Flood Management Plan

Menangle Sand and Soil Quarry

Prepared for Menangle Sand and Soil Pty Ltd
April 2021

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Menangle Sand and Soil Quarry

Flood Management Plan

Report Number

J190166 RP28

Client

Menangle Sand and Soil Pty Ltd

Date

1 April 2021

Version history

Version	Date	Prepared by	Approved by	Comments
v1	4 March 2021	Jason O'Brien	Nick Bartho	Draft for DPIE review
v2	1 April 2021	Jason O'Brien	Philip Towler	Updated based on DPIE review

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1 Introduction

1.1 Context

Menangle Sand and Soil Pty Ltd (Menangle Sand and Soil) operates the Menangle Sand and Soil Quarry at 15 Menangle Road, Menangle. The location and regional context of the quarry is shown in Figure 1.1. Quarrying has been undertaken in the location for over 40 years by a number of operators and at varying rates of production. Extraction, processing and rehabilitation activities have been undertaken by Menangle Sand and Soil since 1978.

The quarry, located in the Wollondilly local government area (LGA), extracts sand and soil along the Nepean River as approved by Development Consent 85/2865, granted by the Minister for Planning on 15 November 1989.

Extractive activities have involved the construction and operation of the quarry in seven stages. Sand and soil has been extracted from Stages 1 to 2 and 4 to 7 (Figure 1.2). While previously approved, sand and soil will not be extracted from Stage 3.

1.2 Background

On 10 September 2020, the NSW Land and Environment Court (LEC) approved the Menangle Quarry Extension – Modification 1 (MOD1) to Development Consent 85/2865. Approval conditions are provided in the Notice of Orders for LEC 2018/342158 (the Approval).

The Approval allows the extraction of sand and soil in a new area, the Stage 8 area (Figure 1.2), that is about 13 hectares (ha), and extends about 2 kilometres (km) along the Nepean River south of the Stage 7 area. The quarry is approved to extract 760,000 tonnes of sand and soil from the Stage 8 area at a rate of up to 150,000 tonnes per annum (tpa) and over 15 years.

The extracted material will be transported to the processing area where it will be stockpiled, processed and blended with materials imported to the site, prior to being dispatched from the quarry.

The Extension Project (as approved by Modification 1) will extend the life of the quarry by 15 years.

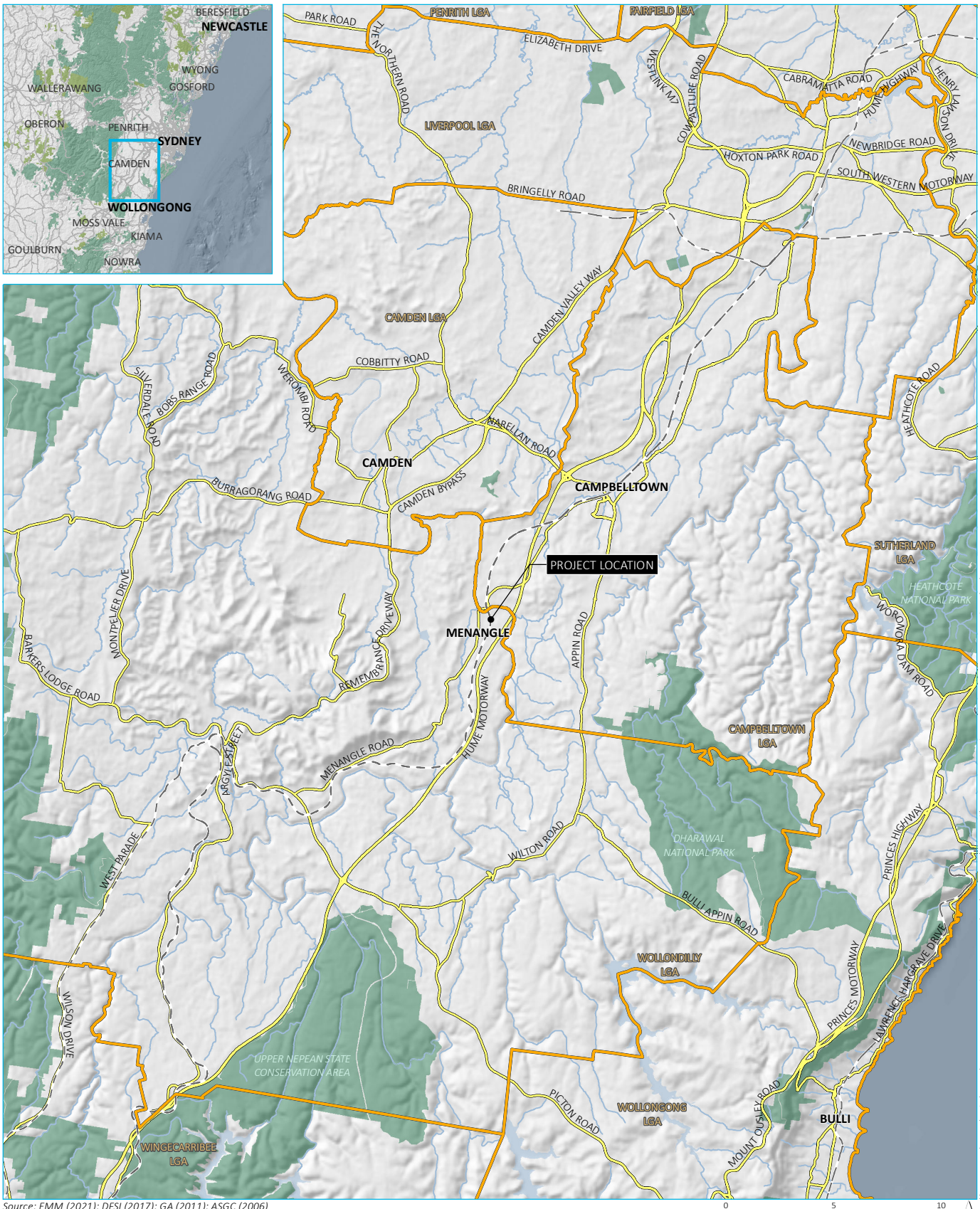
An Environmental Management Strategy (EMS) presenting the environmental management framework the quarry and has been prepared (EMM 2021a) to address the Approval conditions.

This Flood Management Plan (FMP) forms part of the overall EMS.

1.3 Project overview

As well as the extraction areas, key components of the quarry include:

- a wheel wash and weighbridge;
- a site office and amenity building, and a workshop west of the site office;
- fuel supply tanks north of the storage shed;
- sand and soils storage and processing area; and
- other minor infrastructure.



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

0 5 10 km

GDA 1994 MGA Zone 56

N

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KEY

- Rail line
- Major road
- Named watercourse
- Named waterbody
- Local government area
- NPWS reserve

INSET KEY

- Main road
- State forest

Project location

Menangle Quarry
Figure 1.1

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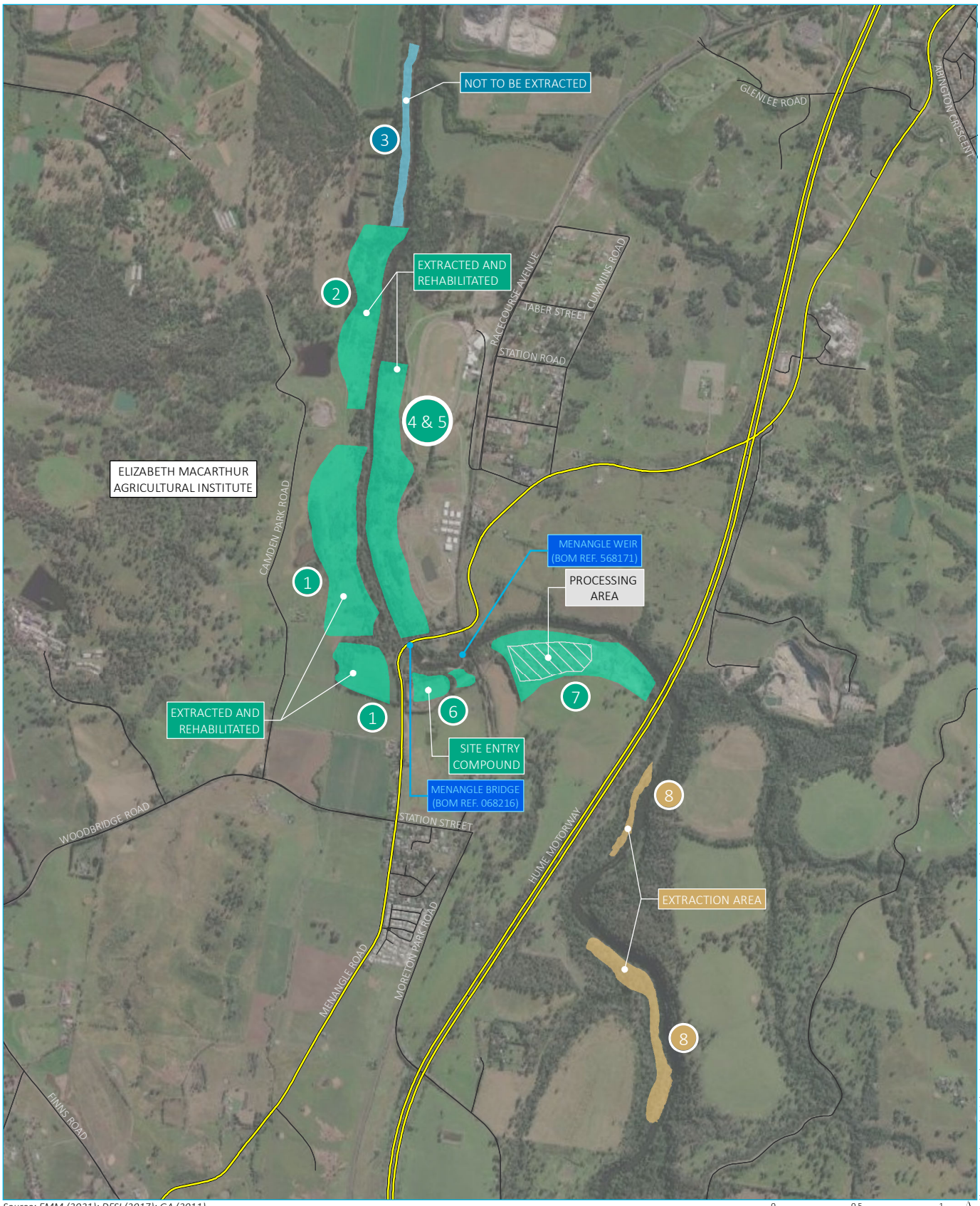

Source: EMM (2021); DFSI (2017); GA (2011)

0 0.5 1 km

GDA 1994 MGA Zone 56

N

KEY

- Main road
- Local road
- Processing area
- Stages 1-2 and 4-7
- Stage 3 (not to be extracted)
- Stage 8 - extraction/rehabilitation area

Menangle Quarry Stages 1 to 8

Menangle Quarry Extension
Flood management plan
Figure 1.3

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These components will be used to support activities in the Stage 8 area which include:

- extraction in the Stage 8 extraction area followed by rehabilitation;
- restoration of areas adjacent to the extraction areas;
- a conveyor (if required); and
- internal haul roads.

