification studies demonstrate that TAPM performs well in a variety of regions throughout Australia and for a range of important phenomena such as convective dispersion (Hurley *et al*., 2002). A select number of these studies are detailed below:

The TAPM software was used to simulate the meteorology in Melbourne for winter (July 1998) and summer (December 1998). These predictions were compared with observational data measured as part of the EPA Victoria air quality monitoring. The results of this comparison indicate that TAPM predicts both winds and temperature very well, with no significant biases (Hurley *et al*., 2002).

The effectiveness of TAPM in estimating annual urban meteorology was assessed by comparing a TAPM-simulated data set for Perth with meteorological observations. An analysis of ambient temperature, wind speed and wind direction demonstrates that the meteorology of Perth was well-simulated by the TAPM software throughout the year (Hurley *et al*., 2002).

A comparison of observed and predicted meteorology was undertaken for Kwinana, a coastal industrial region south of Perth, Western Australia. A comparison of these data sets indicates that TAPM simulates the meteorology of the area well, particularly with respect to wind speed and wind direction (Luhar & Hurley, 2002). **Figure A** demonstrates the comparison of observed results with TAPM predictions for these parameters.

Figure A
Hourly Average Wind Speed and Wind Direction (Observed and TAPM-Generated) at Kwinana, WA (Source: Luhar & Hurley, 2002)



TAPM predictions of wind speed, wind direction, temperature and relative humidity were compared with observational data for the Pilbara region, WA. The comparison indicates that there is a strong correlation between predicted and observed results at this site, demonstrating that TAPM-generated meteorology is a useful tool in dispersion modelling (Hurley *et al.,* 2003).

Appendix 2

Emissions Inventory Results

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Scenario - Current Quarry Operations

VOLUME SOURCES	Source ID	TSP Emission Rate	PM10 Emission Rate	PM2.5 Emission Rate	Emission Rate Units	X-coordinate	Y-coordinate	Horizontal Spread (m)	Vertical Spread (m)	Height (m)	Emission Times
Vehicle entrainment - paved road section	PAV01	0.01194	0.00229	0.00033	g/s	281033	6132927	10	0.25	1	07h00 - 16h00, weekdays
	PAV02	0.01194	0.00229	0.00033	g/s	281018	6132926	10	0.25	1	07h00 - 16h00, weekdays
	PAV03	0.01194	0.00229	0.00033	g/s	281005	6132926	10	0.25	1	07h00 - 16h00, weekdays
	PAV04	0.01194	0.00229	0.00033	g/s	280988	6132924	10	0.25	1	07h00 - 16h00, weekdays
Vehicle entrainment - unpaved -	UNPAV1	0.06607	0.01602	0.00160	g/s	280970	6132918	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV2	0.06607	0.01602	0.00160	g/s	280962	6132913	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV3	0.06607	0.01602	0.00160	g/s	280965	6132903	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV4	0.06607	0.01602	0.00160	g/s	280969	6132889	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV5	0.06607	0.01602	0.00160	g/s	280972	6132877	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV6	0.06607	0.01602	0.00160	g/s	280978	6132862	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV7	0.06607	0.01602	0.00160	g/s	280983	6132847	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV8	0.06607	0.01602	0.00160	g/s	280988	6132831	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV9	0.06607	0.01602	0.00160	g/s	280993	6132811	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV10	0.06607	0.01602	0.00160	g/s	280997	6132791	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV11	0.06607	0.01602	0.00160	g/s	281002	6132769	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV12	0.06607	0.01602	0.00160	g/s	281002	6132746	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV13	0.06607	0.01602	0.00160	g/s	281002	6132715	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV14	0.06607	0.01602	0.00160	g/s	281000	6132695	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV15	0.06607	0.01602	0.00160	g/s	280993	6132677	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV16	0.06607	0.01602	0.00160	g/s	280980	6132663	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV17	0.06607	0.01602	0.00160	g/s	280971	6132655	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV18	0.06607	0.01602	0.00160	g/s	280955	6132642	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV19	0.06607	0.01602	0.00160	g/s	280937	6132627	10	0.25	1	07h00 - 16h00, weekdays
	UNPAV20	0.06607	0.01602	0.00160	g/s	280924	6132616	10	0.25	1	07h00 - 16h00, weekdays
Material handling - weathered rip shale	MH01	0.00071	0.00034	0.00005	g/s	281005	6132612	1.5	0.75	1.5	07h00 - 16h00, weekdays
Material handling - hard shale, imports & product	MH02	0.12806	0.12114	0.01834	g/s	280933	6132558	1.5	0.75	0.0	07h00 - 16h00, weekdays
Primary crushing	CR01	0.02646	0.02117	0.00392	g/s	280934	6132603	3	0.75	0.0	07h00 - 16h00, weekdays
Secondary crushing	CR02	0.07939	0.06351	0.01175	g/s	280951	6132598	3	0.75	0.0	07h00 - 16h00, weekdays
Screening	CR03	0.21170	0.31755	0.10670	g/s	280935	6132588	3	0.75	0.0	07h00 - 16h00, weekdays
Wind erosion	WIND	1.14E-06	5.69E-07	8.54E-08	g/m2/s	280884	6132445	120	200	0	wind speed dependent (wind speeds >10 m/s)
Dozer operations	DOZER	1.45E-05	3.42E-06	3.42E-07	g/m2/s	280884	6132445	120	200	0	07h00 - 16h00, weekdays

Pit retention reduction of 50% assumed for TSP emissions and 95% for PM_{10} and $PM_{2.5}$ emissions occurring within the pit as per the NPI EETM for Mining.

Future Scenario 1 – Proposed Controls

VOLUME SOURCES	Source ID	TSP Emission Rate	PM10 Emission Rate	PM2.5 Emission Rate	Emission Rate Units	X-coordinate	Y-coordinate	Horizontal Spread (m)	Vertical Spread (m)	Height (m)	Emission Times
Vehicle entrainment - paved road section	VP01	0.02388	0.00457	0.00065	g/s	281033	6132927	10	0.25	1	07h00 - 18h00, weekdays
	VP02	0.02388	0.00457	0.00065	g/s	281018	6132926	10	0.25	1	07h00 - 18h00, weekdays
	VP03	0.02388	0.00457	0.00065	g/s	281005	6132926	10	0.25	1	07h00 - 18h00, weekdays
	VP04	0.02388	0.00457	0.00065	g/s	280988	6132924	10	0.25	1	07h00 - 18h00, weekdays
Vehicle entrainment - unpaved -	UNPAV1	0.12638	0.03065	0.00306	g/s	280974	6132918	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV2	0.12638	0.03065	0.00306	g/s	280965	6132903	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV3	0.12638	0.03065	0.00306	g/s	280974	6132879	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV4	0.12638	0.03065	0.00306	g/s	280985	6132849	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV5	0.12638	0.03065	0.00306	g/s	280994	6132811	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV6	0.12638	0.03065	0.00306	g/s	281004	6132762	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV7	0.12638	0.03065	0.00306	g/s	281006	6132713	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV8	0.12638	0.03065	0.00306	g/s	281005	6132644	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV9	0.12638	0.03065	0.00306	g/s	281005	6132594	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV10	0.12638	0.03065	0.00306	g/s	281007	6132546	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV11	0.12638	0.03065	0.00306	g/s	281002	6132498	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV12	0.12638	0.03065	0.00306	g/s	280996	6132465	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV13	0.12638	0.03065	0.00306	g/s	280982	6132425	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV14	0.12638	0.03065	0.00306	g/s	280964	6132394	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV15	0.12638	0.03065	0.00306	g/s	280962	6132360	10	0.25	1	07h00 - 18h00, weekdays

VOLUME SOURCES	**Source ID**	**TSP Emission Rate**	**PM10 Emission Rate**	**PM2.5 Emission Rate**	**Emission Rate Units**	**X-coordinate**	**Y-coordinate**	**Horizontal Spread (m)**	**Vertical Spread (m)**	**Height (m)**	**Emission Times**
Vehicle entrainment - unpaved	UNPAV16	0.12638	0.03065	0.00306	g/s	280975	6132322	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV17	0.12638	0.03065	0.00306	g/s	280963	6132287	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV18	0.12638	0.03065	0.00306	g/s	280953	6132248	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV19	0.12638	0.03065	0.00306	g/s	280950	6132203	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV20	0.12638	0.03065	0.00306	g/s	280924	6132156	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV21	0.12638	0.03065	0.00306	g/s	280909	6132115	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV22	0.12638	0.03065	0.00306	g/s	280884	6132094	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV23	0.12638	0.03065	0.00306	g/s	280835	6132096	10	0.25	1	07h00 - 18h00, weekdays
AREA SOURCES	**Source ID**	**TSP Emission Rate**	**PM10 Emission Rate**	**Pm2.5 Emission Rate**	**Emission Rate Units**	**SW corner – X coord**	**SW Corner – Y coord**	**x length (m)**	**y length (m)**	**Angle of Rotation**	**Emission Times**
Wind erosion	WIND	1.14E-06	5.69E-07	8.54E-08	g/m2/s	280884	6132445	120	200	0	wind speed dependent (wind speeds >10 m/s)
Stage4 (rehabilitation)	STAGE4	7.5E-05	1.9E-05	2.1E-06	g/m2/s	280745	6132240	210	80	10	07h00 - 18h00, weekdays
Stage5 (unweathered shale extraction)	STAGE5	5.48E-05	6.07E-05	1.73E-05	g/m2/s	280732	6132155	210	80	10	07h00 - 18h00, weekdays
Stage6 (rip shale extraction)	STAGE6	6.80E-05	1.60E-05	1.61E-06	g/m2/s	280716	6132075	210	80	10	07h00 - 18h00, weekdays

Pit retention reduction of 50% assumed for TSP emissions and 95% for PM_{10} and $PM_{2.5}$ emissions occurring within the pit as per the NPI EETM for Mining.

Future Scenario 2 – Additional Dust Controls

VOLUME SOURCES	Source ID	TSP Emission Rate	PM10 Emission Rate	PM2.5 Emission Rate	Emission Rate Units	X-coordinate	Y-coordinate	Horizontal Spread (m)	Vertical Spread (m)	Height (m)	Emission Times
Vehicle entrainment - paved road section	VP01	0.02388	0.00457	0.00065	g/s	281033	6132927	10	0.25	1	07h00 - 18h00, weekdays
	VP02	0.02388	0.00457	0.00065	g/s	281018	6132926	10	0.25	1	07h00 - 18h00, weekdays
	VP03	0.02388	0.00457	0.00065	g/s	281005	6132926	10	0.25	1	07h00 - 18h00, weekdays
	VP04	0.02388	0.00457	0.00065	g/s	280988	6132924	10	0.25	1	07h00 - 18h00, weekdays
Vehicle entrainment - unpaved -	UNPAV1	0.05055	0.01226	0.00123	g/s	280974	6132918	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV2	0.05055	0.01226	0.00123	g/s	280965	6132903	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV3	0.05055	0.01226	0.00123	g/s	280974	6132879	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV4	0.05055	0.01226	0.00123	g/s	280985	6132849	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV5	0.05055	0.01226	0.00123	g/s	280994	6132811	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV6	0.05055	0.01226	0.00123	g/s	281004	6132762	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV7	0.05055	0.01226	0.00123	g/s	281006	6132713	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV8	0.05055	0.01226	0.00123	g/s	281005	6132644	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV9	0.05055	0.01226	0.00123	g/s	281005	6132594	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV10	0.05055	0.01226	0.00123	g/s	281007	6132546	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV11	0.05055	0.01226	0.00123	g/s	281002	6132498	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV12	0.05055	0.01226	0.00123	g/s	280996	6132465	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV13	0.05055	0.01226	0.00123	g/s	280982	6132425	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV14	0.05055	0.01226	0.00123	g/s	280964	6132394	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV15	0.05055	0.01226	0.00123	g/s	280962	6132360	10	0.25	1	07h00 - 18h00, weekdays

VOLUME SOURCES	**Source ID**	**TSP Emission Rate**	**PM10 Emission Rate**	**PM2.5 Emission Rate**	**Emission Rate Units**	**X-coordinate**	**Y-coordinate**	**Horizontal Spread (m)**	**Vertical Spread (m)**	**Height (m)**	**Emission Times**
Vehicle entrainment - unpaved	UNPAV16	0.05055	0.01226	0.00123	g/s	280975	6132322	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV17	0.05055	0.01226	0.00123	g/s	280963	6132287	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV18	0.05055	0.01226	0.00123	g/s	280953	6132248	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV19	0.05055	0.01226	0.00123	g/s	280950	6132203	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV20	0.05055	0.01226	0.00123	g/s	280924	6132156	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV21	0.05055	0.01226	0.00123	g/s	280909	6132115	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV22	0.05055	0.01226	0.00123	g/s	280884	6132094	10	0.25	1	07h00 - 18h00, weekdays
	UNPAV23	0.05055	0.01226	0.00123	g/s	280835	6132096	10	0.25	1	07h00 - 18h00, weekdays
AREA SOURCES	**Source ID**	**TSP Emission Rate**	**PM10 Emission Rate**	**Pm2.5 Emission Rate**	**Emission Rate Units**	**SW corner – X coord**	**SW Corner – Y coord**	**x length (m)**	**y length (m)**	**Angle of Rotation**	**Emission Times**
Wind erosion	WIND	1.14E-06	5.69E-07	8.54E-08	g/m2/s	280884	6132445	120	200	0	wind speed dependent (wind speeds >10 m/s)
Stage4 (rehabilitation)	STAGE4	3.5E-05	9.9E-06	1.2E-06	g/m2/s	280745	6132240	210	80	10	07h00 - 18h00, weekdays
Stage5 (unweathered shale extraction)	STAGE5	3.67E-05	3.89E-05	1.07E-05	g/m2/s	280732	6132155	210	80	10	07h00 - 18h00, weekdays
Stage6 (rip shale extraction)	STAGE6	2.73E-05	6.44E-06	6.47E-07	g/m2/s	280716	6132075	210	80	10	07h00 - 18h00, weekdays

Pit retention reduction of 50% assumed for TSP emissions and 95% for PM_{10} and $PM_{2.5}$ emissions occurring within the pit as per the NPI EETM for Mining.

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Appendix 3

Dispersion Simulation Results

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Note: A colour copy of this Appendix will be presented on the Project CD.

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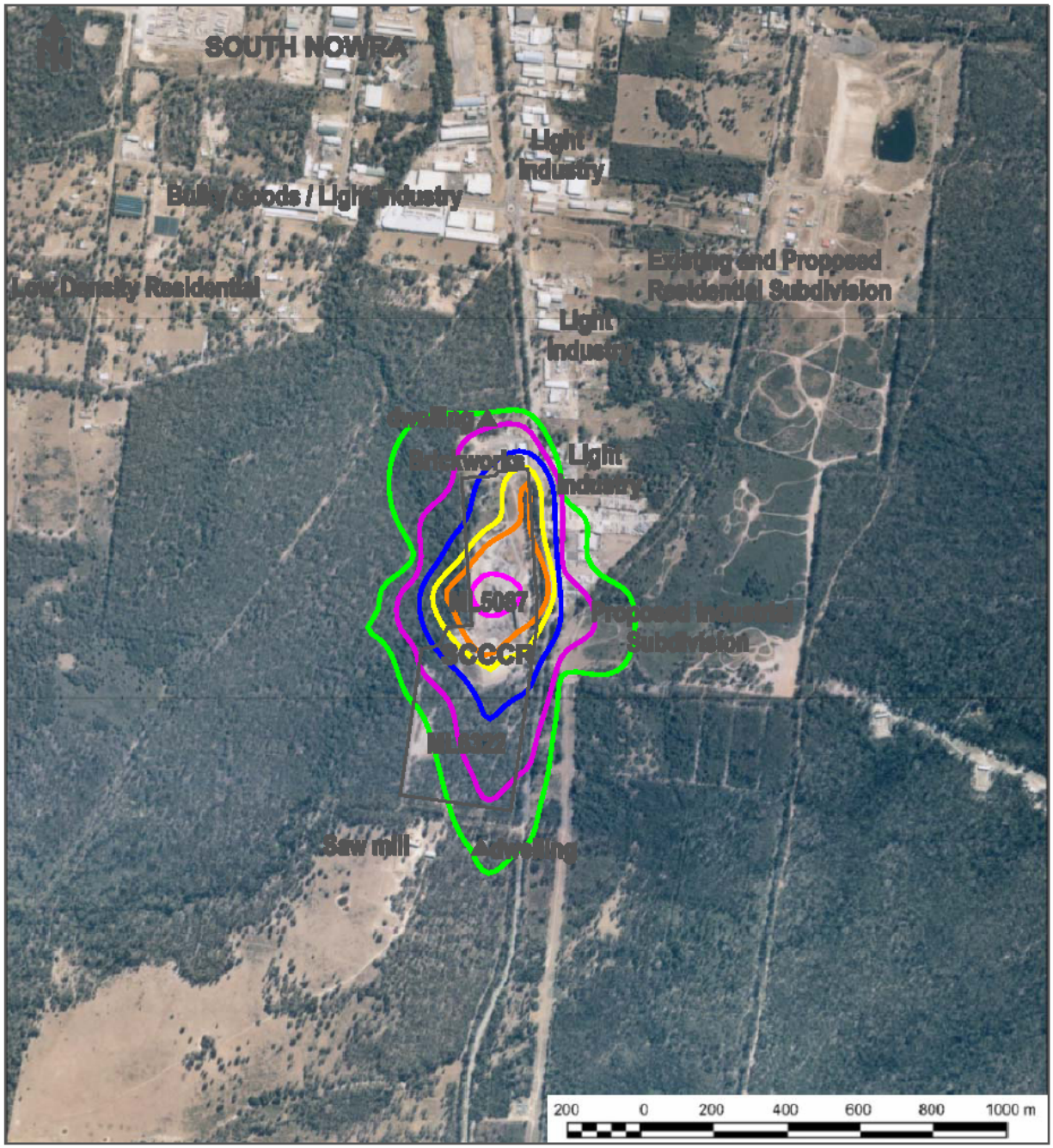
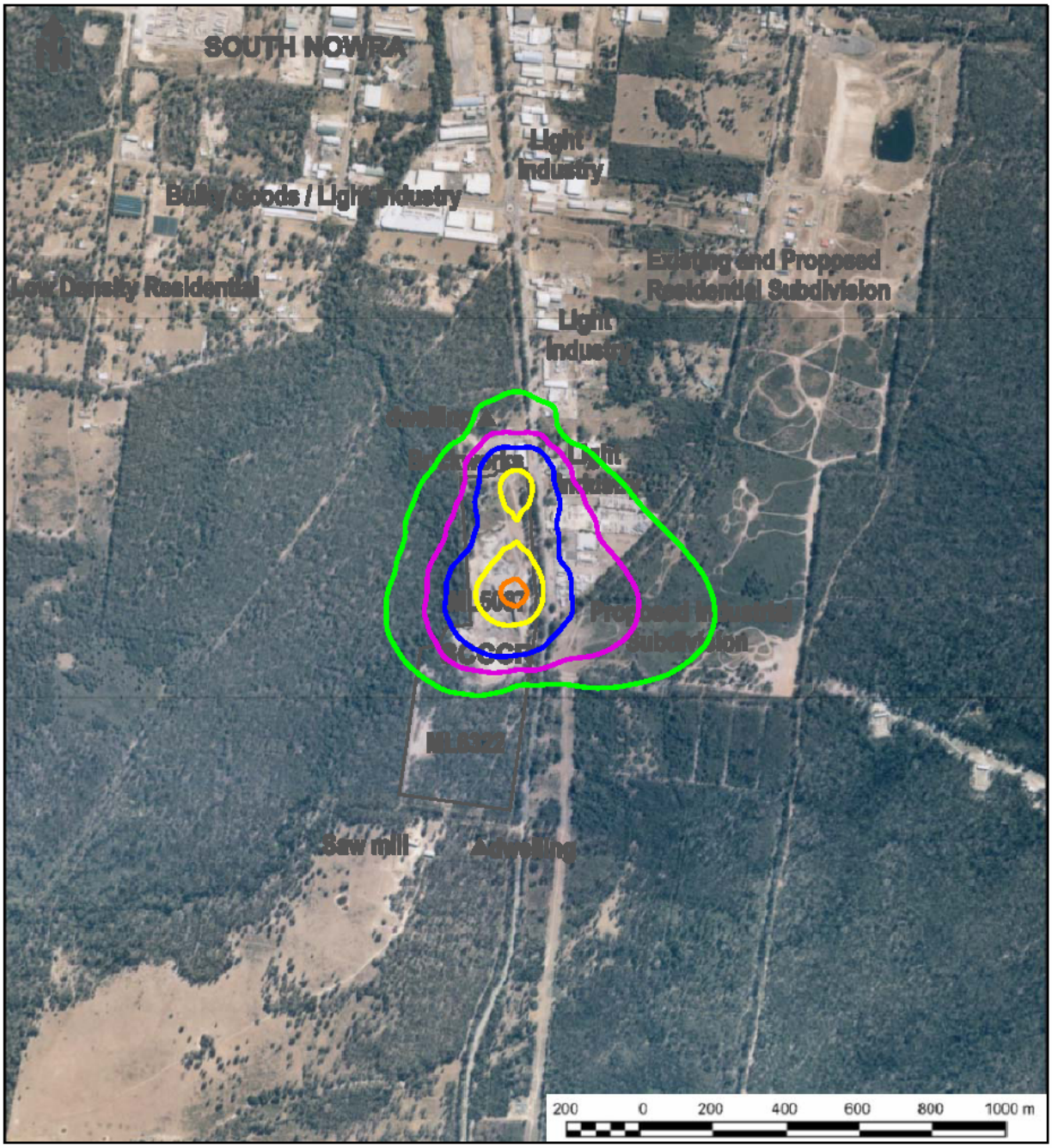


	30µg/m³
	35µg/m³
	50µg/m³ (Air Quality Criterion)
	75µg/m³
	100µg/m³
	200µg/m³

Heggies Pty Ltd
2 Lincoln Street
Lane Cove NSW 2066 Australia
PO Box 176 Lane Cove NSW 1595
Email address sydney@heggies.com.au
Telephone 02 9427 6100 Facsimile 02 9427 8200

Highest Daily Average PM_{10} Concentrations (µg/m³) due to Current Quarry Operations (including background concentrations



	11µg/m³
	12µg/m³
	15µg/m³
	30µg/m³ (Air Quality Criterion)
	50µg/m³
	100µg/m³

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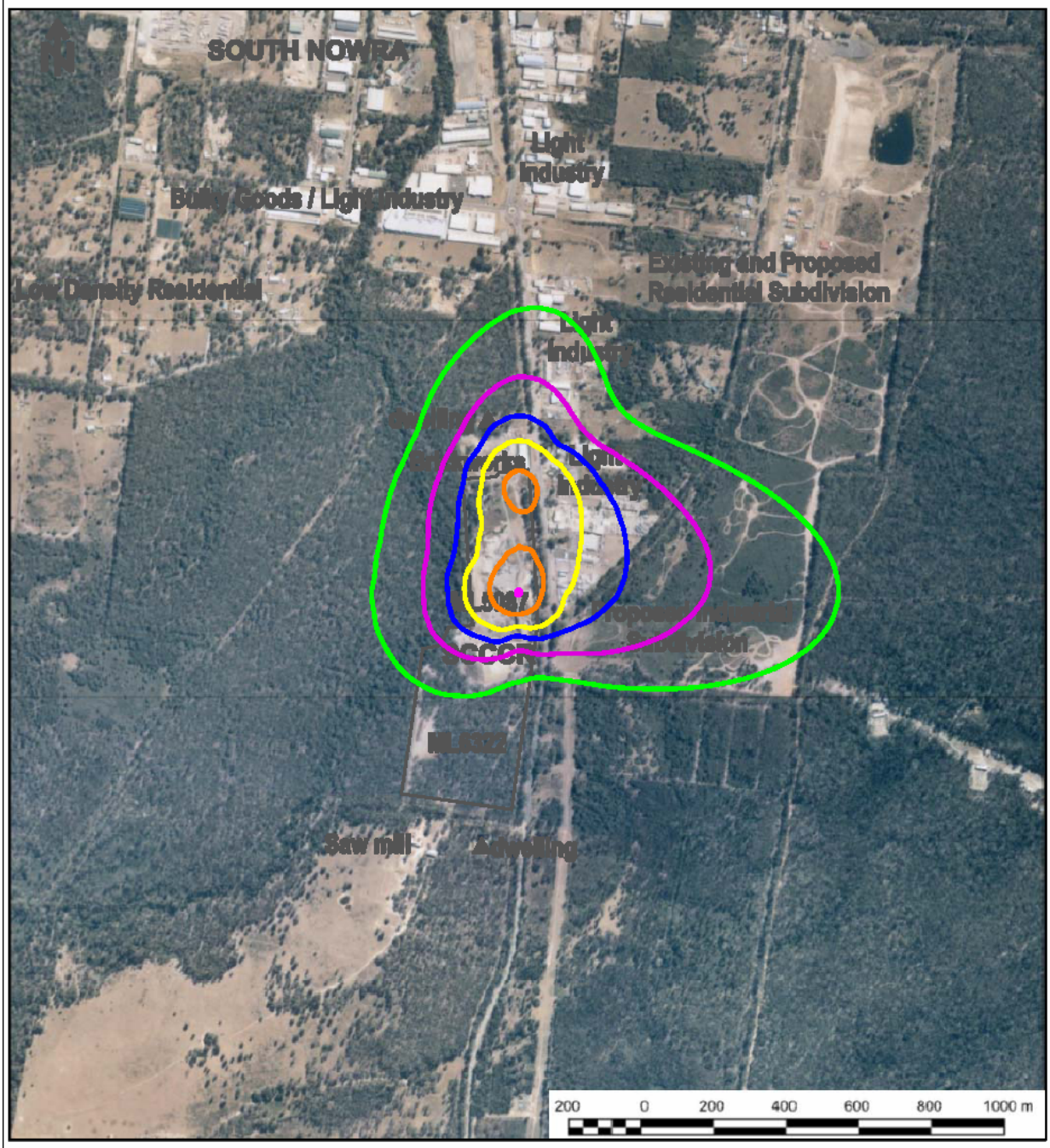
Email address sydney@heggies.com.au
Telephone 02 9427 8100 Facsimile 02 9427 8200

Annual Average PM_{10} Concentrations (µg/m³) due to Current Quarry Operations (including background concentrations



	0.5mg/m²/day
	1mg/m²/day
	2mg/m²/day
	4mg/m²/day
	10mg/m²/day
	20mg/m²/day

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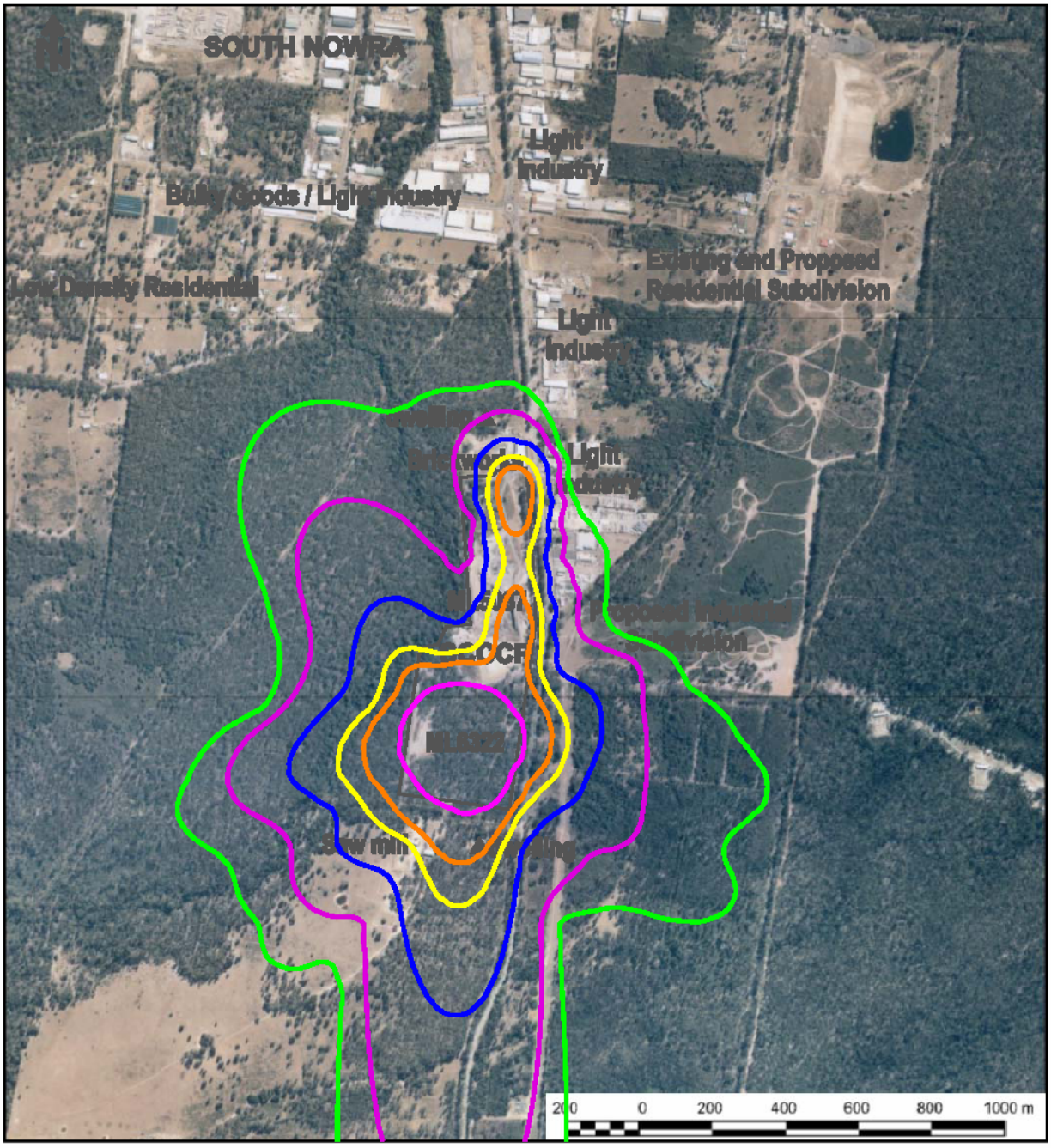
Email address sydney@heggies.com.au
Telephone 02 9427 6100 Facsimile 02 9427 8200

Incremental Dust Deposition (mg/m²/day) due to Current Quarry Operations



	30µg/m³
	35µg/m³
	50µg/m³ (Air Quality Criterion)
	75µg/m³
	100µg/m³
	200µg/m³

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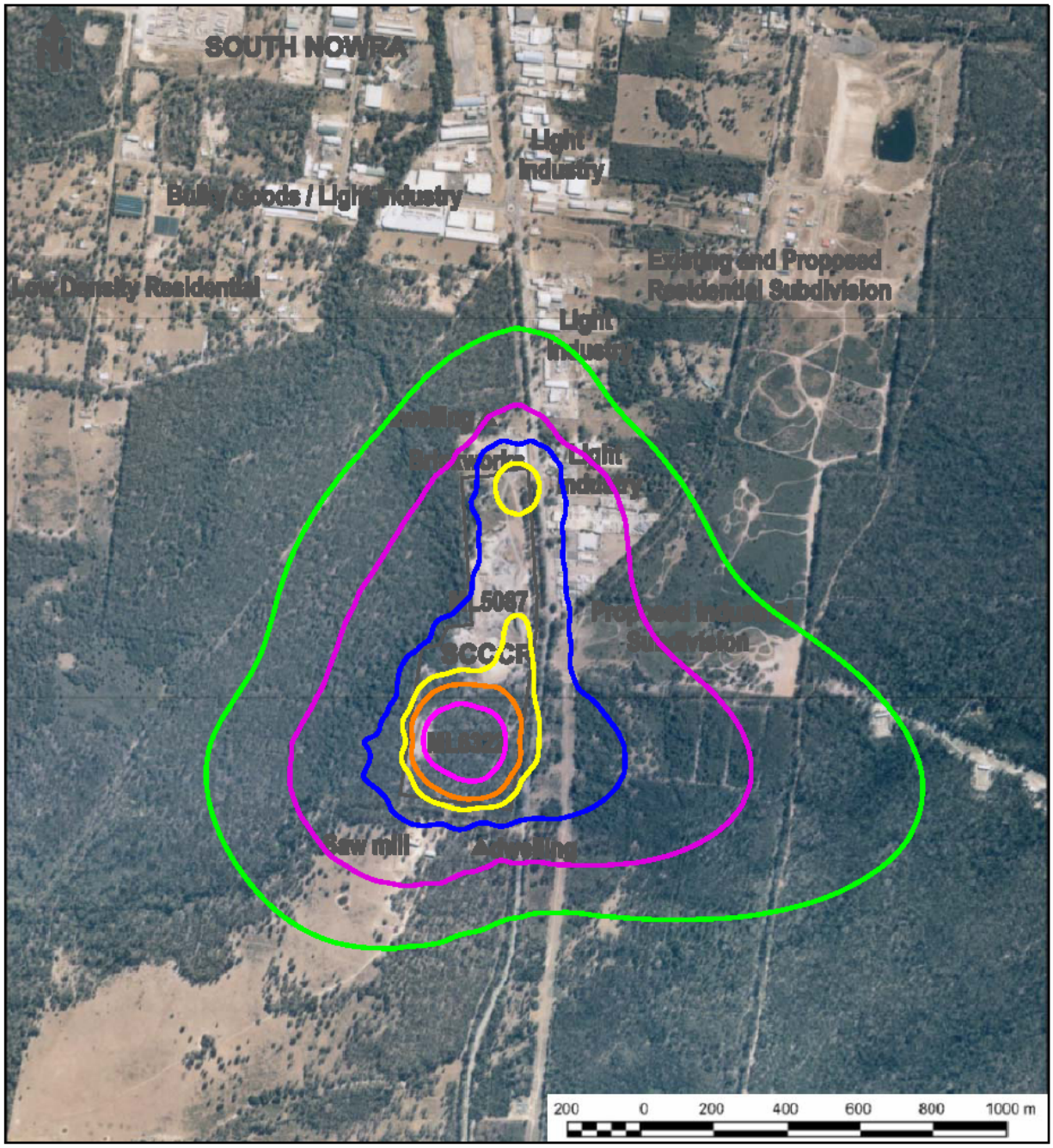
Telephone 02 9427 8100 Facsimile 02 9427 8200

Highest Daily Average PM_{10} Concentrations (µg/m³) due to Future Quarry Operations - Scenario 1, Current Controls (includes background levels)



	11µg/m³
	12µg/m³
	15µg/m³
	30µg/m³ (Air Quality Criterion)
	50µg/m³
	100µg/m³

Heggies Pty Ltd
2 Lincoln Street
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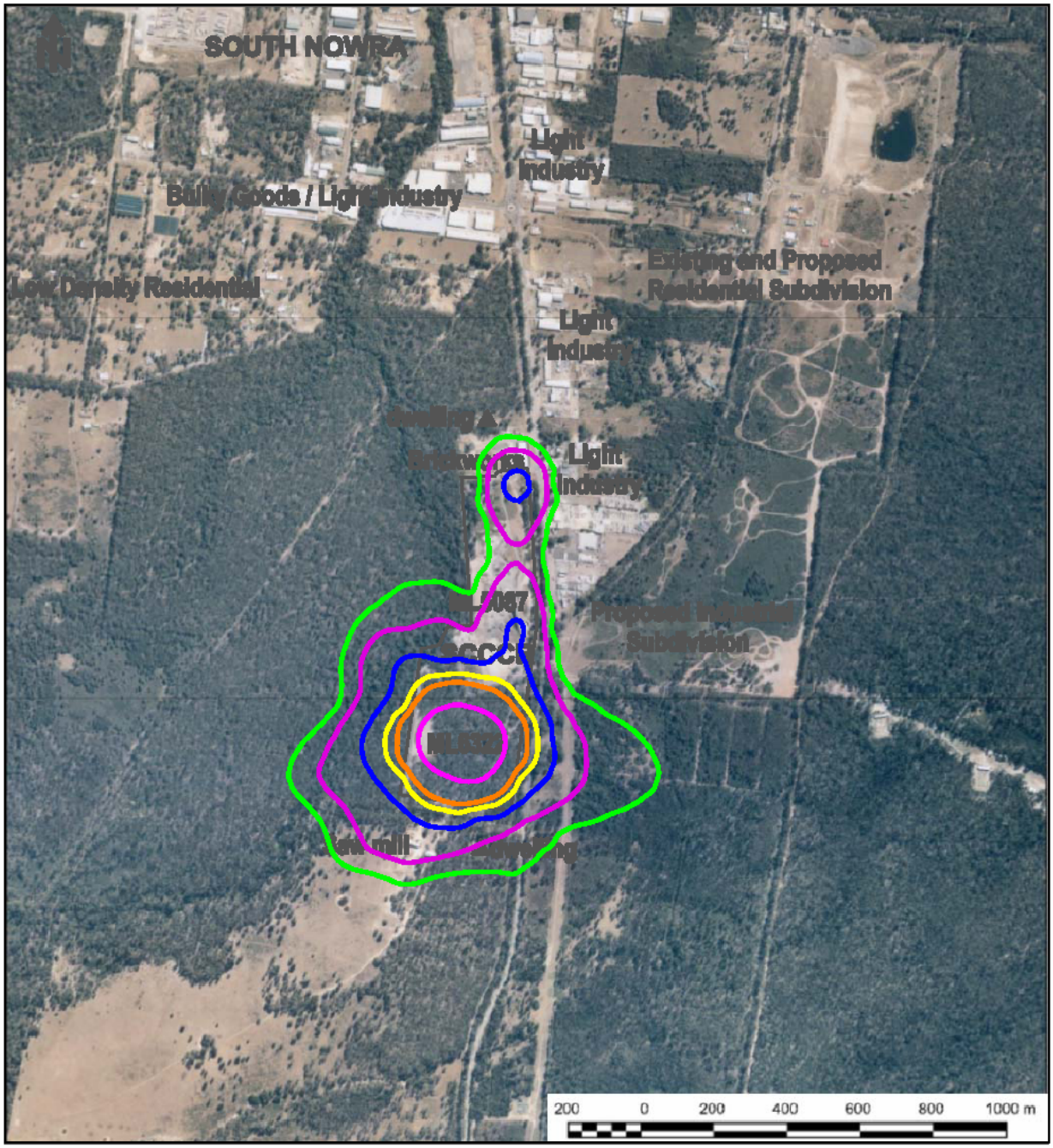
Telephone 02 9427 6100 Facsimile 02 9427 8200

Annual Average PM_{10} Concentrations (µg/m³) due to Future Quarry Operations - Scenario 1, Current Controls (including background levels)



	30µg/m³
	35µg/m³
	50µg/m³ (Air Quality Criterion)
	75µg/m³
	100µg/m³
	200µg/m³

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2 Lincoln Street
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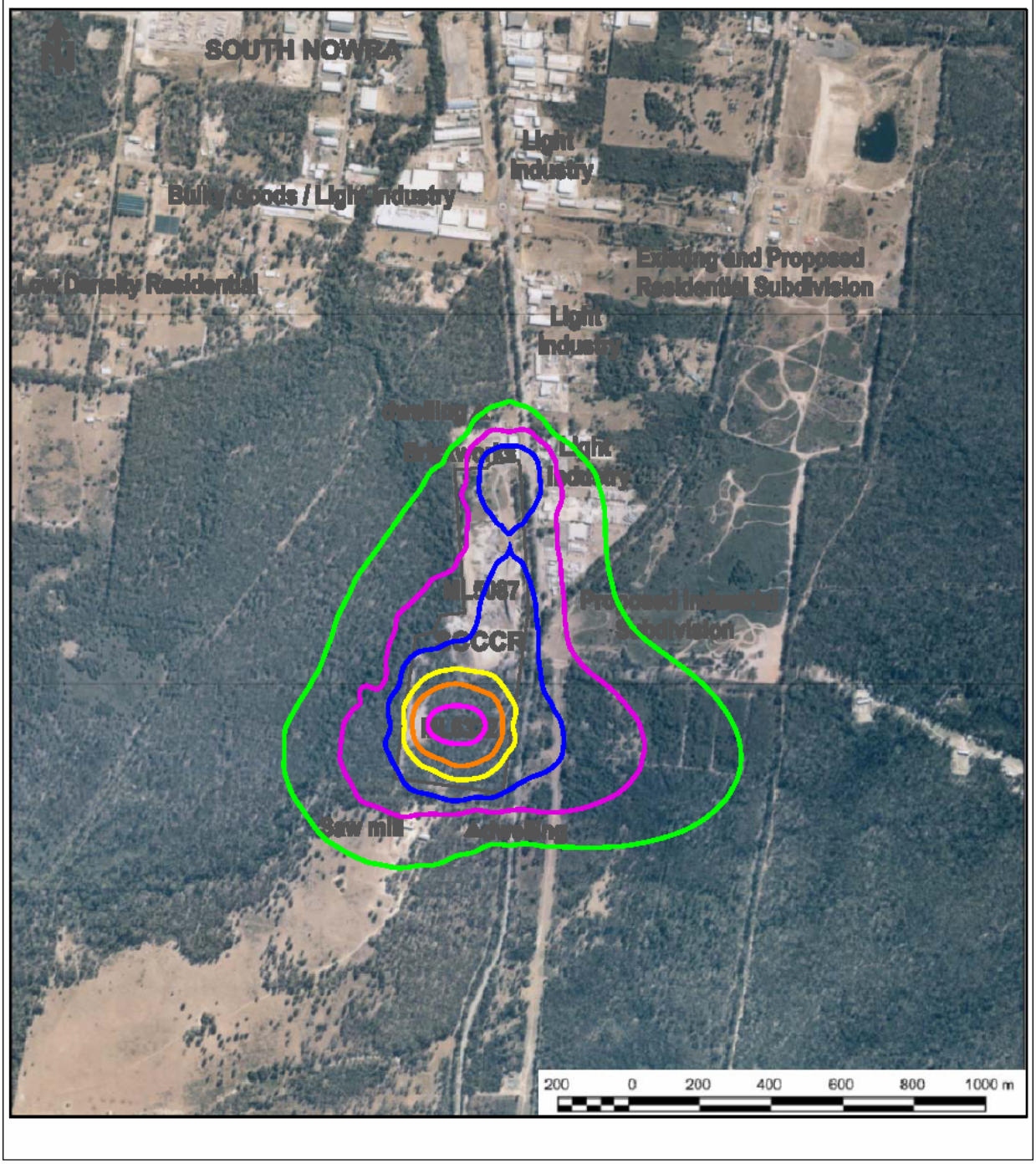
Highest Daily Average PM_{10} Concentrations (µg/m³) due to Future Quarry Operations - Scenario 2 Additional Controls (includes background levels)


SOUTH NOWRA
Light Industry
Bulky Goods / Light Industry
Low Density Residential
Existing and Proposed Residential Subdivision
Light Industry
Dwelling
Light Industry
Proposed Industrial Subdivision
CCCR
Saw mill
Dwelling
200 0 200 400 600 800 1000 m
11µg/m³
12µg/m³
15µg/m³
30µg/m³ (Air Quality Criterion)
50µg/m³
100µg/m³
Heggies Pty Ltd
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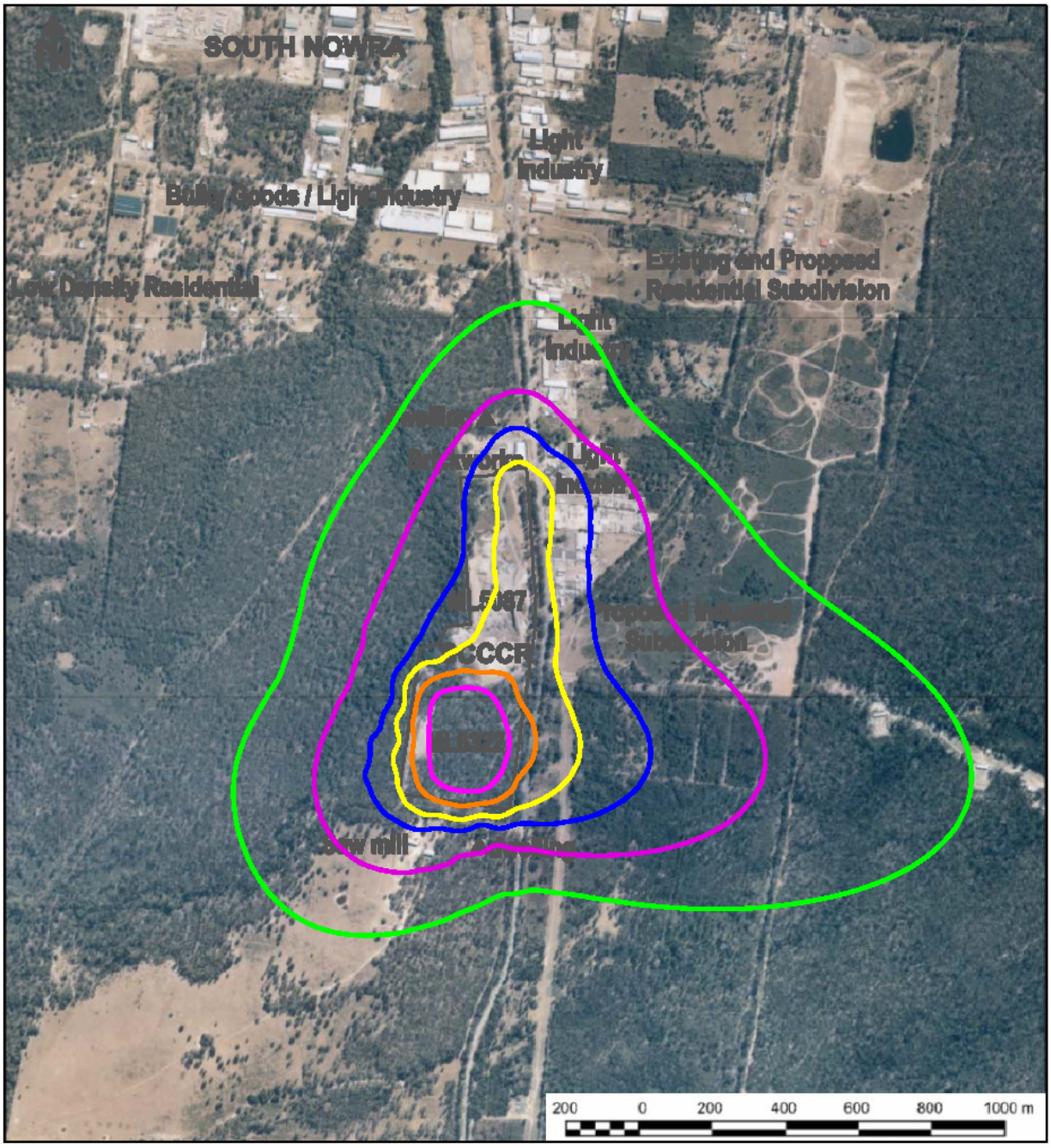
Telephone 02 9427 8100 Facsimile 02 9427 8200
Annual Average PM10 Concentrations (µg/m³) due to Future Quarry Operations - Scenario 2 Additional Controls (including background levels)



	0.5mg/m²/day
	1mg/m²/day
	2mg/m²/day
	4mg/m²/day
	10mg/m²/day
	20mg/m²/day

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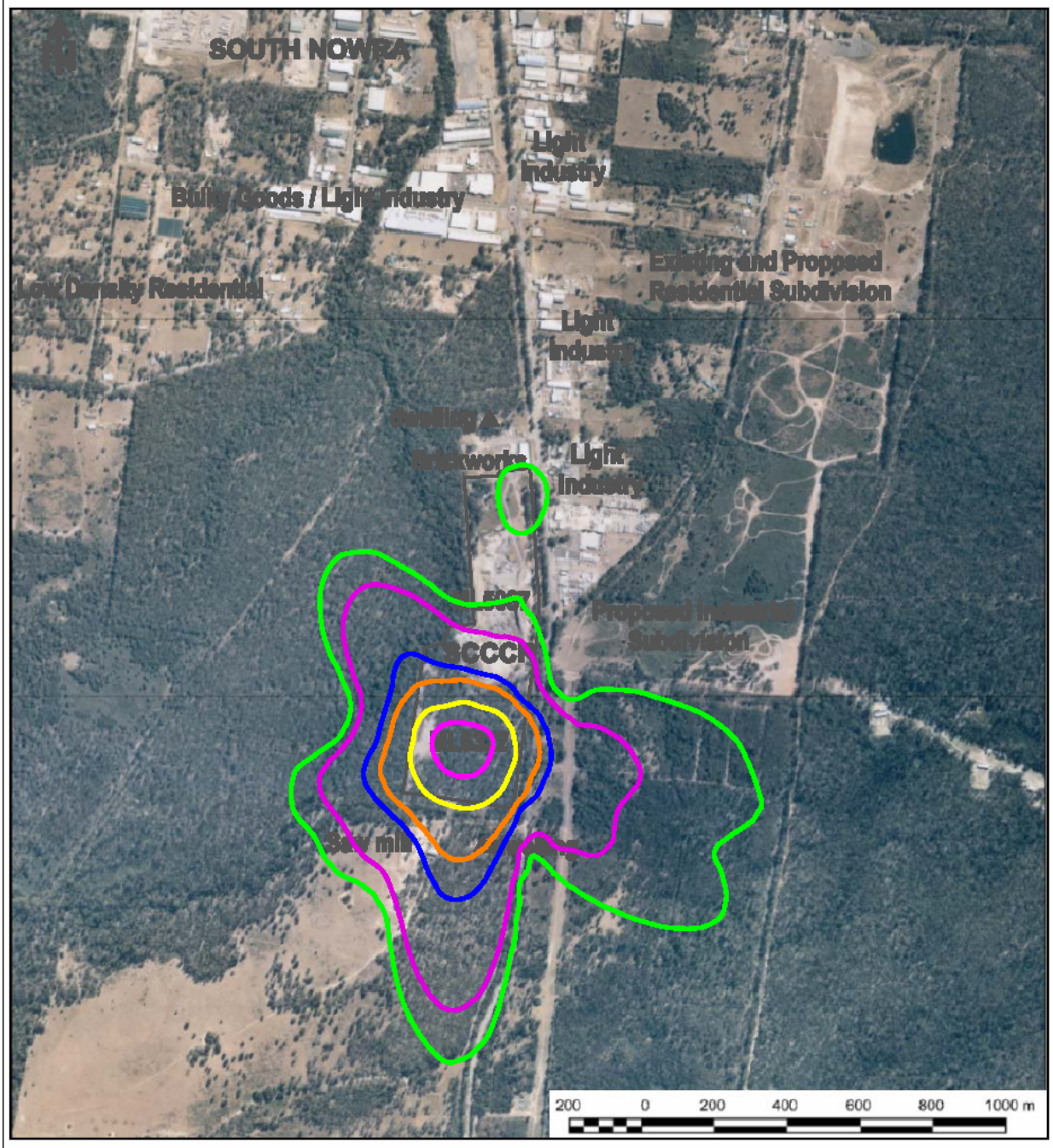
Incremental Dust Deposition (mg/m²/day) due to Future Quarry Operations - Scenario 2 Additional Controls



	14µg/m³
	15µg/m³
	20µg/m³
	25µg/m³ (Air Quality Criterion)
	50µg/m³
	100µg/m³

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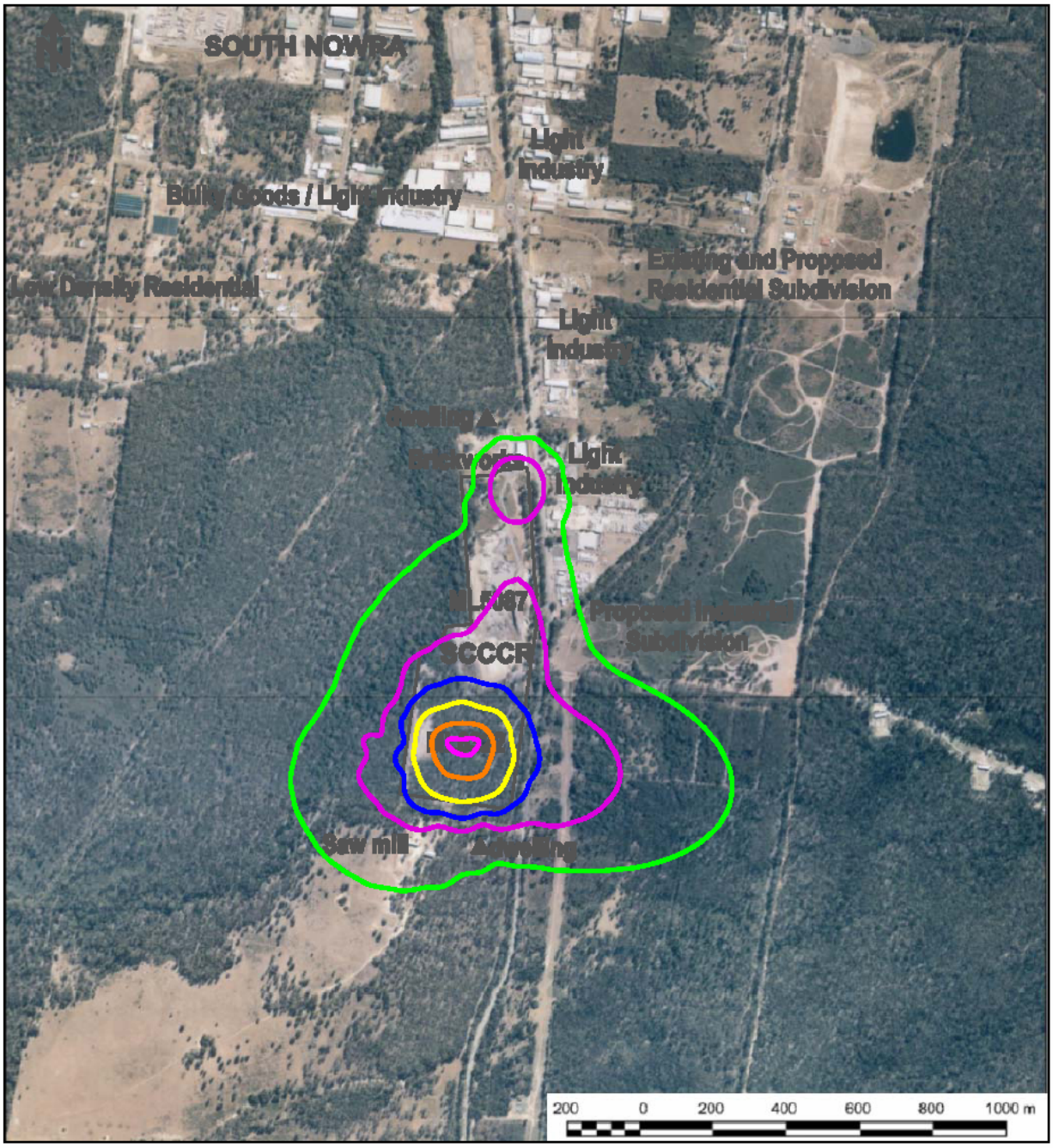
Telephone 02 9427 8100 Facsimile 02 9427 8200

Highest Daily Average $PM_{2.5}$ Concentrations (µg/m³) due to Future Quarry Operations - Scenario 2 Additional Controls



	5µg/m³
	6µg/m³
	8µg/m³ (Air Quality Criterion)
	15µg/m³
	30µg/m³
	40µg/m³

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Annual Average $PM_{2.5}$ Concentrations (µg/m³) due to Future Quarry Operations - Scenario 2 Additional Controls

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Noise and Blasting Assessment

Prepared by

Heggies Pty Ltd

January, 2009

Specialist Consultant Studies Compendium:
Part 5

Noise -and Blasting Assessment

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

Prepared for:

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January, 2009

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CONTENTS

Page

1 INTRODUCTION 5-5

2 DESCRIPTION OF THE PROPOSAL 5-5

3 AMBIENT NOISE SURVEY 5-9
3.1 Introduction 5-9
3.2 Unattended Noise Survey 5-9
3.2.1 Discussion 5-12
3.3 Attended Noise Survey 5-12

4 NOISE ASSESSMENT CRITERIA 5-13
4.1 Industrial Noise Policy Criteria 5-13
4.2 Intrusive Noise Criterion 5-13
4.3 Amenity Noise Criterion 5-13
4.4 Project Specific Noise Assessment Criteria 5-15
4.4.1 Introduction 5-15
4.4.2 Intrusive Noise Criteria 5-15
4.4.3 Amenity Noise Criteria 5-15

5 ROAD TRANSPORTATION NOISE ASSESSMENT CRITERIA 5-16

6 BLAST EMISSIONS ASSESSMENT CRITERIA 5-17
6.1 Ground Vibration - Structural Damage 5-17
6.2 Airblast - Structural Damage 5-19
6.3 Human Comfort and Disturbance Considerations 5-19

7 OPERATIONAL NOISE EMISSIONS 5-20
7.1 Introduction 5-20
7.2 Equipment Noise Levels 5-20
7.3 Noise Modelling Methodology 5-21
7.4 Modelling Scenarios 5-21
7.5 On-Site Truck Movements 5-23
7.6 Modelled Weather Conditions 5-23

8 NOISE IMPACT ASSESSMENT 5-24
8.1 Noise Sensitive Receivers 5-24
8.2 Operational Noise Impact Assessment 5-24
8.3 On-site Haulage Trucks - Evening and Early Morning 5-25
8.4 Road Traffic Noise Impact Assessment 5-25
8.5 Proposed Blasting Practices 5-27
8.6 Blast Emission Site Laws 5-27
8.7 Blast Emission Assessment 5-29

9 CONCLUSION 5-31

CONTENTS

Page

TABLES

Table 1 Measured Ambient Noise Levels 5-12
Table 2 Attended Ambient Noise Survey Results - 25 July 2007 5-12
Table 3 Amenity Criteria - Recommended Amenity (LAeq1) Noise Levels from Industrial Noise Sources 5-14
Table 4 Operation Noise Emission Criteria - dB(A) 20 µPa 5-16
Table 5 Road Traffic Noise Criteria 5-16
Table 6 Transient Vibration Guide Values for Cosmetic Damage 5-17
Table 7 US Bureau of Mines Recommended Peak Airblast Limits 5-19
Table 8 Probability of Window Damage from Airblast 5-19
Table 9 Modelled Environmental Noise Emissions 5-25
Table 10 Modelled Environmental Noise Emissions 5-25
Table 11 Average Hourly Traffic Movements - Princes Highway Daytime (7.00am - 10.00pm) 5-26
Table 12 Predicted Traffic Noise Levels 5-26
Table 13 Indicative Blast Design Details 5-27
Table 14 Predicted Levels of Blast Emissions for a 112kg MIC 5-29
Table 15 Controlling General Criterion and Allowable MIC 5-30

FIGURES

Figure 1 Locality Plan 5-6
Figure 2 Project Site Layout 5-7
Figure 3 Noise and Blasting Survey and Receptor Locations 5-10
Figure 4 Graph of Transient Vibration Guide Values for Cosmetic Damage 5-18
Figure 5 Noise Modelling Scenarios 5-22
Figure 6 Peak Vector Sum Ground Vibration for an MIC of 112kg 5-28
Figure 8 Peak Airblast for an MIC of 112kg 5-28

APPENDICES

Appendix A Acoustic Terminology 5-35
Appendix B Unattended Noise Monitoring Results 5-39

1 INTRODUCTION

South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) operates the Nowra Brickworks Quarry within Mining Leases (ML) 5087 and 6322. The operation is located adjacent to the Princes Highway, South Nowra (**Figure 1**). Currently extraction of shale material is ongoing within ML 5087 and is suspended within ML 6322 pending granting of planning approval.

Heggies Pty Ltd (Heggies) was commissioned by City Plan Services Pty Limited to undertake a noise assessment for SCCCR's current and proposed future operations at the Nowra Brickworks Quarry.

The following report assesses the noise impact of the current and proposed future operations at existing residences. Design criteria are based on an ambient noise survey and noise emissions computed and assessed relative to the design criteria.

A summary of the acoustic terminology used in this report is presented in **Appendix A**.

2 DESCRIPTION OF THE PROPOSAL

The Project Site is located at South Nowra within the Shoalhaven City Council. Situated approximately 5km south of the Nowra CBD, the site is adjacent to the Princes Highway. The Project Site comprises two mining lease areas, namely, ML 5087 to the north and ML 6322 to the south. ML 5087 has been largely disturbed by extraction-related activities. By contrast, ML 6322, has been partially disturbed by extraction-related activities, with the majority of the lease area covered by native vegetation.

To the east of the site, across the Princes Highway, is a low density commercial/industrial development. Enterprises situated directly opposite the main entrance to the Project Site include a butchery and a concrete batching operation with various other commercial operations situated along the highway.

The nearest residences to the site are a single isolated residence, adjacent to the southern Project Site boundary (260 Princes Highway), a residence located approximately 140m to the north of the northern boundary of the Project Site, residences on Links Road, approximately 850m to the west-northwest and residences on Old Southern Road, approximately 630m to the northeast. In addition, a single isolated residence associated with a sawmill is located adjacent to the southern boundary of the site.

The proposed continued and expanded use of the Nowra Brickworks Quarry would incorporate the following activities (**Figure 2**).

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark prior to the annual production from the quarry reaching 250 000t.

\\SERVER\RWC\742\Reports\74203\CAD\742Base_Noise 1.DWG

Figure 1
LOCALITY PLAN

Note: A colour version of this figure is available on the Project CD

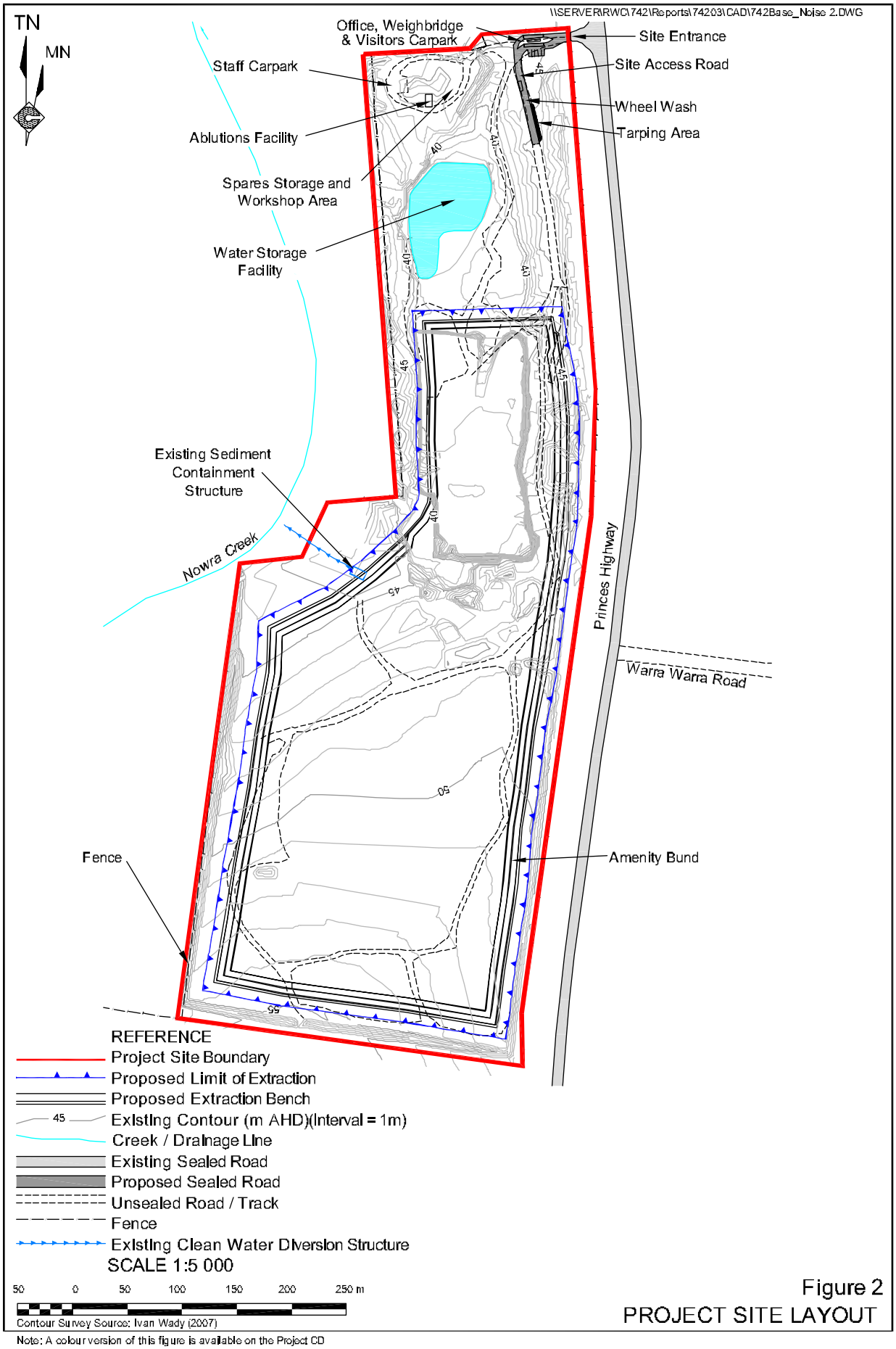


Figure 2
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

- Staged extraction of shale material ("extracted material") from a proposed extraction area of 15.0ha, incorporating an existing extraction area of approximately 2.0ha. Weathered shale material would be extracted using an excavator and stockpiled or direct loaded into road registrable trucks for transportation to the quarry's customers. Unweathered shale material would initially be blasted before being extracted using an excavator. Extraction operations would generally progress from north to south.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted material to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A portion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

The proposed operations within the Project Site would continue to involve the following equipment:

- A mobile crushing plant comprising two jaw crushers, one cone crusher, two screens and conveyors and stackers.
- Two excavators used for feeding the crusher and moving material.
- Two front end loaders for moving material and loading heavy vehicles.
- A bulldozer for overburden removal and rehabilitation.
- A compactor for compacting VENM during placement operations.

Vehicular access the Project Site from the Princess Highway would continue to be via the Site Entrance at the northern end of the Project Site.

The proposed continued and expanded Nowra Brickworks Quarry would operate between the following hours.

- Extraction, processing and backfilling-related activities.
  - 7:00am to 6:00pm, Monday to Friday.
  - 7:00am to 4:00pm, Saturday.
- Product despatch.
  - 7:00am to 6:00pm, Monday to Friday.
  - 7:00am to 4:00pm Saturday.
  - A maximum of 3 unladen trucks may arrive at the Project Site between 6:00am and 7:00am, with a further 3 unladen trucks returning to the Project Site between 6:00pm and 8:00pm, Monday to Friday.
  - A maximum of 3 unladen trucks may arrive at the Project Site between 6:00am and 7:00am, with a further 3 unladen trucks returning to the Project between 6:00pm and 8:00pm Saturday.
- Maintenance-related activities.
  - 7.00am to 6.00pm, Monday to Saturday.

3 AMBIENT NOISE SURVEY

3.1 Introduction

Ambient noise measurements were carried out within the Project Site, as well as at three residential locations in the vicinity of the Project Site using unattended and operator-attended techniques. The purpose of these measurements was to establish the existing ambient noise levels at the nearest residences to the northwest, northeast and to the south of the Project Site.

The NSW Department of Environment and Climate Change's (DECC's) Industrial Noise Policy (INP) generally requires ambient noise surveys to collect at least 7 days of valid data. However as the Project is expected to have only a minimal impact on the surrounding residential areas, a short term noise survey conducted over a period of one day was used to estimate the ambient noise environment (refer to Table 3.1, Section 3 of the INP).

3.2 Unattended Noise Survey

Unattended noise monitoring was carried out at two locations as shown on **Figure 3** and described as follows. Given the proximity of the single residence at 260 Princes Highway (Location 3) to the southern boundary of the Project Site, only attended noise surveys were conducted at this location.

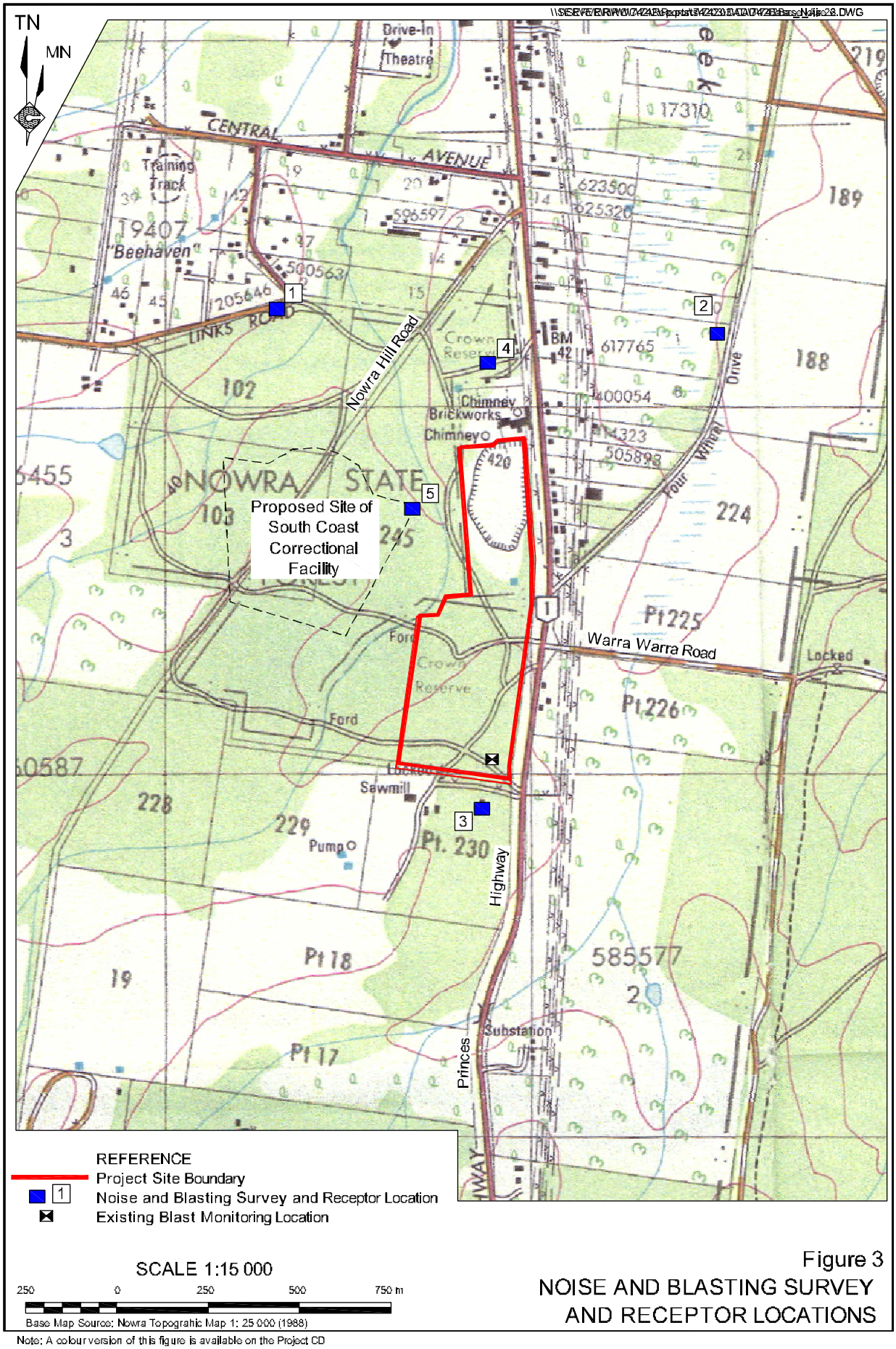


Figure 3
NOISE AND BLASTING SURVEY AND RECEPTOR LOCATIONS

Note: A colour version of this figure is available on the Project CD

- **Location 1 - 80 Links Road, Nowra**

  This residence is situated approximately 850m to the west-northwest of the Project Site and is representative of a group of residences in this area of Links Road. The residences in this area are located in a semi-rural setting with commercial warehouses to the north, separated from the Project Site by dense bushland.

- **Location 2 - 371 Old Southern Road, Nowra**

  This residence is situated approximately 630m to the northeast of the Project Site and is representative of the residences in this area of Old Southern Road. The residences in this area are located in a semi-rural area with the ambient noise environment influenced by traffic noise. It is noted the Project Site is located to the west of, and adjacent to, the Princess Highway. There are also number of commercial businesses adjacent to the Highway between the quarry and the residences.

The noise monitoring was carried out from 7.30pm on Tuesday 24 July to 4.15pm on Wednesday 25 July 2007. ARL noise loggers (Type EL215) were deployed to continuously record the ambient noise levels in 15 minute intervals. Calibration of the noise loggers was checked prior to and following the measurements using a RION NC 73 Calibrator. Operations within the Project Site commenced at 12.00 noon on 25 July 2007. This enabled the ambient noise environment at the above residences to be measured in the absence of quarry generated noise.

The results of the unattended noise monitoring are presented graphically in **Appendix B**. The statistical descriptors shown on the graphs in that Appendix are as follows.

- L_{A90} The L_{A90} is the level of noise exceeded for 90% of the sample time (15 minutes).The L_{A90} noise level is described as the average minimum background sound level or simply the background level.
- L_{A10} The L_{A10} is the noise level exceeded for 10% of the sample time (15-minute) and is typically described as the average maximum noise level.
- L_{A1} The L_{A1} is the noise level exceeded for 1% of the sample time (15-minute) and representative of the highest noise level events, (eg passing heavy vehicles, aircraft etc).
- L_{Aeq} The L_{Aeq} is the energy-average sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time varying sound.

The results of the noise monitoring have been processed in accordance with the procedures contained in the INP so as to establish representative noise levels at the above residences. The calculations were conducted over the morning period when the quarry was not operating, namely, prior to 12 noon on 25 July 2007.

The results of the unattended noise monitoring are presented in **Table 1**.

3.2.1 Discussion

Assessment Background Level (ABL) or L_{A90} background noise levels without the quarry plant operational were found to be controlled by distant traffic. The ABLs determined for the morning with the quarry not operational were 39dB(A) at Location 1 on Links Road and 46dB(A) at Location 2 on Old Southern Road.

Table 1
Measured Ambient Noise Levels

Location	Noise Level - dB(A) re 20µPa					
	Daytime 7.00am - 6.00pm		Evening 6.00pm - 10.00pm		Night 10.00pm - 7.00pm	
	ABL [1]	LAeq [2]	ABL [1]	LAeq [2]	ABL [1]	LAeq [2]
Location 1 80 Links Road	39	48	36	42	31	41
Location 2 371 Old Southern Road	46	51	41	45	35	45

Note 1: The Assessment Background Level (ABL) is representative of the typical minimum background sound level. By definition the ABL is the lowest 10 percent value of the 15 minute background noise level measurements taken over the assessment period.
Note 2: The L_{Aeq} is the logarithmic average of the 15 minute sample in each assessment period. Noise identified as extraneous was not included in the L_{Aeq} calculation.

3.3 Attended Noise Survey

In addition to the unattended monitoring on the 25 July 2007 attended monitoring was conducted at Location 1 and Location 2 above as well as Location 3 - 260 Princess Highway, Nowra. The measurements were conducted using a Brüel & Kjær 2260 Sound Level Analyser fitted with a Brüel & Kjær half inch microphone. The measurement time was 15 minutes in each instance, and recordings were "paused" to eliminate the influence of local traffic events. Calibration was confirmed before and after the measurements using a Brüel & Kjær Type 4231 Acoustic Calibrator. During the measurements the sky was generally clear with occasional wind. The results of the attended noise survey are presented in **Table 2**.

Table 2
Attended Ambient Noise Survey Results - 25 July 2007

Location	Sample Time	Noise Level (dB(A))				Comments
		LAeq (15min)	LA1 (15min)	L10 (15min)	LA90 (15min)	
Location 1	8:38 am	46	56	46	41	Ambient dominated distant traffic, birds, occasional reversing alarms from the north.
	11:06 am	49	61	51	40	Ambient by distant traffic, birds, wind in trees.
Location 2	9:06 am	49	55	51	46	Ambient dominated distant traffic, birds, frogs dumping of aggregate at the concrete batching plant to the west
	10:27 am	50	60	50	44	Ambient dominated distant traffic, birds, Helicopter 55dB(A) to 60dB(A). Traffic typically 45dB(A) to 47dB(A)
Location 3	11:39 am	52	59	53	47	Ambient dominated by Princess Hwy traffic, saw mill on occasion, birds
	14:35 pm [1]	52	57	54	48	Ambient dominated by Princess Hwy traffic, birds. Sawmill 54dB(A) to 56dB(A)

Note 1 The Nowra Brick Quarry was operational after 12 noon on 25 July 2007.

4 NOISE ASSESSMENT CRITERIA

4.1 Industrial Noise Policy Criteria

The objectives for the assessment of noise emissions from industrial/commercial facilities at residential receivers are detailed in the NSW Government's INP. The policy is nominally applied at the residential property boundary.

The INP's objectives are as follows:

- To establish noise criteria that would protect the community from excessive intrusive noise.
- To preserve the amenity for specific noise levels.
- To use the criteria for deriving project specific land uses.
- To promote uniform methods to estimate and measure noise impacts, including a procedure for evaluating meteorological effects.
- To outline a range of mitigation measures that could be used to minimise noise impacts.
- To provide a formal process to guide the determination of feasible and recordable noise limits for consents and licences that reconcile noise impacts with the economic, social and environmental considerations of industrial development.

Implementation is achieved by ensuring:

- That noise from any single source does not intrude greatly above the prevailing background noise level. This is known as the intrusive noise criterion.
- The overall ambient noise level (including the proposed development) does not exceed the level appropriate for the particular locality and land use. This is known as the amenity criterion.

In order to satisfy the above two requirements, intrusive and an amenity noise criteria are established, the lower of which is then used to assess the impacts of the Project.

4.2 Intrusive Noise Criterion

In setting an "Intrusive" noise criterion, the ambient (background) L_{A90} noise level, termed the Rating Background Level (RBL), needs to be established at the nearest sensitive receivers, in the absence of the subject noise source. An "RBL plus 5dB(A)" criterion is then applied (to determine the intrusive noise criterion).

4.3 Amenity Noise Criterion

The "Amenity" noise criterion seeks to limit industrial noise emissions based on industrial noise levels deemed acceptable for various land use categories, ie rural, suburban, urban, etc.

The resulting amenity criterion placed upon noise emissions of a new facility then depends upon whether existing industrial/commercial-related $L_{Aeq(period)}$ levels are lower or higher than the recommended amenity noise level (refer to Section 2.2 of the INP).

In areas where existing industrial/commercial-related noise levels are already high, the amenity noise criterion acts to limit new industrial noise emissions so that the cumulative impact of all industrial/commercial noise emissions does not increase above an acceptable threshold.

Conversely, in areas where there is no existing industrial/commercial noise, the amenity noise criterion would be set at a level which allows new industrial/commercial noise emissions up to recommended amenity levels for the area.

The INP recommends acceptable amenity noise levels for residences located in "Rural", "Suburban", "Urban" and "Urban/Industrial" areas and for commercial premises. Consistent with the INP and for the purpose of this assessment, residences in the general "residential" areas surrounding the site are considered to fall within the Suburban category. In particular, it is noted that the ambient noise environment in these residential areas is influenced by traffic noise from the Princess Highway, and to a lesser extent by the noise from commercial businesses in the area. The recommended amenity noise levels are presented in **Table 3**.

Table 3
Amenity Criteria - Recommended Amenity (L_{Aeq}[1]) Noise Levels from Industrial Noise Sources

Type of Receiver	Indicative Noise Amenity Area	Time of Day[2]	Recommended L_{Aeq} Noise Level	
			Acceptable	Recommended Maximum
Residence	Rural	Day	50dB(A)	55dB(A)
		Evening	45dB(A)	50dB(A)
		Night	40dB(A)	45dB(A)
	Suburban	Day	55dB(A)	60dB(A)
		Evening	45dB(A)	50dB(A)
		Night	40dB(A)	45dB(A)
	Urban	Day	60dB(A)	65dB(A)
		Evening	50dB(A)	55dB(A)
		Night	45dB(A)	50dB(A)
	Urban/Industrial Interface - for existing situations only	Day	65dB(A)	70dB(A)
		Evening	55dB(A)	60dB(A)
		Night	50dB(A)	55dB(A)
Commercial premises	All	When in use	65dB(A)	70dB(A)

Note 1: The L_{Aeq} index corresponds to the level of noise equivalent to the energy average of noise levels occurring over a measurement period.
Note 2 For Monday to Saturday, Daytime 7.00am - 6.00pm; Evening 6.00pm - 10.00pm; Night-time 10.00pm - 7.00am. On Sundays and Public Holidays, Daytime 8.00am - 6.00pm; Evening 6.00pm - 10.00pm; Night-time 10.00pm - 8.00am.

For the daytime period in a "Suburban" area and at a "Commercial Premises", the INP recommended acceptable amenity noise level is 55dB(A) and 65dB(A) respectively.

The overall noise criterion for noise emissions from the site is the lower of the intrusive and amenity criteria. Note that the intrusive criterion is applicable over any 15 minute period whereas the amenity level is applicable over the whole daytime, evening or night-time period, as appropriate.

4.4 Project Specific Noise Assessment Criteria

4.4.1 Introduction

The intrusive and amenity criteria for the potentially affected residences adjacent to the facility have been determined in accordance with the INP as described in the following subsections. The project would only operate during the day, namely from 7:00am to 6:00pm, with up to 3 unladen truck movements between 6:00am and 7:00am, and between a further 3 unladen truck movements 5:00pm and 8:00pm.

4.4.2 Intrusive Noise Criteria

The daytime intrusive noise criterion (ABL + 5dB(A)) is 44dB(A) in the vicinity of Location 1 and 51dB(A) in the vicinity of Location 2. During the evening, the intrusive noise criterion is 41dB(A) in the vicinity of Location 1 and 46dB(A) in the vicinity of Location 2, and for the morning shoulder period (5.00am to 7.00am) 40dB(A) the vicinity of Location 1 and 45dB(A) in the vicinity of Location 2.

The intrusive noise criteria at Location 3 (260 Princes Highway) was assumed to be the same as for Location 2 based on the similarity of the noise environment at these locations. In addition, the intrusive noise criteria at Location 4 (243 Princes Highway) was assumed to be the same as Location 3 based on the proximity of the residences to the Princes Highway.

It is noted that intrusive noise criteria have not been determined for the proposed South Coast Correctional Facility because the nature of the facility is markedly different to a residence in that the facility will have limited windows, will not be lightly framed and will generate its own noise levels that will be significantly higher than those generated at a residence.

4.4.3 Amenity Noise Criteria

The corresponding daytime amenity noise criteria for residences in the “suburban” category is 55dB(A) in the vicinity of Location 1 and 53dB(A) in the vicinity of Location 2. During the evening the amenity noise criterion is 43dB(A) in the vicinity of Location 1 and 37dB(A) in the vicinity of Location 2 and for the night-time 32dB(A) the vicinity of Location 1 and 35dB(A) in the vicinity of Location 2.

For the proposed South Coast Correctional Facility, which will be located to the west of the quarry, the INP amenity criterion for commercial premises has been adopted ie L_{Aeq} 65dB(A), when in use.

The respective operational intrusive and amenity criteria are presented in **Table 4**.