1.4 Operations

1.4.1 Activities

Operations at the quarry comprise of the following activities:

- vegetation management and clearance;
- sand and soil excavation;
- material transport by off-road haul truck and/or conveyor;
- sorting and screening of excavated material;
- processing of excavated material;
- blending of excavated material with imported materials (permitted by the Approval and EPL 3991);
- stockpiling;
- loading of product into trucks; and
- product dispatch via trucks.

1.4.2 Operating hours

The quarry will operate during the approved hours in accordance with development consent Table 1, Condition A26, as reproduced in Table 1.1 below.

Table 1.1 Operating hours

Activity	Permissible hours
Construction work	• 7 am to 5 pm Monday to Friday • 7 am to 1 pm Saturday • At no time on Sundays or public holidays
Quarrying operations including loading and dispatch of laden trucks	• 6 am to 5 pm Monday to Friday • 6 am to 12 noon Saturday • At no time on Sundays or public holidays
Maintenance, security, office work, cleaning, etc.	• May be conducted at any time, provided that these activities are not audible at any residence on privately-owned land

1.5 Purpose and objectives

EMM Consulting Pty Limited (EMM) has been engaged by Menangle Sand and Soil to prepare this FMP in accordance with Approval Condition B32.

The FMP addresses flood risk management for the Stage 8 extraction area, processing area and site office area. The FMP identifies potential flood risks and management measures during extraction and rehabilitation of the final landform. The overall objectives of the FMP are to:

- describe how flood emergency response will be managed for the active extraction area, processing area and site entry compound;
- ensure the safety of site personnel by providing procedures to prepare for and respond to flood events that may inundate the active extraction area, processing area and site entry compound;
- ensure appropriate controls and procedures are implemented to minimise potential adverse impacts to the environment from flooding of the active extraction area and processing area; and
- implement the flood management commitments made in the *Menangle Quarry Extension Environmental Assessment* (EMM 2017a), the *Menangle Quarry Extension Response to Submissions* (EMM 2017b), and as updated by further commitments made during the LEC Proceedings 342158 of 2018 as described in the *Applicant's Description of Amended Project* (EMM 2020).

Menangle Sand and Soil will not commence quarrying operations in the Stage 8 Area until thus FMP is approved by the Planning Secretary.

Menangle Sand and Soil will implement the FMP as approved by the Planning Secretary.

1.6 Report preparation

This FMP has been prepared by Nick Bartho and Jason O'Brien. Nick holds a Bachelor of Engineering (Civil and Environmental) (Hons) and is EMM's Surface Water Team Leader. Nick has 19 years' experience as a water resources engineer, specialising in hydrologic and hydraulic modelling, flood impact assessment and flood risk management, including flood emergency and response planning. Jason holds a Bachelor of Engineering (Environmental) (Hons). Jason has five years' experience working as an environmental and water resources engineer, specialising in surface water assessments, water management plans, flood impact assessment, hydrologic and hydraulic modelling and stormwater drainage investigations.

1.7 Consultation

There is no requirement in the Approval for formal consultation during preparation of this FMP.

The FMP will be provided to the NSW State Emergency Service (SES) and Wollondilly Shire Council.

2 Environmental requirements

2.1 Legislation, plans and guidelines

The FMP provides recommended flood management measures for the quarry. The FMP has been prepared to address the Approval conditions (refer Section 2.3).

The following legislation is relevant to the scope of the FMP:

- *Environmental Planning and Assessment Act 1979* (EP&A Act);
- *Protection of the Environment Operations Act 1997* (POEO Act);
- *State Emergency Service Act 1989*; and
- *State Emergency and Rescue Management Act 1989*.

The FMP has been developed consistent with the principles contained in the following guidelines:

- *Floodplain Development Manual: the management of flood liable land* (DIPNR 2005) (FDM);
- *Australian Rainfall and Runoff* (Ball et al. 2019) (ARR2019);
- *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004); and
- *Managing Urban Stormwater: Soils and Construction – Volume 2E – mines and quarries* (DECC 2008).

2.2 Existing flood risk management planning

The FMP has been developed with consideration of existing formal plans that relate to flood risk management and emergency response in the Wollondilly LGA.

There is no existing floodplain risk management study or plan that relates to the quarry site. Wollondilly Shire Council are in the process of undertaking an LGA-wide flood study to better understand flooding across the whole of the LGA. It is expected the flood study will inform a future floodplain risk management plan for the Wollondilly LGA which will include the quarry area.

Flood emergency response in the LGA is guided by the *Wollondilly Shire Flood Emergency Sub Plan* (SES 2015), which is relevant to the quarry and outlines the roles and responsibilities of the SES and supporting agencies in management of flood events.

2.3 Project consent conditions

Table 2.1 lists the requirements of the Approval conditions relevant to flood management and references the section of the FMP where each requirement has been addressed.

Table 2.1 Requirements of the Approval conditions

Condition Number	Condition	Relevant section of FMP
Flood Management		
B32	The Applicant must prepare a Flood Management Plan for the development to the satisfaction of the Planning Secretary. This plan must:	
	(a) be prepared by suitably qualified and experienced person/s;	Section 1.6
	(b) identify measures to:	
	(i) proactively prepare for, and respond to, any flood event in which the active extraction area is likely to be inundated by floodwaters emanating from the Nepean River;	Section 5.4
	(ii) ensure the safety of site personnel;	Table 5.1
	(iii) minimise, to the greatest extent practicable, the areas of exposed ground on the site that would be susceptible to flood risks (including scour and erosion and potential transport of sediment to downstream waters);	Section 5.4.3
	(iv) ensure that the active extraction area in any Substage does not exceed 0.33 hectares at any one time;	Table 5.1
	(v) ensure that the batter adjacent to the Nepean River Buffer Zone does not exceed: a maximum slope of 1:1 at any time; and a maximum slope of 1:5 in preparation for flood events;	Section 5.3.1
	(vi) ensure that no more than a 30 metres length of the batter adjacent to the Nepean River Buffer Zone (measured in total) has a slope exceeding 1:5 at any one time; and	Section 5.3.1
	(vii) rectify any flood-related damage to areas undergoing rehabilitation; and	Table 5.1
	(c) include a Trigger Action Response Plan which outlines actions to be undertaken in preparation for, and immediately following, a flood event including detailed protocols and timeframes for:	-
	(i) backfilling the active extraction area to achieve a maximum batter slope of 1:5 adjacent to the Nepean River Buffer Zone in preparation for flood events;	Table 5.2
	(ii) avoiding the downstream movement of debris from the site;	Table 5.2
	(iii) recommencing Quarrying Operations following a flood event; and	Table 5.2
	(iv) rectifying any damage to areas undergoing rehabilitation following a flood event.	Table 5.2
B33	The Applicant must not commence Quarrying Operations in the Stage 8 Area until the Flood Management Plan is approved by the Planning Secretary.	Section 1.5
B34	The Applicant must implement the Flood Management Plan as approved by the Planning Secretary.	-
B35	The Applicant must ensure that the flood storage capacity of the final rehabilitated landform is no less than the pre-existing flood storage capacity at all stages of the development, unless otherwise approved in writing by the Planning Secretary. Details of the available flood storage capacity must be reported in the Annual Review.	Section 5.5 Appendix B Appendix C

3 Existing environment

3.1 Setting

The quarry is located in a semi-rural environment in the southwest of the Greater Sydney Metropolitan Region (refer Figure 1.1). The surrounding land use includes scattered rural residential properties, agriculture and other extractive industry. The residential suburb of Menangle is located about 1 km to the south of the site entry compound and processing area (refer Figure 1.2).

The site entry compound and processing area is located on the southern bank of the Nepean River, to the east and downstream of the Hume Motorway. The ground surface elevation of these areas increases from approximately 61 m Australian Height Datum (AHD) at the bottom of the Nepean River riverbank to approximately 70 m AHD at the southern boundary of the processing area. The terrain is terraced with lower elevations adjacent to the Nepean River and higher elevations forming the processing area.

The Stage 8 extraction area is located along the western side of the Nepean River to the south of the processing area, upstream of the Hume Motorway. The topography of the Stage 8 extraction area is steeper than for the processing area, with a pronounced slope climbing up from the Nepean River to the eastern side of the Hume Motorway. Extraction within the Stage 8 area will require cutting into this slope to remove sand and soil resources. The slope is generally milder at the northern end of the Stage 8 area, increasing in steepness to the south.

3.2 Flooding mechanisms

The quarry is subject to inundation as a result of two primary flooding mechanisms:

1. mainstream flooding along the Nepean River; and

2. local tributary flooding and overland flows.

The focus of this FMP is on the more substantial risks to safety, operations and the environment posed by Nepean River flooding, however local tributary flooding and overland flows are also addressed.

3.2.1 Nepean River flooding

The quarry is located on the floodplain of the Nepean River. The Nepean River is a major perennial watercourse and forms part of the greater Hawkesbury-Nepean system. The Nepean River has a catchment area of 1,280 km^2 upstream of the Menangle Weir (WorleyParsons 2015) and is comprised of mixed land use including residential, agricultural, conservation and drinking water catchment.

The Nepean River forms the northern boundary of the processing area and is to the east of the Stage 8 extraction area. Mainstream flooding along the Nepean River, with river levels sufficiently high to overtop the riverbank and inundate parts of the site entry compound and processing area, as well as the Stage 8 extraction areas, is expected to occur periodically. Given the large upstream catchment, flooding of this magnitude occurs as a result of prolonged rainfall events, typically over a period of 24 hours or more. This is likely to be associated with large scale weather systems such as east coast lows and other significant low-pressure systems affecting the broader Sydney basin.