The overall project specific criterion is the lower of the intrusive and amenity criteria, resulting in an intrusive daytime ($L_{Aeq(15minute)}$) criterion of 44dB(A) in the vicinity of Location 1 and 51dB(A) in the vicinity of Location 2. The 51dB(A) intrusive criterion has also been adopted for Locations 3 and 4 on the basis that the noise environment at these locations was estimated from the attended ambient noise survey to be similar to that at Location 2.

Table 4
Operation Noise Emission Criteria - dB(A) 20 µPa

Receiver	Intrusiveness Criterion $L_{Aeq(15minute)}$			Amenity Criterion $L_{Aeq(Period)}$		
	Daytime 7.00am-6.00pm	Evening 6.00pm-10.00pm	Early Morning 5.00am-7.00am	Daytime 7.00am-6.00pm	Evening 6.00pm-10.00pm	Early Morning 5.00am-7.00am
Location 1 80 Links Road	44	41	40	55	43	32
Location 2 371 Old Southern Road	51	45	45	53	37	35
Location 3 260 Princes Highway	51	45	45	53	37	35
Location 4 243 Princes Highway	51	45	45	53	37	35
Location 5 Proposed Correctional Facility	N/A	N/A	N/A	65[1]	65[1]	65[1]
Note 1: Criterion applicable "when in use".						

Similarly, the evening intrusive criterion is 41dB(A) at Location 1 and 46dB(A) at Locations 2 to 4, and the early morning criterion 40dB(A) at Location 1 and 45dB(A) at Locations 2 to 4.

5 ROAD TRANSPORTATION NOISE ASSESSMENT CRITERIA

Whilst operating on the Project Site, the assessment procedure for vehicle noise is as previously outlined in **Section 4**. That is, road vehicle noise contributions are included in the overall predicted $L_{Aeq(15minute)}$ quarry operational noise emissions. On public roads, different noise assessment criteria apply to the vehicles, which would be regarded as "traffic", rather than as part of the quarrying operations noise sources.

In June 1999, the DECC (then the EPA) issued a document entitled "*Environmental Criteria for Road Traffic Noise*" (ECRTN).

Based on the ECTRN, the traffic on the Princes Highway has been assessed as an arterial road. The relevant road transportation noise assessment criteria for the Nowra Brickworks Quarry are presented in **Table 5**.

Table 5
Road Traffic Noise Criteria

Type of Development	Criteria $L_{Aeq(15hour)}$ Daytime	Criteria $L_{Aeq(9hour)}$ Night-time	Where Criteria Are Already Exceeded
7. Land use developments with potential to create additional traffic on existing freeways/ arterials	60dB(A)	55 dB(A)	Where feasible and reasonable, existing noise levels should be mitigated to meet the noise criteria. Examples of applicable strategies include appropriate location of private access roads; regulating times of use; using clustering; using "quiet" vehicles; and using barriers and acoustic treatments. In all cases, traffic arising from the development should not lead to an increase in existing noise levels of more than 2dB(A)
Note: The ECRTN states that "where the existing road traffic noise levels lie within 2dB of the noise criteria, the 2dB allowance can be applied where all feasible and reasonable mitigation measures have been used."			

6 BLAST EMISSIONS ASSESSMENT CRITERIA

6.1 Ground Vibration - Structural Damage

In terms of the most recent relevant blast vibration damage criteria, British Standard 7385:Part 2-1993 "*Evaluation and Measurement for Vibration in Buildings Part 2"* is a definitive standard against which the likelihood of building damage from ground vibration can be assessed. This is the Standard recommended in Australian Standard AS 2187:Part 2-2006 as the guideline values and assessment methods "are applicable to Australian conditions".

Although there is a lack of reliable data on the threshold of vibration-induced damage in buildings both in countries where national standards already exist and in the UK, BS 7385:Part 2 (the "Standard") has been developed from an extensive review of UK data, relevant national and international documents and other published data. The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration which are considered in the Standard include blasting (carried out during mineral extraction or construction excavation), demolition, piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

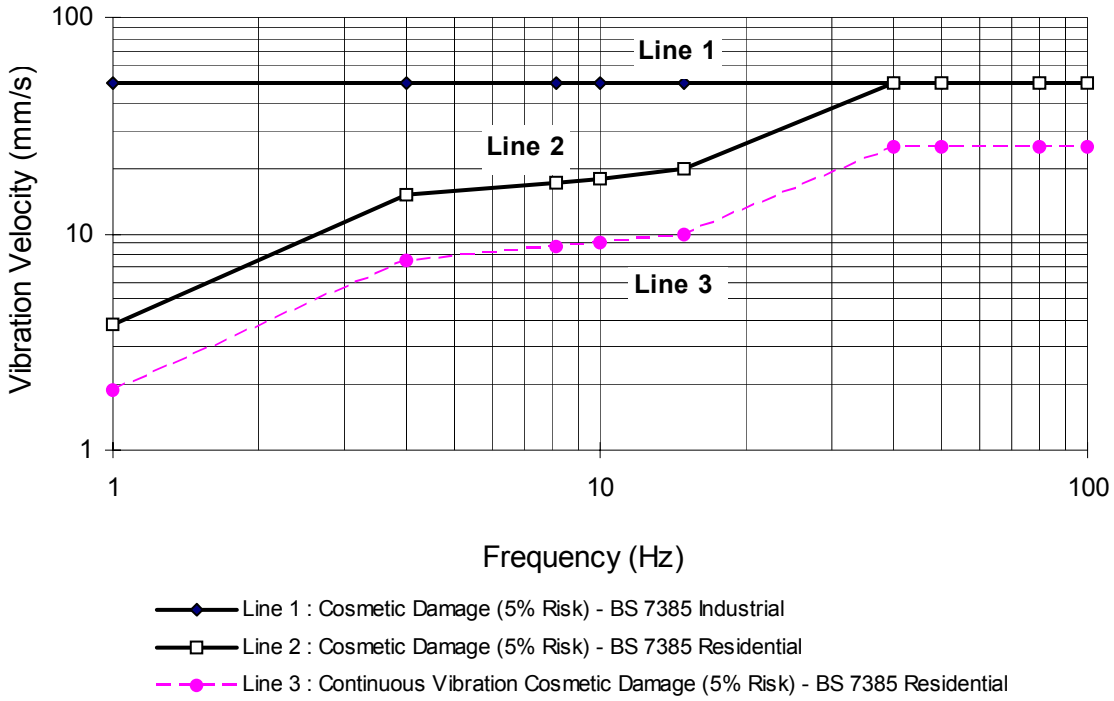
As the strain imposed on a building at the foundation level is proportional to the peak particle velocity, but is inversely proportional to the propagation velocity of the shear or compressional waves in the ground, this quantity (ie peak particle velocity) has been found to be the best single descriptor for correlating with case history data on the recurrence of vibration-induced damage.

The guide values from this Standard for transient vibration judged to result in a minimal risk of cosmetic damage to residential buildings and industrial buildings are presented numerically in **Table 6** and graphically in **Figure 4**.

Table 6
Transient Vibration Guide Values for Cosmetic Damage

Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Figure 4
Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 6** and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 6** should not be reduced for fatigue considerations.

It is noteworthy that extra to the guide values nominated in **Table 6**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

6.2 Airblast - Structural Damage

Based largely on work carried out by the US Bureau of Mines, the US Office of Surface Mining recommends the regulatory limits for airblast from blasting (depending on the low frequency limit of the measuring system) presented in **Table 7**.

Table 7
US Bureau of Mines Recommended Peak Airblast Limits

Low Frequency Limit	Peak Airblast Level Limit
2 Hz or lower	132 dB Linear
6 Hz or lower	130 dB Linear

The levels presented in **Table 7** are generally consistent with the level of 133 dB Linear nominated in AS 2187.2-2006.

The US Bureau of Mines criteria are structural damage limits based on relationship between the level of airblast and the probability of window breakage, and include a significant safety margin. It has been well documented that windows are the elements of residential buildings most at risk to damage from airblast from blasting.

While cracked plaster is the type of damage most frequently monitored in airblast complaints, research has shown that window panes fail before any other structural damage occurs (USBM, RI 8485-1980). The probabilities of damage to windows exposed to a single airblast event are as shown in **Table 8**.

Table 8
Probability of Window Damage from Airblast

Airblast dB Linear	Level kPa	Probability of Damage	Effects and Comments
140	0.2	0.01%	“No damage” - windows rattle
150	0.6	0.5%	Very occasional failure
160	2.0	20%	Substantial failures
180	20.0	95%	Almost all fail

6.3 Human Comfort and Disturbance Considerations

The ground vibration and airblast levels which cause concern or discomfort to residents are significantly lower than the structural damage limits. Humans are sensitive to some types of vibration and can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents.

The criteria normally recommended for blasting in NSW, based on human discomfort, are contained in the DECC's Environmental Noise Control Manual (Chapter 154). However, for recent projects the DECC has advocated the use of the Australian and New Zealand Environment Council (ANZEC) guidelines.

The ANZEC criteria for the control of blasting impact at residences are as follows:

- The recommended maximum level for airblast is 115dBLinear.
- The level of 115dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120dBLinear at any time.

The recommended maximum level for ground vibration is 5 mm/s (peak particle velocity (ppv)).

- The ppv level of 5mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10mm/s at any time.
- Blasting should generally only be permitted during the hours of 9.00am to 5.00pm Monday to Saturday. Blasting should not take place on Sundays and public holidays.

7 OPERATIONAL NOISE EMISSIONS

7.1 Introduction

In order to facilitate computation of environmental noise emissions from the operation of the quarry, near-field noise measurements of plant and equipment operations were carried out on site. The results of these measurements were supplemented by noise data from Heggies database.
It is noteworthy that as the Project would continue and expand the existing quarry operations, that the construction works outlined in **Section 2** will not be conducted in isolation but rather will form part of the land preparation undertaken as operational activities. As a result, no construction noise assessment is required.

A three dimensional computer model was then developed based on this and other site data, including the latest available ground topography and aerial photography (provided by R.W. Corkery & Co. Pty Limited), the location of noise sources and receivers (determined from site inspection), acoustical shielding effects of buildings, bund walls on site, etc. This noise modelling approach was adopted as direct measurements are potentially influenced by other noise contributions (such as road traffic), including natural environmental noise. Also, environmental noise modelling is the only means to estimate the hierarchy of noise emissions at the receivers, which is a necessary step in investigating the feasibility of implementing noise controls and the degree of noise reductions that may be achieved by potential engineering or other noise mitigation treatments.

7.2 Equipment Noise Levels

Heggies conducted on-site noise measurements of the major sources and operations at the quarry on 25 July 2007.

All noise measurements were carried out using a Brüel & Kjær 2260 Precision Sound Level Meter. Octave band noise emission spectra were measured for these major noise sources. The type of noise source and estimated height of the acoustic centre of the various sources were documented in order to provide input to the noise model.

Based on the above measurements and data from Heggies database, the following equipment sound power level (SWL) have been adopted for this study. Note, for the mobile and stationary plant the noise levels are equivalent $L_{Aeq(15\ minute)}$ and for the heavy vehicle the noise level is an L_{Amax} passby level.

- Crushing and Screening Plant 115dB(A)
- Excavator 100dB(A)
- Excavator (overburden) 106dB(A)
- Front End Loader 103dB(A)
- Bulldozer 112dB(A)
- Compactor 110dB(A)
- Blasthole Drill 113dB(A)
- Heavy Vehicle 110dB(A)
- Rockbreaker 117dB(A) - intermittent

7.3 Noise Modelling Methodology

In order to compute the environmental noise emission levels from plant items and operations at the representative noise sensitive receivers, noise emission modelling was undertaken using SoundPLAN noise prediction software, based on the CONCAWE industrial noise algorithm.

The noise modelling algorithm accounts for the octave band sound power levels of the sources, their heights, the distances to the receivers, the natural topography, noise barriers and buildings, air absorption, ground effects and meteorological conditions. The model incorporates estimated sound power levels provided or derived from on-site measurements, topographic data derived from topographic maps and noise barrier locations in conjunction with plant general arrangement drawings and site observations conducted by Heggies during the site visit.

The model calculates the contribution of each plant group and noise source to the total noise level at the receivers. This information enables the ranking of major noise sources at the receivers.

7.4 Modelling Scenarios

Three operational scenarios were developed and modelled to be indicative of the operations, during the life of the Project. The scenarios are illustrated in **Figure 5** and are summarised as follows:

- **Scenario 1**

  Current operations including the mobile crushing and screening plant, one front end loader, one blasthole drill and one excavator.

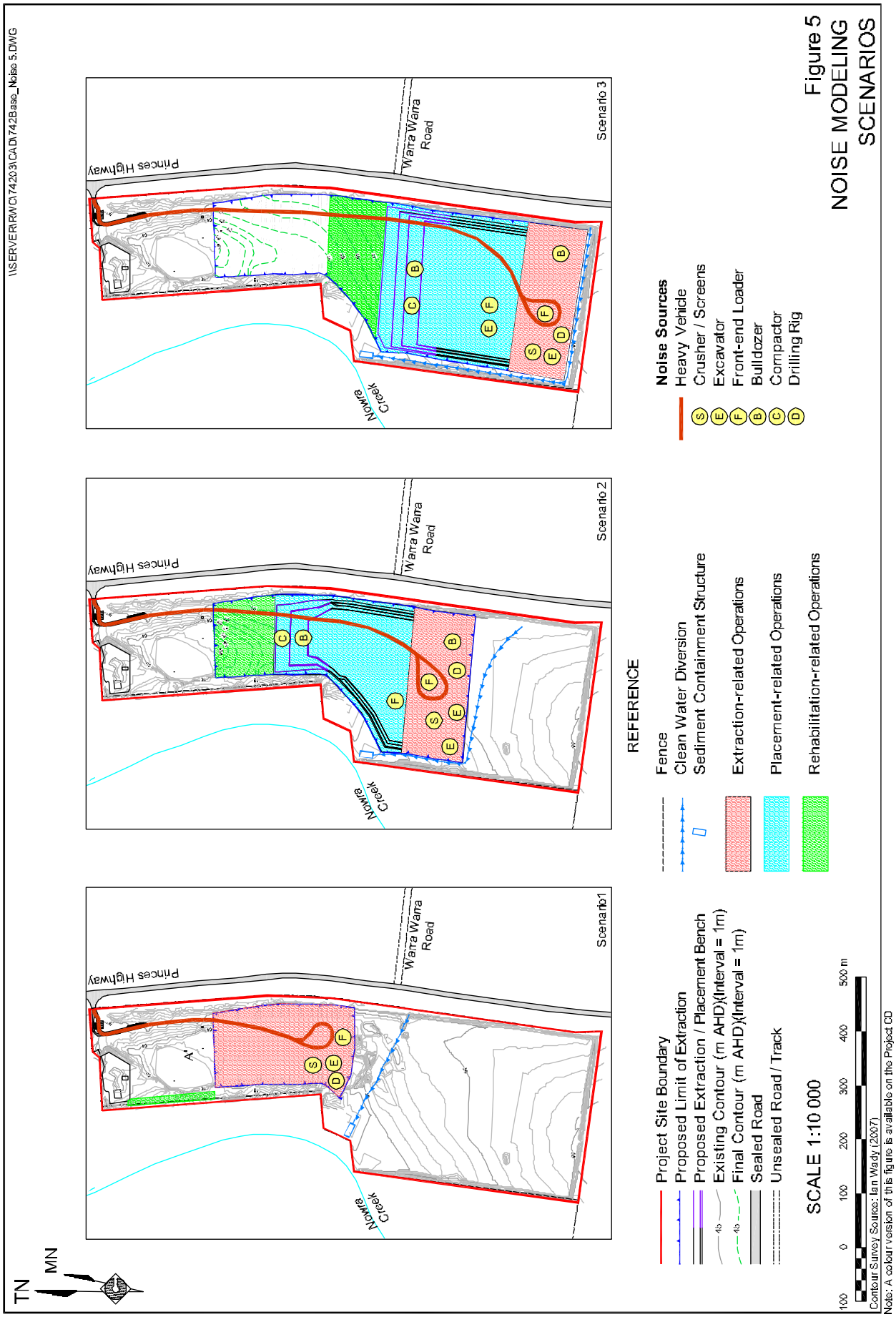


Figure 5
NOISE MODELING SCENARIOS

- **Scenario 2**

  Future operations, including the mobile crushing and screening plant, two FELs, one blasthole drill and two excavators. This equipment was modelled at an elevation of 14.5m below the natural surface on the western side of the active extraction area. Additionally, a bulldozer was modelled at the natural surface on the eastern side of the extraction area, removing overburden. VENM backfilling operations, incorporating a bulldozer and compactor, were modelled as occurring to the north of the active extraction area.

- **Scenario 3**

  Future operations, including the mobile crushing and screening plant, two FELs, one blasthole drill and two excavators. This equipment is located at an elevation of 14.5m below the natural surface on the western side of the Stage 6 area. Additionally, a bulldozer was modelled at the natural surface on the eastern side of the active extraction area removing overburden. VENM backfilling operations, incorporating a bulldozer and compactor, were modelled as occurring to the north of the active extraction area.

7.5 On-Site Truck Movements

Trucks have been modelled travelling from the site entrance to the FEL located in the vicinity of the mobile crushing and screening plant for each scenario. Approximately 74 movements per day were assumed for Scenario 1, representing a production rate of 300,000 tonnes per year and 120 movements per day were assumed for Scenario 2 and Scenario 3 representing a production rate of 500,000 tonnes per year.

Trucks were modelled as entering the extraction area in the centre at the north for Scenario 1 and then for Scenario 2 and Scenario 3, entering along the eastern wall then traversing across the quarry floor, at the stage being quarried.

Additionally, during the evening and early morning there may be 3 truck movements. Accordingly, a worst case of scenario of 2 truck movements to the extraction area during the early morning and evening during a single 15 minute period were assumed.

7.6 Modelled Weather Conditions

Computation of the contributed noise levels and noise contours at the three receiver locations have been based on:

- "Acoustically neutral" weather conditions equivalent to Pasquil Stability Class D, representing calm conditions (ie daytime 20^{O}C, 70% relative humidity and 0m/s wind speed), there being no prevailing adverse weather conditions (based on the Nowra RAN weather data).

8 NOISE IMPACT ASSESSMENT

8.1 Noise Sensitive Receivers

$L_{Aeq(15minute)}$ noise levels have been calculated, under acoustically neutral conditions, for the selected receiver locations. The receivers, chosen as indicative of the closest residences, are as follows (**Figure 3**):

- **Location 1 - 80 Links Road, Nowra**

  This residence is situated approximately 850m to the west-northwest of the Project Site and is representative of a group of residences in this area on Links Road.

- **Location 2 - 371 Old Southern Road, Nowra**

  This residence is situated approximately 630m to the northeast of the Project Site and is representative of a group of residences in this area of Old Southern Road, Nowra.

- **Location 3 - 260 Princes Highway, Nowra**

  This residence is situated adjacent to and south of, the Project Site boundary.

- **Location 4 - 243 Princes Highway, Nowra**

  This residence is located approximately 140m north of the northern Project Site boundary and approximately 380m north of the northern boundary of the extraction area.

- **Location 5 – Proposed South Coast Correctional Facility.**

  The proposed South Coast Correctional Facility has received project approval but has yet to be constructed. The closest point of the proposed facility has been used as the noise sensitive receiver location (**Figure 3**).

A rockbreaker will also be used to break down over sized material on an intermittent basis. Consequently, a rockbreaker was included in the modelled scenarios given in **Table 9** and the resulting noise level predictions appear as the second set of figures in the table. Modelling with the rockbreaker operational indicates that the $L_{Aeq(15minute)}$ noise levels will increase by up to 1 dBA during Scenarios 1, 2 and 3.

8.2 Operational Noise Impact Assessment

The point-to-point operational noise level calculation results are summarised in **Table 9**.

In summary, noise emissions are expected to be less than the Project Specific Noise Assessment Criteria at all surrounding residences, with the exception of Location 3 (260 Princess Highway) during Scenario 3 only. The exceedance at this location results from the bulldozer removing overburden at the surface, with the modelled noise levels reduced to 45dB(A) or (6dB(A) below the assessment criterion) in the absence of the land preparation activities. The predicted noise emissions also comply with the Project-Specific Noise Assessment Criterion at the Correctional Facility.

Table 9
Modelled Environmental Noise Emissions

Location	Project Specific Assessment Criteria (dB(A))	Predicted $L_{Aeq(15\ minute)}$ Noise Levels (dB(A))[1]		
		Scenario 1	Scenario 2	Scenario 3
Location 1 - 80 Links Road	44	22/23	34/35	34/34
Location 2 - 371 Old Southern Road	51	29/30	39/40	38/39
Location 3 - 260 Princes Highway	51	28/29	42/42	56/56
Location 4 - 243 Princes Highway	51	41/42	46/46	45/45
Location 5 – Proposed Correctional Facility	65	38/39	48/49	49/49
Note 1: Noise level without/with the operation of a rockbreaker.				

Potential control measures include:

- fitting of noise mitigation equipment to the bulldozer;
- negotiation of an appropriate arrangement with the owner of 260 Princes Highway; and/or
- limiting operations to Scenarios 1 and 2 only.

8.3 On-site Haulage Trucks - Evening and Early Morning

$L_{Aeq(15minute)}$ noise levels have been calculated under acoustically neutral conditions for the selected receiver locations. The receivers, chosen as being representative of the closest residences, are identified **in Section 8.1**.

The point-to-point on-site haulage truck noise level calculation results are summarised in **Table 10**.

Table 10
Modelled Environmental Noise Emissions

Location	Project Specific Assessment Criteria (dB(A))		Predicted $L_{Aeq(15\ minute)}$ Noise Levels (dB(A))
	Evening	Early Morning	
Location 1 - 80 Links Road	41	40	17
Location 2 - 371 Old Southern Road	45	45	21
Location 3 - 260 Princes Highway	45	45	19
Location 4 - 243 Princes Highway	45	45	36
Location 5 - Proposed Correctional Facility	65	65	29

In summary, anticipated emissions are expected to be less than the Project Specific Noise Assessment Criteria at all surrounding residences and the proposed Correctional Facility.

8.4 Road Traffic Noise Impact Assessment

The noise impact of the quarry related road traffic on the Princes Highway was conducted via the prediction of the existing and future (with the quarry expansion operating) traffic noise levels on the subject road.

The US Environment Protection Agency's method was used for the prediction of the L_{Aeq} traffic noise levels for the offset distances of the closest residences adjacent to the Project Site.
The US EPA's method for prediction of the L_{Aeq} noise levels from traffic is an internationally accepted theoretical traffic noise prediction model which takes into account the L_{Amax} vehicle noise levels (light and heavy), receiver offset distance, passby duration, vehicle speed, ground absorption (based on the ratio of soft ground and average height of propagation), number of hourly vehicle movements, receiver height, truck exhaust height and the height and location of any intervening barriers.

The road traffic volumes used in the road traffic noise impact assessment was based on the existing traffic flows (and an assumed 10% heavy vehicle traffic mix) presented in the *Nowra Brickworks Quarry, South Nowra - Traffic and Transportation* Assessment prepared by John Coady Consulting Pty Ltd (2007) presented as Part 3 of the Specialist Consultant Studies Compendium. **Table 11** summarises the existing and future traffic flow data.

Table 11
Average Hourly Traffic Movements - Princes Highway
Daytime (7.00am - 10.00pm)

Vehicle Classification	Existing (2007) Without Quarry	Existing (2007) With Quarry	Existing (2007) with Future Quarry
Light	1,280	1,283	1,284
Heavy	131	143	169

The daytime (15 hour) traffic noise level predictions for the Princes Highway at the closest residential receiver to the Princes Highway in the vicinity of the Project Site (**Figure 6**) are presented in **Table 12**. The road traffic noise impacts were determined at the closest residence to the Princes Highway, namely 365 Princes Highway, located approximately 2km to the south of the Project Site entrance and approximately 85m to the east of the Princes Highway.

Table 12
Predicted Traffic Noise Levels

Operations	Daytime Criteria $L_{Aeq\ (15\ hour)}$	Daytime (15 hour) Traffic Noise Levels
Existing (2007) Highway Traffic Without Quarry	60dB(A)	58.1dB(A)
Existing (2007) Highway Traffic With Existing Quarry	60dB(A)	58.3dB(A)
Existing (2007) Highway Traffic With Future Expanded Quarry	60dB(A)	58.8dB(A)

Review of the road traffic noise level predictions presented in **Table 12** indicates the following:

- The existing daytime $L_{Aeq(15hour)}$ noise levels without the Nowra Brickworks Quarry operations are lower than the NSW DECC's recommended assessment criterion of 60dB(A) at the closest residence on the Princes Highway, close to (south of) the quarry entrance.
- The predicted increase in the daytime $L_{Aeq(15hour)}$ traffic noise level from the Princes Highway resulting from the existing (2007) quarry operations is 0.2dB(A).

- The predicted increase in the daytime $L_{Aeq(15hour)}$ traffic noise level from the Princes Highway with the proposed future quarry expansion, relative to the existing traffic noise level without the quarry is 0.7dB(A).
- The predicted future traffic $L_{Aeq(15hour)}$ noise level with the quarry expansion is 58.8dB(A). This noise level is lower than the DECC's recommended assessment criterion of 60dB(A) and would result in a traffic noise level increase of less than 2dB(A), thereby complying with the DECC's second criterion.

8.5 Proposed Blasting Practices

The proposed method of material extraction for the Nowra Brickworks Quarry is by drill and blast techniques incorporating free-face blasting. A summary of indicative blast design details is presented in **Table 13**.

Table 13
Indicative Blast Design Details

Parameter	Free-Face
Bench height	Up to 11.5m
Sub-drill	0.5m
Stemming (using 14 mm aggregate)	2.7m
Blasthole diameter	76mm
Blasthole inclination (to vertical)	10^{o}
Blasthole spacing	3.0m
Burden	2.0m
Blastholes per Delay	2
Explosives weight/Lineal metre	6kg
Maximum Instantaneous Charge (MIC)	112kg (for 11.5m bench)

8.6 Blast Emission Site Laws

Blasting site laws were developed from the blast emission data originally obtained from trial blasting conducted at the site in September 2002, supplemented by recent blast emissions monitoring results from blasting conducted between April and October 2007 at the quarry. The original site laws were presented in Heggies letter report to SCCC dated 11 September 2002. Only the blast emission results above the lower limit of measurement of the monitor were used in the analysis.

The ground vibration and airblast criteria advocated by the DECC and the ANZEC cater for the inherent variation in emission levels from a given blast design by allowing a five percent exceedance of a general criterion up to a (never to be exceeded) maximum. Correspondingly, the "5% exceedance" prediction formulae were generated in the blast emission site laws.

The resulting 5% site laws for ground vibration and airblast are:

- **Ground Vibration**

  $PVS\ (mm/s)\ (5\%) = 2{,}789\ (R/Q^{1/2})^{-1.68}$

- **Airblast**

  SPL (dBL) (5%) =147.0 -15.4 log (R/Q$^{1/3}$)

  PVS = Peak Vector Sum ground vibration level (mm/s)

  SPL = Peak airblast level (dBLinear)

  R = Distance between charge and receiver (m)

  Q = Charge mass per delay (kg)

  Where PVS (5%) and SPL (5%) are the levels of ground vibration (Peak Vector Sum - mm/s) and airblast (dBLinear) respectively, above which 5% of the total population (of data points) will lie, assuming that the population has the same statistical distribution as the underlying measured sample.

The relationship between distance and the peak vector sum (PVS) ground vibration and peak airblast from the quarry blasting are presented in **Figure 6** and **Figure 7** respectively for an MIC of 112kg (corresponding to firing a full 11.5m bench with two blastholes per delay).

Figure 6
Peak Vector Sum Ground Vibration for an MIC of 112kg

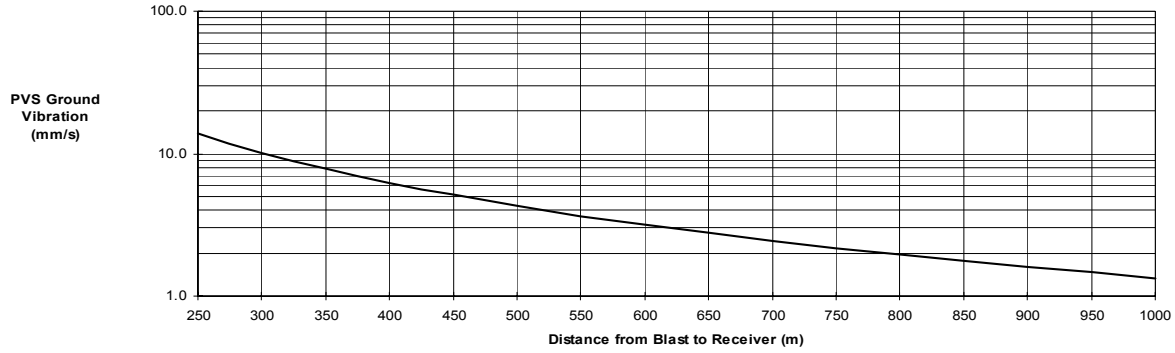
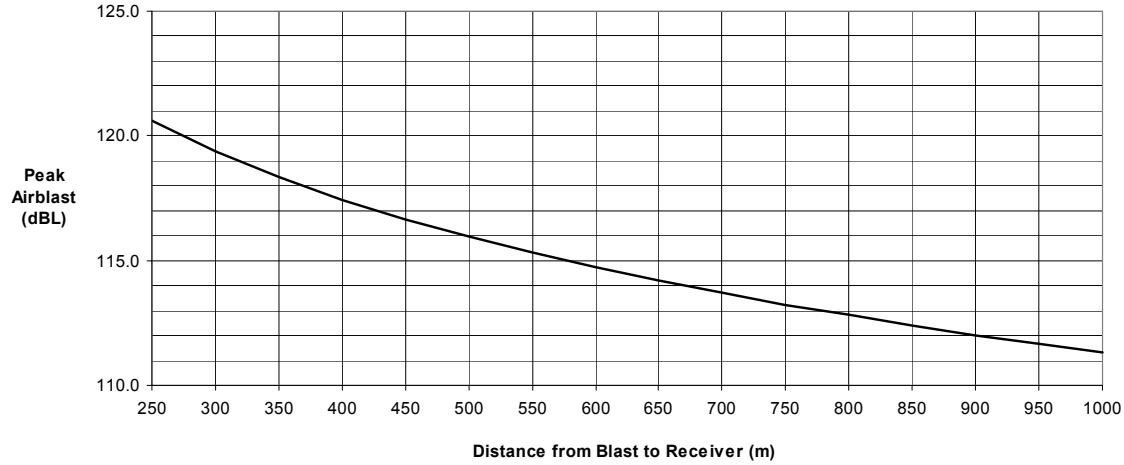


Figure 7
Peak Airblast for an MIC of 112kg



8.7 Blast Emission Assessment

The predicted level of blast emissions based on the indicative blast design parameters presented in **Table 13** were determined using the near distances to the quarry extraction boundary. The predicted levels of Peak Vector Sum (PVS) ground vibration velocity and peak airblast at the nearest potentially affected properties to the quarry blasting are presented in **Table 14**. Included in **Table 14** is the closest commercial property to the extraction area, Location 5 - 292 Princes Highway as well as the proposed Correctional Facility.

Table 14
Predicted Levels of Blast Emissions for a 112kg MIC

Residence/ Receiver	Distance from Blasting	PVS Ground Vibration		Peak Airblast	
		General/ Maximum Criterion (mm/s)	Anticipated Emissions (mm/s)	Criterion (dBLinear)	Anticipated Emissions (dBLinear)
Location 1 - 80 Links Road	850m	5/10mm/s	1.8mm/s	115/120dBLinear	112dBLinear
Location 2 - 371 Old Southern Road	630m	5/10mm/s	2.9mm/s	115/120dBLinear	114dBLinear
Location 3 - 260 Princes Highway	80m	5/10mm/s	93.2mm/s	115/120dBLinear	128dBLinear
Location 4 - 243 Princes Highway	380m	5/10mm/s	6.8mm/s	115/120dBLinear	118dBLinear
Location 5 - 292 Princes Highway	90m	50mm/s	76.5mm/s	132dBLinear	127dBLinear
Proposed Correctional Facility	210m	50mm/s	18.4mm/s	132dBLinear	122dBLinear

The following information is derived from the predicted levels of blast emissions:

- The predicted levels of ground vibration at the residences at Locations 1 and 2 comply with the ANZEC general human comfort criterion (of 5 mm/s) and consequently with the ANZEC maximum human comfort criterion (of 10mm/s) as well as the BS 7385 structural damage criterion of 15mm/s (at 4Hz).
- The predicted level of ground vibration at the residence at Location 4 exceeds the ANZEC general human comfort criterion but complies with the ANZEC maximum human comfort criterion.
- The predicted level of ground vibration at the residence at Location 3 exceeds the ANZEC maximum human comfort criterion (of 10mm/s) by 83.2mm/s and also exceeds the BS 7385 structural damage criterion of 15mm/s (at 4Hz) for residential buildings by 77.2mm/s for a 112kg MIC at the nearpoint of blasting.
- The maximum predicted ground vibration level of 93.2mm/s occurs at the Location 3 residence using an MIC of 112kg (corresponding to blasting a full height 11.5m bench).
- In relation to Location 5, the ANZEC criteria only relate to noise sensitive receivers (eg residences, hospitals, schools, etc) and not commercial buildings. Notwithstanding, the predicted maximum vibration level (of 76.5mm/s) exceeds the guide value of 50mm/s recommended for the prevention of cosmetic damage in BS 7385, refer to **Table 6** and **Figure 4**.

- The predicted maximum level of ground vibration at the proposed Correctional Facility complies with the guide value of 50mm/s recommended for the prevention of cosmetic damage in BS 7385, refer to **Table 6** and **Figure 4**.
- The predicted levels of peak airblast at the residences at Locations 1 and 2 comply with the ANZEC general human comfort criterion of 115dBLinear and consequently with the ANZEC maximum human comfort criterion.
- The predicted level of airblast at the residence at Location 4 exceeds the ANZEC general human comfort criterion but complies with the ANZEC maximum human comfort criteria.
- The predicted levels of peak airblast at the residence at Location 3 as well as at the exceeds the ANZEC maximum comfort criterion of 120dBLinear by 8dBLinear for a 112kg MIC at the nearpoint of blasting.
- The maximum predicted peak airblast level of 128dBLinear occurs at the Location 3 residence using an MIC of 112kg.
- The predicted levels of peak airblast are below the US Bureau of Mines damage limit of 132dBLinear (2Hz cut off) at all residences as well as at the proposed Correction Facility and Location 5.

Based on the current blast emissions site laws, **Table 15** presents the allowable MIC for compliance with the controlling general and maximum DECC criteria as well as damage criteria, where applicable.

Table 15
Controlling General Criterion and Allowable MIC

Residence/ Receiver	Distance from Blasting	Controlling General Criterion	Allowable MIC	Controlling Maximum Criterion	Allowable MIC
Location 1 - 80 Links Road	850m	115dBLinear	380kg	10mm/s	890kg
Location 2 - 371 Old Southern Road	630m	115dBLinear	154kg	10mm/s	485kg
Location 3 - 260 Princes Highway	80m	115dBLinear	0.3kg	120dBLinear	2.9kg
Location 4 - 243 Princes Highway	380m	115dBLinear	33kg	10mm/s	178kg
Location 5 - 292 Princes Highway	90m	50mm/s	68kg	50mm/s	68kg
Proposed Correctional Facility	210m	50mm/s	367kg	50mm/s	367kg

Based on the above, it is strongly recommended that all blasts are monitored at the closest/potentially most affected residence in order to establish compliance with the nominated criteria and to progressively update the blast emissions site laws (ground vibration and airblast) in order to optimise future blast designs, based on actual site conditions. In this way, the site laws can be used to assist with the blast designs in order to ensure compliance with the ANZEC criteria at all nearby receivers.

By adopting this approach, in conjunction with the inevitable future introduction of improved blasting products, it is anticipated that the blast emissions criteria can be met, except at Location 3, without imposing any significant constraints on the blast designs throughout the life of the quarry.

9 CONCLUSION

Heggies Pty Ltd (Heggies) has conducted a noise and blasting impact assessment for the proposed continued and future use of the Nowra Brickworks Quarry, Princes Highway, South Nowra. The results of the noise study are summarised as follows.

- An ambient noise survey was conducted and assessment criteria developed in accordance with the NSW Industrial Noise Policy. For the existing residences, a daytime goal of 44dB(A) and 51dB(A) for the dwellings to the west-northwest and northeast respectively were set. The 51dB(A) criterion was also adopted for the residence at 260 Princes Highway, to the south and at 243 Princes Highway to the north of the Project Site.
- Predicted daytime noise levels comply with the assessment criteria at the existing residences to west-northwest, north and northeast of the quarry for all Scenarios.
- At 260 Princes Highway, immediately to the south of the Project Site, the predicted daytime noise levels comply with the criterion for both Scenarios 1 and 2. However, the noise level for Scenario 3 at this residence was calculated to be 56dB(A), or 5dB(A) more than the assessment criteria.
- This exceedance relates to the use of a bulldozer at the surface to remove overburden. Removing this item of equipment from the noise assessment returns a noise level of 45dB(A) at the residence.

Potential control measures include:

- Fitting of noise mitigation equipment to the bulldozer.
- Negotiation of an appropriate arrangement with the owner of 260 Princes Highway.
- Limiting operations to Scenarios 1 and 2.

The corresponding results of the blast emissions study are summarised as follows:

- Blasting site laws were developed from the blast emission data originally obtained from trial blasting conducted at the site in September 2002 supplemented by recent blast emissions monitoring results from blasting conducted between April and October 2007 at the quarry.
- Based on the results of the blasting impact assessment, it is strongly recommended that all blasts are monitored at the closest/potentially most affected residence in order to establish compliance with the nominated criteria and to progressively update the blast emissions site laws (ground vibration and airblast) in order to optimise future blast designs, based on actual site conditions. In this way, the site laws can be used to assist with the blast designs in order to ensure compliance with the ANZEC criteria at all nearby residence.

- By adopting this approach, in conjunction with the inevitable future introduction of improved blasting products, it is anticipated that the blast emissions criteria can be met, except at Location 3, without imposing any significant constraints on the blast designs throughout the life of the quarry.

Potential control measures include:

- Progressively reducing the MIC down to approximately 35kg when approaching the nearpoint of the extraction to Location 4 residence (based on compliance with 115dBLinear airblast).
- Reducing the bench height to 6 m (minimum height economically viable) and firing only one blasthole per delay (MIC 23kg) as blasting approaches the Location 3 residence (260 Princes Highway). However, in order to comply with the DECC's general human comfort criterion of 115dBLinear (the limiting criterion), the site law predicts that blasting could still not comply when conducted closer than 350m from the residence. The corresponding ground vibration at this distance is 2.1mm/s.
- Negotiation of an appropriate arrangement with the owner of Location 3 (260 Princes Highway) before blasting occurs within 350m of the residence (as for noise) in order to ensure that the residence becomes project-related.

APPENDICES

(No. of pages excluding this page = 5)

Appendix A Acoustic Terminology

Appendix B Unattended Noise Monitoring Results

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Appendix A

Acoustic Terminology

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1 Sound Level or Noise Level

The terms "sound" and "noise" are almost interchangeable, except that in common usage "noise" is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-5} Pa.

2 "A" Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an "A-weighting" filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
140	Threshold of pain	Intolerable
130		
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Rural house at night	Almost silent
10	Recording studio	

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as "linear", and the units are expressed as dB(lin) or dB.

3 Sound Power Level

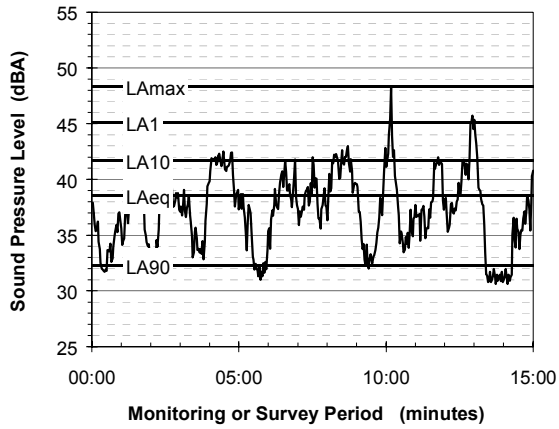
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

- L_{A1} The noise level exceeded for 1% of the 15 minute interval.
- L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.
- L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.
- L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the "repeatable minimum" L_{A90} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or "average" levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than "broad band" noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

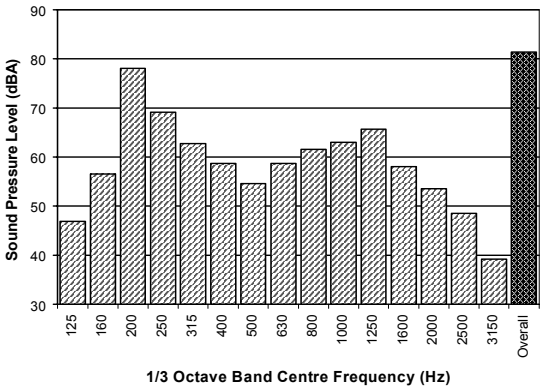
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of "peak" velocity or "rms" velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as "peak particle velocity", or PPV. The latter incorporates "root mean squared" averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to "feel" vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

10 Overpressure

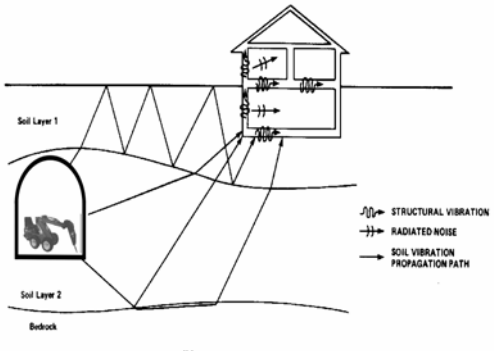
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed "structure-borne noise", "ground-borne noise" or "regenerated noise". This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



The term "regenerated noise" is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise

Appendix B

Unattended Noise Monitoring Results

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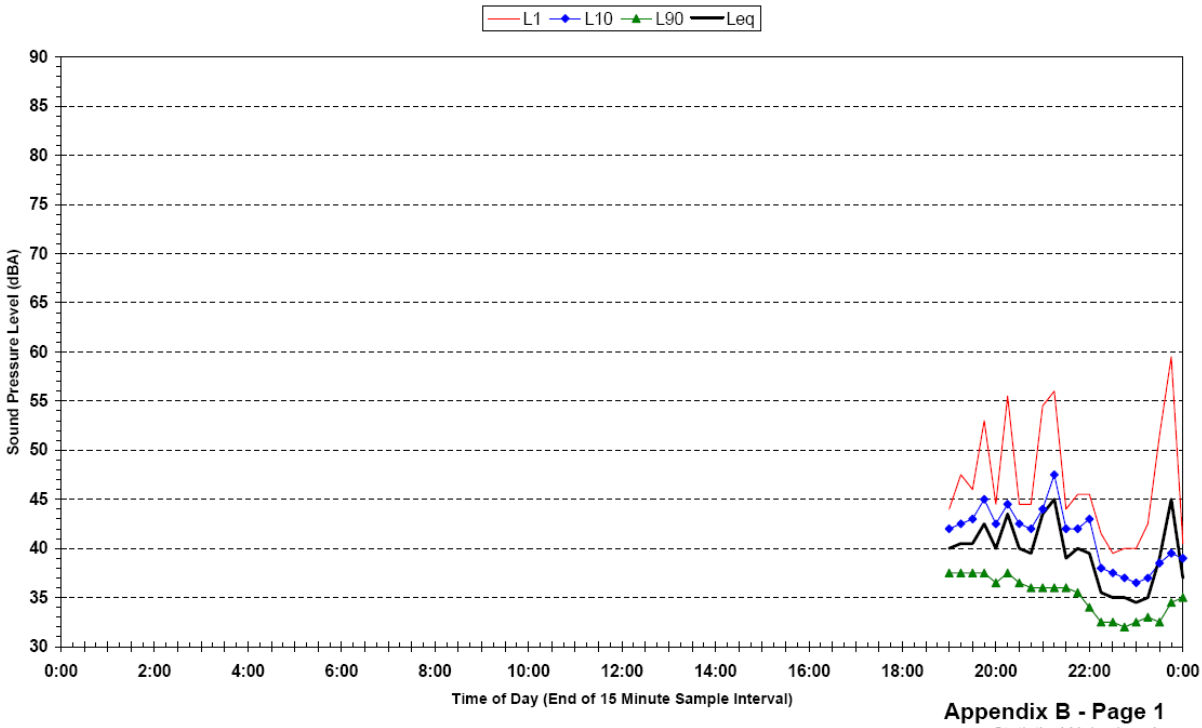
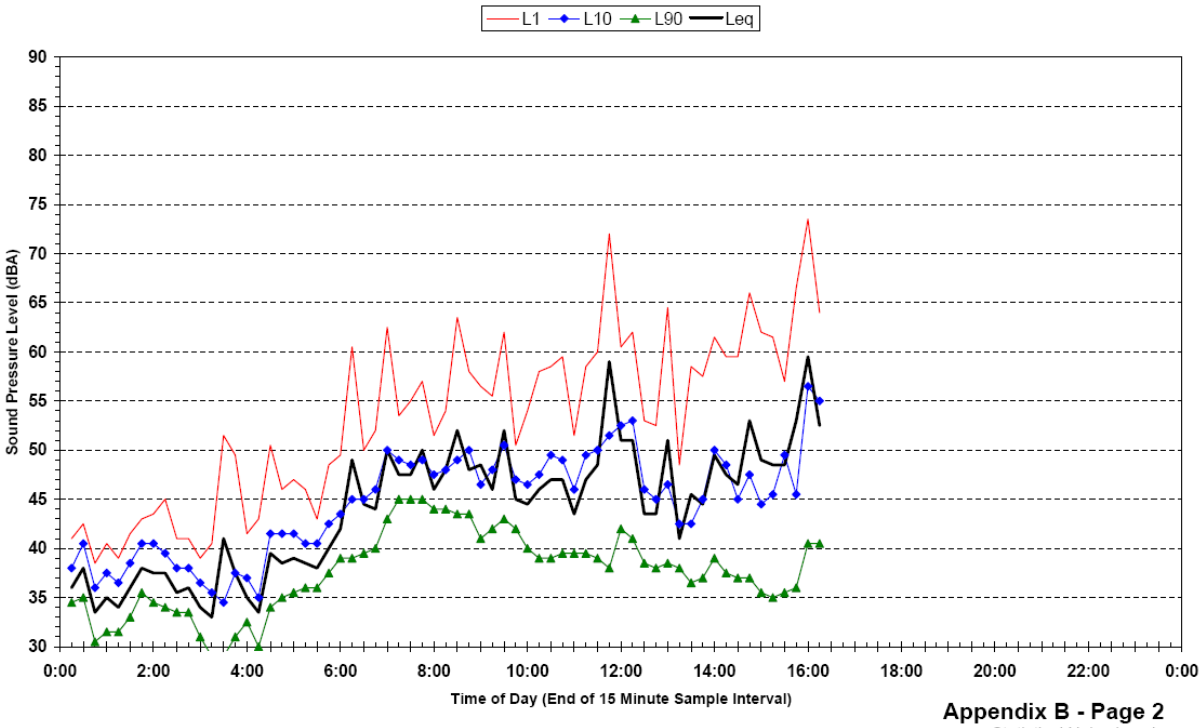
Statistical Ambient Noise Levels
Links Road, Nowra - Tuesday 24 July 2007

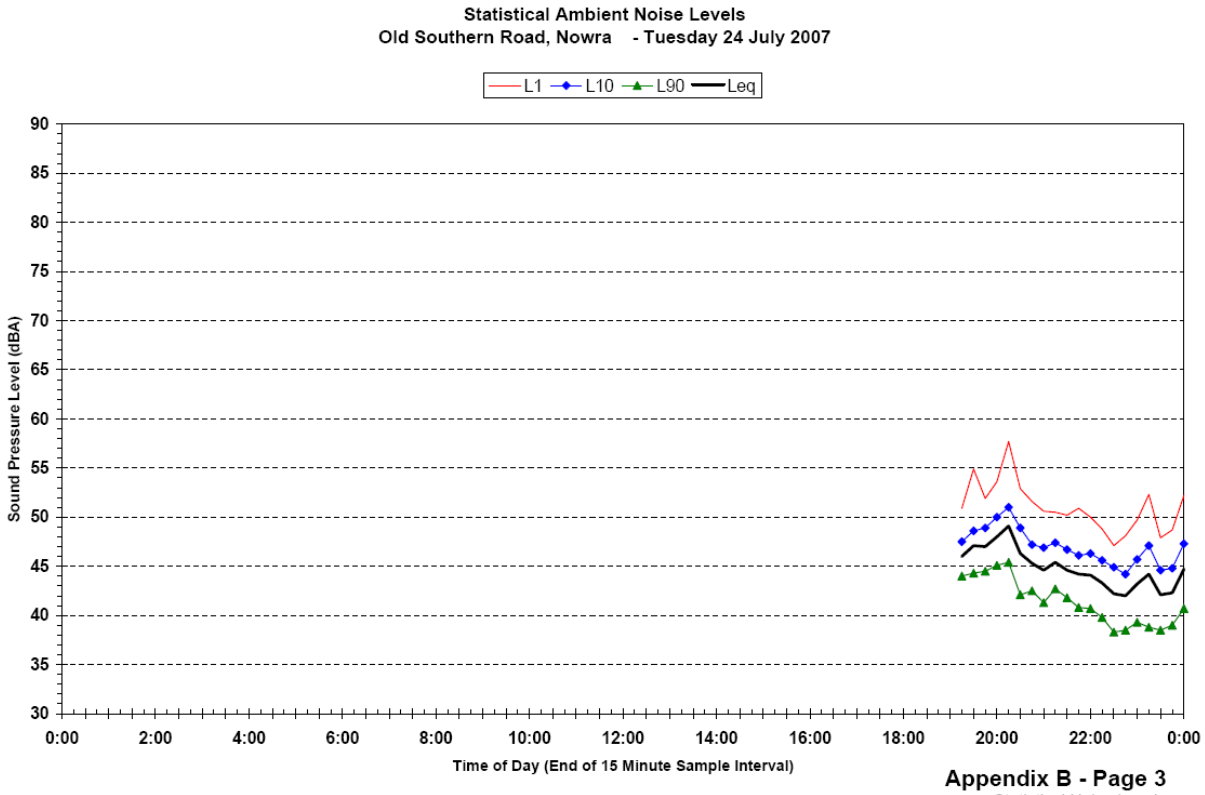


Appendix B - Page 1
Statistical Noise Levels
Heggies Report 10-5695

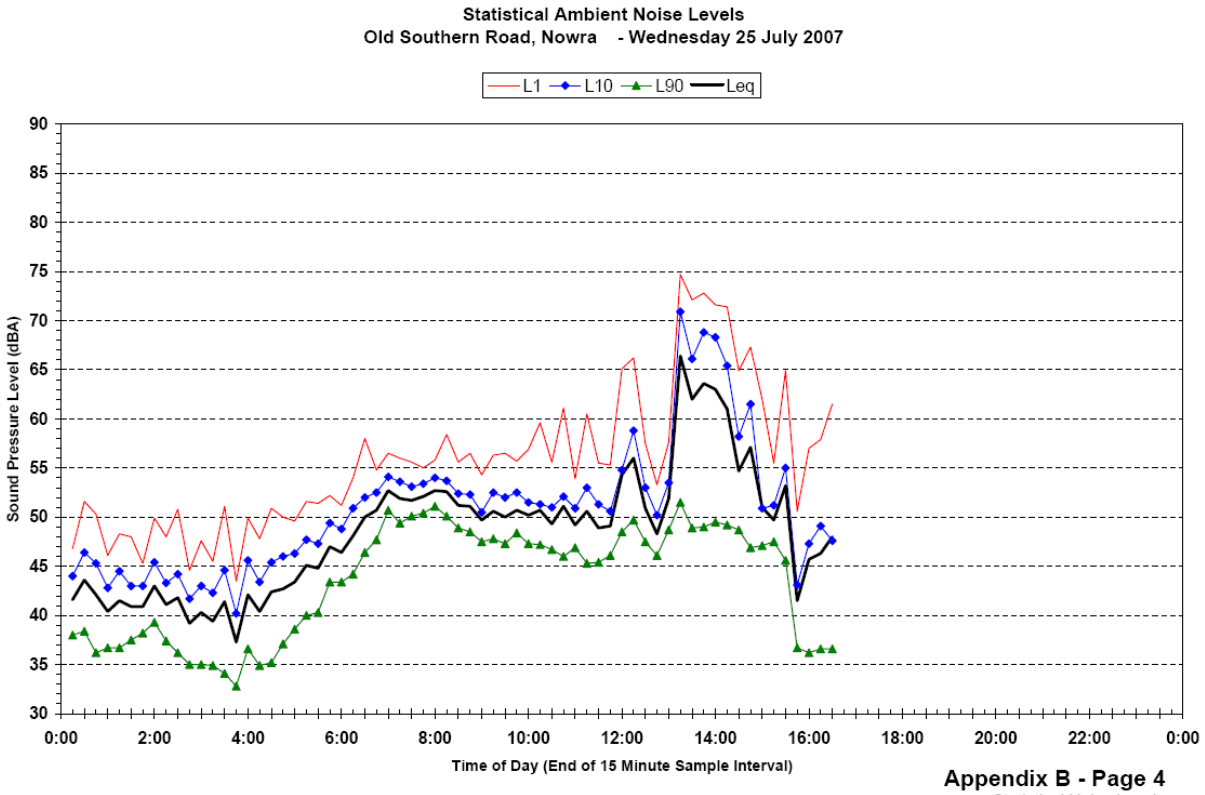
Statistical Ambient Noise Levels
Links Road, Nowra - Wednesday 25 July 2007



Appendix B - Page 2
Statistical Noise Levels
Heggies Report 10-5695



Appendix B - Page 3
Statistical Noise Levels
Heggies Report 10-5695



Appendix B - Page 4
Statistical Noise Levels
Heggies Report 10-5695

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Aboriginal Heritage Assessment

Prepared by

Cultural Heritage Management Australia

December, 2007

Specialist Consultant Studies Compendium:
Part 6

Aboriginal Heritage Assessment

of the
Continuation and Expansion of Extractive Operations
at the
Nowra Brickworks Quarry, South Nowra

Prepared for:

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CONTENTS

Page

EXECUTIVE SUMMARY 6-5

1 INTRODUCTION 6-8

1.1 Project Background 6-8
1.2 Project Overview 6-8
1.3 Aims of the Assessment 6-9
1.4 Project Methodology 6-9

2 ABORIGINAL COMMUNITY CONSULTATION 6-15

2.1 Introduction 6-15
2.2 Notification and Registration of Interest 6-16
2.3 Preparation for the Assessment 6-17
2.4 The Field Survey 6-17
2.5 Post Field Work Consultation 6-17

3 STATUTORY CONTROLS AND LEGISLATIVE REQUIREMENTS 6-18

3.1 State Legislation 6-18

3.1.1 The National Parks and Wildlife Act 1974 (NPW Act) 6-18
3.1.2 Environment Planning & Assessment Act (1979) 6-19

3.2 Commonwealth Legislation 6-20

3.2.1 Australian Heritage Council Act 2003 (Comm) 6-21
3.2.2 The Aboriginal and Torres Strait Islander Heritage Protection Act 1987 6-21
3.2.3 Environment Protection and Biodiversity Conservation Act 1999 (Comm) 6-22

4 BACKGROUND ARCHAEOLOGY 6-22

4.1 Regional Studies 6-22
4.2 Local studies 6-25
4.3 Previously identified Sites in Close Proximity to the Project Site 6-28

5 DESCRIPTION OF THE PROJECT SITE, RESULTS OF THE FIELD SURVEY AND DISCUSSION 6-29

5.1 Description of the Project Site 6-29
5.2 Results of the Field Survey and Discussion 6-29

6 MANAGEMENT RECOMMENDATIONS 6-30

CONTENTS

Page

APPENDICES

Appendix 1 Photographs 6-39
Appendix 2 Letters From Aboriginal Stakeholder Groups 6-43

FIGURES

Figure 1 Locality Plan 6-10
Figure 2 Project Site Layout..... 6-11
Figure 3 Survey Transects..... 6-13
Figure 4 Area to be monitored 6-32

TABLES

Table 1 Aboriginal Sites Located in Close Proximity to the Study Area..... 6-28

EXECUTIVE SUMMARY

Project Background

Abib Pty Ltd is the holder of two Mining Leases (ML5087 and ML6322) both of which are located within Lot 464, DP1058778, Princess Highway, South Nowra (*see* **Figure 1**). This site, which is also known as the Nowra Brickworks Quarry, is located approximately 5km south of the Nowra CBD, and is referred to in this report as the Project Site. The area of ML5087 is approximately 7.4ha and ML6322 comprises approximately 14.6ha (*see* **Figure 2**).

South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) has operated the Nowra Brickworks Quarry within the two Mineral Leases since these leases were acquired from the previous operator in 2002. The Proponent proposes to continue and expand extractive operations within the Project Site (the "project"), as described in Section 1.2. To this end, an application for planning approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (the "Act") has been made to the NSW Minister for Planning.

City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited have been engaged by SCCCR to prepare an *Environmental Assessment* as required under Part 3A of the Act. Rob Paton Archaeological Studies Pty Ltd (trading as CHMA) has been engaged to undertake an Aboriginal cultural heritage assessment for the Project Site. This report presents the findings of this Aboriginal cultural heritage assessment.

The Field Survey

The field survey for this project was carried out over a period of two days (21-11-2007 and 26-11-2007). On the 21-11-2007, Stuart Huys (CHMA archaeologist) and Jason Davidson (Aboriginal representative from Dungarn Consultancy) carried out a field survey within the Project Site. On the 26-11-2007, Charmain O'Halloran (CHMA archaeologist) and Peter Moore (Nowra Local Aboriginal Land Council representative) also undertook a field survey of the Project Site. On both days the field teams were accompanied by an Employee of SCCCR.

Results and Discussion

Approximately 4.5km of survey transects were walked through the Project, with each survey transect being approximately 20m in width, giving a total of a 90 000m square area surveyed. The total area of the Project Site is around 220 000m square (22ha) which means that approximately 40% of the Project Site was surveyed. When taking into account conditions of surface visibility etc, the effective survey coverage was around 40 000m square or 15% of the Project Site. This can be considered as an effective survey coverage percentage. It should however be noted that approximately 10ha of the Project Site has been heavily impacted through previous quarrying activity and the construction of associated infrastructure. This area is effectively unavailable for survey assessment. Taking this into account, a total of 120 000 square metres of the site was available for assessment, meaning that effective coverage was around 33% of the Project Site.

In the course of the field investigations, no Aboriginal sites or cultural materials were identified within the Project Site.

As mentioned above, the effective survey coverage of the Project Site was around 15%, which can be considered as being quite high when compared with other surveys undertaken in the region. The negative findings of the field survey within the Project Site can therefore be taken as being a reasonably accurate indication as to the low archaeological potential of the Project Site.

This assessment generally correlates with the patterns of site and artefact distributions generated from the findings of previous archaeological investigations in the Shoalhaven region. Previous findings show that in the Shoalhaven, hinterland sites tend to be located on elevated level landscape features, in close proximity to watercourses. Typically, artefact scatters are small and sparse and are located on elevated level ground, both on ridgelines in the foothills and on the coastal plane (Navin 1987).

The Project Site is characteristically flat to very gently undulating and quite low lying. There are no prominent landscape features located in the Project Site, such as the spines of spurs, ridges or raised terraces, where sites could be expected to occur. On this basis, it would be anticipated that Indigenous cultural sites and artefact densities within the Project Site would generally be very low. The possible exception may be the western edge of the Project Site, which lies between 50-100m from Nowra Creek. Densities in this area may be expected to be slightly higher, given the proximity to a water course. However, again given that this area is flat, with no elevated terraces or landscape features present, site and artefact densities would still be low to very low.

Any sites or artefacts that are present within the Project Site will have been subject to a very high level of prior disturbance associated with prior land clearing and land use activities.

Management Recommendations

Heritage management options and recommendations provided in this report are made based on the following.

- Consultation with representatives of the identified Aboriginal stakeholder groups.
- The legal and procedural requirements of NSW DECC.
- The results of the investigation as documented in this report.
- An analysis of the findings of previous archaeological investigations carried out in the study area.
- Relevant environmental information for the study area.

The following recommendations for the management of Aboriginal sites and cultural materials should be implemented during the life of the Project.

- No Aboriginal sites, artefacts or cultural material was identified within the bounds of the Project Site. As such, there are no site specific management recommendations.
- Based on the absence of Aboriginal sites or cultural material identified during the field investigation, the high level of prior land disturbance and patterns of site and artefact distributions for the region, the vast majority of the Project Site has been assessed as being of very low archaeological sensitivity. The exception is the western edge of the Project Site, adjacent to Nowra Creek which is assessed as being of potential low to very low archaeological sensitivity. This is based on the potential for low artefact densities to be present close to the margins of this creek. In accordance with the slight increase in archaeological sensitivity of this western portion of the Project Site, it is recommended that monitoring of earth disturbance in this area be undertaken. Figure 5 shows the area where monitoring is required.

- Monitoring should be carried out by Jason Davidson (Dungarn Consultancy) and a representative from the Nowra LALC. Monitoring will only be required for the removal of the top 10cm off soil in this area. This soil should be removed by grader or excavator. The area should then be inspected by the monitors. If artefact material is identified in this area then the following procedures should be implemented.
    - **Step 1** No further earth disturbing works should be undertaken in the area.
    - **Step 2** A buffer protection zone of 20m x 20m should be established around the suspected artefact materials. No unauthorised entry or earth disturbance should be allowed with this buffer zone until such time as the area has been assessed.
    - **Step 3** A qualified archaeologist or NSW DECC personnel should be contacted to make an assessment of the discovery. Mitigation procedures will then be developed and implemented based on the assessment.
    - **Step 4** Once the mitigation requirements have been implemented, work in the buffer zone area may proceed.
- If, during the course of the prescribed general monitoring and salvage program or development activity, suspected human remains are encountered, the following procedures should be implemented.
    - **Step 1** Under no circumstances should the suspected skeletal remains be touched or disturbed. If these are human remains, then this area potentially is a crime scene. Tampering with a crime scene is a criminal offence.
    - **Step 2** Any person discovering suspected skeletal remains should notify machinery operators that are working in the general vicinity of the area that earth disturbing works should stop immediately. Remember health and safety requirements when approaching machinery operators.
    - **Step 3** A buffer protection zone of 50m x 50m should be established around the suspected skeletal remains. No unauthorised entry or earth disturbance will be allowed with this buffer zone until such time as the suspected skeletal remains have been assessed.
    - **Step 4** The police and the NSW DECC should be contacted and informed of the discovery. A time will be arranged for these parties to meet on site to carry out an assessment of the suspected skeletal remains.
    - **Step 5** Should the skeletal remains be declared an Indigenous burial site, appropriate mitigation procedures should be developed by the NSW DECC, Jason Davidson (Dungarn Consultancy) and the Nowra LALC. These mitigation procedures should be fully implemented prior to any earth disturbance works recommencing within the identified buffer zone.
- Copies of this report should be submitted to the Nowra LALC, Jason Davidson (Dungarn Consultancy) and the NSW DECC.

1 INTRODUCTION

1.1 Project Background

Abib Pty Ltd is the holder of two Mining Leases (ML5087 and ML6322) both of which are located within Lot 464, DP1058778, Princess Highway, South Nowra (*see* **Figure 1**). This site, which is also known as the Nowra Brickworks Quarry, is located approximately 5km south of the Nowra CBD, and is referred to in this report as the Project Site. The area of ML5087 is approximately 7.4ha and ML6322 comprises approximately 14.6ha (*see* **Figure 2**).

South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) has operated the Nowra Brickworks Quarry within the two Mineral Leases since these leases were acquired from the previous operator in 2002. The Proponent proposes to continue and expand extractive operations within the Project Site (the "project"), as described in Section 1.2. To this end, an application for planning approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (the "Act") has been made to the NSW Minister for Planning.

City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited have been engaged by SCCCR to prepare an *Environmental Assessment* as required under Part 3A of the Act. Rob Paton Archaeological Studies Pty Ltd (trading as CHMA) has been engaged to undertake an Aboriginal cultural heritage assessment for the Project Site. This report presents the findings of this Aboriginal cultural heritage assessment.

1.2 Project Overview

In summary, the proposed continued and expanded use of the Nowra Brickworks Quarry would incorporate the following activities. **Figure 2** presents the Project Site Layout.

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark prior to the annual production from the quarry reaching 250 000t.
- Staged extraction of shale material ("extracted material") from a proposed extraction area of 15.0ha, incorporating an existing extraction area of approximately 2.0ha. Weathered shale material would be extracted using an excavator and stockpiled or direct loaded into road registrable trucks for transportation to the quarry's customers. Unweathered shale material would initially be blasted before being extracted using an excavator. Extraction operations would generally progress from north to south.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted material to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.

- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A portion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

1.3 Aims of the Assessment

The principle aims of this Aboriginal heritage assessment are as follows.

- To ensure that the appropriate Indigenous stakeholder groups are involved in the assessment process.
- To review the available archaeological information for the area surrounding the Project Site.
- To carry out a comprehensive field inspection within the designated bounds of the Project Site.
- Record and plot the location of all Indigenous heritage sites identified during the course of the field investigations.
- Identify areas of potential archaeological sensitivity within the Project Site.
- Assess the significance of all Indigenous heritage sites or objects identified within the Project Site.
- Develop a set of management procedures for all Indigenous heritage sites and areas of potential archaeological sensitivity identified within the Project Site.

1.4 Project Methodology

In order to fulfil the outlined aims of this assessment, a three stage methodological approach has been adopted for the investigations.

Stage 1 (Background Research, Consultation and Project Planning)

Stage 1 entailed the background component of the project, wherein the following tasks were undertaken.

- *Identification and Initial Consultation with Aboriginal Stakeholder Groups*

  CHMA has developed and implemented an extensive Aboriginal community consultation program for this project.

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Base Map Source: Kiama and Jervis Bay 1: 100 000 Topographic Maps (1983)

Note: A colour version of this figure is available on the Project CD

Figure 1
LOCALITY PLAN

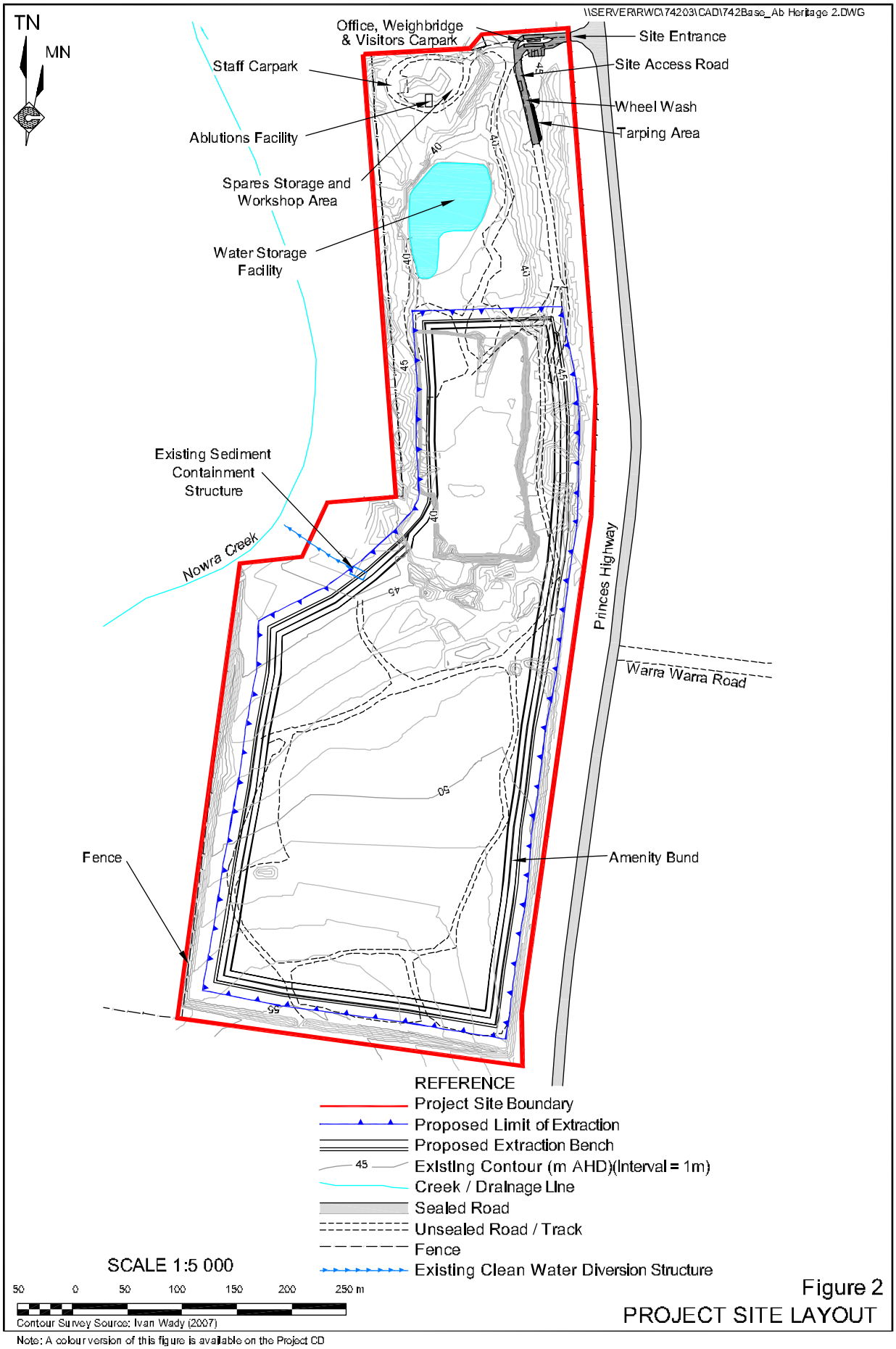


Figure 2
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

The consultation for this project has been undertaken in accordance with the NSW Department of Environment and Climate Change (DECC) *Interim Guidelines for Aboriginal Community Consultation – Requirements for Applicants (IGACC)*. The full details of this consultation process are provided in Section 2 of this report. For Stage 1 of this project, the consultation process involved actively seeking to identify Aboriginal stakeholder groups, and then meeting with identified Aboriginal stakeholders to discuss the details of the project, and to ratify the research methodology for the project.

- *The collation of relevant documentation for the project*

  As part of the background research for this project, the following information was collated:

  – 1 : 25 000 scale maps and aerial photographs of the Project Site;

  – Proposed development plans for the Project Site;

  – Land use history of the Project Site.

- *Development of a Research Methodology*

  As part of the planning component of this project, an interim draft methodology was developed for the proposed field survey investigations. This draft methodology was later reviewed and ratified by the Aboriginal stakeholder representatives involved in the project.

- *Aboriginal Heritage Information Management System Search*

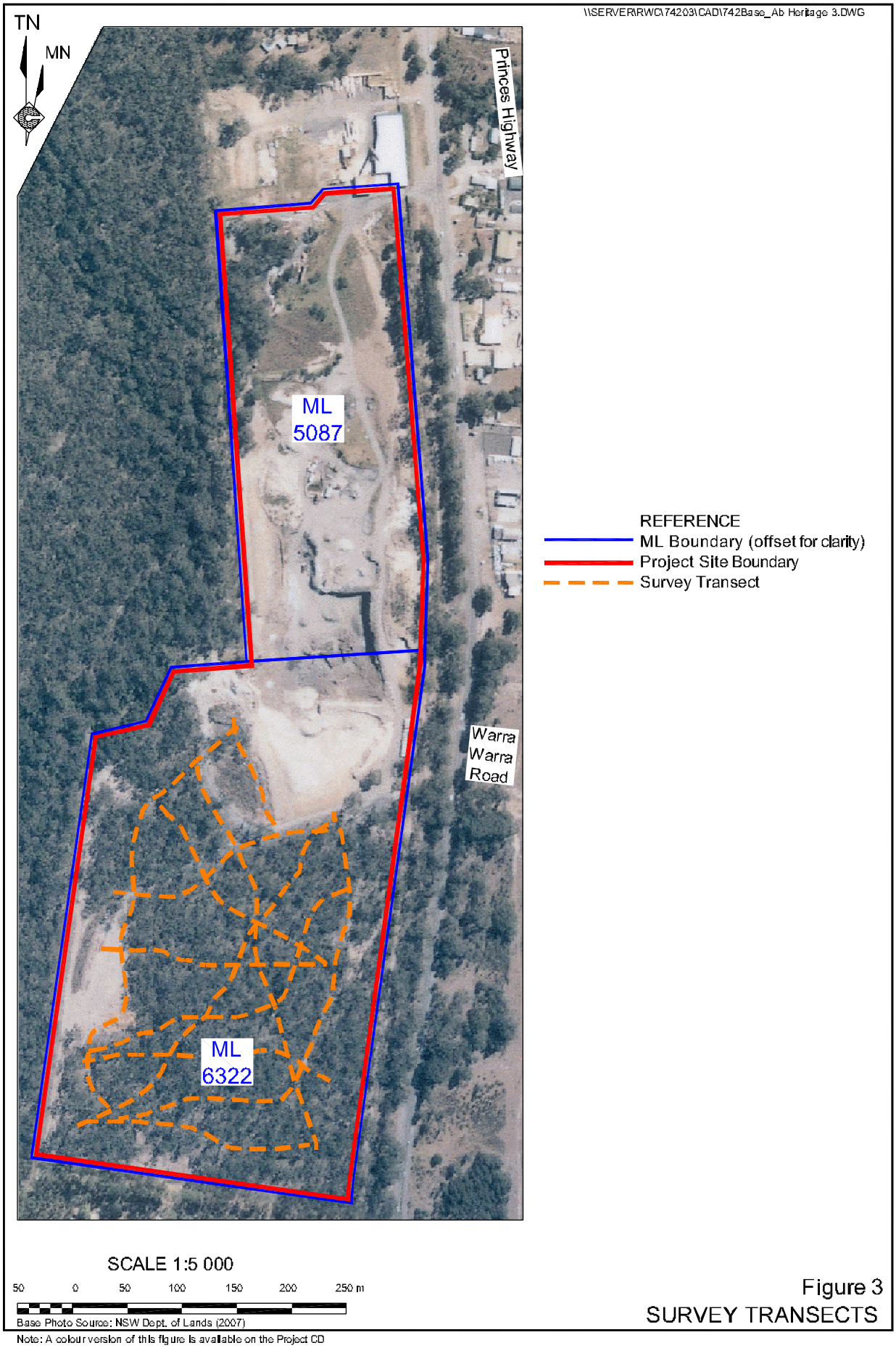
  CHMA carried out a search of the NSW DECC Aboriginal Heritage Information Management System (AHIMS) to determine the extent of previously recorded Aboriginal sites within and surrounding the Project Site. The AHIMS search was within the bounded co-ordinates of E276000 - E286000; N6127000 – N6137000 (AHIMS search #20527). No previously recorded Aboriginal sites have been registered within the bounds of the Project Site.

Stage 2 (The Field Survey Work)

Stage 2 of the assessment entailed the implementation of a field survey program to locate and record sites within the identified bounds of the Project Site. The field survey was carried out over a period of two days (21-11-2007 and 26-11-2007).

On the 21-11-2007, Stuart Huys (CHMA archaeologist) and Jason Davidson (Aboriginal representative from Dungarn Consultancy) carried out a field survey within the Project Site. On the 26-11-2007, Charmain O'Halloran (CHMA archaeologist) and Peter Moore (Nowra Local Aboriginal Land Council representative) also undertook a field survey of the Project Site. On both days the field teams were accompanied by an Employee of SCCCR.

Both field teams walked a series of survey transects within the bounds of the Project Site. These survey transects were different for each survey team. **Figure 3** indicates the location of the survey transects. The following provides a more detailed account of the survey coverage achieved by the field survey teams.



Note: A colour version of this figure is available on the Project CD

Figure 3
SURVEY TRANSECTS

Survey Coverage

Clearly conditions of ground surface visibility will affect how many sites are found. Visibility may also skew the results of a survey. If, for example, conditions of ground surface visibility vary dramatically between environmental zones, then this in turn will be reflected in the numbers of sites reported for each zone. Zones with the best visibility may be reported as having the most sites (because they are visible on the ground), while another zone with less visibility, but perhaps more sites, will be reported as having very little occupation. It is important therefore to consider the nature of ground surface visibility as part of any archaeological investigation.

Throughout the majority of the study area, surface visibility generally averaged around 15%, with the main impediment to visibility being vegetation cover. There were a number of graded vehicle tracks, erosion scalds and animal tracks throughout the project Site which provided transects of improved visibility (60-90%).

Witter (Witter and Hughes 1983) discusses the concept of *actual* area surveyed for any study, given that conditions of ground surface visibility and sedimentation etc. will vary from area to area. This is a useful measurement to allow cultural resource managers to assess surveys from adjacent areas and it also allows some meaningful calculation of the actual sample size surveyed.

Witter has calculated actual areas surveyed via the formula:

(D1) x (s) x (v) x (b) = (D2)

where:

- *D1* = area in metres squared surveyed. In this case a total of 4.5km of survey transects were walked within the Project Site, with each transect being 20m in width. This means that the area surveyed was around 90 000 square metres.
- *s* = index of sedimentation
  - 0.1 = aggrading surface
  - 0.5 = stable or uncertain
  - 1.0 = degrading surface **(generally applies in this case)**
- *v* = index of *visibility*
  - 0.1 = negligible visibility
  - 0.2 = 10% visibility
  - 0.5 = 20% visibility **(applies in this case)**
  - 1.0 = 30% and greater visibility
- *b* = background effects (i.e. the presence of natural quartz)
  - = massive amounts of natural quartz
  - 0.5 = small amounts of natural quartz
  - 0.9 = minimal amount of natural quartz **(applies generally in this case)**
  - = no natural quartz
- *D2 = distance in square metres of effective coverage.*

Applying the formula the following calculations are achieved:

90 000 x 1.0 x 0.5 x 0.9 = 40 500 square metres.

If we consider that the total area of the Project Site constitutes about 220 000 square metres (22ha) then the actual effective coverage of the Project Site is about 18%. It should however be noted that approximately 10ha of the Project Site has been heavily impacted through previous quarrying activity and the construction of associated infrastructure. This area is effectively unavailable for survey assessment. Taking this into account, a total of 120 000 square metres of the site was available for assessment, meaning that effective coverage was around 33% of the Project Site.

Stage 3

Stage three of the assessment involved the production of a Draft and Final Report which includes an analysis of the data obtained from the field survey, an assessment of site significance and provision of management recommendations.

2 ABORIGINAL COMMUNITY CONSULTATION

2.1 Introduction

The NSW DECC, formerly Department of Environment and Conservation (DEC) manages Aboriginal cultural heritage in NSW, in accordance with the ***National Parks and Wildlife Act 1974 (NSW)*** ("the NPW Act").

In 2004, the NSW DECC released *Interim Guidelines for Aboriginal Community Consultation – Requirements for Applicants (IGACC)*. This document focuses on the requirements for consulting with the Aboriginal community as part of the preparation of an application for a consent or permit under Part 6 of the NPW Act. While permits under Part 6 of the NPW Act are not required for Major Projects such as the current project, this document remains the standard by which Aboriginal heritage assessments should be conducted.

NSW DECC requires applicants to have consulted with the Aboriginal community (communities) about the Aboriginal cultural heritage values (cultural significance) of Aboriginal objects and places present in the area subject to development (NSW DEC 2004). The NSW DECC requires consultation with the Aboriginal community because it recognises the following.

- That Aboriginal heritage has a cultural and archaeological significance and that both should be the subject of assessment to inform its decision process.
- That Aboriginal people are the primary determinants of the significance of their heritage.
- That Aboriginal community involvement should occur early in the assessment process to ensure that their values and concerns can be taken into account and so that their own decision making structures can function.
- That the information arising from consultation allows consideration of Aboriginal community views about significance and impact and allows for management and mitigation measures to be considered in an informed way (NSW DEC 2004).

The Aboriginal community consultation process, as outlined in the IGACC document aims to improve the assessment process and outcomes by providing the Aboriginal community with the opportunity to:

- influence the design of the assessment of cultural and scientific significance;
- provide relevant information regarding the cultural significance values of the objects/places;
- contribute to the development of cultural heritage management recommendations; and
- provide comment on draft assessment reports (NSW DEC 2004).

The Aboriginal Community Consultation process for this project has been undertaken in accordance with the IGACC document. The following provides a detailed overview of the Aboriginal community consultation process.

2.2 Notification and Registration of Interest

The IGACC document sets out clear processes for identifying and registering the interests of stakeholders. It states that:

> "the proponent or their consultant must actively seek to identify stakeholder groups or people wishing to be consulted about the project and invite them to register their interest. To this end, it will be sufficient for the proponent to provide written notification to:
>
> a) the bodies listed below:
> - Local Aboriginal Land Councils;
> - Registrar of Aboriginal Owners;
> - Native Title Services;
> - Local councils;
> - Department of Environment and Climate Change, and
>
> b) via an advertisement in the local print media.

In accordance with these guidelines, written notification regarding the project was supplied to the following bodies.

- NSW DECC (Letter sent on the 30-10-2007).
- Shoalhaven City Council (Letter sent on the 31-10-2007).
- Nowra Local Aboriginal Land Council (Letter sent on the 31-10-2007).
- Native Title Services (Letter sent on the 31-10-2007).

In addition, a representative of CHMA spoke with Mr Adam Black, with the Department of Aboriginal Affairs to discuss the requirements for sending notification to the Registrar of Aboriginal Owners. Mr Black advised that because the project was not situated within a National Park, then notification was not required.

In addition, an advertisement was placed in the Public Notices section of the South Coast Register on the 27-10-2007, providing details of the project and seeking registrations of interest. The closing date provided in the advertisement for Registration of Interests was the 16-11-2007.

On the 31-10-2007, a response to the advertisement was received from Mr Sonny Simms (CEO of the Nowra LALC) advising that the Land Council would like to register their interests as stakeholders in the process. Also on the 31-10-2007 a response was received from Jason Davidson of Dargun Consultancy registering his interest in this project.

2.3 Preparation for the Assessment

The IGACC document advises that the proponent must present and/or provide the proposed methodology for the cultural and archaeological assessment to the registered stakeholders. Stakeholders are then provided with a reasonable time (at least 21 days) to review and provide feed back to the proponent.

The details of the project, including the proposed methodology and timing of the field assessment, were discussed with both Sonny Simms and Jason Davidson on the 31-10-2007 (discussions held by Stuart Huys from CHMA). Both people stated that they were satisfied with the proposed scope and timing of the assessment.

Stuart Huys subsequently met with both Sonny Simms and Jason Davidson on the 21-11-2007 to confirm the details for the assessment.

2.4 The Field Survey

The field survey was carried out over a period of two days (21-11-2007 and 26-11-2007).
The people involved in the field work were:

- Stuart Huys (CHMA Archaeologist) and Jason Davidson (Aboriginal stakeholder) on the 21-11-2007;
- Charmain O'Halloran (CHMA Archaeologist) and Peter Moore (Nowra Local Aboriginal Land Council) on the 26-11-2007.

During the course of the field work process, the findings of the investigations and potential management options were discussed with both Jason Davidson and Peter Moore.