Nepean River height data obtained from the Menangle Weir gauging station (Station 212238, located approximately 2.5 km downstream of Stage 8) indicates the river is highest in July and lowest in February, noting that river flows are likely affected by upstream control structures that include the Avon, Cordeaux, Nepean and Cataract Dams as well as Pheasants Nest and Broughtons Pass Weirs.

3.2.2 Local tributary flooding and overland flows

The local hydrologic context for the quarry is shown in Figure 3.1. Figure 3.1 shows the location of several minor unnamed watercourses that are tributaries of the Nepean River and which run in close proximity to the site entry compound, processing area and Stage 8 extraction area. All of these unnamed watercourses have an ephemeral flow regime.

Watercourse A is a first order stream that flows generally north adjacent to the site entry compound. The watercourse is piped beneath the access road linking the site entry to the processing area. The contributing catchment area is about 51 ha and is comprised primarily of rural grassland with a small area of residential development on the northern fringe of Menangle.

Watercourse B is a second order stream that flows generally to the north adjacent to the processing area. Watercourse B rises approximately 4 km south of the processing area and has a catchment area of about 294 ha. The catchment is primarily comprised of rural grassland with some scattered treed areas and includes parts of the Hume Motorway and Southern Rail Line corridors as well as a small area of residential development at Menangle.

Watercourse C is a second order stream that flows generally to the north and intersects the proposed Stages 8E, 8F and 8G extraction areas. Watercourse C rises approximately 3 km south of the Stage 8 extraction area and has a catchment area of about 166 ha. The catchment is primarily comprised of rural grassland with some scattered treed areas.

An Ephemeral Creek Management Plan will be developed in future specifically for Watercourse C prior to commencement of quarrying in Stages 8E, 8F and 8G in accordance with Approval Condition B40. This may include additional management measures relevant to local flood risk for these stages.

3.3 Flooding conditions and risks

3.3.1 Sources of data

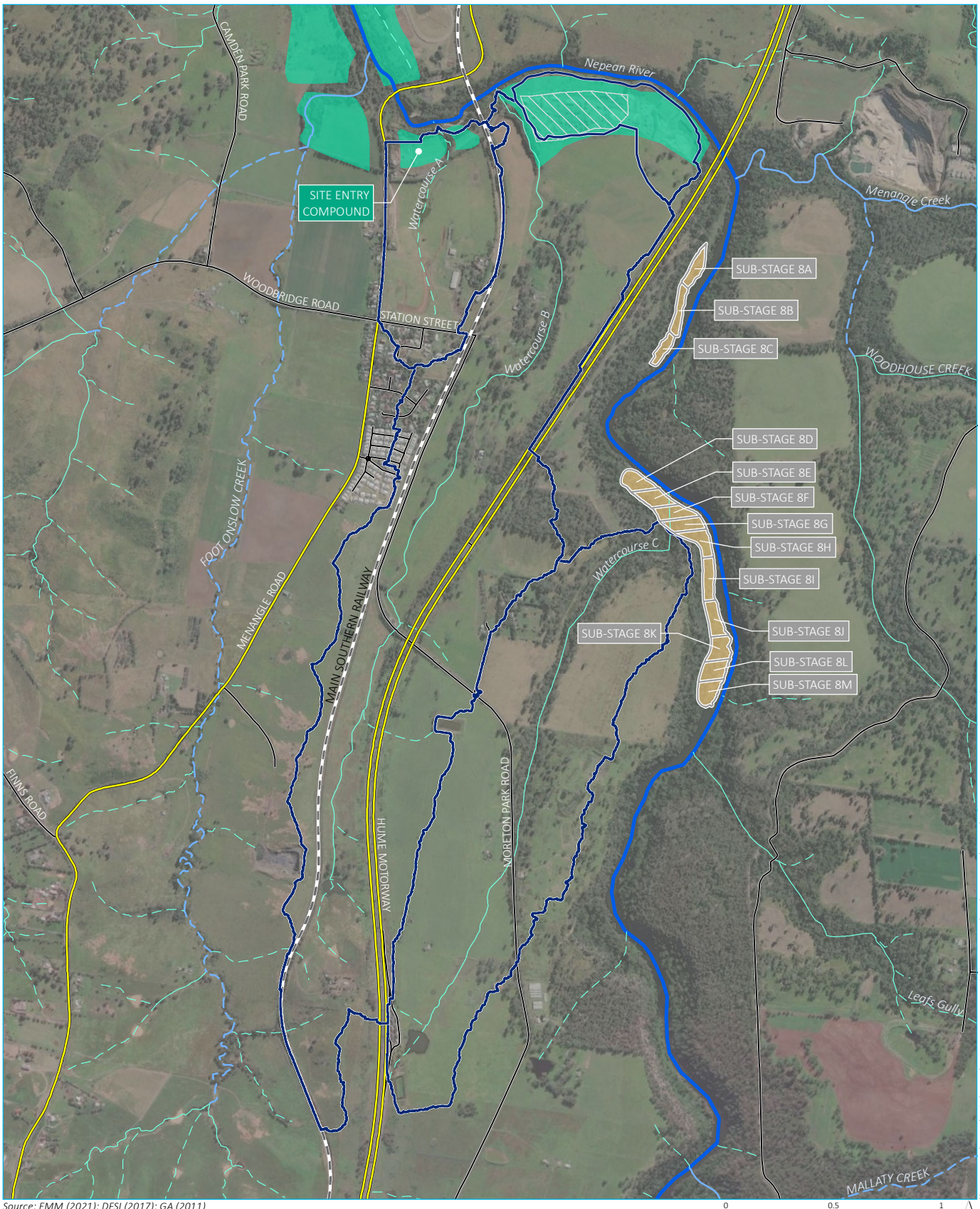
Various flooding investigations have been carried out that inform understanding of Nepean River flooding conditions and risks at the quarry, including during the recent LEC proceedings.

Key sources of data that inform this FMP comprise:

- *Nepean River Flood Study* (WorleyParsons 2015) – this report describes mainstream flooding conditions and risks for areas downstream of the Hume Motorway, including the site entry compound and processing area.

- *Menangle Quarry Extension – Flood Impact Sensitivity Assessment* (Advisian 2019) – this report describes mainstream flooding conditions, risks and predicted impacts associated with the Stage 8 extraction areas, which are located upstream of the Hume Motorway.

The TUFLOW hydrodynamic model used to inform the *Flood Impact Sensitivity Assessment* (Advisian 2019) was modified by Advisian in December 2020 to assess the post extraction topography for all substages using hydraulic roughness Scenario B as per Approval Condition A14. The resulting 1% annual exceedance probability (AEP) flood results for substages 8A–8C, 8D–8G and 8H–8M are provided in Appendix B along with existing conditions flood mapping.



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

0 0.5 1 km

GDA 1994 MGA Zone 56

N

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KEY

- Existing processing area (to be retained)
- Substage boundary
- Stage 8 - extraction/rehabilitation area
- Extractive operations
- Rail line
- Main road
- Local road
- Catchment boundary

Strahler stream order

- 1st order
- 2nd order
- 3rd order
- 4th order
- 7th order

Local watercourses and catchment

Menangle Quarry Extension
Soil and water management plan
Figure 3.2

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3.3.2 Nepean River flooding

i Description of flooding conditions

A summary of mainstream flooding conditions for a range of design flood events, including peak flood levels relevant to the quarry, is provided in Table 3.1. This describes the progressive inundation of parts of the quarry, from the 50% AEP up to the probable maximum flood (PMF).

For context, a flood with an AEP of 50% is a relatively frequent event that could be expected to occur on average once every 1 to 2 years. The PMF is the largest conceivable flood that could occur at a given location, and is an extremely rare event with an approximate AEP in the order of once in 100,000 to 1,00,000 years.

Table 3.1 Summary of mainstream flood conditions and peak flood levels for the quarry

Event	Peak flood levels (m AHD)			Description of flood conditions
	Menangle Weir	Hume Motorway	Stage 8[1]	
50% AEP[2]	69.5	69.7	69.7–69.9	• Inundation of all Stage 8 extraction areas, which are protected up to an elevation of 64.0 m AHD. • Inundation of the processing area water management dams and historic excavation area. • Access road from quarry entrance to processing area is inundated near Watercourse A at a Menangle Wier water level of approximately 66 m AHD. • Inundation of Menangle Road heading south of quarry access point.
20% AEP[3]	74.0	-	-	As above, plus: • Inundation of the processing area stockpiles and processing plant commences at a Menangle Weir water level of approximately 69 m AHD. • Complete inundation of the processing area is experienced at a Menangle Weir water level of 74 m AHD.
5% AEP[2]	76.1	76.8	77.0–78.0	As above, plus: • Inundation of site offices and Menangle Road heading north of quarry access point. This effectively results in complete inundation of the quarry.
1% AEP[2]	77.9	78.6	78.8–80.7	• Complete inundation of quarry.
PMF[3]	82.0	> 82.0[4]	> 82.0[4]	• Complete inundation of quarry.

Notes: 1. Flood level range for Nepean River between Stage 8A and Stage 8G extraction zones.
2. Flood level provided by Advisian (22 April 2020) in relation to *Menangle Quarry Extension – Flood Impact Sensitivity Assessment* (Advisian 2019).
3. Flood level sourced from *Nepean River Flood Study* (WorleyParsons 2015).
4. Flood level estimated.

For floods of progressively larger magnitude, which by definition, will occur progressively less frequently, floodwaters will:

- inundate all Stage 8 extraction areas (which are protected up to an elevation of 64 m AHD) and lower lying parts of the processing area for the 50% AEP and larger floods;
- inundate the higher elevated parts of the processing area (ie where stockpiling occurs and processing plant is located) for the 20% AEP and larger floods; and

- inundate the area around the site entry compound for the 5% AEP and larger floods.

All areas of the quarry operation, including the site entry compound, processing area and all Stage 8 extraction areas, will be inundated for the 5% AEP and larger floods.

Internal access roads will start to be impacted from floods around 50% AEP. Local roads providing access to and egress from the quarry, including Menangle Road, are also expected to be impacted from floods around 50% AEP.