2.5 Post Field Work Consultation

On the completion of field work, a draft set of management recommendations were presented to both Mr Sonny Simms (CEO of the Nowra LALC) and Jason Davidson (Dungarn Consultancy) for review and comment. Both parties have stated that they are in agreement with the management recommendations.

3 STATUTORY CONTROLS AND LEGISLATIVE REQUIREMENTS

3.1 State Legislation

The protection of Indigenous cultural heritage in New South Wales is principally governed by two pieces of legislation, the *National Parks and Wildlife Act 1974 (NPW Act)* (as amended) and the *Environment Planning and Assessment Act 1979*.

3.1.1 The National Parks and Wildlife Act 1974 (NPW Act)

The NPW Act provides the primary basis for the legal protection and management of Aboriginal sites within NSW. The implementation of the Aboriginal heritage provisions of the Act is the responsibility of the NSW Department of Environment and Climate Change (DECC).

The general rationale behind the Act is the prevention of unnecessary, or unwarranted destruction of relics, and the active protection and conservation of relics, which are of high cultural significance.

Section 90 of the Act provides statutory protection for all Aboriginal 'objects', whereby it is an offence (without the Minister's consent) to:

> *damage, deface or destroy Aboriginal sites without the prior consent of the Director of the National Parks and Wildlife Service.*

The Act defines an 'object' as:

> *any deposit, object or material evidence (not being a handicraft for sale) relating to Indigenous and non-European habitation of the area that comprises New South Wales, being habitation both prior to and concurrent with the occupation of that area by persons of European extraction, and includes Aboriginal remains.*

In addition, Section 84 of the Act provides protection for Aboriginal places (broadly defined as areas of cultural significance to the Aboriginal community).

The protection provided to Aboriginal objects applies irrespective of the level of their significance or issues of land tenure. However, areas are only gazetted as Aboriginal Places if the Minister is satisfied that sufficient evidence exists to demonstrate that the location was and/or is of special significance to Aboriginal culture.

The Act, together with the policies of the DECC provide the following constraints and requirements on land owners and managers.

- It is an offence to knowingly disturb an Aboriginal artefact or site without an appropriate permit.
- Prior to instigating any action which may conceivably disturb an 'object' (generally land surface disturbance or felling of mature trees), archaeological survey and assessment is required.
- When the archaeological resource of an area is known or can be reliably predicted, appropriate land use practices should be adopted which will minimize the necessity for the destruction of sites/objects, and prevent destruction to sites/objects which warrant conservation.

- Documented and appropriate consultation with relevant Aboriginal Community representatives is required by the DECC as part of the prerequisite information necessary for endorsement of consultant recommendations or the provision of Consents or Permits by the DECC.

Consent regarding the use of or destruction of relics is managed through a DECC permit system. The issuing of permits is dependent upon adequate archaeological review and assessment, together with an appropriate level of Aboriginal community liaison and involvement. Failure to do so will result in a rejection of the permit application and the inability to undertake any collection of artefactual material (outside of the developmental area) or sub-surface testing.

In their role as regulator of the NPW Act, the DECC has issued a document entitled "Interim Guidelines for Aboriginal Community Consultation – Requirements for Applicants" (December 2004). These guidelines outline the extent of Aboriginal Community consultation required to be documented when applying for Part 6 approvals to impact upon sites (s87 or s90 Permits). This includes public notification of the intent to lodge a permit application and community consultation about the proposed methodologies to be employed under the applications.
Penalties payable under the NSW Act (s.90) for damage/destruction etc of indigenous cultural heritage (relics or areas) are:

- $5,500.00 for individuals + restitution costs and/or 6 months' gaol; and
- $22,000.00 for Corporations + restitution costs

Litigious remedies are also available. Any person (whether they have a 'legal interest' in the area or not) can bring proceedings against a person damaging or destroying indigenous cultural heritage in the Land and Environment Court (NSW) to prevent or remedy that damage or destruction (s.176). In addition to individual penalties of up to $11,000, an order can also be made that compensation is to be paid for the damage or destruction of the relic or area.

If the Director-General of DECC believes that an action will or could have a significant effect on the 'environment of native plants' (which is also an indigenous issue) he can issue a Stop Work Order for 40 days, without any prior notice needing to be given (ss.91AA-EE). That Order can be extended for as many 40 day periods as the Director-General sees fit. If the action that has been stopped is not able to be modified sufficiently to protect the environment in question, the Director--General must recommend an Interim Protection Order be made (s.91EE) that will last for up to 2 years (s.91D). The Director-General can also direct that an Interim Protection Order be put in place if, in his opinion, an area of cultural significance is at risk of damage (s.91A).

Each person has a duty to report the discovery of a relic to DECC within a reasonable period of time unless they have reason to believe that DECC is already aware of its existence (s.91).

3.1.2 Environment Planning & Assessment Act (1979)

The EP&A Act and its regulations, schedules and associated guidelines require that environmental impacts are considered in land use planning and decision making. Environmental impacts include cultural heritage assessment.

The EP&A Act has three main parts that are of direct relevance to Aboriginal cultural heritage. These are Part 3 which governs the preparation of planning instruments, Part 4 which relates to development assessment processes for local government (consent) authorities and Part 5 which relates to activity approvals by governing (determining) authorities.

Part 3 deals primarily with development planning in which sites and places sacred or significant to Aboriginal communities are to be assessed and are to be taken into consideration in initial studies. Planning New South Wales (formerly DUAP) has produced guidelines on the preparation of planning instruments such as State Environmental Planning Policies (SEPP's) REPs and LEP's that explicitly list Aboriginal sites and places of significance as values which should be assessed as part of initial planning studies.

Part 4 deals with decisions to be made within the context of development applications. As a component of this legislative section, an Environmental Impact Study will, under Section 90 (1)9b include consideration of the potential impacts a proposed development may have on Aboriginal cultural heritage.

Part 5 of the Act relates primarily to activities that do not require consent but still require an environmental evaluation, such as proposals by government authorities. State Government agencies which act as the determining authority on the environmental impacts of proposed activities must consider a variety of community and cultural factors in their decision making, including Aboriginal and Historic cultural heritage values.

The *Environmental Planning and Assessment Act, 1979*, as amended, provides for the listing of heritage items and conservation areas and for the protection of these items or areas through environmental planning instruments (like LEPs or REPs) at the Local government and State planning levels. These statutory planning instruments usually contain provisions for the conservation of these items and areas as well as an assessment process to reduce the impacts of new development on the heritage significance of a place, building or conservation area.

In 2005, the NSW Parliament passed amendments to the EP&A Act, which were designed to facilitate major and critical infrastructure developments. Under Part 3A of the amended EP&A Act, separate approvals or permits are not required from DECC, with regard to cultural heritage issues, although the DECC may be consulted to ensure that best practices are being undertaken.

As mentioned in Section 1 of this report, the subject proposal constitutes development as set out in Schedule 1 of the Major Projects SEPP, and is therefore declared to be a project to which Part 3A of the *Environment Planning and Assessment Act 1979* applies.

3.2 Commonwealth Legislation

There are also a number of Federal Legislative Acts that pertain to cultural heritage. The main Acts being:

- *The Australian Heritage Council Act 2003;*
- *The Aboriginal and Torres Strait Islander Heritage Protection Act 1987;* and
- *Environment Protection and Biodiversity Conservation Act 1999*

3.2.1 Australian Heritage Council Act 2003 (Comm)

The *Australian Heritage Council Act 2003* defines the heritage advisory boards and relevant lists, with the Act's Consequential and Transitional Provisions repealing the *Australian Heritage Commission Act 1975*. *The Australian Heritage Council Act 2003*, like the *Australian Heritage Commission Act 1975*, does not provide legislative protection regarding the conservation of heritage items in Australia, but has compiled a list of items recognised as possessing heritage significance to the Australian community. The Register of the National Estate, managed by the Australian Heritage Council, applies no legal constraints on heritage items included on this list.

3.2.2 The Aboriginal and Torres Strait Islander Heritage Protection Act 1987.

This Federal Act is administered by the Department of Environment and Heritage (DEH). The Act was passed to provide protection for the Aboriginal heritage, in circumstances where it could be demonstrated that such protection was not available at a state level. In certain instances the Act overrides relevant state and territory provisions.

The major stated purpose of the Act is to preserve and protect from injury and desecration, areas and objects of significance to Aborigines and Islanders. The Act enables immediate and direct action for protection of threatened areas and objects by a declaration from the Commonwealth minister or authorised officers. The Act must be invoked by, or on behalf of an Aboriginal or Torres Strait Islander or organisation.
Any Aboriginal or Torres Strait Islander person or organization may apply to the Commonwealth Minister for a temporary or permanent 'Stop Order' for protection of threatened areas or objects of significant indigenous cultural heritage.

The Commonwealth Act 'overrides' State legislation if the Commonwealth Minister is of the opinion that the State legislation (or undertaken process) is insufficient to protect the threatened areas or objects. Thus, in the event that an application is made to the Commonwealth Minister for a Stop Order, the Commonwealth Minister will, as a matter of course, contact the Queensland Environmental Protection Agency to ascertain what protection is being imposed by the State and/or what mitigation procedures have been proposed by the landuser/developer.

In addition to the threat of a 'Stop Order' being imposed, the Act also provides for the following:

- If the Federal Court, on application from the Commonwealth Minister, is satisfied that a person has engaged or is proposing to engage in conduct that breaches the 'Stop Order', it may grant an injunction preventing or stopping such a breach (s.26). Penalties for breach of a Court Order can be substantial and may include a term of imprisonment;
- If a person contravenes a declaration in relation to a significant Aboriginal area, penalties for an individual are a fine up to $10,000.00 and/or 5 years gaol and for a Corporation a fine up to $50,000.00 (s.22);
- If the contravention is in relation to a significant Aboriginal object, the penalties are $5,000.00 and/or 2 years gaol and $25,000.00 respectively (s.22);
- In addition, offences under s.22 are considered 'indictable' offences that also attract an individual fine of $2,000 and/or 12 months gaol or, for a Corporation, a fine of $10,000.00 (s.23). Section 23 also includes attempts, inciting, urging and/or being an accessory after the fact within the definition of 'indictable' offences in this regard.

The Commonwealth Act is presently under review by Parliament and it is generally accepted that any new Commonwealth Act will be even more restrictive than the current legislation.

3.2.3 Environment Protection and Biodiversity Conservation Act 1999 (Comm)

This Act has recently been amended, through the *Environment and Heritage Legislation Amendment Act (No1) 2003* to provide protection for cultural heritage sites, in addition to the existing aim of protecting environmental areas and sites of national significance. The Act also promotes the ecologically sustainable use of natural resources, biodiversity and the incorporation of community consultation and knowledge.

The 2003 amendments to the *Environment Protection and Biodiversity Conservation Act 1999* have resulted in the inclusion of indigenous and non-Indigenous heritage sites and areas. These heritage items are defined as:

> *'indigenous heritage value of a place means a heritage value of the place that is of significance to indigenous persons in accordance with their practices, observances, customs, traditions, beliefs or history;*

Items identified under this legislation are given the same penalty as actions taken against environmentally sensitive sites. Specific to cultural heritage sites are §324A-324ZB.

In addition to the above amendments to the *Environment Protection and Biodiversity Conservation Act 1999* to include provisions for the protection and conservation of heritage, the Act also enables the identification and subsequent listing of items for the Commonwealth and National Heritage Lists. The Act establishes the *National Heritage List*, which enables the inclusion of all heritage, natural, Indigenous and non-Indigenous, and the *Commonwealth Heritage List*, which enables listing of sites nationally and internationally that are significant and governed by Australia.

In addition to the *Aboriginal and Torres Strait Islander Heritage Protection Act 1987*, amendments recently made to the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* enables the identification and subsequent listing of indigenous heritage values on the Commonwealth and/or National Heritage Lists (ss. 341D & 324D respectively). Substantial penalties (and, in some instances, gaol sentences) can be imposed on any person who damages items on the National or Commonwealth Heritage Lists (ss. 495 & 497) or provides false or misleading information in relation to certain matters under the Act (ss.488-490). In addition, the wrongdoer may be required to make good any loss or damage suffered due to their actions or omissions (s.500).

4 BACKGROUND ARCHAEOLOGY

4.1 Regional Studies

Previous studies along the south coast of New South Wales have demonstrated Aboriginal occupation of the region dating back to the height of the last glacial period some 20,000 years ago (Lampert, 1971; Bowdler, 1976). During this period sea level was much lower than it is today and consequently the shoreline was up to 16km to the east of the present coast. Present sea levels stabilised some 6 000 to 7 000 years ago and most coastal sites date from this period. Coastal sites older than 7 000 years would have been submerged by rising sea levels associated with the melting of the glaciers and ice caps.

The most commonly encountered archaeological sites in the region are shell middens and open campsites represented by scatters of stone artefacts. Rockshelter sites are also a feature of the regional archaeological record. Lampert (1971) divided these occupation sites into three basic groups:

1) Specialised foreshore sites focussing on the exploitation of coastal resources such as fish, shellfish and marine birds (eg. Durras North, Wollumboola and Wattamolla) where specialised fishing equipment was used (eg. spears tipped with bone points and shellfish hooks).
2) Specialised estuarine sites focussing on the exploitation of inland resources (eg. Bomaderry Creek in the Shoalhaven estuary).
3) Sites besides creeks or estuaries near the seashore where a range of inland and coastal resources were used (eg. Burril Lake, Currarong and Curracurrang).

During the 1970's, several models were constructed regarding the distribution pattern of occupation sites and associated resources. Bowdler (1970) maintained that the coastal regions supported an increased occupation during the summer months, subsequently reducing the utilisation of resources inland during these months. This model differed to Lampert's theories (1971), stating that a collective habitation of coastal and estuarine environments was exploited. Later, Poiner (1976) supported the model of exclusive coastal habitation during summer months, with the addition of both coastal and inland resources being utilised during winter months.

Poiner (1976) argued that Aboriginal occupation of the south coast usually focused upon the resource rich and dependable coastline with occasional hunting and gathering forays into the forested hinterland when the coastal resources were in short supply.

It was not until Byrne (1983) completed a systematic study of some of the southern NSW forests and discovered a sparse, but fairly uniform scatter of stone artefacts, that we became aware that the hinterland had the potential to contain many sites. Byrne (1983) completed a systematic study of some of the southern NSW forests and discovered that the most frequently occurring sites in the hinterland are small, surface scatters of stone artefacts. Byrne (1983) found that these sites are most likely to be found on flat ground along ridgelines or on gentle slopes overlooking creeklines. Byrne (1983) interpreted the abundance of small open campsites along ridgelines in the hinterland as reflecting patterns of movement through the generally rugged terrain rather than the result of long-term settlement.

Byrne's (1983) report is important not only because he describes the suite of small campsites he found, but also because it emphasises the problems of discovering sites in this difficult terrain. He decisively points to the need for the development of new methods of survey to find sites and to understand their character. His recognition of this need gave a fillip to research directed towards developing new approaches.

At about the same time the Department of Prehistory and Anthropology at the Australian National University was continuing its study of sites along the NSW South Coast near Kiola, under the Directorship of Mr Ian Farrington, Lecturer in Prehistory. Until this point the work, involving Honours students, had primarily focussed on the coastal strip. However, interest began to shift inland, as it became apparent that many sites were visible along public roads and forest tracks. Several years later, students have recorded several hundred sites in the hinterland between Ulladulla and Moruya. These sites provide a significant resource for understanding the nature of hinterland occupation.

More recently, the archaeological data gathered by the students over the years has been compiled and analysed by Knight (1996). Knight (1996) acknowledges that the analysis of the collated data was carried out at a basic level. However, several important trends in site type distribution were identified. These are as follows.

- Sites were found to occur in varying degrees throughout all of the environmental zones present in the study area.
- The vast majority of hinterland sites are small surface scatters of stone artefacts numbering less than ten artefacts. Most artefacts at these sites are amorphous flakes and flaked pieces made from quartz, which occurs naturally throughout the region.
- Site complexity (in terms of frequency occurrence of formal tools at sites) appears to be higher for artefact scatters of the hinterland zone compared to along the coast. In the hinterland zone, formal tool occurrence is apparent for sites of all sizes on all land form features.
- Large open artefact scatters in the hinterland zone tend to be located at high point linear feature junctions. These locations also tend to be indirectly associated with nearby river or stream valleys.
- Hinterland valley locations exhibit a lower frequency of larger sites. However, the largest artefact scatters recorded in the study are located on or near stream bank features. The highest frequency of sites containing formal tools also occurs at valley locations. It would therefore appear that site size and site complexity is influenced by close proximity to permanent water, mainly large creeks and the Clyde River.
- Rock shelter sites and grinding groove sites are essentially influenced by geomorphological factors. However, there also appears to be some degree of Aboriginal site selection in operation with regard to the location of grinding grooves. These site complexes are restricted almost entirely to particular sections of the Murramarang Range.

Knight (1996) is of the opinion that on a regional scale, the general site distribution observed for the Batemans Bay Forests is similar with site occurrences recorded for other archaeological studies carried out in the south coast hinterland. Sites generally tend to occur on ridgelines, flatter areas and adjacent to stream banks, with the larger and more complex sites being in relatively close proximity to permanent fresh water. Knight (1996) suggests that this site patterning indicate that Aboriginal activity in the hinterland zone was facilitated by extensive topographic routeways combined with good food and water availability.

As part of his PhD Thesis, Boot carried out extensive research in the hinterland region west of Nowra. In the course of the field surveying, Boot (1997) recorded a total of 410 open artefact scatters, 294 isolated finds and one midden site. Based on the analysis of the data, Boot (1997) made the following observations for site distribution in his study area.

- The greatest density of sites tends to occur along major river valleys and broad well watered ridgelines.
- Major river valleys show a much higher overall artefact density compared to other environmental zones.
- The largest sites (in terms of artefact numbers) occurred within the major river valleys. The smallest sites occur at high altitudes, showing that the exploitation of these high altitude areas was not intensive.

Boot (1997) states that the data indicates that Aboriginal people accessed all areas of the south coast hinterland, but that major river valleys appeared to have been favoured over other environments. Some major ridgelines also appear to be a focus of activity, particularly those that were heavily forested (Boot 1997). These areas of high resource availability were probably repeatedly visited and occupied for long periods. Most of the open sites recorded in the hinterland are small, and are likely to be representative of short-term campsites (Boot 1997).

In addition to the field survey, Boot (1993) excavated a total of 10 sites. Seven of these sites were rock shelters, with the remaining three sites being open artefact scatters. Boot (1997) has obtained radiocarbon dates for each of these sites. For the rock shelters, the dates range between 250± 80 BP and 12040 ± 630 BP. For the open sites, the dates ranged between 850 ± 160 BP and 4050 ± 210 BP.

These dates show conclusively that the coastal ranges were occupied during the late Pleistocene. Prior to Boot's investigation, the oldest dates for Aboriginal occupation of the coastal ranges was 3770 ± 150 BP, which was obtained by Flood (1980) from the Sassafras 1 site (Boot 1997).

Based on these findings, Boot (1997) is now of the opinion that Aboriginal occupation of the south coast hinterland during the Pleistocene was probably widespread but sparse. Boot (1997) further postulates that occupation of the hinterland became widespread and very dense in the last 4000 years, particularly since around 3000BP.

4.2 Local studies

In addition to the regional studies mentioned above, there have been numerous more localised archaeological studies undertaken in the south coast region.

The amount of archaeological survey undertaken on the Illawarra coastal plain is considerable and directly reflects the degree of development which has occurred over the past two decades. The most commonly encountered archaeological sites in the region are shell middens and open campsites represented by scatters of stone artefacts. Nearly all of these sites are located directly along the coastal fringe.

Relatively few Aboriginal sites have been located in the course of archaeological surveys within the western coastal plain and foothills region. There are three possible reasons for the paucity of sites. Firstly, lack of ground surface visibility poses a considerable constraint to site detection. Secondly, these areas represent a relatively less economically attractive area than the adjacent coastal and estuarine margins – resource zones which offered the most cost-productive return in terms of food exploitation. A third and related reason may be that most investigations have taken place in the lower country immediately abutting the coastline. Here most sites consist of shell middens and/or surface scatters of stone artefacts associated with the exploitation of the coastal fringe.

All of the studies located in the foothills and associated plains below the Illawarra Escarpment have been either scarred trees or small artefact scatters (sometimes associated with archaeological deposit) on elevated level landscape features, in close proximity to watercourses. Typically, artefact scatters are small and sparse and are located on dry level ground, both on ridgelines in the foothills and on the coastal plane. They are, with few exceptions, located within fifty metres of drainage lines (Navin 1987).

In the Jervis Bay area archaeological excavations of rockshelter deposits have uncovered evidence which demonstrates an Aboriginal presence over the past 3,000 years (Lampert, 1971; Paton and Macfarlane, 1988). The highest concentration of recorded archaeological sites in the Jervis Bay area is on the Beecroft Peninsula (eg. Cane, 1988). This area has been listed on the Register of the National Estate because of its unique heritage values. The neighbouring Bhewerre Peninsula also has an abundance of archaeological sites (eg. Sullivan, 1977).

Early archaeological interest in the Nowra district focussed on the Permian sediments of the Shoalhaven Group where rockshelter sites and axe-head grinding grooves are abundant. Lampert (1971a) excavated the floor of a rockshelter adjacent to Bomaderry Creek (NPWS Site no. 52-5-35) but was disappointed with the results. The occupation horizon was thin and the stone and faunal assemblages sparse. The site appeared to have been occupied by people exploiting terrestrial resources rather than an estuarine-coastal environment. More `fabricators' than backed blades were recovered and Lampert concluded that occupation of the shelter was recent.

Many more rockshelters were recorded in the Nowra district by Peter Bindon as part of his Honours research (Bindon, 1976). These are largely restricted to the Nowra Sandstone, which outcrops along Bomaderry Creek and Nowra Creek and along the Shoalhaven River upstream from Nowra. A string of ten rockshelters (including three with art) are known along the clifflines of Bomaderry and Nowra creeks. Three sets of axe-head grinding grooves are also associated with the clifflines alongside these two creeks.

Similar sandstone sites are located along the clifflines of the Shoalhaven River. Bindon recorded a rockshelter with art (NPWS Site Nos. 52-5-5) close to the Bamarang water treatment plant. Attenbrow (1981) located two more rockshelters (NPWS Site nos. 52-5-146 and 158) in close proximity to this site. Grinding grooves are known nearby at the Bamarang punt (NPWS Site no. 52-5-93) and near Bamarang Gap (NPWS Site no. 52-5-94). These sites appear to have been among those investigated earlier this century by C.C. Towle.

Other site types in the vicinity of Nowra include an Aboriginal burial site (NPWS Site no. 52-5-258), a stone arrangement (NPWS Site no. 52-5-19) and a scarred tree (NPWS Site no. 52-5-18). The burial was located on the banks of the Shoalhaven River near the mouth of Cabbage Tree Creek (Donlon, 1991). It comprised the bones of a skull eroding from the edge of a river terrace at Cabbage Tree Flat. Towle (1942) described the stone arrangement as an elongate enclosure of some 85 sandstone rocks. This unusual site and the scarred tree were located in the Wogamia area of Mundamia Creek.

Archaeological surveys by Navin (1991, 1992) in the Nowra area have located two more rockshelters along Bomaderry Creek and an isolated volcanic stone axe-head and isolated volcanic flaked pebble along the Bolong Road opposite Pig Island. The rockshelters (NPWS Site nos. 52-5-262 and 263) were located some 400m north of the site excavated by Lampert (1971a). These sites comprise overhangs with sparse scatters of chert flakes on the floor of some deposit.

Further to the north and east of Nowra archaeological sites have been investigated by Corkhill (1986). At Moeyan Hill near Berry she attempted to relocate the Bunan ground (ceremonial site) recorded by Mathews (1896) but could not find any traces of it (see NPWS Site no. 52-5-135). She did, however, succeed in locating some grinding grooves (NPWS Site no. 52-5-191) on Moeyan Hill and a nearby rockshelter which had pipi shell on the floor of the deposit (NPWS Site no. 52-5-192). Much further south she recorded an open campsite on the western side of Brundee Swamp (NPWS Site no. 52-5-205). This comprised ten small flakes made from quartzite, silcrete and quartz.

At Falls Creek south of Nowra Bindon recorded a rockshelter site (NPWS Site no. 52-5-38) and one set of grinding grooves (NPWS Site no. 52-5-37). Mathew Barber has more recently recorded an open campsite nearby (Rod Wellington, pers. comm.). These sites were all located near the confluence of Parma Creek and Currambene Creek. Further upstream along Parma Creek Lance (1987) located an open campsite on an alluvial flat. This site comprised a scatter of five stone flakes and cores. These were made from quartzite, silcrete, chert, petrified wood and quartz. Further along Parma Creek he located three isolated stone artefacts.

Further south near Tomerong a number of archaeological sites have been recorded. Koettig (1989) and Silcox (1990) located three open campsites in hilly terrain east of Suffolk Creek. Six more archaeological sites were located by Navin (1990) in the hills to the west of Suffolk Creek. These sites comprised two sets of grinding grooves and four open campsites. Navin also located two small shell scatters on ridgelines closer to St. Georges Basin. These were interpreted as remnant middens. However, no stone artefacts were associated with these sites.

West of the Princes Highway along Wandandian Creek is one of the region's most significant archaeological sites (NPWS Site no. 58-1-62). First recorded by Bindon, it is a rockshelter with Aboriginal paintings and drawings, grinding grooves and occupation deposit. It is located above a pool in Wandandian Creek known as the Perch Hole. The significance of the site has been assessed by Officer and is discussed by Lance (1987). According to Officer the site contains the most southerly example of a stencilled boomerang on the East Coast of Australia and is the only lowland Sydney Basin art site south of Jervis Bay.

Silcox (1990a) located two open campsites alongside the Princes Highway at Myrtle Gully west of Conjola Lake. The first was very small and consisted of only three silcrete and quartz artefacts. The second site was uncovered by test-pitting a gently sloping bench adjacent to Myrtle Gully. Twelve 1m X 0.25m test-pits were excavated and 15 undiagnostic stone artefacts recovered. These were mostly quartz with minor elements of silcrete and a volcanic piece. This insignificant site is located near the proposed water pipeline route (Scheme 1). Another open campsite (NPWS Site no. 58-1-191) has been recorded in the local area by Michael Darcy on a ridgeline overlooking Yooralla Bay.

Numerous sites have been recorded in the escarpment country to the north and west of Milton by Phil Boot and other students from the Australian National University (see also Hughes and Attenbrow, 1981; Hughes et al, 1982). These sites are mostly surface scatters of stone artefacts but rockshelters with art and grinding grooves have also been recorded.

In the ranges to the west of the Project Site, Tim Stone was contracted by the NSW NPWS to survey Sections 1 and 2 of the Two Rivers Walking Track (1996a and 1996b).

Section 1 of the proposed walking track is 16.5km in length. Two areas along this Section of the track were surveyed. The first area was a 100m length of the route which runs along a sandstone plateau. The second area is a 500m length of the route which ran down and across a sandstone cliffline. Stone (1996a) did not record any Aboriginal sites for Section 1 of the proposed track.

Section 2 of the proposed track is approximately 23km in length. The survey of Section 2 focused on the ridgelines and slopes overlooking Yarramunmun and Boolijong Creeks and the ascent from Boolijong Creek onto the Turpentine Range Plateau. In the course of the survey Stone (1996b) located one archaeological site, this being a set of axe grinding grooves. The grooves are located on a sandstone spur beneath Jinkbilly ridge. Two grooves were identified on a sandstone slab measuring 1.5m x 1m.

Stone (1996b) considered the potential for additional sites to be present along Section 2 of the proposed track to be low.

Also in the ranges to the west of the Project Site, Paton (1997) was commissioned by the NSW NPWS to undertake an archaeological assessment of a 16km section of the Yalwal Fire Trail. In the course of the field survey, Paton (1997) recorded six previously unidentified Aboriginal sites (See Fig. 3). These consist of two isolated artefacts and four artefact scatters. Table 2 provides the basic details for these sites.

Paton (1997) found that the most striking feature of the distribution of the archaeological sites is their clustering on the flat well-watered terrain, especially at creek intersections and river/creek crossings. With the exception of the two isolated finds (YW1-2), all sites are located in this land unit. However, Paton (1997) states that a number of caveats should be considered, as this site patterning may not be entirely straightforward as a representation of actual occupation patterns.

4.3 Previously identified Sites in Close Proximity to the Project Site

One of the tasks identified for this project, was to carry out a search of the NSW DECC Aboriginal Heritage Information Management System (AHIMS) to determine the extent of previously recorded Aboriginal sites within and surrounding the Project Site. The AHIMS search was within the bounded co-ordinates of E276000 – 286000; N6127000 – 6137000 (AHIMS search #20527).

Revealed 15 recorded sites within the search area as detailed in **Table 1**. None of these sites were located within the Project Site Of the 15 sites registered, five sites are located approximately 5km south of the Project Site. These sites, consisting two shelters with artefact deposits, an axe grinding groove and two open camp sites, were recorded during four separate investigations. Another six sites are located approximately three to four kilometres north west of the Project Site, these sites also consisting axe grinding grooves, shelters with deposits and open camp sites. The closest registered site to the Project Site, an open camp site, is located approximately two kilometres south west of the Project site

Table 1
Aboriginal Sites Located in Close Proximity to the Study Area

NPWS Site No	Site Type
48-6-2540	Isolated Find
52-2-1874	Isolated Find
52-2-1875	Isolated Find
52-5-0031	Shelter with deposit
52-5-0033	Axe Grinding Groove, Shelter with Art
52-5-0037	Axe Grinding Groove
52-5-0038	Shelter with Deposit
52-5-0110	Shelter with Art
52-5-0214	Open Camp Site
52-5-0285	Open Camp Site
52-5-0298	Open Camp Site
52-5-0299	Open Camp Site
52-5-0361	Open Camp Site
52-5-0362	Open Camp Site
52-5-0364	Open Camp Site

5 DESCRIPTION OF THE PROJECT SITE, RESULTS OF THE FIELD SURVEY AND DISCUSSION

5.1 Description of the Project Site

The terrain within the Project Site is characteristically flat to very gently sloping, with the slope running at a gradient of 1º or less, from south-east to north-west. The soils in the study area are a gravelly silt/sand loam. Preliminary geological investigations, indicates that underlying bedrock of the Project Site is a dark blue-grey slightly sandy siltstone.

There are no watercourses located within the Project Site itself. However, Nowra Creek, a semi-permanent water course, is located immediately to the west of the Project Site. This creek flows in a south to north direction, eventually merging with the Shoalhaven River to the north of the Project Site. The creek is situated approximately 50m to the west of western boundary of the Project Site.

The vegetation within the Project Site consists primarily of spotted gums, the occasional ironbark and a variety of acacia species. There is only the occasional mature tree present within the Project Site. The vast majority of the vegetation is comparatively recent re-growth (less than 30 years old).

The Project Site has been subject to a very high level of prior disturbance. An existing extraction area is located in the northern portion of the Project Site and encompasses an area of around 1.64ha. To the south of this extraction area there are a series of graded vehicle tracks that run throughout the Project Site. These tracks are all around 4-5m in width and the majority of them have been sealed with gravel road base. A visual and acoustic bund wall has been constructed around the entire perimeter of the Project Site. This bund wall is approximately 3-4m high and thick, and has been constructed from soils that have been pushed up from within the Project Site. This has resulted in a 5m strip of top soil having been removed from the entire perimeter of the site.

As mentioned previously, the vegetation within the Project Site has been extensively cleared, presumably as part of past timber production activity. The vegetation within the study area now consists primarily of re-growth. Many parts of the study area have also been used for the deposition of a wide range of materials including waste bricks (presumably from the brickworks to the north of the Project Site), construction materials and general waste.

5.2 Results of the Field Survey and Discussion

As specified in Section 1.4 of this report, approximately 4.5km of survey transects were surveyed within the Project Site, with each survey transect being approximately 20m in width, giving a total of 90 000m square surveyed. The total area of the Project Site is around 220 000m square (22ha), which means that approximately 40% of the Project Site was surveyed. When taking into account conditions of surface visibility etc, the effective survey coverage was around 40 000m square or 15% of the Project Site. This can be considered as an effective survey coverage percentage of any given study area. It should however be noted that approximately 10ha of the Project Site has been heavily impacted through previous quarrying activity and the construction of associated infrastructure. This area is effectively unavailable for survey assessment. Taking this into account, a total of 120 000 square metres of the site was available for assessment, meaning that effective coverage was around 33% of the Project Site.

In the course of the field investigations, no Aboriginal sites or cultural materials were identified within the identified bounds of the Project Site. Some shell material was identified in two locations within the Project Site. In one of the locations the shell material comprised several whole oyster shells. This shell was identified as *Crassostrea commercialis* (Sydney Rock Oyster). The shell was found in direct association with a pile of rubbish (mainly bottles and tins) that had been dumped on the Project Site. At the second location a single *Anadaria trapezia* (Sydney Cockle) shell and a single *Pyrazus ebeninus* (Hercules Club Whelk) was identified. Again, this shell was found in direct association with a pile of deposited rubbish. In this instance it was primarily rubble, including bricks and rubble. In both instances the most likely interpretation for the presence of this shell material is that it has been introduced into the Project Site with the rubble and rubbish that it is associated with. It is possible that this rubble and rubbish material originally came from the adjacent Brickworks site, where the shell was being used as a source of lime for the manufacture of bricks.

As mentioned above, the effective survey coverage of the Project Site was around 15%, which can be considered as being quite high when compared with other surveys undertaken in the region. As a result, the absence of identified Aboriginal sites or cultural materials, together with the high survey coverage, indicates that the Project Site has a low archaeological potential.

This assessment generally correlates with the patterns of site and artefact distributions generated from the findings of previous archaeological investigations in the Shoalhaven region. As specified in Section 4.2 of this report, previous findings show that in the Shoalhaven hinterland sites tend to be located on elevated level landscape features, in close proximity to watercourses. Typically, artefact scatters are small and sparse and are located on elevated level ground, both on ridgelines in the foothills and on the coastal plane (Navin 1987).

The Project Site is characteristically flat to very gently undulating and quite low lying. There are no prominent landscape features located in the Project Site, such as the spines of spurs, ridges or raised terraces, where sites could be expected to occur. On this basis, it would be anticipated that site and artefact densities within the Project Site would generally be very low. The possible exception may be the western edge of the Project Site, which lies between 50-100m from Nowra Creek. Densities in this area may be expected to be slightly higher, given the proximity to a water course. However, again given that this area is flat, with no elevated terraces or landscape features present, site and artefact densities would still be low to very low.

Any sites or artefacts that are present within the Project Site will have been subject to a very high level of prior disturbance associated with prior land clearing and land use activities.

6 MANAGEMENT RECOMMENDATIONS

Heritage management options and recommendations provided in this report are made based on the following.

- consultation with representatives of the identified Aboriginal stakeholder groups;
- the legal and procedural requirements of NSW DECC;
- the results of the investigation as documented in this report;
- an analysis of the findings of previous archaeological investigations carried out in the study area; and
- relevant environmental information for the study area.

The following recommendations for the management of Aboriginal sites and cultural materials should be implemented during the life of the Project.

- No Aboriginal sites, artefacts or cultural material was identified within the bounds of the Project Site. As such, there are no site specific management recommendations.
- Based on the absence of Aboriginal sites or cultural material identified during the field investigation, the high level of prior land disturbance and patterns of site and artefact distributions for the region, the vast majority of the Project Site has been assessed as being of very low archaeological sensitivity (**Figure 4**). The exception is the western edge of the Project Site, adjacent to Nowra Creek which is assessed as being of potential low to very low archaeological sensitivity. This is based on the potential for low artefact densities to be present close to the margins of this creek. In accordance with the slight increase in archaeological sensitivity of this western portion of the Project Site, it is recommended that monitoring of earth disturbance in this area be undertaken. Figure 5 shows the area where monitoring is required.
- Monitoring should be carried out by Jason Davidson (Dungarn Consultancy) and a representative from the Nowra LALC. Monitoring will only be required for the removal of the top 10cm off soil in this area. This soil should be removed by grader or excavator. The area should then be inspected by the monitors. If artefact material is identified in this area then the following procedures should be implemented.
    - **Step 1** No further earth disturbing works should be undertaken in the area.
    - **Step 2** A buffer protection zone of 20m x 20m should be established around the suspected artefact materials. No unauthorised entry or earth disturbance should be allowed with this buffer zone until such time as the area has been assessed.
    - **Step 3** A qualified archaeologist or NSW DECC personnel should be contacted to make an assessment of the discovery. Mitigation procedures will then be developed and implemented based on the assessment.
    - **Step 4** Once the mitigation requirements have been implemented, work in the buffer zone area may proceed.
- If, during the course of the prescribed general monitoring and salvage program or development activity, suspected human remains are encountered, the following procedures should be implemented.
    - **Step 1** Under no circumstances should the suspected skeletal remains be touched or disturbed. If these are human remains, then this area potentially is a crime scene. Tampering with a crime scene is a criminal offence.
    - **Step 2** Any person discovering suspected skeletal remains should notify machinery operators that are working in the general vicinity of the area that earth disturbing works should stop immediately. Remember health and safety requirements when approaching machinery operators.

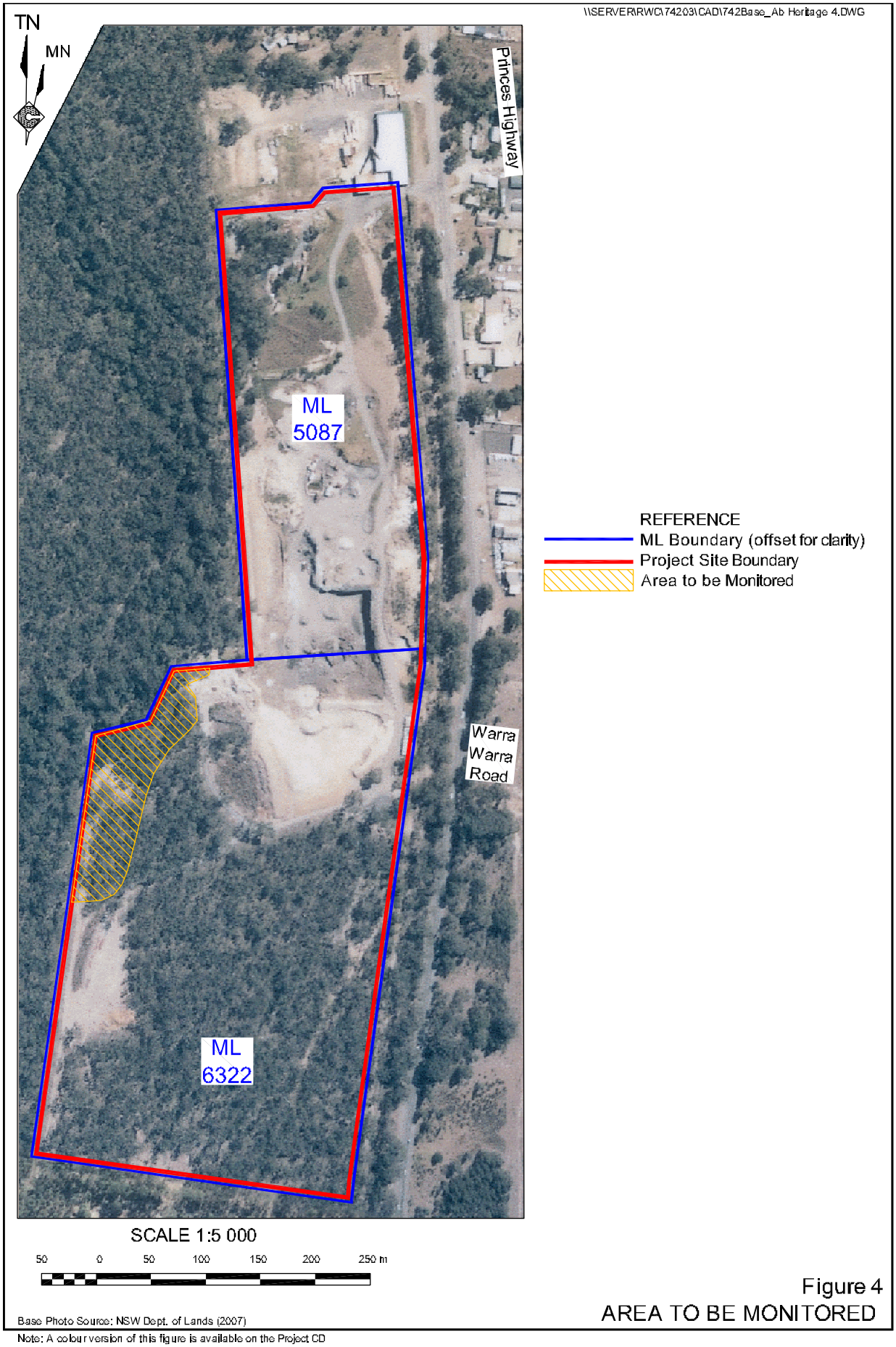


Figure 4
AREA TO BE MONITORED

Note: A colour version of this figure is available on the Project CD

- **Step 3** A buffer protection zone of 50m x 50m should be established around the suspected skeletal remains. No unauthorised entry or earth disturbance will be allowed with this buffer zone until such time as the suspected skeletal remains have been assessed.
- **Step 4** The police and the NSW DECC should be contacted and informed of the discovery. A time will be arranged for these parties to meet on site to carry out an assessment of the suspected skeletal remains.
- **Step 5** Should the skeletal remains be declared an Indigenous burial site, appropriate mitigation procedures should be developed by the NSW DECC, Jason Davidson (Dungarn Consultancy and the Nowra LALC. These mitigation procedures should be fully implemented prior to any earth disturbance works recommencing within the identified buffer zone.

- Copies of this report should be submitted to the Nowra LALC, Jaon Davidson (Dungarn Consultancy) and the NSW DECC.