The flood level adjacent to Stage 8 is shown to be higher than the flood level at Menangle Wier. Table 3.1 shows the flood level at Stage 8A and Stage 8G is 0.3 m and 0.4 m above the Menangle Weir flood level for the 50% AEP event. Assuming a similar difference in flood levels occurs for smaller flood events, a flood level of 63.6 m AHD at Menangle Weir would correspond to a flood level of 64 m AHD adjacent to the Stage 8 extraction areas.

Appendix A contains flood mapping extracts from WorleyParsons (2015) that show predicted depths of flooding and provisional hazard for the 5% AEP, 1% AEP and PMF events. This is relevant to quarry areas downstream of the Hume Motorway, including the site entry compound and processing area.

Appendix A contains flood mapping extracts from Advisian (2019) that show predicted flood extents and flow velocity for the 5% and 1% AEP events. This is relevant to the Stage 8 extraction areas upstream of the Hume Motorway.

ii Flood risk characterisation

WorleyParsons (2015) classifies the low-lying areas of the quarry as 'floodway' and the higher elevation areas as 'flood storage'. Most of the quarry is categorised as 'high flood hazard' for flood events of 5% AEP magnitude and greater. The hazard categorisation is based on Figure L2 of the FDM, which was current at the time of the work. Effectively this approach determines flood hazard as a function of the depth and velocity of floodwaters. High flood hazard typically refers to conditions that are unsafe for people, vehicles and with potential for damage to structures.

Flood hazard categorisation for the quarry is not expected to be materially influenced by use of topographic data from 2011 to inform the flood modelling undertaken as part of WorleyParsons (2015), which excludes consideration of post 2011 landform changes within the processing area and Stage 7 extraction area.

iii Flood warning time

The critical storm duration for the Nepean River near the quarry ranges from 36 hours for flood events of 1% AEP magnitude and greater to 48 hours for flood events less than the 1% AEP (WorleyParsons 2015). Flood levels resulting from the critical storm are expected to remain elevated for a relatively long period of time. However, reasonable warning times are expected to be available identifying potential flood conditions in the river adjacent to the quarry.

Historical observations at the quarry indicate there is generally a minimum of 12 hours warning time preceding a flood event sufficiently large to impact the quarry. This provides sufficient time for some site preparation activities to prepare for a flood ahead of safe evacuation of areas potentially subject to inundation or isolation.

3.3.3 Local tributary flooding and overland flows

i Description of flood conditions and risks

There is no existing flood modelling that provides a detailed assessment of local tributary flooding conditions. However, the qualitative description of expected flooding conditions provided below is sufficient to inform appropriate and conservative management responses.

Flooding along Watercourse A will impact the site entry compound and internal site access road that links to the processing area further to the east. Flows from frequent storm events are piped under the site access road, however flows for larger and less frequent storms will overtop the road and likely prove impassable and prevent egress for a period of time. This is likely to be short given the relatively small size of the contributing catchment, in the order of minutes up to several hours depending on the intensity and duration of local rainfall.

Floodwaters that break out of Watercourse A may inundate parts of the site entry compound and impact infrastructure and facilities located in this area.

Flooding along Watercourse B will impact on the processing area and internal site access road. Floodwaters that break out of Watercourse B may encroach on the western portion of the processing area. However, the extent of inundation is likely to be localised as the topography indicates floodwaters preferentially drain north towards the Nepean River rather than east across the processing area. Flows from frequent storm events are piped under the site access road, however flows for larger and less frequent storms will overtop the road and likely prove impassable and prevent egress. Again, this is likely to be for a short period given the small size of the contributing catchment, in the order of minutes up to several hours depending on the intensity and duration of local rainfall.

Flooding along Watercourse C will impact on Stage 8 extraction areas, specifically Stages 8E, 8F and 8G. All runoff conveyed along Watercourse C and its floodplain will drain directly into the extraction areas and will need to be managed during quarrying. An Ephemeral Creek Management Plan will be developed in future specifically for Watercourse C prior to commencement of quarrying in Stages 8E, 8F and 8G in accordance with Condition B40 of the development consent. This may include additional management measures relevant to local flood risk for these stages.

Remote from Watercourse C, runoff impacting the remainder of the Stage 8 extraction area will be primarily comprised of shallow and low hazard overland flow generated in relatively small contributing catchments adjacent to the extraction areas.

ii Local tributary flood warning time

Available flood warning time from the onset of flood-producing rainfall over the local catchments is expected to be short and potentially in the order of 30 to 60 minutes due to the relatively fast runoff response likely to occur for small catchments.

This limits meaningful flood response to a focus on worker safety and to ensure the safe evacuation of areas potentially subject to inundation or isolation ahead of the flood.

4 Environmental aspects and impacts

4.1 Impact summary

Key environmental aspects, impacts and risks associated with flooding at the quarry are described in Table 4.1.

Table 4.1 Summary of environmental aspects and impacts

Aspect	Potential impact
Risks to worker safety	Floodwaters from either the Nepean River or local tributary flooding and overland flows will periodically overtop the riverbank, or exceed the capacity of water management infrastructure at the quarry (eg clean water diversions, culverts under access tracks, etc.) and result in risks to worker safety due to: • inundation of worksites; or • inundation of egress routes. These issues are addressed in the management measures identified in Section 5.
Risk of loss and/or damage to quarry infrastructure	Floodwaters from either the Nepean River or local tributary flooding and overland flows will periodically overtop the riverbank, or exceed the capacity of water management infrastructure at the quarry (eg clean water diversions, culverts under access tracks, etc.) and result in risk of loss and/or damage of ancillary facilities, quarrying equipment and plant. These issues are addressed in the management measures identified in Section 5.
Risk of downstream environmental impacts	Floodwaters from either the Nepean River or local tributary flooding and overland flows will periodically overtop the riverbank, or exceed the capacity of water management infrastructure at the quarry (eg clean water diversions, culverts under access tracks, etc.) and result in risk of environmental impacts due to: • scour and erosion of the active excavation landform and/or material stockpiles; and/or • potential transport of sediment, vegetation, plant/equipment, hazardous substances/chemicals and other debris downstream into the Nepean River due to entrainment in floodwaters. These issues are addressed in the management measures identified in Section 5.
Risk of offsite flooding impacts	Hydraulic analysis (Advisian 2019) has identified the potential to impact flood behaviour as a result of excavation activities. Impacts to flow characteristics within the Stage 8 extraction area and adjacent Nepean River channel may include: • increased area and depth of inundation; • increased flood storage; and • changes to flow velocities. The final landform plans provided in Appendix C show the quarry will not reduce the existing flood storage following extraction and hence no adverse offsite impacts are expected. These issues are addressed in the management measures identified in Section 5.

5 Environmental management measures

5.1 Overview

This section describes the specific flooding related measures and requirements to meet the objectives of this FMP (refer Section 1.4) and to address potential impacts resulting from flooding. The flooding related measures described in this section should be read in conjunction with Figure 5.1 which schematically shows the quarry method.

5.2 Horizontal setback

The level of the Nepean River adjacent to the Stage 8 area is controlled by the downstream Menangle Weir to be about 61 m AHD during normal low flow. A horizontal setback will be implemented to separate the active extraction area from the Nepean River as follows:

- The lower riverbank will be retained below the 64 m AHD contour and remain untouched (except for hand removal of weeds, felling of non-native trees leaving the roots in place, and very selective herbicide application).
- The riverbank will also be retained in a horizontal setback that extends at least 10 m (measured horizontally) inland from the 64 m AHD contour up the bank (referred to as the '10-m-wide horizontal setback area').
- Where there are native trees within the 10-m-wide horizontal setback area, the width of the setback will be increased so that edge of the setback area/start of extraction area is at least 7.5 m (measured horizontally) from the trunk of these trees.

The active extraction area will be separated from the river by the lower riverbank (ie between 61 m AHD and 64 m AHD) and additionally by the horizontal setback that will be between 10 and 17.5 m wide. The undisturbed bank (ie the combined lower riverbank and horizontal setback) will vary in height but will be at least 3 m above the low-flow river level where the bank slope is shallow but will be higher where the bank slope is steeper.

Stage 8 quarrying schematic

Menangle Quarry Extension

Figure 5.1

EMM creating opportunities

5.3 Batter angles

5.3.1 Riverside batter

The riverside batter will be between the horizontal setback area and the base of the pit. It is proposed that:

- a short-term riverside batter with a maximum slope of 1:1, is used during sand and soil extraction – this will allow the efficient extraction of the resource;
- following extraction of material above this batter, the batter will be built up with suitable site material to give a permanent slope of 1:5 – this will provide additional assurance that the bank will be stable if the active extraction area is flooded during extraction;
- the maximum length of the riverside batter that has a slope between 1:1 and 1:5 will be restricted so that it can be covered with a 1:5 batter within 12 hours if flooding is predicted (see below);
- regardless of the amount of material required, the maximum length of the riverside batter that has a slope between 1:1 and 1:5 will be restricted to 30 m;
- in the final landform, the riverside batter will have a permanent slope of 1:5 – this will provide additional assurance that the back will be stable in the long term; and
- if over the life of the quarry, activities temporarily cease in the extraction area such that the excavator is relocated from the Stage 8 area, the riverside batter will be covered to form a 1:5 batter.

The horizontal setback area will be a mixture of graded and ungraded areas, of varying widths and of varying heights, so the width of the final 1:5 riverside batter will vary along the length extraction area. This will provide a varied, more natural looking final landform.

5.3.2 Advancing quarry face

The quarry will progressively advance upstream at an average rate of 150 m/year. The advancing quarry face will face downstream.

During large floods, river water may overtop the lower riverbank and horizontal setback area and flow into the active extraction area or may overtop the riverbank upstream of the active extraction area and flow along the bank to enter the active extraction area over the advancing face. A maximum batter angle of 1:2 will be applied to the advancing face so as to minimise any scour occurring as the water initially flows down the batter, until the water level in the extraction area is at the same level as the river.

5.3.3 Trailing quarry face

The trailing quarry face, between the active extraction area and backfilled extracted area, will face upstream.

A maximum landward batter angle of 1:5 is proposed for this face as it will face upstream in a flood. As for the riverside batter, this will mitigate the scour risk.

5.3.4 Landward batter

The landward batter is on the far side of the extraction area from the river.