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APPENDICES

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Appendix 1: Photographs

Appendix 2: Letters from Aboriginal Stakeholder Groups

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Appendix 1

Photographs

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Note: Colour copies of the photographs are available on the Project CD.

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Shell fragments located within Project Site

Shell fragments located within Project Site

Facing north toward brickworks from Project Site

Facing south toward creek at
south west boundary of Project Site

Field crew inspecting tree within Project Site

Facing south to project site from haul road

Appendix 2

Letters From Aboriginal Stakeholder Groups

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Note: Responses are awaited from the relevant Aboriginal Stakeholder Groups.

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SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Soils Assessment

Prepared by

SEEC Morse McVey

December, 2007

Specialist Consultant Studies Compendium:
Part 7A

Soils Assessment

of the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

Prepared for:

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December, 2007

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CONTENTS

Page

1 INTRODUCTION 7A-7

2 PROPOSED ACTIVITIES 7A-7

3 EXISTING CONDITIONS 7A-8

3.1 General Conditions 7A-8
3.2 Soils 7A-10

3.2.1 Soil Landscape Mapping 7A-10
3.2.2 Onsite Soil Testing – Physical Properties 7A-10

3.3 Soil Laboratory Testing 7A-12

3.3.1 Results Summary 7A-12
3.3.2 Management Implications 7A-15

3.4 Existing Quarry Areas 7A-16
3.5 Agricultural Land Capability 7A-16

4 RECOMMENDATIONS FOR MANAGEMENT 7A-17

4.1 Soil Handing 7A-17
4.2 Stripping Depths 7A-17
4.3 Soil Inventory 7A-18
4.4 Stockpiling 7A-18
4.5 Replacing Soils and Using Soils for Progressive Rehabilitation 7A-19

4.5.1 Soil Suitability 7A-19
4.5.2 Soil Handling 7A-19
4.5.3 Use of Biosolids 7A-21
4.5.4 Importation of Soil Materials 7A-21
4.5.5 Final Land Capability 7A-22

4.6 Monitoring and Maintenance 7A-22
4.7 Conclusion 7A-23

5 REFERENCES 7A-24

CONTENTS

Page

APPENDICES

Appendix 1 Soil Test Pit Logs 7A-27
Appendix 2 Soil Laboratory Results 7A-39

FIGURES

Figure 1 Project Site Layout 7A-9
Figure 2 Test Pit Locations 7A-11
Figure 3 Topsoil Stripping Depth 7A-13
Figure 4 Subsoil Stripping Depth 7A-14
Figure 5 Soil Stockpile Construction 7A-20

EXECUTIVE SUMMARY

SEEC Morse McVey have prepared this Soils Assessment as part of an Environmental Assessment (EA) being prepared by City Plan Services and RW Corkery & Co.

A series of test pits were excavated in the southern portion of the subject site. The northern portion of the site has already been quarried and is basically devoid of soil. Representative samples from the soil profiles were sent to a registered laboratory for testing to determine physical and chemical properties as they relate to revegetation and erosion.

Two distinct layers were identified in the soil, with the proposed clay/shale resource immediately underlying them. Topsoils are acidic silty clay loams with an average depth of 215 mm. They are infertile, weakly structured and have significant chemical and physical limitations for use during rehabilitation. However, these limitations can be overcome relatively simply with good management and light applications of lime.

Subsoils have low fertility but are far better at retaining nutrients than the topsoils for plants. They are reddish-brown to olive-brown clays with an average layer thickness of 290 mm. They are sodic, which affects structural stability and are acidic. Their ability to absorb phosphorus and fix it in a form available for plants is relatively good, so it is important that subsoils are placed below topsoils during rehabilitation to minimise the potential for leaching of nutrients into groundwater.

Soil stripping, stockpiling and replacement recommendations are included in this report. Erosion and sediment control measures are included in an accompanying plan, also by SEEC Morse McVey.

Land Capability Class is determined as Class IV. We believe that, providing appropriate soil management techniques are adopted and vegetation re-established, the final land shaping will achieve a similar class of land.

The use of biosolids during the rehabilitation process is appropriate providing suitable subsoil depth is included, as subsoils have a good capacity to capture, retain and fix phosphorus in a form that is available for plants. However, application rates should be low to minimise the risk of leaching into groundwater.

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1 INTRODUCTION

SEEC Morse McVey have been commissioned by South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) to undertake an assessment of the soils within part of Lot 464 DP 1058778 ("the quarry site") and to make recommendations regarding soil management for the proposed, continued and expanded operation of the Nowra Brickworks Quarry. This report supports part of an *Environmental Assessment* for the site being prepared by City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited. The aims of this report are:

1. to establish the nature of the natural soils at the Project Site, confined to the 14 ha of mostly undisturbed lands in the Project Site's southern portion (identified here as Mining Lease ML 6322);
2. to determine appropriate soil management measures to facilitate quarrying activities within ML 6322;
3. to make recommendations for soil handling based on the inherent physical and structural properties of the soil;
4. to make recommendations for stockpiling of soil to enhance its potential for use in progressive rehabilitation activities; and
5. to provide soil-related recommendations for site rehabilitation and reshaping.

Nearly all of the quarry site's northern portion (i.e. ML 5087) has previously been disturbed by previous and ongoing quarrying activities. Soils are generally absent in this area, having been stripped long ago and, in many cases, have been used to create the existing site perimeter bunds. As such, this study focuses only on those areas in the south of the site where natural soils remain (hereafter referred to as the "subject site").

2 PROPOSED ACTIVITIES

In summary, the Project would involve the following activities.

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark prior to the annual production from the quarry reaching 250 000t.
- Staged extraction of shale material ("extracted material") from a proposed extraction area of 15.0ha, incorporating an existing extraction area of approximately 2.0ha. Weathered shale material would be extracted using an excavator and stockpiled or direct loaded into road registrable trucks for transportation to the quarry's customers. Unweathered shale material would initially be blasted before being extracted using an excavator. Extraction operations would generally progress from north to south.

- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.
- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted material to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A portion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

Figure 1 provides the Project Site Layout.

3 EXISTING CONDITIONS

3.1 General Conditions

The subject site occupies a very gently inclined rise and is mostly under native vegetation. The highest point occurs adjacent to the southern boundary, with slopes falling away very gently (less than 2% in most cases) to the north-east or north-west from a very slight north-south trending ridge. A series of gravel tracks run through the woodland. High (approximately 5 m) earth bunds have been established around the perimeter of the site. The condition of these ranges from good (completely stabilised with vegetation) to moderate (only partially stabilised, with minor evidence of sheet and rill erosion).

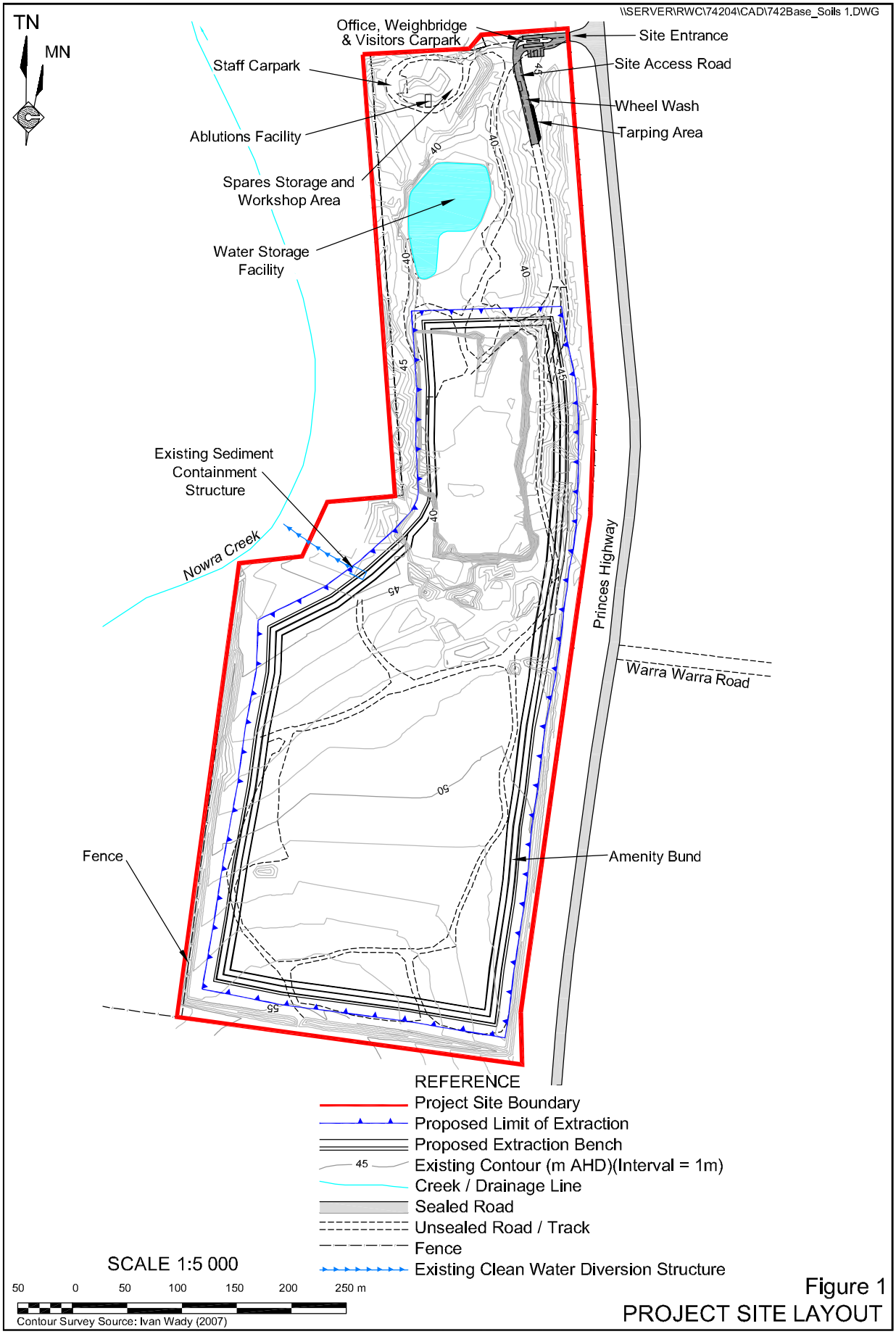


Figure 1
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

3.2 Soils

3.2.1 Soil Landscape Mapping

This site is included in soil landscape mapping by the Soil Conservation Service (Hazelton, 1992) for the 1:100,000 scale Kiama sheet (9028). Mapping suggests that the site lies on the Nowra Soil Landscape, which occurs on moderately to gently undulating rises on Nowra Sandstone, but with occasional shale lenses. Site and soil investigations by SEEC Morse McVey staff confirm that this delineation is correct.

According to Hazelton (1992), soils of the Nowra Soil Landscape include:

1. Brown or Yellow Podzolic Soils,
2. Soloths, and
3. Occasional Yellow Earths

The soils identified during our investigation were primarily Brown Podzolic Soils and Soloths. Soloths tended to occur in areas of sandstone and siltstone and the underlying grey, clayey layer occurred at shallower depths in the profile. Brown Podzolic Soils tended to occur over shale or in better drained areas and often had a slight reddish hue in the subsoil. The underlying grey, clayey layer was generally slightly deeper in these soils.

3.2.2 Onsite Soil Testing – Physical Properties

A series of nine test pits were excavated and sampled, in the locations shown on **Figure 2**. Only the A and B2 horizons were investigated (note that a B1 horizon is generally absent or is masked as a sharp texture change between the A and B2 horizons). Below the B2 horizon lies a zone of grey, pallid clay (B3 horizon) that is the uppermost layer exploited for quarrying activities. Additional visual soil observations were conducted in opportunistic locations across the subject site to confirm that the soils identified represented a typical cross-section of the overall conditions.

Each of the nine soil test pits is detailed in **Appendix 1**.

Soils across the subject site were found to be fairly homogenous, but with minor differences in the depth and colour of each layer. Generally, two distinct layers were identified as follows:

Layer	Lower depth range	Average layer thickness	Description
1 – topsoil (A)	110 to 310 mm	215 mm	Dark brown massive to weakly pedal silty clay loam. 5% coarse fragments.
2 – subsoil (B2)	330 to 720 mm	290 mm	Olive-brown to reddish-brown weakly pedal medium-heavy clay. <5% coarse fragments. Sodic. Occasional grey mottling.

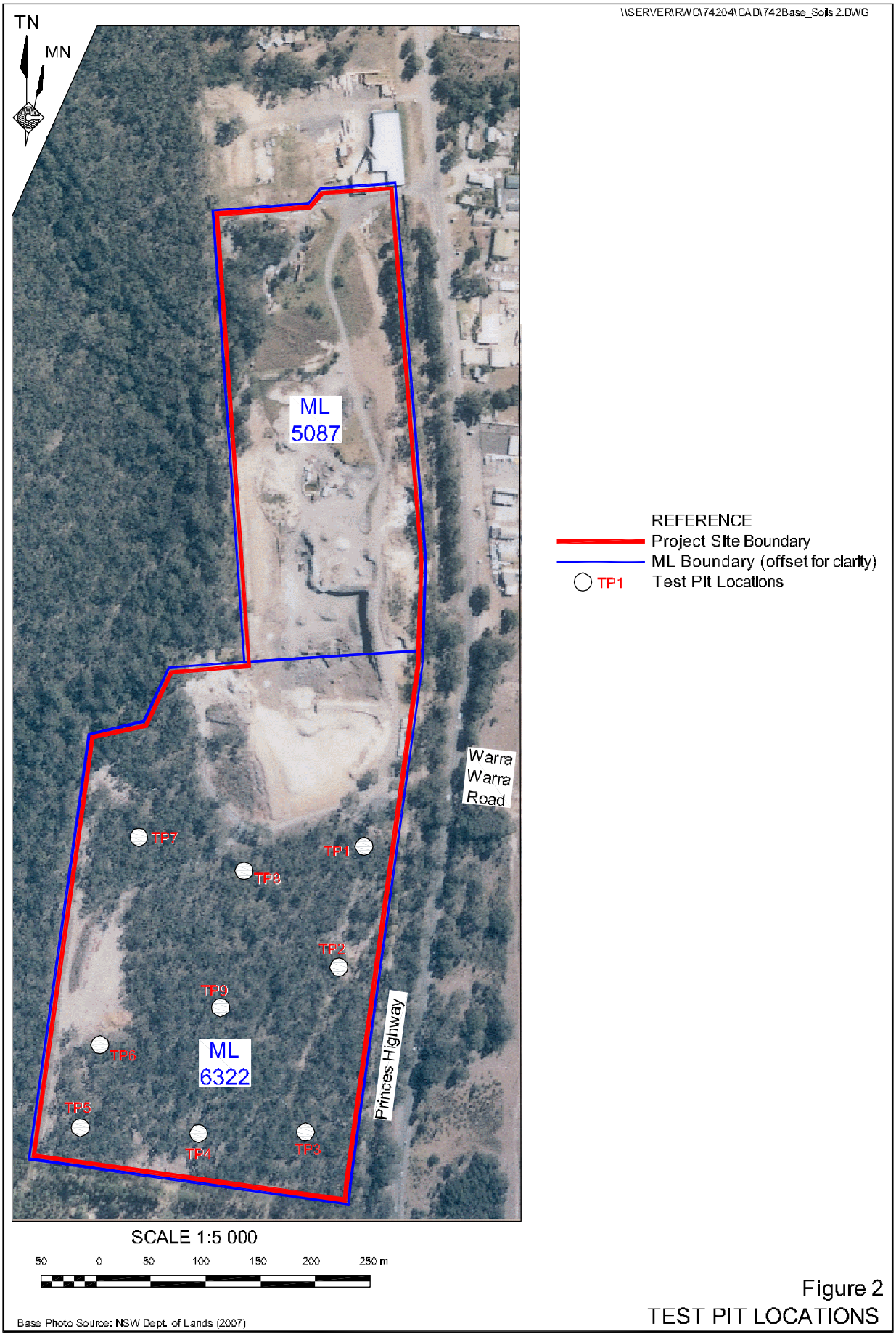


Figure 2
TEST PIT LOCATIONS

The A horizons were fairly consistent across the site, apart from variations in depth. **Figure 3** shows our interpolation of the topsoil layer depth showing the approximate stripping depths relative to the existing ground surface. Topsoils are prone to becoming hardest when dry and could easily suffer structural decline and bogginess if worked when too wet.

The B2 horizons had fairly consistent texture (medium to medium-heavy clays) and were universally sodic (soapy to the touch when moistened). Colour varied from olive-brown to reddish-brown. Areas with olive-brown B2 horizons were typically shallower overall and indicate impeded drainage and/or underlying siltstone, sandstone or mudstone. Areas with reddish-brown B2 horizons were typically slightly deeper and indicative of better-drained soils and/or underlying shale. Landscape position (i.e. ridge, midslope etc.) had very little bearing on overall soil depth nor on soil profile characteristics. We assume that this is because there is insufficient slope to significantly influence colluvial patterns of soil formation in this landscape. Rather, soils have formed *in situ* from direct weathering of the underlying rock. Hence the observable differences in soil characteristics over relatively short distances.

Figure 4 shows our interpolation of the subsoil layer depth, showing the approximate relative stripping depths after topsoil is removed.

3.3 Soil Laboratory Testing

3.3.1 Results Summary

Representative samples from Test Pit 1 (Layer 2 - subsoil), Test Pit 3 (Layer 1 - topsoil), Test Pit 5 (Layers 1 and 2, topsoil and subsoil) and Test Pit 7 (Layers 1 and 2, topsoil and subsoil) were sent to the Department of Lands Soil Research Laboratory in Scone, NSW. The raw results of this testing are included in **Appendix 2**. In summary, the results of the testing are as follows.

1. Soils are infertile. Available phosphorus values for all layers were 1.0 or below, which is very low. This will limit the potential to use these soils for revegetation of any species other than specifically-adapted native species.
2. All soils are strongly acidic (pH ranged from 5.0 to 5.3, with very little variation across the site and between topsoils and subsoils). This reduces the soil's suitability as a growing media and leads to minor to moderate aluminium toxicity potential (see below).
3. Topsoils have low Cation Exchange Capacity (CEC) but subsoils have high CEC. As such:
   (i) topsoils have a low capacity to hold and exchange cations for plant growth and will most likely leach nutrients into the subsoils; and
   (ii) subsoils have a high capacity to hold and exchange cations for plant growth and will most likely retain nutrients and help to minimise the risk of leaching into subsurface groundwater aquifers.

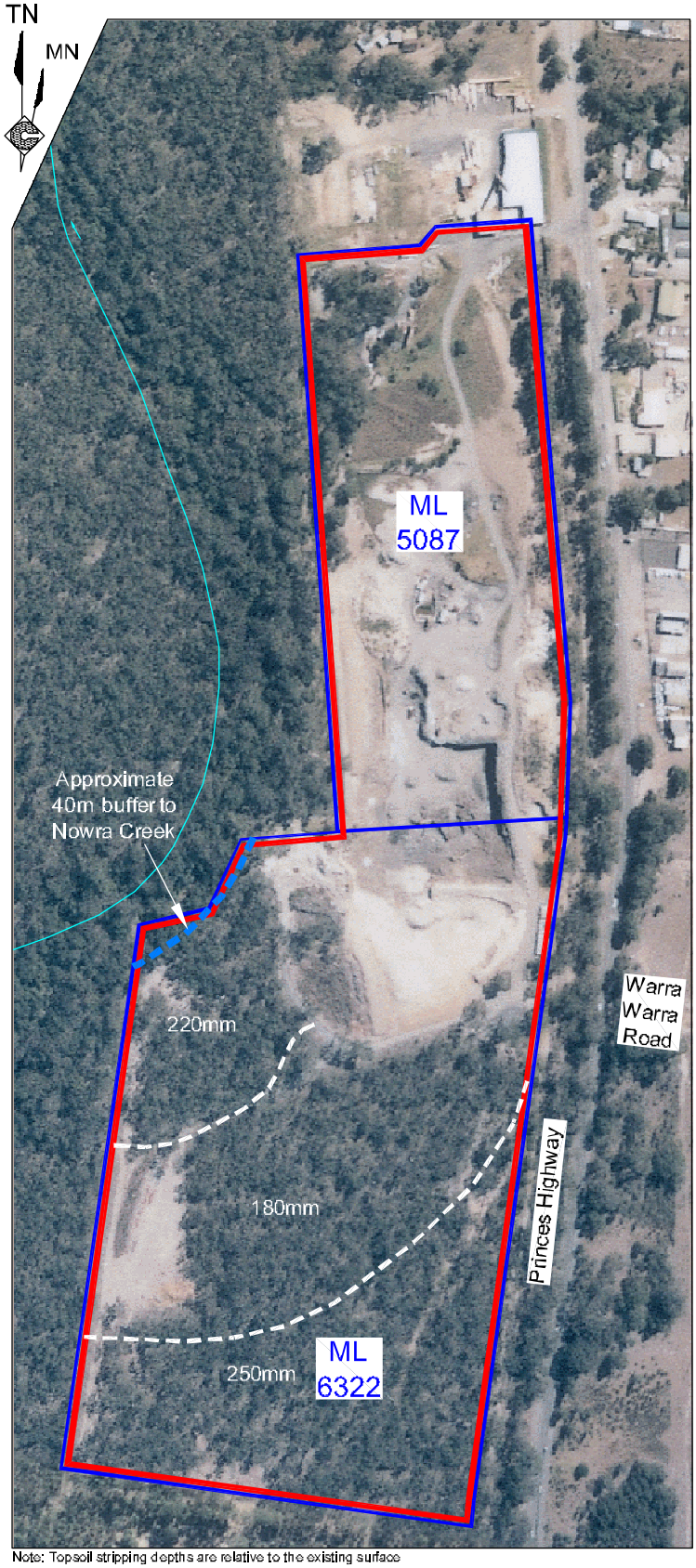


Figure 3
TOPSOIL STRIPPING DEPTH

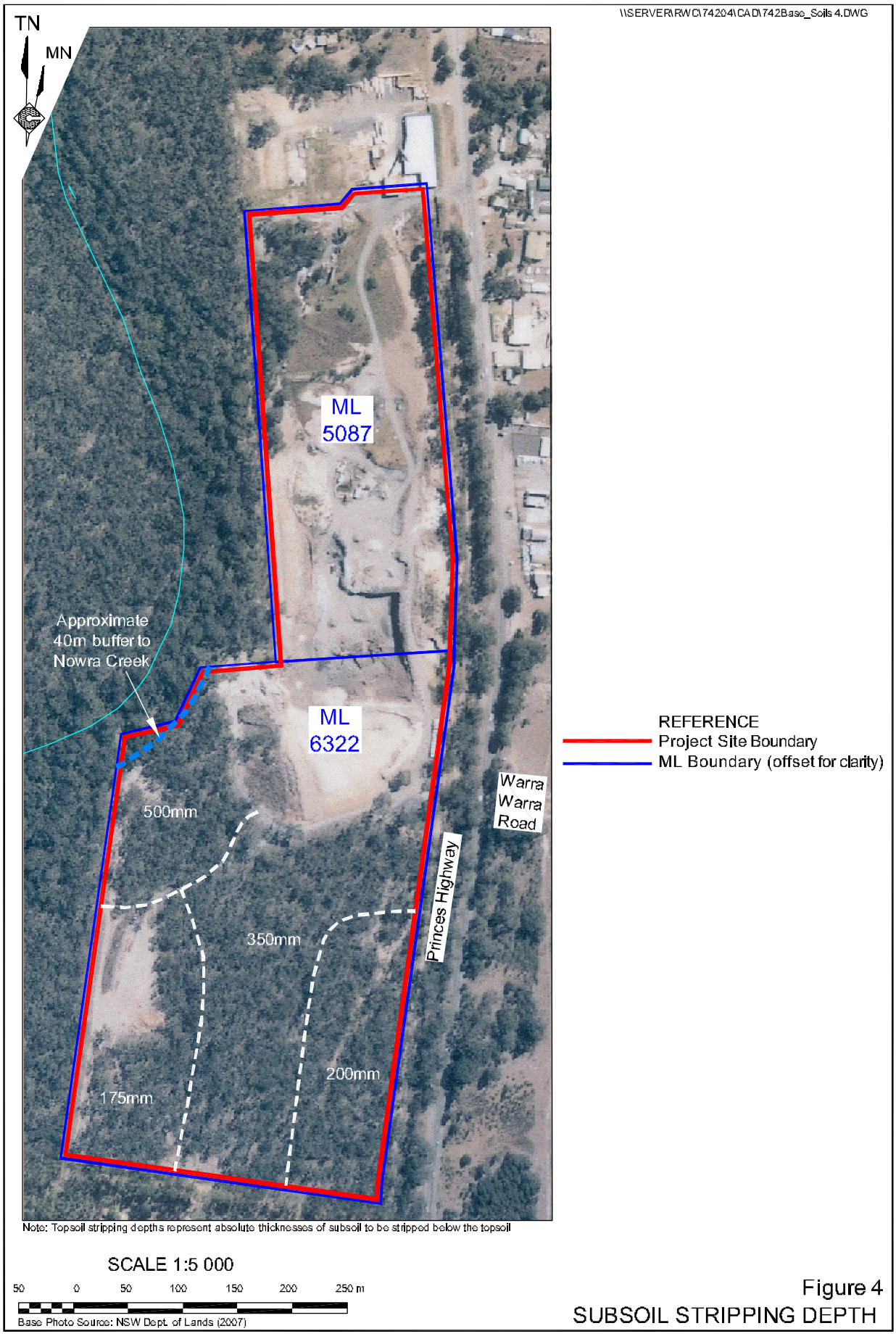


Figure 4
SUBSOIL STRIPPING DEPTH

4. Topsoils have moderate levels of exchangeable sodium and subsoils have high levels. This influences soil structure, as sodium tends to lead to higher dispersion potential. However, physical testing for aggregate stability (i.e. Emerson Aggregate Test) found that soils had a low risk of dispersibility. This suggests that the soil structure is important in limiting its erosion potential, and breaking the existing structure (e.g. by handling soils when they are wet) will lead to dispersion problems. As such, sediment retention structures (e.g. sediment basins) should be designed assuming soils are dispersible.
5. Soils have adequate exchangeable potassium and will not require application of potassium fertilizers.
6. All soil layers are calcium deficient (using the Ca:Mg ratio), which influences their relatively strong acidity and will limit plant growth.
7. The Aluminium:CEC ratio suggests that aluminium toxicity is not an issue for subsoils (due to their relatively high CEC) but is marginal in topsoils, where acid conditions cause aluminium to become soluble and there is insufficient buffering capacity in the soil naturally.
8. All soils are non-saline (i.e. EC values below 2.0).
9. The phosphorus sorption potential of the soils ranges from low-moderate (in topsoils) to high (in subsoils). As such, soils have a relatively good capacity to hold and exchange phosphorus in a form that is available to plants.

(Interpretations based on information in Hazelton and Murphy, 1992).

3.3.2 Management Implications

For the purposes of soil management and re-use of soils for rehabilitation of disturbed areas, the above laboratory results have the following management implications.

1. Vegetation establishment will be difficult due to limited fertility. Native species will fare better but might still require some fertilizer applications for initial growth.
2. Subsoils are as important as topsoils when rehabilitating disturbed areas. The subsoils contain more readily-available nutrients and have a far greater capacity to retain fertilizer materials.
3. Lime will be required at 250 grams per square metre to raise (i.e. make less acidic) soil pH when first establishing new vegetation.
4. Soil structure is fragile and is highly important for reducing the dispersion potential. Soils should not be worked when too dry or too wet (a moist condition is best).
5. Potential rises in EC (i.e. salinity) due to the application of biosolids are not a significant issue because the soils are naturally non-saline. However, this is conditional on biosolid applications being relatively light.
6. Applications of lime will be required to help address the calcium deficiency inherent in these soils.

3.4 Existing Quarry Areas

The existing quarry areas have been extensively disturbed and there is virtually none of the original soil resource remaining. For the most part, topsoils from this area have been stockpiled on site already or used to create the perimeter earth bunds around the entire site.

Our investigations of the site and its surrounding landscape indicate that the northern portion of the site (i.e. those areas already quarried) would have had similar soil and landscape conditions to those encountered in the mostly undisturbed areas in the southern portion. The geology and topography are the same, with only a minor difference in elevation (<20 m overall) and the surrounding lands are all identified as the Nowra Soil Landscape by Hazelton (1992). As a result, we consider that soil resources stripped from the southern part of the site are suitable for use in the progressive rehabilitation in the north, as they are sufficiently similar to those that would have existing prior to the commencement of quarry works.

3.5 Agricultural Land Capability

Agricultural land capability is assessed for this site using the following standard criteria (Emery, 1985).

1. **Climate.** At this site, climate is a low-moderate risk. Although rainfall is adequate, there is a significant risk of wind erosion in this area.
2. **Soil texture and structure.** At this site, topsoils have significant amounts of fine sandy material and have poor structure. Subsoils are sodic (i.e. potentially dispersive). Soils will rapidly erode if exposed to erosive forces. Topsoils have a high risk of sheet erosion (i.e. from non-concentrated flows) and subsoils have a high risk of rill and gully erosion (i.e. from concentrated flows).
3. **Slope gradient, length and topographic position.** At this site, slope gradients are very low and there is very little run-on.
4. **Existing erosion and erosion risk.** Apart from some sheet erosion in cleared areas, there is little evidence of existing erosion. By our estimation, the anticipated soil loss from this site if disturbed is 105 t/ha/year, which is very low. This is based on the Revised Universal Soil Loss Equation (RUSLE) using the following inputs:
   (i) R-factor of 4230
   (ii) K-factor of 0.047 (calculated from particle-size data in Hazelton, 1992)
   (iii) Slope of 2% and slope length 80 m
   (iv) P-factor of 1.3 (i.e. assuming no specific surface management)
   (v) C-factor of 1.0 (i.e. assuming no ground cover).
5. **Salinity risk.** The climatic, soil and landscape conditions are not conducive to the formation of salinity. As such, there is a very low risk of salinity at this site.

6. **Soil chemistry (e.g. pH).** Soils are typically acidic which might affect the potential to grow anything other than native species. Hazelton (1992) identified these soils as having low to low-moderate fertility.
7. **Drainage issues.** Soils have imperfect drainage, as indicated by the presence of the pallid, grey B3 soil layer and by sporadic mottling in the subsoils.
8. **Water table depths.** We are advised by other consultants that the depth to groundwater exceeds 10 m.
9. **Flooding.** Although we have not conducted any flood modelling for this site, the geomorphic and topographical conditions do not indicate that flooding is an issue.
10. **Presence of surface or near-surface rock.** Rock outcrops are generally absent at this site.

Site conditions are generally favourable but soil conditions negatively affect the land capability class. Primary issues include lack of soil fertility, lack of soil structure, potential for soil structural decline (particularly if soils are worked when wet), wind erosion risk (topsoils only) and rill erosion (exposed subsoils only). As such, we consider that these soils are generally not suitable for cultivation but could support grazing activities with appropriate management. We conclude that the land capability class is IV.

4 RECOMMENDATIONS FOR MANAGEMENT

4.1 Soil Handing

Soils at this site have massive to weak structure and are prone to structural decline if worked when wet. This is a particular concern for topsoils, as they are structurally weak and have a sandy fabric. As such, soils should not be handled (stripped, stockpiled or worked) when they are too wet or too dry. A moderately moist condition is best. While the definition of “moderately moist” is fairly subjective, a general guide would be to work soils 48 hours after soaking rainfall and before six (summer) or ten (winter) days have passed. This will help avoid pulverisation of soil structure, the formation of hardsetting surfaces on stockpiles and excessive bogginess caused by waterlogging.

4.2 Stripping Depths

Vegetation within the subject site should be coarsely mulched onsite and can then be used to armour stockpiles against erosion if so desired.

Figures 2 and **3** show the recommended stripping depths across the subject site for topsoil and subsoil respectively. Topsoils and subsoils should be stripped and stockpiled separately. Note that the depths shown for the subsoil are relative, based on the newly exposed surface levels after the topsoil has been stripped as indicated.

4.3 Soil Inventory

Approximately 10ha would require vegetation removal and soil stripping. Using an average topsoil layer thickness of 215 mm and assuming a bulk density of 1.3 (topsoil) this equates to 27,950 tonnes of topsoil to be stripped in total. For the purposes of rehabilitation, this could potentially be used across 10.75 ha of previously disturbed land, assuming that topsoil is spread to a depth of approximately 200 mm and is not significantly compacted (either during stockpiling or placement) and its existing structure, although weak, is intact.

For subsoils requiring stripping, the average layer thickness is 290 mm. Based on an area to be stripped of 10 ha and an estimated bulk density of 1.5, this equates to 43,500 tonnes of subsoil. For the purposes of rehabilitation, this could potentially be used across 11.6 ha of previously disturbed land, assuming that subsoil is spread to a depth of approximately 250 mm and is not significantly compacted (either during stockpiling or placement) and its existing structure, although weak, is intact.

For the purposes of rehabilitation, we recommend that subsoils be placed first, and not to a thickness of less than 250 mm. Topsoils are to be placed over subsoils to a thickness of not less than 200 mm. Further recommendations for managing soils for rehabilitation purposes are included below.

The existing perimeter earth bunds are estimated to contain some 60,000 m^3 of soil, comprising a mixture of top- and sub-soil. This is suitable for use as a substitute subsoil material during rehabilitation activities although should be placed to a thickness of not less than 0.5 m, rather than 0.25 m for unmixed subsoil to compensate for texture and structure changes. This equates to approximately 12 ha of rehabilitation area.

4.4 Stockpiling

Topsoil and subsoil are to be stockpiled separately and the details of each stockpile recorded appropriately. Stockpiles are to be constructed in accordance with **Figure 4**. The following general guidelines apply to the construction of all stockpiles:

1. Stockpiles are to be placed at least 2 m from:
   (i) existing vegetation;
   (ii) concentrated water flowpaths (e.g. creeks, swales, diversion drains etc.);
   (iii) roads; and
   (iv) other hazard areas (e.g. edge of quarry pit wall).
2. Stockpiles are to be low, flat, elongated mounds and, as far as is practicable, are to be no more than 2 m high (to maintain the viability of seed in the mound. Any higher and the centre of the mound can become oxygen-depleted, reducing the potential viability of the seed store).

3. If they are to be in place for more than 10 days, stockpiles are to be stabilised following their establishment. This can occur through the application of mulch (e.g. from vegetation slashed onsite), hydroseeding/hydromulching or equivalent.
4. Stockpile side slopes are to be no steeper than 1(V):2(H) on eastern and southern faces and 1(V):3(H) on western and northern faces.
5. A sediment fence is to be constructed 1 m from the toe of the stockpile on its downslope side.
6. As far as is practical given the limited site area, stockpiles are to be in place for no more than six months.

Note that, in most cases, stockpiles at this site won't require upslope diversion drains or earth banks due to the very low slope gradients and very low risk of run-on or undermining by upslope surface water flows.

4.5 Replacing Soils and Using Soils for Progressive Rehabilitation

4.5.1 Soil Suitability

As previously discussed, we consider the soils to be stripped from the southern portion of the site suitable for use in progressive rehabilitation of the existing disturbed lands. We recommend that these soils can be used to make up the upper 450 mm of the reformed ground surface. Below this, appropriate clean fill material or virgin excavated natural material (VENM) can be used to fill in the quarry pit.

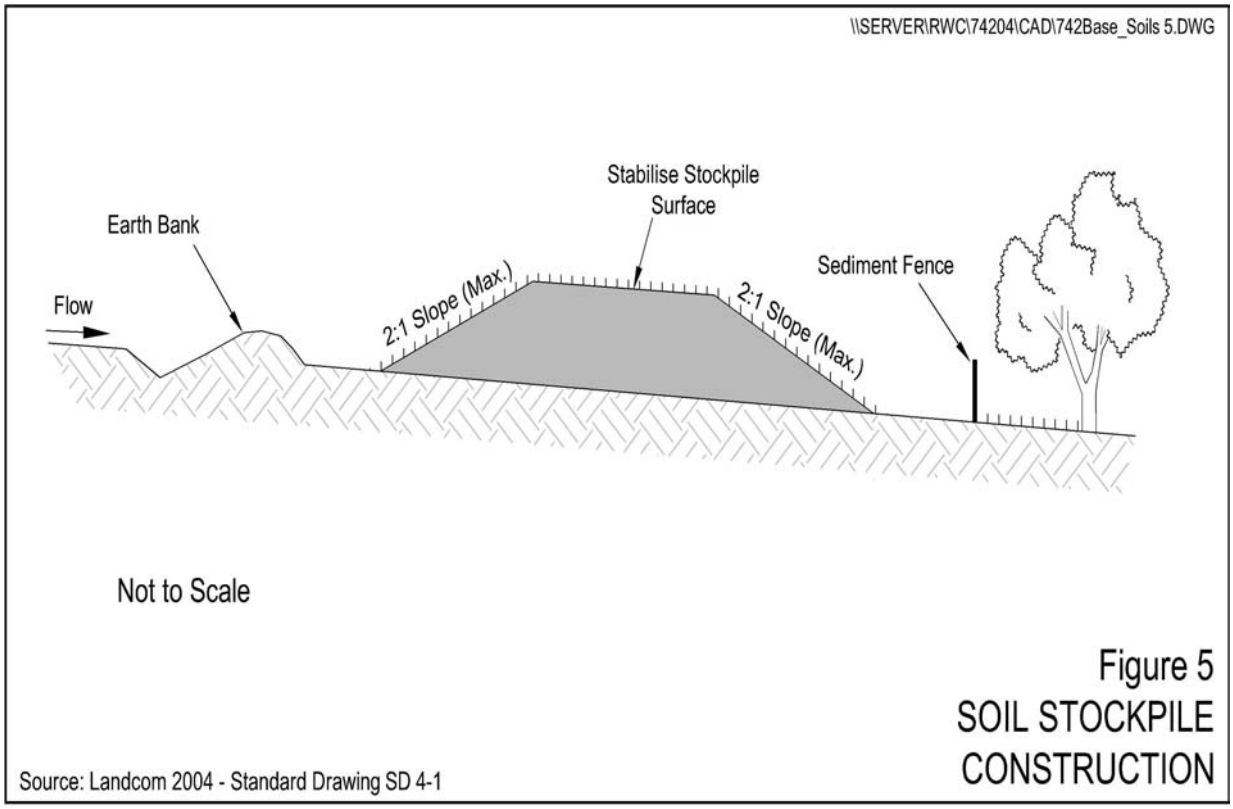
Our inspection of the existing perimeter earth bunds indicates that they are a mixture of topsoil and subsoil and, as such, are not suitable for use as a top layer for the purposes of rehabilitation unless appropriately modified (see Section 4.5.4). However, we consider these stockpiles to be suitable for use as a subsoil material when creating the final landform. Note that they must be overlain with at least 200mm of topsoil.

The final landform contours are detailed in the *Environmental Assessment*.

4.5.2 Soil Handling

When placing soils, the following procedures are to be applied.

1. Stockpiled subsoils are to be placed to a thickness of not less than 250 mm over the filled area.
2. Subsoils are to be left in a scarified, rough condition to assist in keying-in of topsoil.



3. Any compacted areas of subsoil or the underlying fill are to be ripped to a depth of 200 mm before material is placed over them.
4. Any ripping or scarifying should be done along the contour, with blades no more than 1 m apart.
5. As previously discussed, soils should be handled when they are neither too dry nor too wet. A moist condition is best.
6. After placement of the subsoils, stockpiled topsoil is to be spread over the subsoil to a depth of at least 200 mm.
7. Compaction of soils when placing topsoil is to be avoided.
8. After placing topsoil, leave the ground surface in a rough condition to minimise wind and water erosion and to promote infiltration of incident rainfall.
9. The newly formed ground surface is to be protected from erosion following formation through the use of appropriate broadscale measures such as (but not limited to):
   (i) Native mulch (20 – 40 mm thick only, mulches thicker than 75 mm can inhibit seed germination);
   (ii) bitumen-sprayed straw mulch (approximately 250 bales per hectare, with bitumen emulsion at 2,500 L/ha); or
   (iii) hydroseed or hydromulch (native species are to be used).

Note that, if exotic species (annuals) are to be used to establish a quick protective cover of vegetation over the newly formed soil surface, they are to preferably be self-sterile, non-invasive species.

4.5.3 Use of Biosolids

In general, the use of biosolids at this site is feasible providing application rates are light (e.g. less than 20 dry tonnes per hectare). The reasons for this are as follows.

1. Excess phosphorus in typical biosolids is often bound by elemental iron (which is typically high in biosolids themselves), meaning that phosphorus becomes harder for plants to obtain. This can lead to leaching of excess phosphorus. However, this would most likely be offset by the relatively good phosphorus sorption capacity of the subsoils, which are likely to retain nutrients.
2. Biosolids can lead to increases in EC (i.e. salinity) and subsequent decreases in pH (i.e. becomes more acidic). Given the already acidic nature of the soils at this site, further acidification could be detrimental to plant establishment and growth and could lead to problems with aluminium toxicity. However, this can be offset by accompanying applications of lime at approximately 300 grams per square metre. Note that ongoing applications of lime will be required annually for the first three years to offset changes in pH as biosolids are absorbed.
3. The makeup of the underlying material is not known at this stage. If crushed, sandy material is used, excess nutrients could leach into groundwater. Note, however, that if appropriate clay material was used beneath the replaced soil (e.g. VENM), biosolids could be used if that material was shown (by laboratory testing) to have moderate to high phosphorus sorption capabilities.

4.5.4 Importation of Soil Materials

As specified in Section 4.2, stripped topsoil is available for rehabilitation purposes and is suitable for this purpose. Approximately 10.75 ha of area can be rehabilitated using the available topsoil resource. Similarly, subsoil stripped from onsite can be used to rehabilitate approximately 11.6 ha, and this can be augmented using soil stored in the perimeter bunds.