A maximum landward batter angle of 1:1 is proposed as it will be exposed to far lower flood current speeds and peak shear stress than the riverside batter. There may be a steeper angle on the landward side of the extraction area where it is formed by the natural sandstone rock escarpment, which in places, may be vertical.

5.4 Flood mitigation

5.4.1 Controlling the length of 1:1 riverside batter

As stated above, the length of the riverside batter with a slope between 1:1 and 1:5 will be limited such that it can be built up to a 1:5 batter within 12 hours of predicted flooding. The Stage 8 area will be serviced by an excavator and a haul truck, there are also about four front-end loaders in the Stage 7 processing area that can be quickly driven (within 5 minutes) to the Stage 8 area to move sand and soil.

5.4.2 Flood warnings

The quarry has experienced a number of floods over the past 40 years of operations. Quarry personnel, six of whom have worked at the quarry for over 25 years, remain alert to the weather conditions that can cause the flooding in the Nepean River. This includes remaining vigilant when the quarry is closed as mobile plant may need to be moved to higher ground at night prior to flooding so that the plant is not inundated.

The Bureau of Meteorology (BoM) provides flood warnings for the Nepean River. These warning are generally checked daily, and hourly during periods of heavy rain. The SES also telephone the quarry when flooding is predicted.

Flood warnings based on weather predictions are generally provided two to three days before flooding occurs at Menangle. However, at times there has been only 12-hours notice, the time it takes for dam water released upstream to travel to Menangle.

5.4.3 Flood prediction actions

The following actions will be taken when flooding of the Nepean River above 64 m AHD in the Stage 8 area is predicted:

- any riverside batter that has a batter angle of less than 1:5 will be built up so that it has a maximum 1:5 slope;
- exposed batters and the base of the pit will be flattened so that there are no isolated highpoints susceptible to scour;
- all exposed sand and soil will be smoothed such that there are no rapid changes in slopes, particularly at the intersections of different batters; and
- unattended earthmoving equipment will not be left within the Stage 8 area while a flood warning is current.

5.5 Final landform

Final landform plans are provided Appendix C. The final landform has been designed to ensure there is no reduction in flood storage capacity of the Nepean River. Annual reporting of rehabilitation activities will include details of final landform in comparison to pre-existing landforms. This information will be used to describe the available flood storage capacity in the Annual Review.

5.6 Groundwater model update

If a potential flood event (equivalent to a level of 64 m AHD at Menangle weir, which represents the approximate heigh of overtopping of the Nepean River bank) does not occur between 17 June 2020 to 16 June 2021, then the groundwater model described in the *Soil and Water Management Plan* (EMM 2021b) will be updated following the first flood event equivalent to or greater than this level when it occurs.

Refer to the *Soil and Water Management Plan* (EMM 2021b) for further details on groundwater modelling commitments.

5.7 Summary of flood management measures

A summary of flood mitigation and management measures is provided in Table 5.1. Based on the mitigation and management measures it is considered that potential flood related risks and impacts that may arise due to the operation of the quarry can be effectively managed.

Table 5.1 Summary of flood management measures

ID	Management measure/requirement	Implementation stage	Responsibility	Reference
General				
FM01	All quarry personnel will be provided with information and training regarding the importance of flood warning, flood action protocols and evacuation requirements.	Extraction and operation	Quarry Manager	-
FM02	Removal of quarrying infrastructure (where practical) and plant from flood prone areas in the event of a forecast flood to minimise the risk of damage to infrastructure/plant and the risk to downstream property.	Extraction and operation	Quarry Manager	-
Quarrying method				
FM03	The stage 8 extraction area is setback from the river a minimum of 10 m from the 64 m AHD contour leaving the Nepean River Buffer Zone and lower riverbank undisturbed. The setback will provide a buffer between flows in the main channel of the Nepean River and the excavation area during a flood.	Extraction	Quarry Manager	Approval Condition A10
FM04	The riverside batter is to be between the Nepean River Buffer Zone and the base of the pit. The following management measures apply to the riverside batter: • Constructed with a maximum slope of 1:1 during sand and soil extraction – this will allow the efficient extraction of the resource. • Following extraction, the riverside batter will be built up with suitable site material to give a permanent slope of 1:5 – this will provide additional assurance that the bank will be stable if the active extraction area is flooded during or post extraction. • The maximum length of the riverside batter that has a slope between 1:1 and 1:5 will be restricted to 30 m at any one time to allow sufficient time to reshape batters prior to the occurrence of a flood event. If over the life of the quarry, activities temporarily cease in the extraction area such that the excavator is relocated from the Stage 8 area, the riverside batter will be covered to form a 1:5 batter.	Extraction and post extraction	Quarry Manager	Approval Condition B32b(v) Approval Condition B32b(vii) Approval Condition B70
FM05	The quarry is anticipated to progressively advance upstream at an average rate of 150 m/year depending on customer demand and in-situ resource. The advancing quarry face will face downstream. A maximum batter angle of 1:2 is to be applied to the advancing face to minimise any scour occurring as the elevated floodwaters (if high enough) initially flow down the advancing face batter.	Extraction	Quarry Manager	-

Table 5.1 Summary of flood management measures

ID	Management measure/requirement	Implementation stage	Responsibility	Reference
FM06	The trailing quarry face will face upstream. A maximum landward batter angle of 1:5 will be applied for this face to minimise any scour occurring as elevated floodwaters initially move up the batter.	Extraction	Quarry Manager	Approval Condition B70
FM07	The landward batter is on the far side of the extraction area from the river. A landward batter angle of 1:1 is permitted as it will be exposed to lower flood current speeds and peak shear stress than the riverside batter. Natural sandstone faces may be steeper, up to vertical or overhanging.	Extraction	Quarry Manager	Approval Condition B70
FM08	The active extraction area in any Stage 8 subarea is not to exceed 0.33 ha at any one time to minimise the disturbance area that may contribute to the entrainment of in-situ materials in floodwaters should flooding occur.	Extraction	Quarry Manager	Approval Condition 32b(iv)
FM09	The final landform is to be vegetated and have a maximum permanent riverside batter slope of 1:5 and a maximum landward batter slope of 1:1 to minimise the risk of flood impacts of the rehabilitated landform.	Post extraction	Quarry Manager	Approval Condition B70
FM10	The final landform will not reduce flood storage within the Nepean River and overbank area as shown in Appendix C. Annual reporting of rehabilitation activities will include details of final landform in comparison to pre-existing landforms.	Post extraction	Quarry Manager	Approval Condition B35
Monitoring for potential flood				
FM11	Monitor BoM rainfall forecasts daily in dry weather and hourly during periods of heavy rain.	Extraction and operation	Quarry Manager	-
FM12	Monitor BoM flood warnings for the Nepean River daily in dry weather and hourly during periods of heavy rain.	Extraction and operation	Quarry Manager	-
Notifications				
FM13	Declaring the flood potential to quarry personnel and enacting the Trigger Action Response Plan (TARP).	When BoM website has a flood warning for the area or when the SES informs the quarry that flooding is predicted.	Quarry Manager	-

Table 5.1 Summary of flood management measures

ID	Management measure/requirement	Implementation stage	Responsibility	Reference
FM14	Declaring temporary cessation of quarry activities until flood risk has passed.	When BoM website has a flood warning for the area or when the SES informs the quarry that flooding is predicted.	Quarry Manager	-
FM15	Declaring the quarry reopened.	When SES have given the all clear or the river level is below 64 m AHD.	Quarry Manager	-
Actions prior to flooding				
FM16	The following actions will be taken when flooding of the Nepean River above 64 m AHD in the Stage 8 area is predicted: • any riverside batter that has a batter angle of less than 1:5 will be built up so that it has a maximum 1:5 slope; • exposed batters and the base of the pit will be flattened so that there are no isolated highpoints susceptible to scour; • all exposed sand and soil will be smoothed such that there are no rapid changes in slopes, particularly at the intersections of different batters; and • unattended earthmoving equipment will not be left below the 1% AEP level within the Stage 8 area while a flood warning is current.	When BoM website identify flood warning for the area or when the SES informs the quarry that flooding is predicted.	Quarry Manager	Approval Condition 32b(iii) Approval Condition 32b(v) Approval Condition 32c(i)
Evacuation				
FM17	The emergency exit route to be taken before flood waters rise is to exit the quarry onto Menangle Road and then north to Menangle Village.	When site evacuation declared.	Quarry Manager	-
FM18	During flooding the SES will advise through radio and the internet what roads are passable in the area. All site personnel will have secured and left the quarry by this time.	During flooding.	Quarry Manager	-
FM19	No attempt should be made to enter or cross any floodwater.	During flooding.	All personnel	-

Table 5.1 Summary of flood management measures

ID	Management measure/requirement	Implementation stage	Responsibility	Reference
Post flood event actions				
FM20	Ensure that damage is assessed and reported to Quarry Manager when all clear is given to return to the quarry.	Following flood event.	Quarry Manager	-
FM21	Rectify any flood-related damage, including areas undergoing rehabilitation.	Following flood event.	Quarry Manager	Approval Condition 32c(vii)
FM22	Debrief all key personnel and update/modify this FMP as necessary.	Following flood event.	Quarry Manager	-
FM23	If a flood event equivalent to 63 m AHD at Menangle weir does not occur between 17 June 2020 and 16 June 2021, then update the groundwater model following the first flood event equivalent to or greater than this level when it occurs[1].	Following flood event.	Quarry Manager	Approval Condition B36

1. A flood with a peak of approximately 10 m (approximately 71 m AHD) occurred between 21 and 25 March 2021.

5.8 Trigger Action Response Plan

A Trigger Action Response Plan (TARP) documents a set of conditions 'triggers' with a set of corresponding actions that must be followed when those trigger events occur. A TARP for forecast or actual flood events at the quarry is provided in Table 5.2.

The BoM define the following flood levels:

- Minor flooding: Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

- Moderate flooding: In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.

- Major flooding: In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.

The TARP reflects the BoM flood levels described above for equivalent activities within the quarry site. The flood levels used to trigger each subsequent tier of the TARP are based on the level at which inundation commences for a particular quarry area. Publicly available LiDAR data has been used to determine the ground levels and subsequent inundation levels at the quarry.