However, there is approximately 15 ha of land that will require rehabilitation during the life-cycle of the quarry, meaning that there is a shortfall of 4.25 ha of topsoil. Assuming that topsoil is required to a depth of at least 200 mm, this equates to 8,500 m^3 of soil (i.e. approximately 11,050 tonnes, assuming a bulk density of 1.3).

To make up the shortfall, we recommend that either suitable material be imported to the site or any excess material in the existing perimeter bunds be made suitable by the addition of native mulch and gypsum.

If material is to be imported to the site, it should be similar in terms of:

1. Geology and topography. i.e. sourced from gently inclined (i.e. less than 10%) sandstone plain or plateau country.
2. Geographic location. i.e. material should be from a coastal area within 100 km of the site.
3. Texture, structure and colour (refer to Section 3.2.2 for details).
4. Soil landscape. If possible, source materials from the Nowra Soil Landscape, which occurs extensively in coastal regions within the Shoalhaven district. The geographic extent of the Nowra Soil Landscape is available in Hazelton (1992).

If existing material stored in the perimeter bunds is to be used for topsoil replacement purposes, it must be modified as follows:

1. native mulch is to be mixed with the soil material at a rate of 1 m^3 of mulch to 10 m^3 of soil.
2. gypsum (clay breaker) is to be added at a rate of 2 tonnes per hectare after soil has been spread. This can be by direct (dry) application or mixed into irrigation water at a rate of 600 kg/ML, assuming 100 mm of water is applied across the entire area.

4.5.5 Final Land Capability

Providing soils are appropriately managed, the above recommendations are followed and appropriate vegetation cover is established, we consider the final, rehabilitated land surfaces will have a similar land capability to that occurring pre-development (i.e. Class IV).

4.6 Monitoring and Maintenance

The following soil-related monitoring and maintenance measures are recommended.

1. Ensure that topsoils (A horizon) and subsoils (B2 horizon) are stockpiled separately and that stockpiles are appropriately marked on a plan (or equivalent).
2. Ensure stockpiles are stabilised within 10 days of establishment. They should be checked after 20 days and again after 60 days to ensure that vegetation or other suitable protective measures are stabilising them. Any obvious signs of erosion or bare patches on stockpiles after 60 days should be addressed.
3. Sediment fences at the toe of stockpiles should be cleaned out at two-monthly intervals or as needed. Removed sediment should be deposited in a location where it cannot be re-entrained by concentrated flows, namely within the extraction area.
4. When using stockpiled soils for rehabilitation purposes, ensure that the oldest are used first. This might need to be considered when stockpile locations are being determined.
5. Rehabilitated areas should be checked after 20 days of soil placement and seed establishment to ensure that vegetation is taking root.

6. Rehabilitated areas should be checked after 60 days of soil placement and seed establishment to ensure that vegetation has successfully established and is growing vigorously.

7. Rehabilitated areas will require regular watering to promote germination of seed and to sustain growth if rainfall is insufficient.

8. Rehabilitated areas should be weeded (either by direct removal or by spraying, if appropriate) at two-monthly intervals or as required until native vegetation has successfully established and can out-compete weeds.

9. Erosion and sediment control measures are to remain in place until rehabilitated lands have been suitably stabilised. Refer to the accompanying Erosion and Sediment Control Plan (also by SEEC Morse McVey) for details and definitions of stabilisation.

10. If biosolids are to be used during the rehabilitation process, testing of the underlying backfilled material is required to determine its phosphorus sorption capability. If this is found to be less than 500 mg/kg (calculated using the top 2 m of material only), biosolids should not be used. In addition, if biosolids are used in the rehabilitation process:

    (i) water quality monitoring is to be conducted before and after in nearby watercourses and at regular intervals to determine if leaching of phosphorus occurs; and

    (ii) soil testing is to be conducted annually to determine pH and EC values, to quickly determine if soil chemistry is being negatively affected in a manner that could be detrimental to vegetation. Lime is to be applied at 300 gsm (or higher) if pH levels decrease (i.e. become more acidic).

4.7 Conclusion

We conclude that, from a soil management perspective, there is a low risk of environmental impact associated with the proposed development providing the requirements detailed above are addressed. Soils are suitable for stripping and stockpiling, providing topsoils and subsoils are duly separated. Similarly, topsoils and subsoils are to be placed individually during the rehabilitation process. Soil landscape conditions indicate that lands in the north of the site have similar soils to those in the south. As such, materials stripped and stockpiled from the southern portion (ML 6322) are suitable for use in progressive rehabilitation of the northern portion (ML 5087).

Land Capability Class is determined as Class IV. We believe that, providing the above soil management techniques are adopted and vegetation is re-established, the final landform will achieve a similar class of land.

5 REFERENCES

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APPENDICES

(No. of pages excluding this page = 11)

Appendix 1 Soil Test Pit Logs

Appendix 2 Soil Laboratory Results

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Appendix 1

Soil Test Pit Logs

Note: Colour versions of the photographs are available on the Project CD.

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Test Pit Logs

Test Pit Number:	1	**GPS:**	0280969, 6132567
Topography:	Simple slope	**Slope and aspect:**	1%, NNE

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 180 mm (180 mm)	Dark greyish brown weakly pedal silty clay loam. <5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	180 – 500 mm (320 mm)	Olive-brown (with minor red colouring) soapy, blocky medium-heavy clay. Mildly to moderately reactive. 5% coarse fragments. Roots common.

Grey, pallid clay zone starts at around 500 mm depth below the soil surface.

Test Pit Number:	2	**GPS:**	0280965, 6132248
Topography:	Simple slope	**Slope and aspect:**	2%, ENE

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 260 mm (260 mm)	Strong brown weakly pedal silty clay loam. <5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	260 – 460 mm (200 mm)	Dark reddish brown to olive brown (with minor grey mottling) soapy, weakly pedal silty clay to clay. <1% coarse fragments. Roots common.

Grey, pallid clay zone starts at around 460 mm depth below the soil surface.

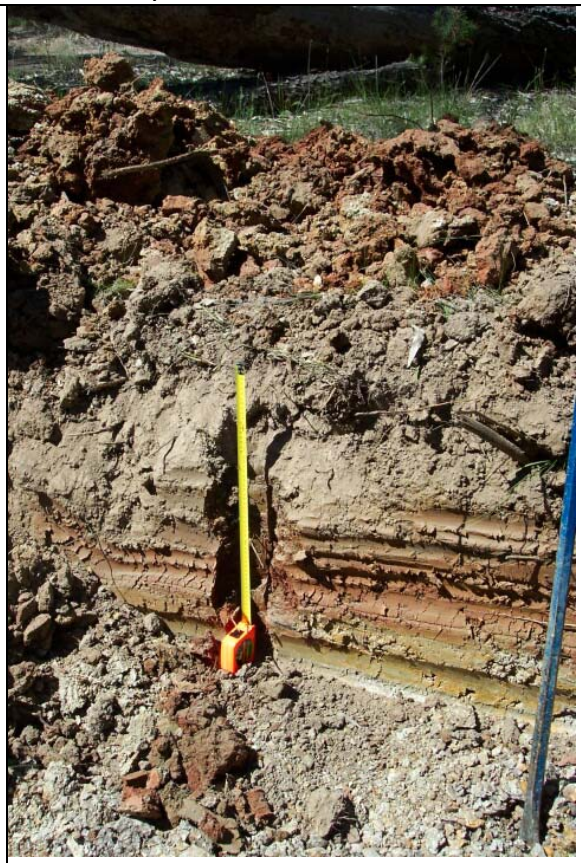
Test Pit Number:	3	**GPS:**	0280875, 6132081	
Topography:	Simple slope		**Slope and aspect:**	2%, East

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 230 mm (230 mm)	Dark brown weakly pedal fine, light sandy clay loam. 5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	230 – 440 mm (210 mm)	Olive-brown (with minor grey mottling), soapy, weakly pedal medium silty clay to clay. 5% coarse fragments. Roots common.

Grey, pallid clay zone starts abruptly at around 440 mm depth below the soil surface.

Test Pit Number:	4	**GPS:**	0280795, 6132085
Topography:	Simple slope	**Slope and aspect:**	1%, East

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 310 mm (310 mm)	Strong brown (with minor yellow colouring) massive to weakly pedal fine, light sandy clay loam. 5 - 10% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	310 – 630 mm (320 mm)	Dark reddish brown (with occasionally grey mottling) soapy, weakly pedal medium-heavy clay. 5% coarse fragments. Roots common.
Grey, pallid clay zone starts abruptly at around 630 mm depth below the soil surface.		



Test Pit Number:	5	**GPS:**	0280710, 6132076
Topography:	Simple slope	**Slope and aspect:**	2%, NW

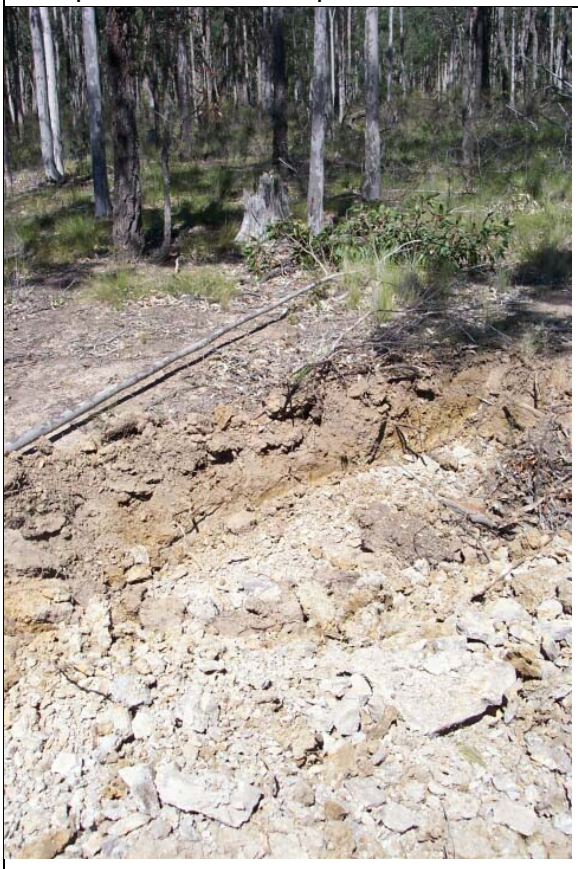
Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 290 mm (290 mm)	Dark brown weakly pedal fine sandy clay loam. 20% coarse fragments (iron nodules and indurations – possibly formed from *in situ* lateritisation of sedimentary parent materials). Abundant roots.
2 (subsoil; B2 horizon)	290 – 450 mm (160 mm)	Olive-brown, soapy, weakly pedal medium-heavy clay. 10% coarse fragments. Roots common.

Grey, pallid clay zone starts abruptly at around 450 mm depth below the soil surface.

Test Pit Number:	6	**GPS:**	0280702, 6132144	
Topography:	Simple slope		**Slope and aspect:**	1%, West

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 110 mm (110 mm)	Strong brown massive to weakly pedal fine, light sandy clay loam. 5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	110 – 330 mm (220 mm)	Olive-brown (with minor red colouring) soapy, weakly pedal medium-heavy clay. 5% coarse fragments. Roots common.

Grey, pallid clay zone starts at around 330 mm depth below the soil surface. Nearby evidence of topsoil loss and compaction in cleared area. Stockpile placed nearby.



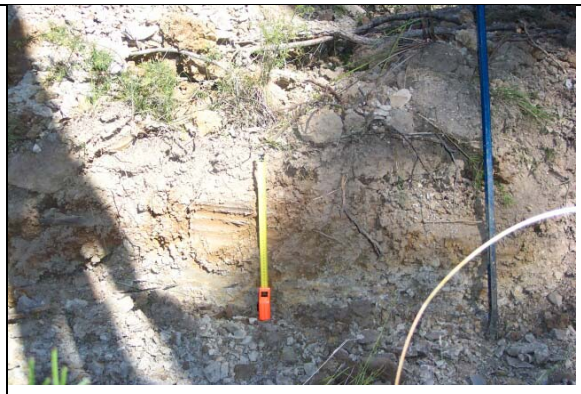
Test Pit Number:	7	**GPS:**	0280738, 6132293
Topography:	Simple slope	**Slope and aspect:**	2%, NW

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 210 mm (210 mm)	Light brown, massive silty clay loam. 10 to 20% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	210 – 720 mm (510 mm)	Reddish-brown (plus occasionally olive-brown with grey mottling) soapy, weakly pedal medium-heavy clay. <5% coarse fragments. Roots common.

Grey, pallid clay zone starts at around 720 mm depth below the soil surface. Soil is overlain by up to 5 mm of leaf litter.

Test Pit Number:	8	**GPS:**	0280799, 6132300	
Topography:	Simple slope		**Slope and aspect:**	3%, NNW

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 170 mm (170 mm)	Strong greyish brown massive silty clay loam. 5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	170 – 500 mm (330 mm)	Olive-brown (with minor red colouring) slightly soapy, weakly pedal medium clay. <5% coarse fragments. Roots common.
Grey, pallid clay (and siltstone) zone starts at around 500 mm depth below the soil surface.		



Test Pit Number:	9	**GPS:**	0280812, 6132187
Topography:	Simple slope	**Slope and aspect:**	1%, North

Layer	**Depth and thickness**	**Description**
1 (topsoil)	0 – 190 mm (190 mm)	Strong greyish brown massive, fine, light silty clay loam. 5% coarse fragments. Abundant roots.
2 (subsoil; B2 horizon)	190 – 540 mm (350 mm)	Olive-brown (with minor red colouring) soapy, weakly pedal medium-heavy clay. <5% coarse fragments. Roots common.

Grey, pallid clay zone starts abruptly at around 540 to 550 mm depth below the soil surface.

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Appendix 2

Soil Laboratory Results

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Department of Lands
Land Administration & Management
Property & Spatial Information

Soil Conservation Service

SOIL TEST REPORT

Page 1 of 2

Scone Research Centre

REPORT NO:	SCO07/286R1
REPORT TO:	Andrew Macleod SEEC Morse McVey PO Box 1098 Bowral NSW 2576
REPORT ON:	Six soil samples Job No: 07000469
PRELIMINARY RESULTS ISSUED:	Not issued
REPORT STATUS:	Final
DATE REPORTED:	23 October 2007
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

G Holman
(Technical Officer)

Scone Research Centre, PO Box 283 Scone 2337, 709 Gundy Road Scone 2337
Ph: 02 6545 1666 Fax: 02 6545 2520

23-OCT-2007 14:14 FROM DEPT OF LANDS TO 48623088 P.02

Page 2 of 2

SOIL AND WATER TESTING LABORATORY
Scone Research Centre

Report No: SCO07/286R1
Client Reference: Andrew Macleod
SEEC Morse McVey
PO Box 1098
Bowral NSW 2576

Lab No	Method	C1A/4	C2A/3	C5A/3 CEC & exchangeable cations (me/100g)						C8A/2	C8B/1		P9B/2	
	Sample Id	EC (dS/m)	pH	CEC	Na	K	Ca	Mg	Al	P (mg/kg)	P sorp (mg/kg)	P sorp index	EAT	Texture
1	07000469 TP1 L2	0.11	5.0	26.5	2.2	0.8	0.3	8.0	8.0	1	713	4.8	5	medium clay
2	07000469 TP3 L1	0.03	5.2	9.2	0.6	0.4	0.5	1.9	1.7	1	554	3.8	8/3(2)	loam
3	07000469 TP5 L1	0.02	5.3	9.6	0.5	0.5	0.4	1.8	2.4	1	534	3.7	8/3(3)	clay loam
4	07000469 TP5 L2	0.06	5.2	23.8	1.5	0.8	0.3	5.8	7.7	<1	758	5.3	5	sandy clay
5	07000469 TP7 L1	0.02	5.1	8.7	0.4	0.4	0.7	1.6	1.8	1	475	3.3	8/3(1)	sandy loam
6	07000469 TP7 L2	0.10	5.0	26.9	1.6	0.4	0.2	7.9	8.5	<1	780	5.6	6	sandy clay

END OF TEST REPORT

TOTAL P.02

SCCCR

South Coast Concrete Crushing and Recycling Pty Ltd

ABN: 76 095 243 584

Continuation and Expansion of Extractive Operations
at the

Nowra Brickworks Quarry,
South Nowra

Erosion and Sediment Control Plan

Prepared by

SEEC Morse McVey
December, 2007

Specialist Consultant Studies Compendium:

Part 7B

Erosion and Sediment Control Plan

for the

Continuation and Expansion of Extractive Operations at the Nowra Brickworks Quarry, South Nowra

Prepared for:

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December, 2007

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MORSE MCVEY

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CONTENTS

Page

1 INTRODUCTION 7B-7

2 PROPOSED ACTIVITIES 7B-7

3 EXISTING CONDITIONS 7B-8

3.1 General Conditions 7B-8
3.2 Soils 7B-10

3.2.1 Soil Landscape Mapping 7B-10
3.2.2 Onsite Soil Testing – Physical Properties 7B-10

3.3 Soil Laboratory Testing 7B-11

4 BACKGROUND INFORMATION FOR EROSION AND SEDIMENT CONTROL 7B-11

5 EROSION AND SEDIMENT CONTROL PLAN 7B-13

5.1 Introduction 7B-13
5.2 General Requirements 7B-13
5.3 Schedule of Works 7B-14
5.4 Erosion Control 7B-15
5.5 Sediment Control 7B-16
5.6 Water Management 7B-17
5.7 Pollution Control 7B-18
5.8 Rehabilitation and Soil Management 7B-19

5.8.1 Soil Handling and Timing Measures 7B-19
5.8.2 Topsoil and Subsoil Stockpiling 7B-19
5.8.3 Topsoil and Subsoil Replacement 7B-20
5.8.4 Revegetation 7B-20

5.9 Site Monitoring and Maintenance of Erosion and Sediment Control Works 7B-21

6 REFERENCES 7B-23

APPENDICES

Appendix 1 Soil Laboratory Test Results 7B-27
Appendix 2 Standard Drawings (from Landcom, 2004) 7B-31
Appendix 3 Sediment Basin and Diversion Drain Calculations 7B-41
Appendix 4 Flocculation 7B-47

CONTENTS

Page

FIGURES

Figure 1 Project Site Layout.....7B-9

TABLES

Table 1 Summary of Soil Characteristics.....7B-10
Table 2 Maximum acceptable C-Factors at nominated times during works.....7B-16

EXECUTIVE SUMMARY

SEEC Morse McVey have prepared this Erosion and Sediment Control Plan as part of an Environmental Assessment (EA) being prepared by City Plan Services and RW Corkery & Co. Pty Limited.

It has been prepared following the guidelines and recommendations for a Soil and Water Management Plan (SWMP) in Landcom, 2004 (The "Blue Book").

This Plan includes an assessment of the inherent site constraints and opportunities for erosion and sediment control as they existed at the time of inspection, plus identification of how the proposed works might affect the natural conditions. A plan for managing erosion and controlling sediment is included, with the ultimate aim being to minimise the risk of pollution to receiving waters.

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1 INTRODUCTION

SEEC Morse McVey have been commissioned by South Coast Concrete Crushing and Recycling Pty Ltd (SCCCR) to prepare an Erosion and Sediment Control Plan for the continuation and expansion of extractive operations at the Nowra Brickworks Quarry, South Nowra (the "quarry site"). This report forms part of an *Environmental Assessment* for the site being prepared by City Plan Services Pty Limited and R.W. Corkery & Co. Pty Limited. This report includes:

- an assessment of soil and water related issues as they relate to erosion and sediment control;
- details for how erosion and sediment control can occur at this site given the nature and scope of the proposed activities; and
- a plan drawing showing the location of erosion and sediment control works.

This report forms a companion report to a *Soils Assessment* report prepared by SEEC Morse McVey for the site and presented as Part 7A of the *Specialist Consultant Studies Compendium*. That report is referred to hereafter as the "Part 7A Report".

Nearly all of the site's northern portion (i.e. ML 5087) has been disturbed by previous and ongoing quarrying activities. Soils are generally absent in this area having been stripped long ago and, in many cases, used to create the existing site perimeter bunds.

2 PROPOSED ACTIVITIES

In summary, the Project would involve the following activities.

- Construction of a sealed site access road from the intersection of the site access road and the Princes Highway for a distance of approximately 150m.
- Construction of a wheel wash facility, dual weighbridge and office and a sealed visitor's carpark prior to the annual production from the quarry reaching 250 000t.
- Staged extraction of shale material ("extracted material") from a proposed extraction area of 15.0ha, incorporating an existing extraction area of approximately 2.0ha. Weathered shale material would be extracted using an excavator and stockpiled or direct loaded into road registrable trucks for transportation to the quarry's customers. Unweathered shale material would initially be blasted before being extracted using an excavator. Extraction operations would generally progress from north to south.
- Importation and stockpiling of up to approximately 50 000t per year of selected construction, concrete and waste bitumen material ("recycling material") for recycling by crushing and blending with extracted material to produce quarry products.

- Importation and stockpiling of up to approximately 125 000t per year of quarry products from other quarries ("blending materials") for blending with extracted material to produce saleable products.
- Processing and blending of extracted, recycling and blending material to produce general and specialised products for construction, road maintenance and other purposes. Processing operations would be undertaken with a mobile processing plant which would be located as close as practicable to the active extraction area and would be relocated regularly within the extraction area.
- Stockpiling of quarry products within the extraction area.
- Loading, sale and dispatch of an average of approximately 300 000t per year, to a maximum of approximately 500 000t per year, of quarry products using road registered heavy vehicles.
- Importation and placement of up to approximately 200 000t per year of VENM. A portion of this material would be processed and blended with other materials to produce saleable products. The remainder would be placed within completed sections of the extraction area to establish a final landform that mimics the pre-extraction landform within the Project Site. Placement operations would generally progress from north to south.
- Progressive rehabilitation of areas no longer required for extraction or placement-related activities.
- Implementation of comprehensive systems to manage noise, vibration, air quality, hydrology, traffic, ecology, noise and blasting, air quality, Aboriginal heritage, soils and land capability-related issues.

Figure 1 provides the Project Site Layout.

3 EXISTING CONDITIONS

3.1 General Conditions

The southern portion of the site is covered by woodland and occupies a very gently inclined rise and is mostly under native vegetation. The highest point occurs adjacent to the southern boundary, with slopes falling away very gently (less than 2% in most cases) to the north-east or north-west from a very slight north-south trending ridge. A series of gravel tracks run through the woodland. High (approximately 5 m) earth bunds have been established around the perimeter of the site. The stability of these ranges from good (completely stabilised with vegetation) to moderate (only partially stabilised, with minor evidence of sheet and rill erosion). The entire northern portion of the site has been modified for quarrying activities.

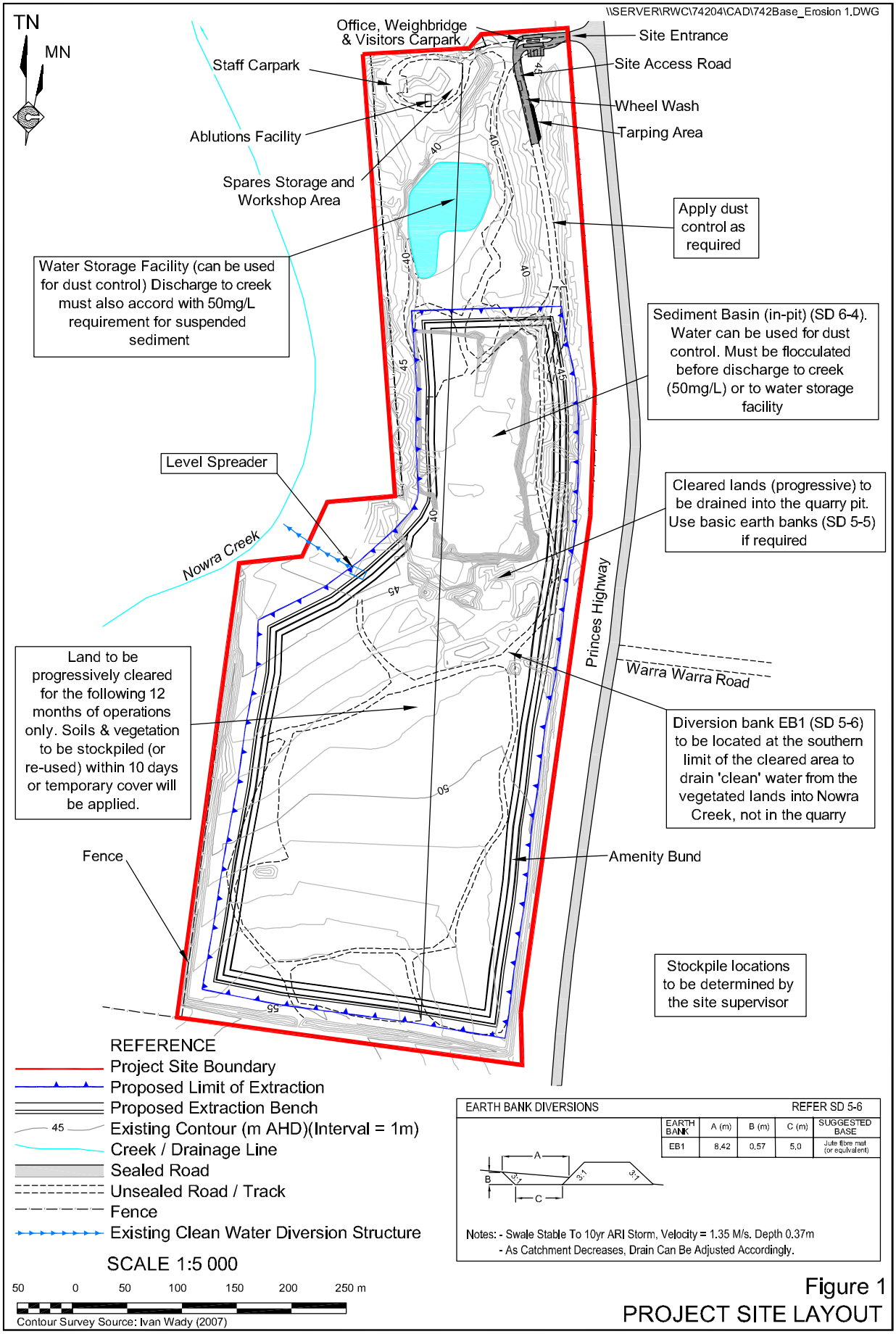

Figure 1
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD

3.2 Soils

3.2.1 Soil Landscape Mapping

This site is included in soil landscape mapping by the Soil Conservation Service (Hazelton, 1992) for the 1:100,000 scale Kiama sheet (9028). Mapping suggests that the site lies on the Nowra Soil Landscape, which occurs on moderately to gently undulating rises on Nowra Sandstone, but with occasional shale lenses. Site and soil investigations by SEEC Morse McVey staff confirm that this delineation is correct.

According to Hazelton (1992), soils of the Nowra Soil Landscape include:

- Brown or Yellow Podzolic Soils,
- Soloths, and
- Occasional Yellow Earths

The soils identified during the soil assessment (Part 7A Report) were primarily Brown Podzolic Soils and Soloths. Soloths tended to occur in areas of sandstone and siltstone and the underlying grey, clayey layer occurred at shallower depths in the profile. Brown Podzolic Soils tended to occur over shale or in better drained areas and often had a slight reddish hue in the subsoil. The underlying grey, clayey layer was generally slightly deeper in these soils.

3.2.2 Onsite Soil Testing – Physical Properties

A series of nine test pits were excavated and sampled for the Part 7A Report in the southern, undisturbed section of the site. Only the A and B2 horizons were investigated (note that a B1 horizon is generally absent or is masked as a sharp texture change between the A and B2 horizons). Below the B2 horizon lies a zone of grey, pallid clay (B3 horizon) that is the uppermost layer exploited for quarrying activities. Additional visual soil observations were conducted in opportunistic locations across the subject site to confirm that the soils identified represented a typical cross-section of the overall conditions.

Soils across the southern, undisturbed section of the site were found to be fairly homogenous, with minor differences in the depth and colour of each layer. Generally, two distinct layers were identified described in **Table 1**.

Table 1
Summary of Soil Characteristics

Layer	Lower depth range	Average layer thickness	Description
1 – topsoil (A)	110 to 310 mm	215 mm	Dark brown massive to weakly pedal silty clay loam. 5% coarse fragments.
2 – subsoil (B2)	330 to 720 mm	290 mm	Olive-brown to reddish-brown weakly pedal medium-heavy clay. <5% coarse fragments. Sodic. Occasional grey mottling.

The A horizons are fairly consistent across the site, apart from variations in depth. These are discussed in detail in the Part 7A Report. Topsoils are prone to becoming hardest when dry and could easily suffer structural decline and bogginess if worked when too wet.

The B2 horizons have fairly consistent texture (medium to medium-heavy clays) and are universally sodic (soapy to the touch when moistened). Colour varies from olive-brown to reddish-brown. Areas with olive-brown B2 horizons are typically shallower overall and indicate impeded drainage and/or underlying siltstone, sandstone or mudstone. Areas with reddish-brown B2 horizons are typically slightly deeper and indicative of better-drained soils and/or underlying shale. Landscape position (i.e. ridge, midslope etc.) has very little bearing on overall soil depth nor on soil profile characteristics. We assume that this is because there is insufficient slope to significantly influence colluvial patterns of soil formation in this landscape. Rather, soils have formed *in situ* from direct weathering of the underlying rock. Hence the observable differences in soil characteristics over relatively short distances.

Subsoil layer depth is explored in further detail in the Part 7A Report.

3.3 Soil Laboratory Testing

Representative samples from Test Pit 9 (Layers 1 and 2) were sent to the Department of Lands Soil Research Laboratory in Scone, NSW for testing to establish their erodibility. At our request, the laboratory conducted both chemically (i.e. using a dispersing agent such as Calgon) and mechanically (i.e. no dispersing agent added, but soils are mechanically shaken for 6 hours) dispersed Particle Size Analysis (PSA). For erosion and sediment control purposes, the mechanically dispersed test results are far more relevant than the chemically dispersed tests. A copy of the results is included in **Appendix 1**.

K-factors (i.e. erodibility) were calculated at 0.022 to 0.049 for the chemically dispersed samples and 0.037 to 0.055 for the mechanically dispersed samples. All calculations for erosion and sediment control will, therefore assume a worst-case figure of 0.055.

Other physical and chemical properties (particularly relating to the use of the soils in rehabilitation activities) is included in the Part 7A Report.

4 BACKGROUND INFORMATION FOR EROSION AND SEDIMENT CONTROL

The following information is relevant background information that was taken into account during preparation of this Erosion and Sediment Control Plan.

- Soil disturbance within the site will be staged, with operations proceeding from north to south as indicated elsewhere within the *Environmental Assessment*. We are advised that each year, the proponent would identify the area needed for the following 12 months of operations and would only clear and strip soil from that specific area. For the purposes of this report, we will certainly assume a worst-case scenario for soil disturbance of 2.5 ha (i.e. one entire Stage area in a single year, which is highly unlikely);

- According to Landcom (2004), the soils are Hydrologic Group C (i.e. low infiltration and moderate runoff potential). In addition, soils:
  - are duplex (i.e. strong texture contrast between top- and sub-soil);
  - often have heavy clay subsoils;
  - have weak structure which is easily degraded by poor management practices;
  - are imperfectly drained in many locations, indicated by subsoil mottling and pallid clay zones; and
  - have a moderately high runoff potential when ground cover is removed and soil surfaces are smooth and compacted.
- According to Landcom, (2004), soils are sediment Type D (dispersible). This is confirmed by the laboratory testing for Test Pit 9, layer 2;
- According to Landcom, (2004), these soils are suitable for use in earth walls for sediment basins, providing adequate compaction is achieved with soils in a moist condition;
- The potential soil loss is calculated at 123 tonnes/hectare/year (Soil Loss Class 1, which is very low) using the Revised Universal Soil Loss Equation (RUSLE) using the following inputs.
  - R-Factor (rainfall erosivity): 4230.
  - K-Factor (soil erodibility): 0.055 (TP9, Layer 1).
  - LS-Factor of 0.407 (Slope of 2% and slope length 80 m).
  - P-factor of 1.3 (i.e. assuming no specific surface management).
  - C-factor of 1.0 (i.e. assuming no ground cover).
- The peak flow runoff coefficient (C_{10}) for the site is 0.88 for Group C soils on disturbed lands (Landcom, 2004). The value for C_{10} reduces to 0.8 on stable, undisturbed lands (Pilgrim,1987);
- The rainfall depths for the 75th percentile are used to size sediment basins. Figures are from Table 6.3a in Landcom, (2004) and are based on rainfall records from Batemans Bay.
  - 5-day: 22.1 mm.
  - 10-day: 37.4 mm.
  - 20-day: 72.0 mm.
- The volumetric runoff coefficient (C_v) for the site is based on the selected rainfall depth and the soil hydrologic group, with figures from Table F2 in Landcom, 2004:
  - 5-day basin volume: 0.35
  - 10-day basin volume: 0.51

  - 20-day basin volume: 0.70

- All temporary erosion and sediment control structures, including catch drains, earth banks, level spreaders etc. are to be constructed for stability in the 10-year ARI time-of-concentration event. Note that sediment basin spillways are to be designed for stability in the 100-year ARI event;
- Permanent water control structures are to be designed for stability in at least the 20-year ARI event;
- The volume of any sediment retention structure(s) such as sediment basins, may need to change over the life of the development as the relative area of disturbance changes;
- When dry, soils are prone to wind erosion if protective ground cover is removed.

5 EROSION AND SEDIMENT CONTROL PLAN

5.1 Introduction

Figure 1 presents the conceptual location of the various components of the Sediment and Erosion Control Plan. The location of various components of the plan would be relocated during the life of the Project as extraction and placement operations progress.

The following subsections present the various components of the Erosion and Sediment Control Plan.

5.2 General Requirements

The following general requirements should be implemented.

- Ensure contractors undertake all soil and water management works as instructed in this document and following the guidelines in Landcom, (2004).
- Inform all workers of their responsibility in minimising the potential for soil erosion and pollution to downstream areas.
- Make ongoing changes to this plan as works proceed, taking into consideration the area of disturbance at any one time.
- Runoff from the undisturbed areas in the south of the site is mostly “clean”. This water can be diverted into local watercourses with a minimum of treatment.
- Potentially sediment-laden runoff from cleared areas (i.e. those lands to be quarried in the following 12 months) is to be diverted into sediment retention structures. Note that sediment basin(s) can be sited in the quarry pit if so desired and runoff directed into it.
- Ensure erosion and sediment control works remain in place until lands are rehabilitated and successfully stabilised.

5.3 Schedule of Works

The following works would be implemented immediately following receipt of planning approval. Note reference to drawings refer to standard drawings from Landcom (2004). The relevant drawings are presented in **Appendix 2**.

- If not already in place, install perimeter bunds around the site. These are to be earth banks made from soil stripped on the site. They are to be approximately 5 m high, with side batters no greater than 1(V):2(H) on eastern and southern faces and 1(V):3(H) on western and northern faces.
- Stabilise perimeter bunds to achieve a C-factor of 0.1 within 10 days of their formation. Note that a C-factor of 0.1 is achievable with 60% vegetation cover.
- Install sediment fencing (Drawing SD 6-8 – **Appendix 2**) along the toe of any newly formed perimeter bunds and at the downhill edge of cleared areas to retain the coarse sediment fraction.
- Stabilise the site access to minimise the risk of sediment being tracked onto public roads.
- Should a sediment basin be constructed at the natural surface, establish the basin, including the basin outlet, for the 100 year ARI storm event in accordance with Drawing SD 6-4 (**Appendix 2**). Install marker pegs to show the top of the sediment storage zone and the settling (water) zone.
- Alternatively, divert all potentially sediment-laden water into the extraction area. Potentially sediment-laden water within the extraction area will require treatment in accordance with Landcom (2004) prior to being released, if it is to be released.
- Construct earth bank EB1 (SD 5-6) to direct flows from the mostly-vegetated, undisturbed lands in the south of the site as shown on **Figure 1**. This runoff is unlikely to contain significant volumes of sediment and, as such, is considered “clean”.
- Divert all runoff from disturbed areas into the Sediment Basin or the extraction area. This may require establishing several basic earth banks (SD 5-5).
- Stabilise land surfaces disturbed by construction of erosion and sediment control structures as soon as final levels are established. Refer to Section 4.7 below for details of stabilisation.
- Only lands required for extraction-related purposes during the following 12 months are to be cleared and stripped. Otherwise, they are to be left undisturbed.
- Conduct regular monitoring of erosion and sediment control measures to identify problems or maintain various measures as required. Section 4.8 below contains further details of monitoring and maintenance schedules.
- Progressively rehabilitate disturbed areas as works are completed. Sediment control structures are to remain in place until rehabilitated lands have successfully stabilised and are to be removed at the end of the quarry’s operation.

5.4 Erosion Control

The following erosion control measures would be implemented during the life of the Project.

- The soil erosion hazard on the site would be kept as low as practical by minimising the overall area of disturbance. Some ways of doing this include the following.
  - Staging works so that only lands to be quarried in the following 12 months are cleared and stripped.
  - Limiting access to minimise the area of disturbance and limit the amount of land requiring regular applications of water for dust-control.
  - Limiting the width of haul roads to that which is safe for heavy vehicle passage.
  - Establishing barrier fencing (note that this can simply be tape wound around star pickets) to delineate no-go areas (i.e. areas that are outside of the regular works zone at that time) and minimise the risk of accidental entry.
- Plan works so that, where practicable, the amount of time that soils are exposed to the forces of erosion is minimised.
- Stockpiles are to be sited at least five metres from areas of likely concentrated or high-velocity surface water flows, especially diversion drains and roads (including road drains). Install a sediment fence a the toe of stockpiles on their downhill side.
- Lands cleared for the following 12 months of quarrying operations are to be stripped within 10 days of vegetation clearing occurring or else a temporary cover will be applied to lower C-factors to 0.1 within 20 days (see **Table 2**).
  - While C-factors are likely to rise to 1.0 during the operations phase, they should not exceed those given in **Table 2** in the long term. The requirements of **Table 1** can be achieved with a temporary vegetative cover of suitable sterile species.
- Vegetation cleared from on site would be coarsely mulched and stockpiled for later re-use as a protective ground cover during rehabilitation works or as a temporary cover for cleared areas until they are ready for stripping.
- During windy weather, unprotected areas (including haul roads) would be kept moist (not wet) by sprinkling with water to reduce wind erosion (or use an alternative spray-applied wind-erosion control measure).
- When rehabilitating surfaces, soils would be left with a loose surface to encourage water infiltration and help with keying topsoils later.
- Final landscaping will be undertaken as soon as possible and within 15 working days from placement of topsoil in a particular area. This will include primary revegetation/mulching to provide a quick, temporary cover before a more permanent cover of native vegetation is established.
- Revegetation areas will be watered regularly until an effective cover has properly established and plants are growing vigorously.

Table 2
Maximum acceptable C-Factors at nominated times during works

Lands	Maximum C-Factor	Remarks
Waterways and other areas subjected to concentrated flows, post construction	0.05	Applies after ten working days from completion of formation and before they are allowed to carry any concentrated flows. Flows will be limited to those shown in Table 5.2 of Landcom, 2004. Foot and vehicular traffic will be prohibited in these areas.
Stockpiles, post construction	0.10	Applies after ten working days from completion of formation. Maximum C-Factor of 0.10 equals 60% ground cover.
Waterways and stockpiles during construction and all other lands after construction has ceased	0.15	Applies after 20 working days of inactivity, even though works might continue later. Maximum C-Factor of 0.15 equals 50% ground cover.

5.5 Sediment Control

The following Sediment Control measures would be implemented during the life of the Project.

- Install sediment fencing following SD 6-8 along the toe of any newly formed perimeter bunds, at the downhill edge of cleared areas and in other areas of potential erosion to retain the coarse sediment fraction.
- Install the sediment basin as described in Section 4.3, or, alternatively direct all potential sediment-laden water into a sediment basin within the extraction area. **Appendix 3** contains calculations detailing the sizing of the basin that will be required if potentially sediment-laden water is to be discharged from site.
- Based on the 20-day rainfall depth, the sediment basin will:
  - Have a total volume of 6,088 m^3; and
  - Contain a sediment settling zone (i.e. water zone) of 6,048 m^3 and a sediment storage zone of 40 m^3.
- Note that, if so desired, the sediment basin can be made smaller to accommodate only the 10-day or 5-day rainfall depth. However, if this occurs, the maintenance intervals must be shortened accordingly.
- Note that sediment basin capacity can be adjusted if the catchment area conditions change. The above calculation assumes 12 ha drains into the basin. If progressive rehabilitation activities stabilise lands in the north of the site and these lands no longer drain into the basin, the basin can be made smaller accordingly. Refer to the calculations in **Appendix 3** for details of basin sizing.
- The sediment basin can be drained by pumping it to the existing Water Storage Facility (see **Figure 1**). However any water to be discharged from the Water Storage Facility can only contain a maximum of 50 mg/L of suspended sediment.

We recommend that flocculation occur in the sediment basin prior to pumping it to the Water Storage Facility unless the presence of intercepted groundwater makes this impossible. If flocculation won't occur in the Sediment Basin, the Water Storage Facility must be designed to accommodate at least the same sediment storage volumes as Sediment Basin 1 and will need to be flocculated to achieve 50 mg/L of suspended sediment in discharge waters.

- The Sediment Basin should be flocculated within sixteen days (for a 20-day basin) of the design storm event (or if the design storm event is exceeded). Refer to **Appendix 4** for flocculation procedures or see Appendix E of Landcom, (2004).
- Water should only be discharged from the storage basin after allowing sufficient time for flocculation of sediment so that the level of suspended solids in discharge waters is less than 50 mg/L. This provision applies even if water from the sediment basin is being pumped to the Water Storage Dam.
- Should the Sediment Basin be constructed on the natural ground surface, it would have one or more pegs placed on the floor or side walls to clearly indicate where the base of the settling zone and the upper limit of the sediment storage zone occurs.
- The Storage Basin would be drained following significant storm events to regain design capacity within sixteen days (for a 20-day basin) of the storm event.
- The Storage Basin would have any accumulated sediment removed when design capacity is exceeded.
- Should the Sediment Basin be constructed on the natural ground surface, it would have a single outlet designed following Drawing SD 5-6 (**Appendix 2**) to convey runoff in excess of the design storm volume. This outlet will be designed for stability in the 100-year ARI event and will discharge into local watercourses.
- Sediment removed from any trapping device will be disposed of within the area of extraction undergoing backfilling operations.

5.6 Water Management

The following water management measures would be implemented during the life of the Project.

- A series of basic diversion drains would be constructed in accordance with Drawing SD 5-5 (**Appendix 2**). These drains would be located in a manner to ensure that all potentially sediment-laden surface water is directed to the Storage Basin.
- An Earth Bank Diversion (EB1) would be constructed according to Drawing SD 5-6 (Appendix 2).

- Capture all runoff from uncleared, undisturbed lands in the south of the site. This drain:
  - would be sized and lined according to Drawing 07000469-01 to divert runoff from the vegetated lands to the south away from the works area;
  - would direct flows to a basic sediment retention structure (note that, for the most part, these lands are well vegetated so the amount of sediment will be minimal) and a level spreader (SD 5-6); and
  - would be moved progressively south as the operations area proceeds southward. The original outlet structure can be used if so desired, or a new level spreader installed each time EB1 is relocated.
- Where haul roads or access tracks cross the diversion drains, pipes would need to be installed. Pipe inlet and outlet points will need to be stabilised using an energy dissipater;
- Install temporary earth diversion drains (SD 5-5) at the discretion of the site manager to mitigate against unforseen erosion hazards, particularly when heavy rainfall is forecast. These can be used to break up long slopes into lengths no greater than 80 m;
- On the site access road, install berms where there is a consistent slope greater than 80 m long. These are designed to reduce the velocity of water flowing down the road and divert it onto adjacent, stabilised lands.

5.7 Pollution Control

The following pollution control measures would be implemented during the life of the Project.

- Water detained in the Sediment Basin would be tested for concentration of suspended solids. If the level is less than 50 mg/L it may, subject to the terms of the Environment Protection Licence, be discharged straight to local watercourses. If not, it must be flocculated prior to discharge.
- As previously mentioned, we expect that water from the basin would be pumped to the Water Storage Facility. If this occurs, any discharge from the Water Storage Facility would need to comply with the same requirements for suspended sediment (i.e. 50 mg/L), flocculation and maintenance as the sediment basin.
- If the level of suspended solids is greater than 50 mg/L, basins will be flocculated (Appendix 4) before discharge occurs (unless the design storm event is exceeded).
- Sediment removed from any trapping device will be disposed of within the area of active backfill within the Extraction Area.

5.8 Rehabilitation and Soil Management

5.8.1 Soil Handling and Timing Measures

The following soil handling and timing measures would be implemented during the life of the Project.

- Soils at the site have massive to weak structure and are prone to structural decline if worked when wet. As such, soils are not to be handled (stripped, stockpiled or worked) when they are too wet or too dry. A moderately moist condition is best. This will help minimise the risk of soil structural decline, the formation of hardsetting surfaces on stockpiles and excessive bogginess caused by waterlogging.
- Schedule works so that the duration from the conclusion of land shaping (i.e. progressive rehabilitation to establish the final land form) to completion of final vegetation establishment is less than 15 working days..
- While C-factors are likely to rise to 1.0 regularly during the works program, they will not exceed those given in **Table 2**.
- The requirements of **Table 2** can be achieved in a variety of ways, including:
  - through the use of an appropriate soil binder (e.g. Terra-Control) in areas of sheet flow such as on stockpiles;
  - through the use of anionic bitumen emulsion sprayed over Hessian cloth (at 0.5 L/m2) in areas of concentrated flow;
  - by using a temporary vegetative cover (e.g. on stockpiles); and
  - by using Reinforced Erosion Control Products in areas of concentrated flow (e.g. diversion drains, basin outlets).

5.8.2 Topsoil and Subsoil Stockpiling

- Topsoil and subsoil would be stockpiled separately and the details of each stockpile recorded appropriately. For further details, refer to the Part 7A Report..
- Stockpiles would be constructed following Drawing SD 4-1 (**Appendix 2**);
- Stockpiles would be placed at least 2 m from:
  - existing vegetation;
  - concentrated water flowpaths (e.g. creeks, swales, diversion drains etc.);
  - roads; and
  - other hazard areas (e.g. edge of quarry pit wall);
- Stockpiles would be low, flat, elongated mounds and, as far as is practicable, would be no more than 2 m high (to maintain the viability of seed in the mound.

Any higher and the centre of the mound can become oxygen-depleted, reducing the potential viability of the seed store).

- If they are to be in place for more than 10 days, stockpiles would be stabilised following their establishment. This may occur through the application of mulch (e.g. from vegetation slashed onsite), hydroseeding/hydromulching or equivalent. Refer to Table 1 for C-Factor requirements on stockpiles.
- Stockpile side slopes would be no steeper than 1(V):2(H) on eastern and southern faces and 1(V):3(H) on western and northern faces.
- A sediment fence would be constructed 1 m from the toe of any stockpile on its downslope side.
- Where practicable, stockpiles would be in place for no more than six months.

5.8.3 Topsoil and Subsoil Replacement

Note that topsoil replacement depths are detailed in the accompanying the Part 7A Report. In summary, the following topsoil and subsoil control measures would be implemented.

- In all areas subjected to disturbance and requiring permanent vegetative stabilisation, topsoil and subsoil would be replaced to a minimum depth of 250mm and 200mm respectively.
- Handle soils only when they are moist (not wet nor dry) to minimise the risk of soil structural decline.
- Following placement of subsoil materials, the surface would be left in a loose, rough condition to promote moisture infiltration and the keying-in of topsoil layer.
- Leave topsoil in a scarified or ploughed condition once replaced to help moisture infiltration and reduce the risk of soil erosion.
- Avoid compaction of recently topsoiled areas – establish barrier fencing if necessary to keep vehicles out.

5.8.4 Revegetation

Successful revegetation of lands, a principal stabilisation technique, requires:

- availability of acceptable soil materials;
- correct site preparation (see Standard Drawings SD 4-2 and SD 7-1 in **Appendix 2**);
- selection of the most suitable establishment technique;
- selection of appropriate plant species, fetiliser(s) and ameliorant(s);

- application of sufficient water for germination and to sustain plant growth if rainfall is insufficient; and
- an adequate maintenance program.

The following revegetation controls will apply to the Project:

- Soil preparation for rehabilitation would accord with the recommendations included in the Part 7A Report. The proposed final contours are included in this EA and they closely follow the pre-development ground surface levels.
- Areas not satisfactorily revegetated would be investigated to determine the reason for failure. Appropriate remedial action, including replacing any lost topsoil and resowing the site would then be undertaken.
- Clearly visible barriers would be installed to limit access to the rehabilitation areas.
- A temporary cover crop of suitable annual cereal species may be used on areas being revegetated with native species to give natives time to establish and help out-compete weeds. This should be used in conjunction with native mulch (stockpiled from clearing activities in the south of the site).
- Supplementary planting and inoculation of native species will be undertaken if required (i.e. if the soil seed store is not adequate to re-establish native vegetation).
- Any areas of concentrated surface water flow are to be stabilised with a suitable grass species (not Kikuyu) capable of withstanding concentrated flows. Reinforced turf is recommended for post-construction (i.e. final stabilisation) activities where the flow velocity will not exceed 1.8 m/s in the 100-year ARI storm event.
- Extensive watering will be required to assist in the establishment of vegetation in rehabilitation areas if rainfall is insufficient to promote germination and growth.

5.9 Site Monitoring and Maintenance of Erosion and Sediment Control Works

Following the guidelines set out in Landcom (2004), site monitoring would be undertaken during and after construction.

- Waste receptacles will be emptied as necessary. Non-processed wastes will be disposed of at an approved facility.
- An internal auditing program would be initiated for the site. The quarry manager would inspect the site at least fortnightly and maintain a log of inspections, paying particular attention to:
  - removal of spilled soil or other materials from near hazard areas;
  - removal of trapped sediment from sediment fences;

  - the stability of all sediment fences;
  - whether barrier fencing is maintained and exclusion zones are being observed by all site workers and contractors;
  - whether progressive and prompt rehabilitation of lands and that rehabilitation has effectively reduced the erosion hazard (initiate upgrading or repair as appropriate);
  - whether additional erosion and/or sediment control works are necessary to ensure the desired water control is achieved, i.e. make ongoing changes to the Surface Water Management Plan;
  - whether erosion and sediment control measures are in a functioning condition until such time as all earthwork activities are completed and the site is rehabilitated; and

- A rain gauge would be installed at the site and would be monitored by the site superintendent to determine the severity of any rain events;
- Revegetation areas would be inspected regularly to investigate failures and program replanting as necessary;
- An adequate watering and fertilising system would be maintained in revegetation areas;
- Areas of localised soil erosion would be identified and appropriate preventive measures implemented. These may include:
  - planting additional stabilising vegetation or wind breaks;
  - stabilising soils with mulches or alternative soil binders; and
  - taking steps to minimise any concentrated stormwater flows.
- Any areas of localised poor drainage will be identified and appropriate remedial action taken. This may include:
  - installing formalised drainage channels or pipes;
  - improving soil permeability by cultivating the soil surface;
  - improving soil permeability by installing infiltration trenches; and
  - planting moisture tolerant vegetation in problem areas.
- The first time waters are to be discharged, at least one sample will be sent to a NATA-registered laboratory for analysis first to ensure that the 50 mg/L level is being met. Further, a sample will be calibrated to the 50 mg/L level and returned to the site so a visual assessment can be made in future to ensure the criterion is being met. The sample should contain a small quantity of a chemical dispersing agent to prevent settling;
- Check the basin outlets for stability and check the operation of all pumps.

6 REFERENCES

Hazelton, P.A. (1992). *Soil Landscapes of the Kiama 1:100 000 Sheet*. Department of Conservation and Land Management (incorporating the Soil Conservation Service of NSW), Sydney.

Landcom (2004). Managing Urban Stormwater: Soil and Construction. 4th Edition. NSW Government.

Pilgrim, D.H. (ed.) (1987). Australian Rainfall and Runoff – A Guide to Flood Estimation. Institution of Engineers, Australia. Barton, ACT.

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APPENDICES

(No. of pages excluding this page = 13)

Appendix 1 **Soil Laboratory Test Results**

Appendix 2 **Standard Drawings**

Appendix 3 **Catchment and Basin Calculations**

Appendix 4 **Flocculation**

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Appendix 1

Soil Laboratory Test Results

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Department of Lands
Land Administration & Management
Property & Spatial Information

Soil Conservation Service

SOIL TEST REPORT

Page 1 of 2

Scone Research Centre

REPORT NO:	SCO07/287R1
REPORT TO:	Andrew Macleod SEEC Morse McVey PO Box 1098 Bowral NSW 2576
REPORT ON:	Two soil samples Job No: 07000469
PRELIMINARY RESULTS ISSUED:	Not issued
REPORT STATUS:	Final
DATE REPORTED:	22 October 2007
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

G Holman
(Technical Officer)

Scone Research Centre, PO Box 283 Scone 2337, 709 Gundy Road Scone 2337
Ph: 02 6545 1666, Fax: 02 6545 2520

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No: SCO07/287R1
Client Reference: Andrew Macleod
SEEC Morse McVey
PO Box 1098
Bowral NSW 2576

Lab No	Method	P7B/1 Particle Size Analysis (%)						P8A/2	P9B/2
	Sample Id	clay	silt	vf sand	cf sand	c sand	gravel	D%	EAT
1	07000469 TP9 L1	17	27	29	14	12	1	15	8/3(1)
2	07000469 TP9 L2	59	18	12	5	6	<1	16	5

Lab No	Method	P7C/1 Particle Size Analysis – mechanical dispersion (%)						C6A/2
	Sample Id	clay	silt	vf sand	cf sand	c sand	gravel	OC (%)
1	07000469 TP9 L1	8	26	34	14	17	1	1.85
2	07000469 TP9 L2	41	30	15	6	8	<1	0.40

END OF TEST REPORT

Appendix 2

Standard Drawings (from Landcom, 2004)

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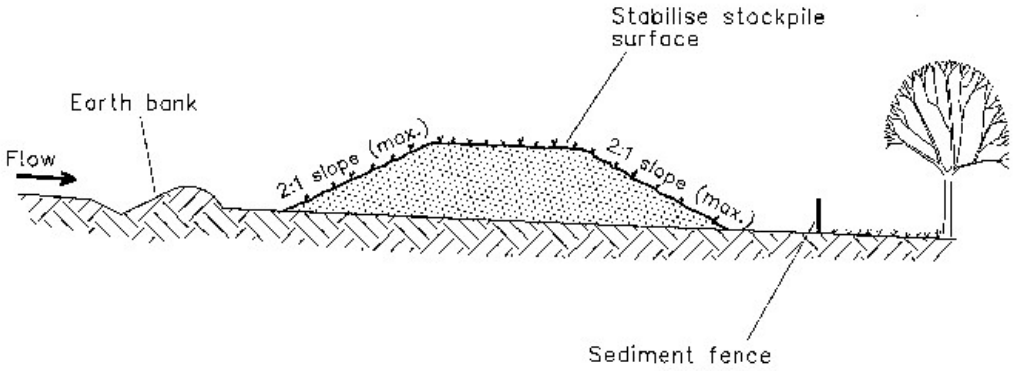
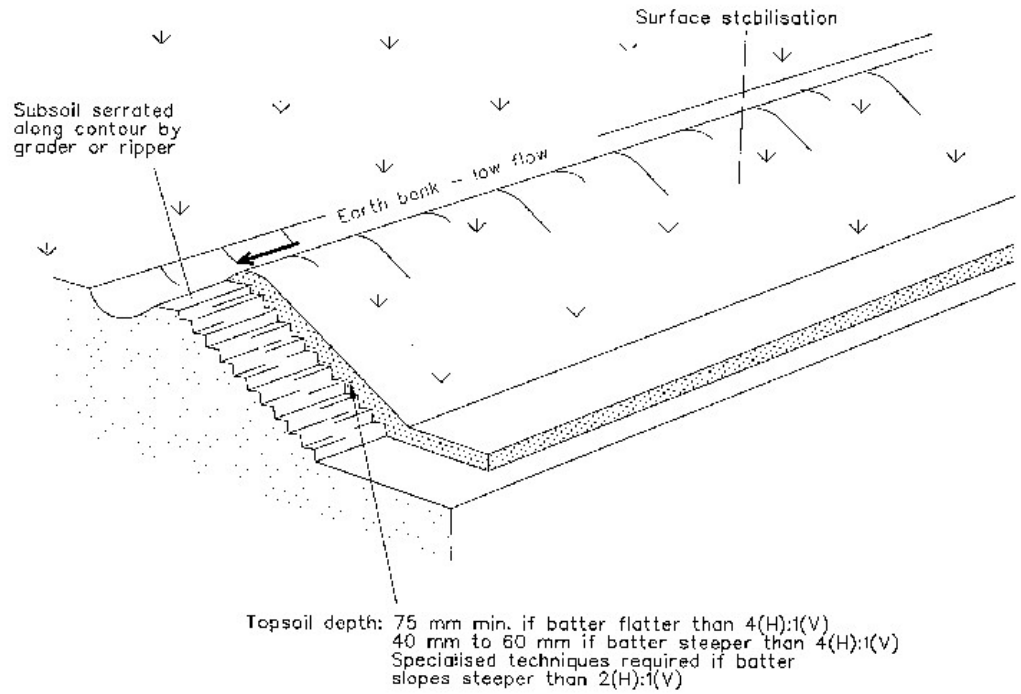


Construction Notes

1. Place stockpiles more than 2 (preferably 5) metres from existing vegetation, concentrated water flow, roads and hazard areas.
2. Construct on the contour as low, flat, elongated mounds.
3. Where there is sufficient area, topsoil stockpiles shall be less than 2 metres in height.
4. Where they are to be in place for more than 10 days, stabilise following the approved ESCP or SWMP to reduce the C-factor to less than 0.10.
5. Construct earth banks (Standard Drawing 5-5) on the upslope side to divert water around stockpiles and sediment fences (Standard Drawing 6-8) 1 to 2 metres downslope.

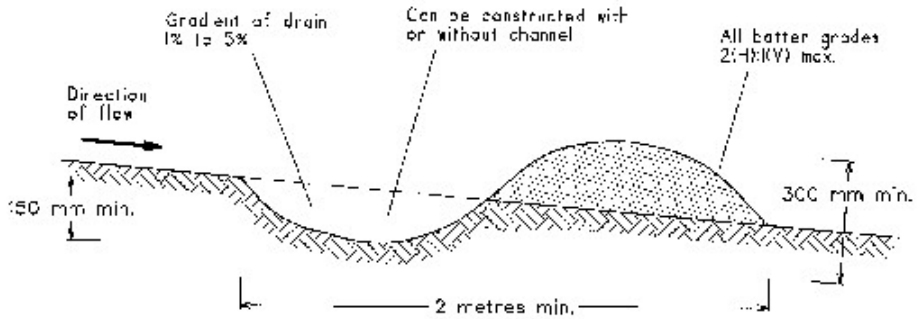
STOCKPILES **SD 4-1**



Construction Notes

1. Scarify the ground surface along the line of the contour to a depth of 50 mm to 100 mm to break up any hardsetting surfaces and to provide a good bond between the respread material and subsoil.
2. Add soil ameliorants as required by the ESCP or SWMP.
3. Rip to a depth of 300 mm if compacted layers occur.
4. Where possible, replace topsoil to a depth of 40 to 60 mm on lands where the slope exceeds 4(H):1(V) and to at least 75 mm on lower gradients.

REPLACING TOPSOIL **SD 4-2**

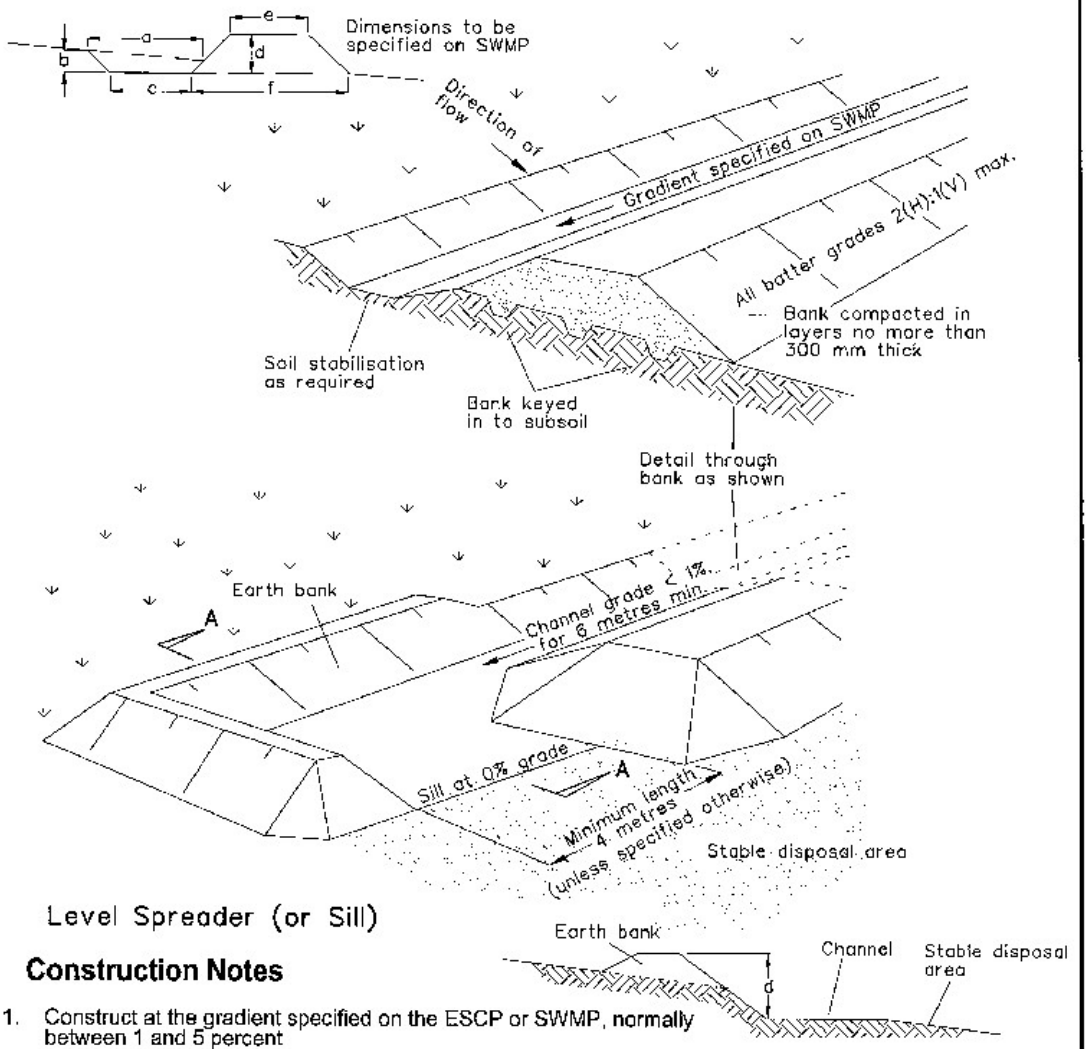


NOTE: Only to be used as temporary bank where maximum upslope length is 80 metres.

Construction Notes

1. Build with gradients between 1 percent and 5 percent.
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V shaped.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction.

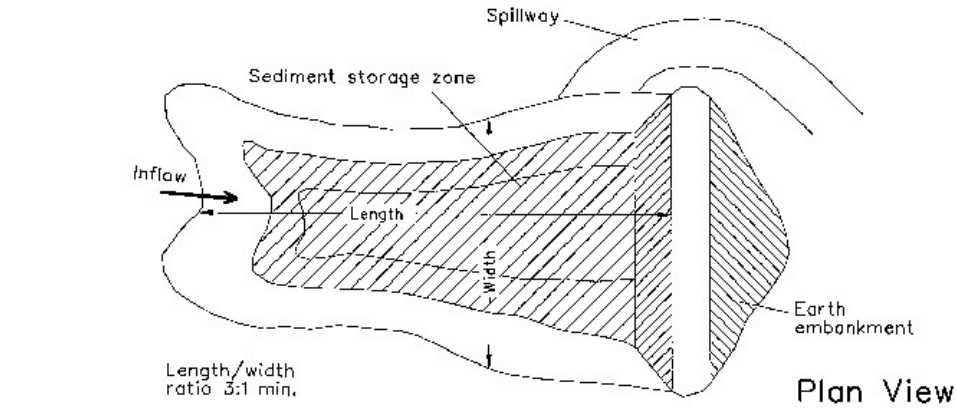
EARTH BANK (LOW FLOW) **SD 5-5**

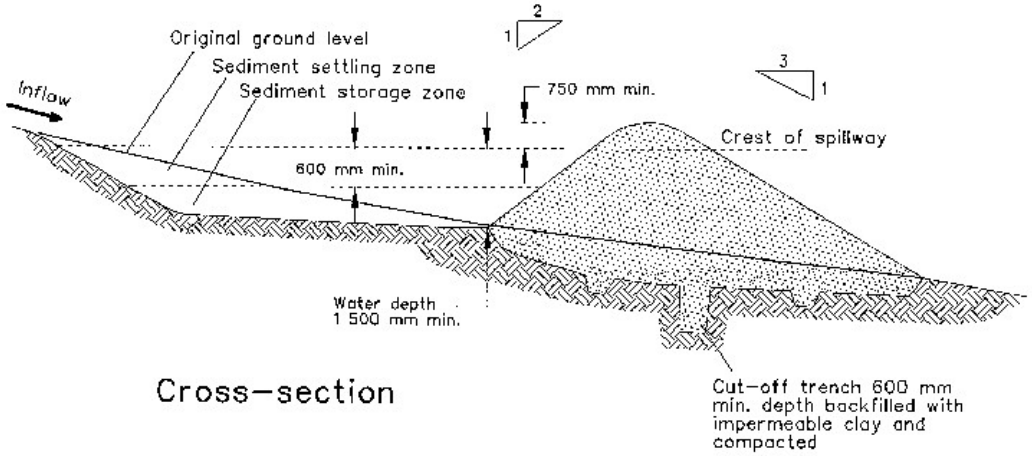


Construction Notes

1. Construct at the gradient specified on the ESCP or SWMP, normally between 1 and 5 percent
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V-shaped, at the dimensions shown on the SWMP.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction following Table 5.2 in Landcom (2004).
7. Where discharging to erodible lands, ensure they outlet through a properly constructed level spreader.
8. Construct the level spreader at the gradient specified on the ESCP or SWMP, normally less than 1 percent or level.
9. Where possible, ensure they discharge waters onto either stabilised or undisturbed disposal sites within the same subcatchment area from which the water originated. Approval might be required to discharge into other subcatchments.

EARTH BANK (HIGH FLOWS) **SD 5-6**



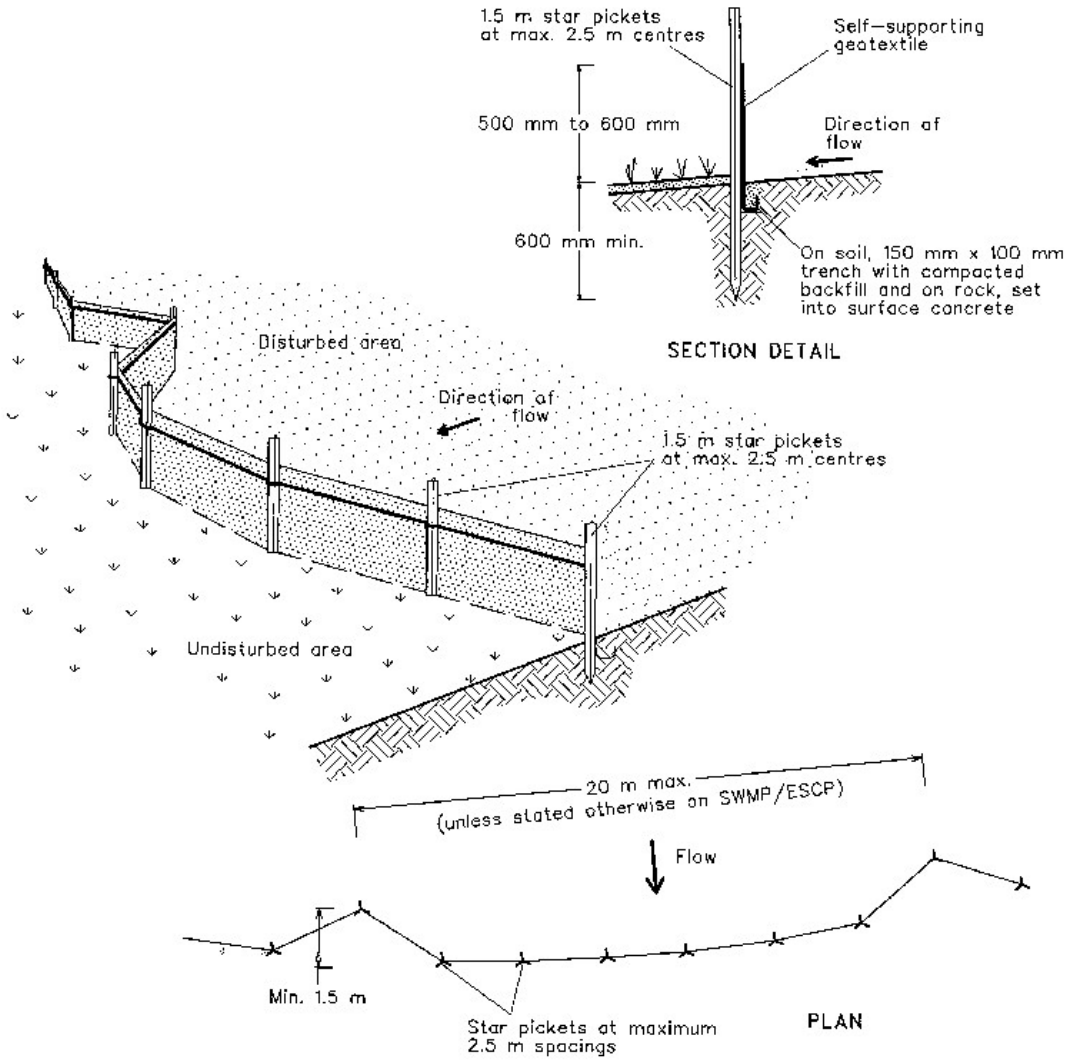


Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET
(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

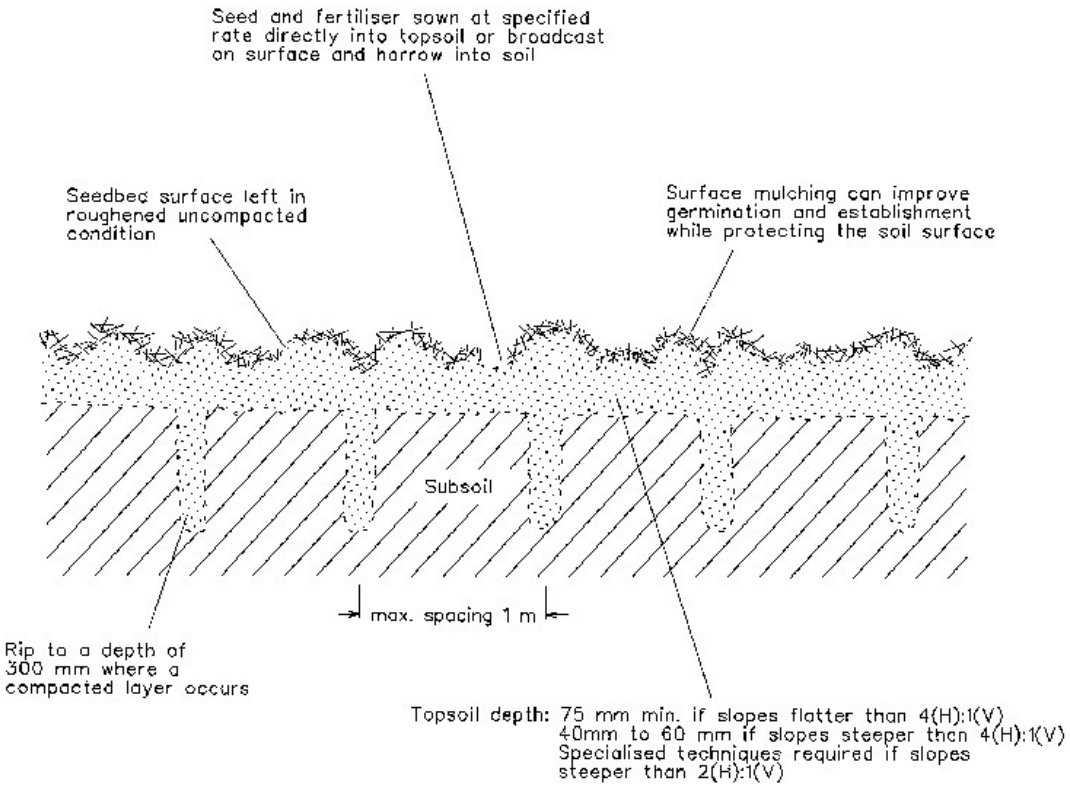
SD 6-4



Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE **SD 6-8**



Construction Notes

1. Loosen compacted soil before sowing any seed. If necessary, rip the soil to a depth of 300 mm. Avoid rotary hoe cultivation.
2. Work the ground only as much as necessary to achieve the desired tilth and prepare a good seedbed.
3. Avoid cultivation in very wet or very dry conditions.
4. Cultivate on or close to the contour where possible, not up and down the slope.

SEEDBED PREPARATION **SD 7-1**

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Appendix 3

Sediment Basin and Diversion Drain Calculations

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SWMP Commentary, Detailed Calculations

Note: These "Detailed Calculation" spreadsheets relate only to high erosion hazard lands as identified in figure 4.6 or where the designer chooses to use the RUSLE to size sediment basins. The "Standard Calculation" spreadsheets should be used on low erosion hazard lands as identified by figure 4.6 and where the designer chooses not to run the RUSLE in calculations.

1. Site Data Sheet

Site Name: Nowra Brickworks

Site Location: Princes Highway, South Nowra

Precinct: Whole Site

Description of Site: Brickworks Quarry

Site area	Sub-catchments						Remarks
	SB1	SB2	DD1				
Total catchment area (ha)	12	12	12				
Disturbed catchment area (ha)	2.5						

Soil analysis (enter sediment type if known, or laboratory particle size data)

Sediment Type (C, F or D) if known:	D	D	D				From Appendix C
% sand (fraction 0.02 to 2.00 mm)							Soil texture should be assessed through mechanical dispersion only. Dispersing agents (e.g. Calgon) should not be used
% silt (fraction 0.002 to 0.02 mm)							
% clay (fraction finer than 0.002 mm)							
Dispersion percentage							E.g. enter 10 for dispersion of 10%
% of whole soil dispersible							See Section 6.3.3(e). Auto-calculated
Soil Texture Group	D	D	D				Automatic calculation from above

Rainfall data

Design rainfall depth (days)	20	20	20				See Sections 6.3.4 (d) and (e)
Design rainfall depth (percentile)	75	75	75				See Sections 6.3.4 (f) and (g)
x-day, y-percentile rainfall event	72	72	72				See Section 6.3.4 (h)
Rainfall R-factor (if known)	4230	4230	4230				See Appendix B
IFD: 2-year, 6-hour storm (if known)							See IFD chart for the site

RUSLE Factors

Rainfall erosivity (*R*-factor)	4230	4230	4230				Auto-filled from above
Soil erodibility (*K*-factor)	0.055						RUSLE LS factor calculated for a high rill/interrill ratio.
Slope length (m)	80						
Slope gradient (%)	2						
Length/gradient (*LS*-factor)	0.41						
Erosion control practice (*P*-factor)	1.3	1.3	1.3	1.3	1.3	1.3	
Ground cover (*C*-factor)	1	1	1	1	1	1	

Calculations

Soil loss (t/ha/yr)	123						
Soil Loss Class	1						See Section 4.4.2(b)
Soil loss (m^3/ha/yr)	95						
Sediment basin storage volume, m^3	40						See Sections 6.3.4(i) and 6.3.5 (e)

SWMP Commentary, Detailed Calculations

2. Storm Flow Calculations

Peak flow is given by the Rational Formula:

$$Qy = 0.00278 \times C_{10} \times F_Y \times I_{y,tc} \times A$$

where:
- Q_y is peak flow rate (m^3/sec) of average recurrence interval (ARI) of "Y" years
- C_{10} is the runoff coefficient (dimensionless) for ARI of 10 years. Rural runoff coefficients are given in Volume 2, figure 5 of Pilgrim (1998), while urban runoff coefficients are given in Volume 1, Book VIII, figure 1.13 of Pilgrim (1998) and construction runoff coefficients are given in Appendix F
- F_y is a frequency factor for "Y" years. Rural values are given in Volume 1, Book IV, Table 1.1 of Pilgrim (1998) while urban coefficients are given in Volume 1, Book VIII, Table 1.6 of Pilgrim (1998)
- A is the catchment area in hectares (ha)
- $I_{y,tc}$ is the average rainfall intensity (mm/hr) for an ARI of "Y" years and a design duration of "tc" (minutes or hours)

Time of concentration (t_c) = $0.76 \times (A/100)^{0.38}$ hrs (Volume 1, Book IV of Pilgrim, 1998)

Note: For urban catchments the time of concentration should be determined by more precise calculations or reduced by a factor of 50 per cent. Place an x in the appropriate column below to automatically halve the time of concentration for that sub-catchment.

Peak flow calculations, 1

Site	A (ha)	Place an x here to halve tc	tc (mins)	Rainfall intensity, I, mm/hr						C_{10}
				$1_{yr,tc}$	$5_{yr,tc}$	$10_{yr,tc}$	$20_{yr,tc}$	$50_{yr,tc}$	$100_{yr,tc}$	
SB1	12	X	10	82	136	153	175	205	228	0.88
SB2	12		20	60	101	115	133	157	175	0.8
DD1	12		20	60	101	115	133	157	175	0.8

Peak flow calculations, 2

ARI (yrs)	Frequency factor (F_y)	Peak flows						Comments
		SB1 (m^3/s)	SB2 (m^3/s)	DD1 (m^3/s)	(m^3/s)	(m^3/s)	(m3/s)	
1 yr,tc	0.8	1.926	1.281	1.281				
5 yr,tc	0.95	3.793	2.561	2.561				
10 yr,tc	1	4.492	3.069	3.069				
20 yr,tc	1.05	5.394	3.727	3.727				
50 yr,tc	1.15	6.921	4.819	4.819				
100 yr,tc	1.2	8.032	5.604	5.604				

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MORSE McVEY

SWMP Commentary, Detailed Calculations

4. Volume of Sediment Basins, *Type D* and *Type F* Soils

Basin volume = settling zone volume + sediment storage zone volume

Settling Zone Volume

The settling zone volume for *Type F* and *Type D* soils is calculated to provide capacity to contain all runoff expected from up to the y-percentile rainfall event. The volume of the basin's settling zone (V) can be determined as a function of the basin's surface area and depth to allow for particles to settle and can be determined by the following equation:

$$V = 10 \times C_v \times A \times R_{x\text{-day, y-\%ile}} \ (m^3)$$

where:

10 = a unit conversion factor

C_v = the volumetric runoff coefficient defined as that portion of rainfall that runs off as stormwater over the x-day period

$R_{x\text{-day, y-\%ile}}$ = is the x-day total rainfall depth (mm) that is not exceeded in y percent of rainfall events. (See Sections 6.3.4(d), (e), (f), (g) and (h)).

A = total catchment area (ha)

Sediment Storage Zone Volume

In the detailed calculation on Soil Loss Classes 1 to 4 lands, the sediment storage zone can be taken as 50 percent of the settling zone capacity. Alternately designers can design the zone to store the 2-month soil loss as calculated by the RUSLE (Section 6.3.4(i)(ii)). However, on Soil Loss Classes 5, 6 and 7 lands, the zone must contain the 2-month soil loss as calculated by the RUSLE (Section 6.3.4(i)(iii).

Place an "X" in the box below to show the sediment storage zone design parameters used here:

	50% of settling zone capacity,
X	2 months soil loss calculated by RUSLE

Total Basin Volume

Site	C_v	$R_{x\text{-day, y-\%ile}}$	Total catchment area (ha)	Settling zone volume (m^3)	Sediment storage volume (m^3)	Total basin volume (m^3)
SB1	0.70	72	12	6048	40	6088
SB2		72	12			
DD1		72	12			

Note that designers should achieve a minimum 3:1 length:width ratio in Type D or F basins

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Appendix 4

Flocculation

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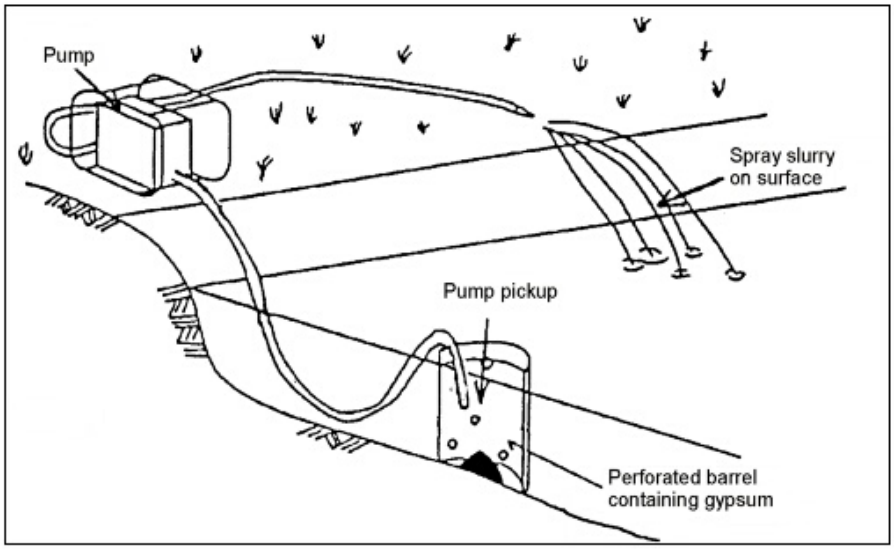
The soils at this site are classified as dispersible. Dispersible soils are those where the clay and fine silt particles (<0.005 mm) are in a state of separation into extremely fine colloidal units. Effectively, these particles can remain suspended in water forever. Flocculation reverses this state by causing the colloidal particles to clump into larger units or "flocs" that can either settle in a reasonable time or be filtered. SCA require entrained runoff to be flocculated before release to the surrounding environment. Runoff must be flocculated to achieve less than or equal to 50 mg/L of suspended solids.

Flocculation may be achieved by using gypsum at a rate of approximately 40 kg/100 m3 of stormwater. Gypsum, if used properly at this rate, will not detrimentally effect the surrounding environment.

Stormwater in the sediment basin should be flocculated after each storm event and before release to the surrounding environment. It is essential that the flocculating agent is spread evenly over the entire pond surface for proper treatment of water unless local experience or other criteria suggest differently—see the figure below.

The application rate should be calibrated after the first two storm events to assess the actual flocculent application rate and settling time required. The final application rate should be sufficiently high to permit sediment flocculation and pond discharge within two to four days from the conclusion of each storm event. The water can be discharged from the basin once the suspended solid load has been lowered to an acceptable level. Achieve discharge with a system that:

1. permits drainage of the pond in less than 24 hours; and
2. has a floating inlet to prevent flocculated sediments being removed as well—it is essential that materials from the sediment layer are not discharged in the pumping process.



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