Table 5.2 Trigger Action Response Plan

Severity	Trigger	Action required	Timing	Follow up actions
Stand-by	Bureau of Meteorology issues 'flood watch' for Nepean River catchment. 'Flood watch' generally issued up to four days in advance of the expected onset of flooding but maybe as short as 12 hours.	• Inform quarry personnel that flooding may impact the quarry in the coming days. • Continue to monitor rainfall and flood watch advice.	• Immediately following the 'flood watch' notification being received by the quarry.	• Inform quarry personnel if BoM updates 'flood watch' so that flooding is no longer expected.
Risk level to be advised	Bureau of Meteorology issues 'flood warning' for Nepean River catchment in vicinity of the quarry.	• Inform quarry personnel that flooding within the Nepean River may inundate quarrying areas. • Monitor rainfall and flood warning advice hourly.	• Immediately following the 'flood warning' notification being received by the quarry	• Continue to monitor BoM flood severity for updates. • Proceed to next level of TARP if flood severity classed as 'minor'.
Minor	Nepean River flooding adjacent to the quarry is predicted to exceed 64 m AHD (ie a predicted Menangle Weir level of 63.5 m AHD).	Prepare the Stage 8 extraction area for potential flood inundation: • Backfill the active Stage 8 extraction area to achieve a maximum batter slope of 1:5 adjacent to the riverside batter. • Flatten exposed batters and the base of the active extraction area to remove isolated highpoints that may be susceptible to scour. • Smooth all exposed sand and soil in the extraction area so that there are no rapid changes in slopes, particularly at the intersections of different batters. • Move all plant and infrastructure from the active extraction area to higher ground (above predicted maximum flood level). • Evacuate personnel from the extraction area. Prepare the processing and infrastructure areas for potential flood inundation. • Move selected plant and infrastructure to higher ground. • Prepare to move all non-fixed plant to higher ground (above predicted maximum flood level). • Prepare to evacuate personnel from the quarry.	• Immediately (if safe to do so) following the prediction that flood levels will exceed 64 m AHD.	• Continue to monitor BoM flood severity for updates. • Proceed to next level of TARP if flood severity classed as 'moderate'. • Proceed to 'event over' when flood warning removed.

Table 5.2 Trigger Action Response Plan

Severity	Trigger	Action required	Timing	Follow up actions
Moderate	Nepean River flooding adjacent to the quarry is predicted to exceed 66 m AHD – access road between site entry and operations area becomes inundated.	Prepare the processing and infrastructure areas for potential flood inundation. • Move all plant to higher ground (above predicted maximum predicted flood level). • Evacuate personnel from the operations area.	• Immediately (if safe to do so) following the prediction that flood levels will exceed 66 m AHD.	• Continue to monitor BoM flood severity for updates. • Proceed to next level of TARP if flood severity classed as 'moderate'. • Proceed to 'event over' when flood warning removed.
Major	Nepean River flooding adjacent to the quarry is predicted to exceed 74 m AHD – entire site inundated	• Evacuate personnel from the site.	• Immediately (if safe to do so) following the prediction that flood levels will exceed 74 m AHD.	• Continue to monitor BoM flood severity for updates. • Proceed to 'event over' when flood warning removed.
Event over	The SES issue safe to return or flood levels have receded below 64 m AHD.	• Assess and report any damage to the active extraction area and operations area. • Remediate areas of damage, including clearing of debris and areas undergoing rehabilitation at the time of the flood event. • Recommence quarrying activities.	• Within 5 days or as soon as practical following the 'event over' trigger is actioned.	• Debrief all key personnel and update/modify this Flood Management Plan as necessary.

6 Compliance management

6.1 Monitoring and inspection

Monitoring of potential flood conditions will be undertaken daily during dry weather and hourly during wet weather periods. Monitoring is required to allow sufficient time to prepare the site and evacuate (if required) prior to the commencement of heavy rainfall and flood events as described in the TARP (see Table 5.2). This includes remaining vigilant outside of operational hours as mobile plant may need to be moved to higher ground at night prior to flooding so that the plant is not inundated. The following environmental conditions will be monitored:

- rainfall forecasts for the Illawarra District issued by BoM; and
- flood warnings for the Nepean River issued by BoM and the SES.

If a flood warning is received/identified the TARP provided in Table 5.2 will be enacted.

Environmental inspections will be completed weekly in accordance with the EMS. Environmental inspections will be used to ensure mitigation and management measures are being implemented correctly and identify any areas of non-conformance.

Environmental monitoring and inspections are described in Section 6 of the EMS.

6.2 Training

All quarry personnel will be provided with information and training regarding the importance of flood warning, flood action protocols identified in the TARP, and evacuation requirements. These aspects will be incorporated into the following training which is outlined in the EMS:

- site induction; and
- environmental awareness training.

Site training is described in Section 4 of the EMS.

6.3 Auditing

Internal and external auditing will be undertaken to assess the effectiveness of mitigation and management measures, compliance with this FMP and the project consent conditions, and other relevant approvals, licences, and guidelines.

Auditing is described in Section 6 of the EMS.

6.4 Reporting

A log will be maintained to record substantiating activities associated with the quarrying process or relevant to the project consent conditions, including measures taken to implement this FMP.

Environmental reporting is described in Section 7 of the EMS.

6.5 Emergencies, incidents and non-compliances

Menangle Sand and Soil will identify environmental non-conformances, including environmental incidents, on-site and will undertake the required corrective actions to address the non-conformance and implement preventative actions where required.

The management of emergencies, incidents and non-compliances is described in Section 8 of the EMS.

6.6 Document review

This FMP will be subject to ongoing review and continual improvement as described in Section 9 of the EMS.

7 References

Advisian 2019, *Menangle Quarry Extension – Flood Impact Sensitivity Assessment*, prepared for Menangle Sand & Soil Pty Ltd by Advisian Pty Ltd.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I (Editors) 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia).

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SES 2015, *Wollondilly Shire Flood Emergency Sub Plan – A Sub-Plan of the Wollondilly Local Emergency Management Plan*, NSW State Emergency Service.

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Abbreviations

AEP	annual exceedance probability
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
EMM	EMM Consulting Pty Limited
EMS	Environmental Management System
FDM	Floodplain Development Manual
FMP	Flood Management Plan
ha	hectare
km	kilometre
LEC	Land and Environment Court
LGA	local government area
NSW	New South Wales
PMF	probable maximum flood
SES	NSW State Emergency Service
TARP	trigger action response plan
tpa	tonnes per annum

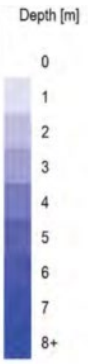
Appendix A

Flood mapping – site entry compound and processing area

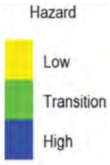
A.1 Flood mapping extracts from Worley Parsons, 2015

Key:

Peak flood depth:

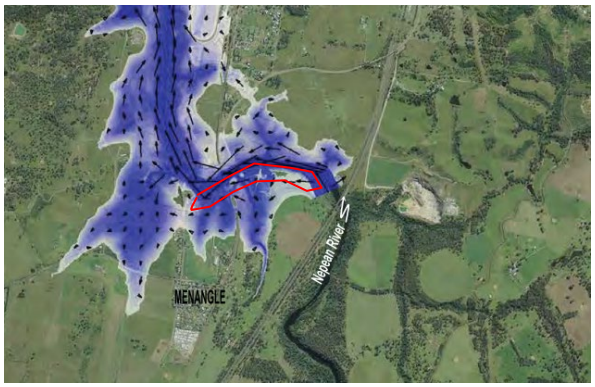


Provisional flood hazard:

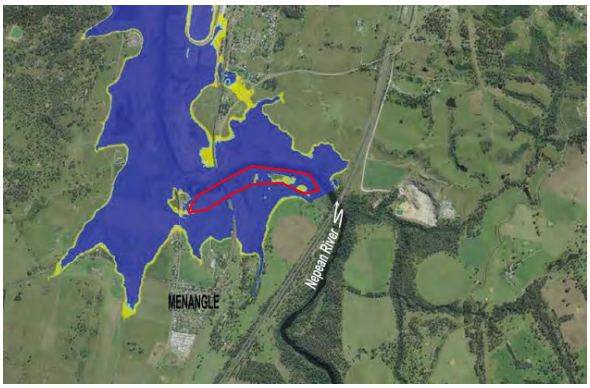


Approximate extent of site entry compound and processing area:

Flood mapping – 5% AEP event:

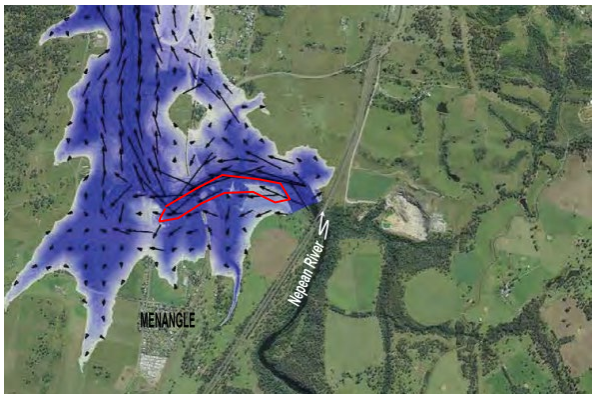


Peak flood depth

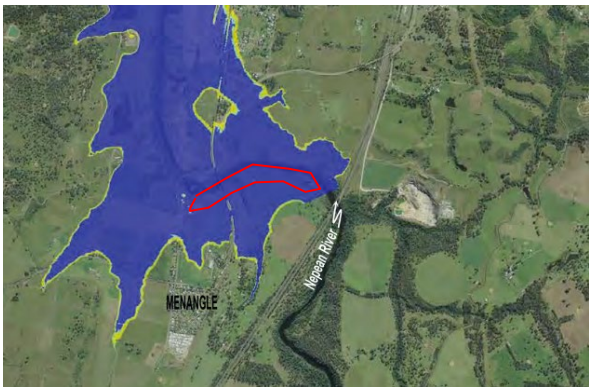


Provisional flood hazard

Flood mapping – 1% AEP event:

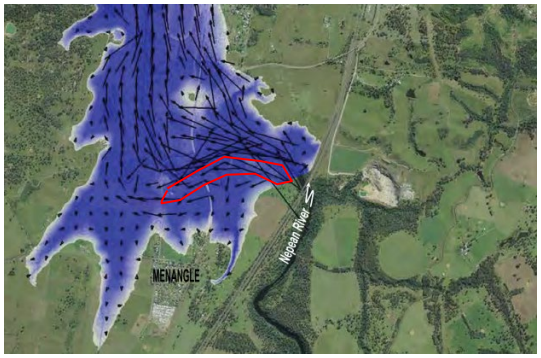


Peak flood depth

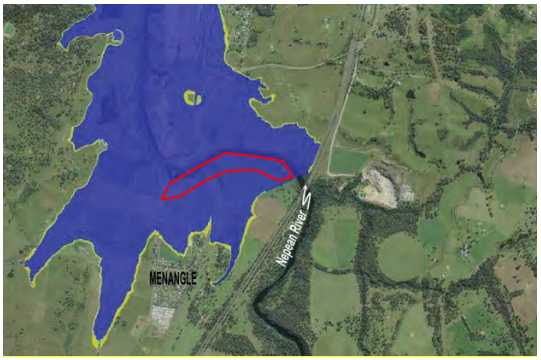


Provisional flood hazard

Flood mapping – PMF event:



Peak flood depth



Provisional flood hazard

Appendix B

Flood mapping – Stage 8 extraction areas

MAP 13

Stage 8A
Extraction Area

Stage 8B
Extraction Area

Stage 8C
Extraction Area

HUME MOTORWAY

NEPEAN RIVER

N

0 25 50 75 100 m

LEGEND

64 mAHD contour (from 2011 LiDAR)

10m setback from 64 mAHD contour

Extraction Stage Centroids

Existing Condition

Peak Velocity (m/s)

0.0 - 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 3.0

3.0 - 4.0

> 4.0

Velocity Vectors

Prepared by:

Advisian
Worley Group

190904_Menangle_Revised Extraction_V_BSS_~event~.qgs

fg301015-04089_190904_MenangleQuarry_A3P.pptx

STAGES 8A-8C EXISTING CONDITIONS
5% AEP SIMULATED PEAK FLOW VELOCITY

MAP 19

NEPEAN RIVER

Stage 8D Extraction Area

Stage 8E Extraction Area

Stage 8F Extraction Area

Stage 8G Extraction Area

N

0 25 50 75 100 m

LEGEND

- 64 mAHD contour (from 2011 LiDAR)
- 10m setback from 64 mAHD contour
- Extraction Stage Centroids

Existing Condition

Peak Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0
- Velocity Vectors

Prepared by:

Advisian
Worley Group

190904_Menangle_Revised Extraction_V_BSS_~event~.qgs

fg301015-04089_190904_MenangleQuarry_A3P.pptx

STAGES 8D-8G EXISTING CONDITIONS 5% AEP SIMULATED PEAK FLOW VELOCITY

MAP 25

Stage 8A
Extraction Area

Stage 8B
Extraction Area

Stage 8C
Extraction Area

HUME MOTORWAY

NEPEAN RIVER

N

0 25 50 75 100 m

LEGEND

64 mAHD contour (from 2011 LiDAR)

10m setback from 64 mAHD contour

Extraction Stage Centroids

Existing Condition

Peak Velocity (m/s)

0.0 - 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 3.0

3.0 - 4.0

> 4.0

Velocity Vectors

Prepared by:

Advisian
Worley Group

190904_Menangle_Revised Extraction_V_BSS_~event~.qgs

fg301015-04089_190904_MenangleQuarry_A3P.pptx

STAGES 8A-8C EXISTING CONDITIONS
1% AEP SIMULATED PEAK FLOW VELOCITY

MAP 31

NEPEAN RIVER

Stage 8D Extraction Area

Stage 8E Extraction Area

Stage 8F Extraction Area

Stage 8G Extraction Area

N

0 25 50 75 100 m

LEGEND

- 64 mAHD contour (from 2011 LiDAR)
- 10m setback from 64 mAHD contour
- Extraction Stage Centroids

Existing Condition

Peak Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0
- Velocity Vectors

Prepared by:

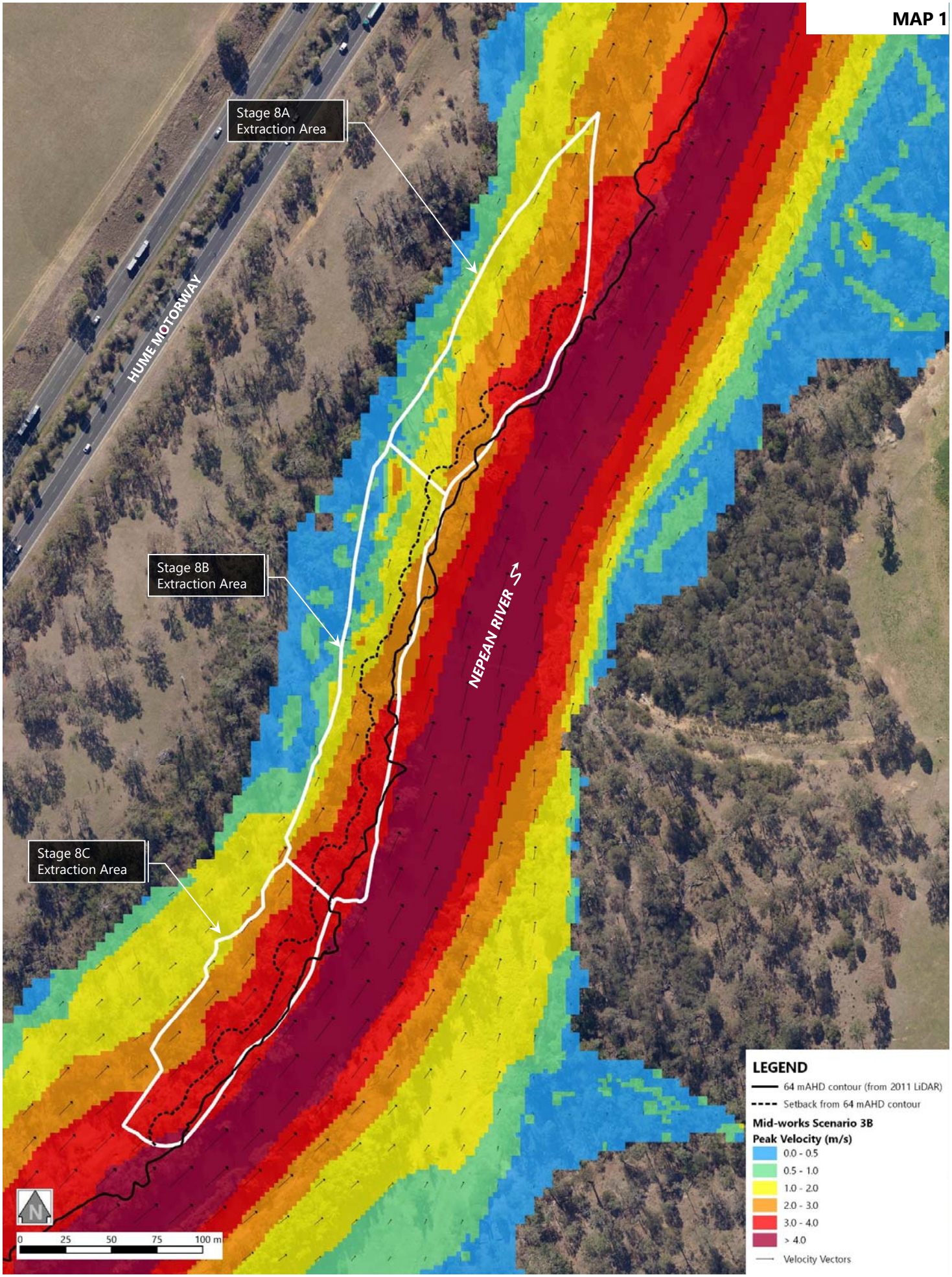
Advisian
Worley Group

190904_Menangle_Revised Extraction_V_BSS_~event~.qgs

fg301015-04089_190904_MenangleQuarry_A3P.pptx

STAGES 8D-8G EXISTING CONDITIONS
1% AEP SIMULATED PEAK FLOW VELOCITY

MAP 1



Prepared by:

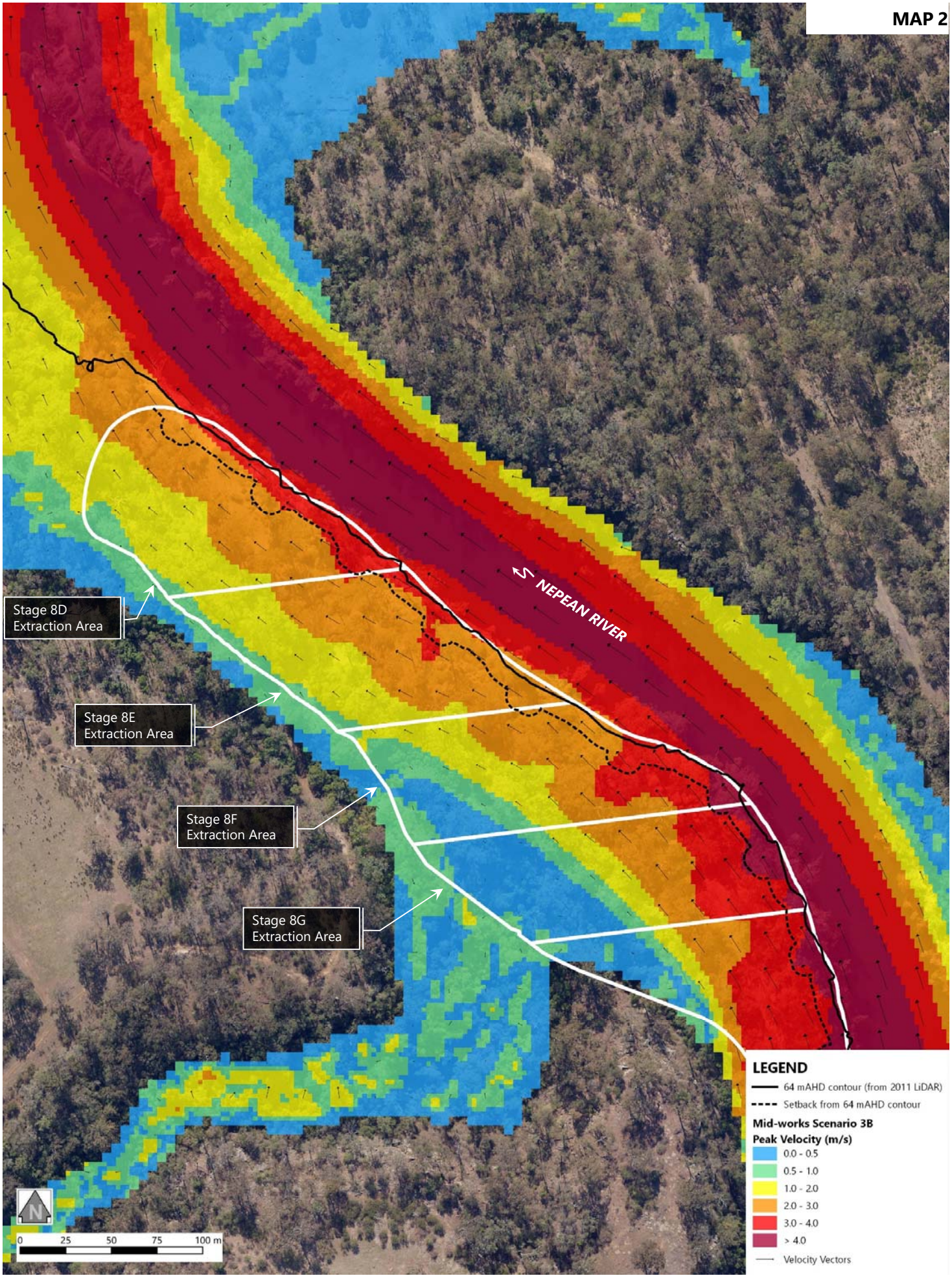
Advisian

201012_Menangle_Extended_Midworks.qgz

fg301015-04089-Menangle Quarry Post Extraction Velocity_A3P.pptx

STAGES 8A-8C MID-WORKS SCENARIO 3B
1% AEP SIMULATED PEAK FLOW VELOCITY

MAP 2



Prepared by:

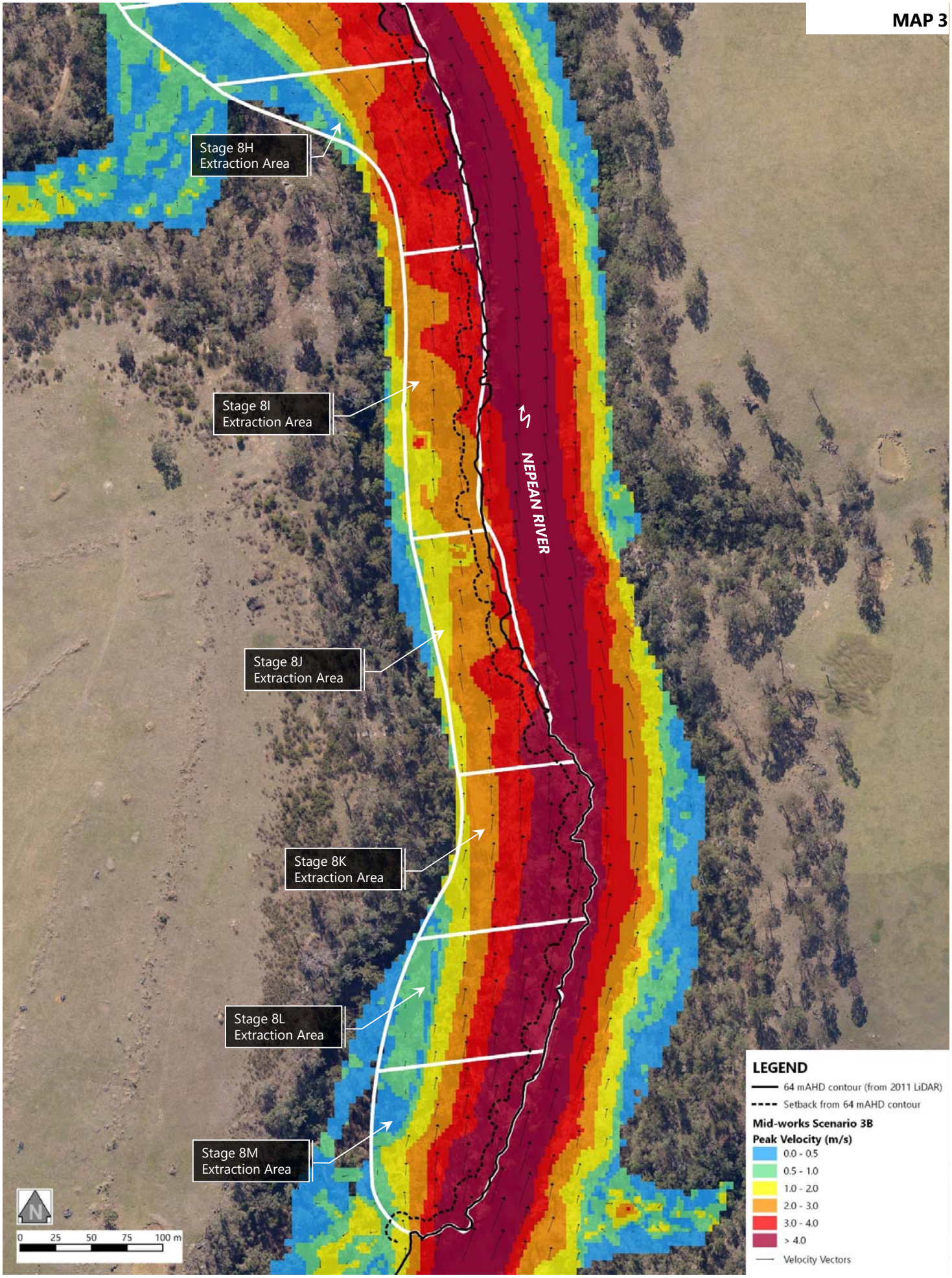
Advisian

201012_Menangle_Extended_Midworks.qgz

fg301015-04089-Menangle Quarry Post Extraction Velocity_A3P.pptx

STAGES 8D-8G MID-WORKS SCENARIO 3B
1% AEP SIMULATED PEAK FLOW VELOCITY

MAP 3



Prepared by:

Advisian

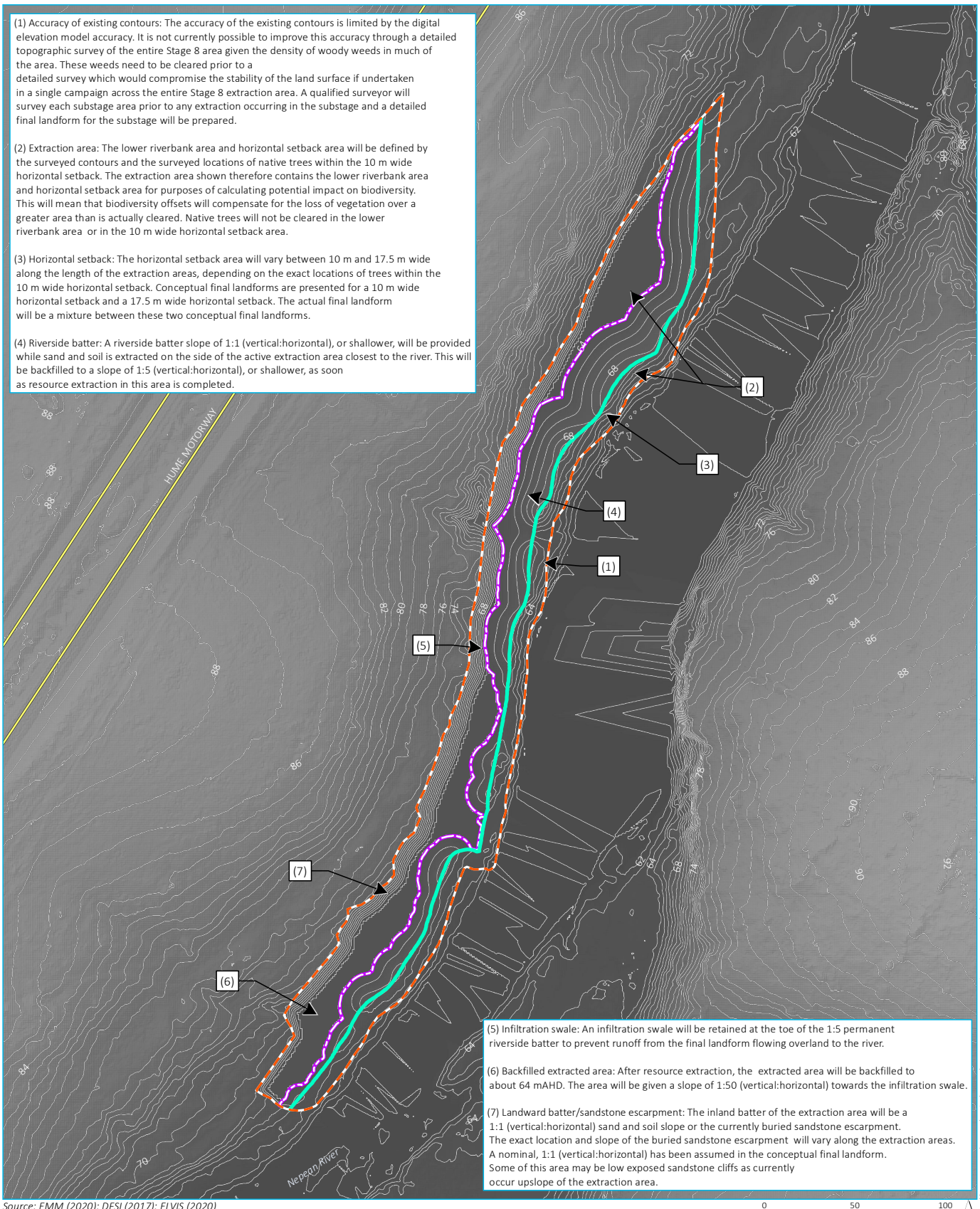
201012_Menangle_Extended_Midworks.qgz

fg301015-04089-Menangle Quarry Post Extraction Velocity_A3P.pptx

STAGES 8H-8M MID-WORKS SCENARIO 3B
1% AEP SIMULATED PEAK FLOW VELOCITY

Appendix C

Final landform – Stage 8 extraction area



Source: EMM (2020); DFSI (2017); ELVIS (2020)

0 50 100 m
GDA 1994 MGA Zone 56
N

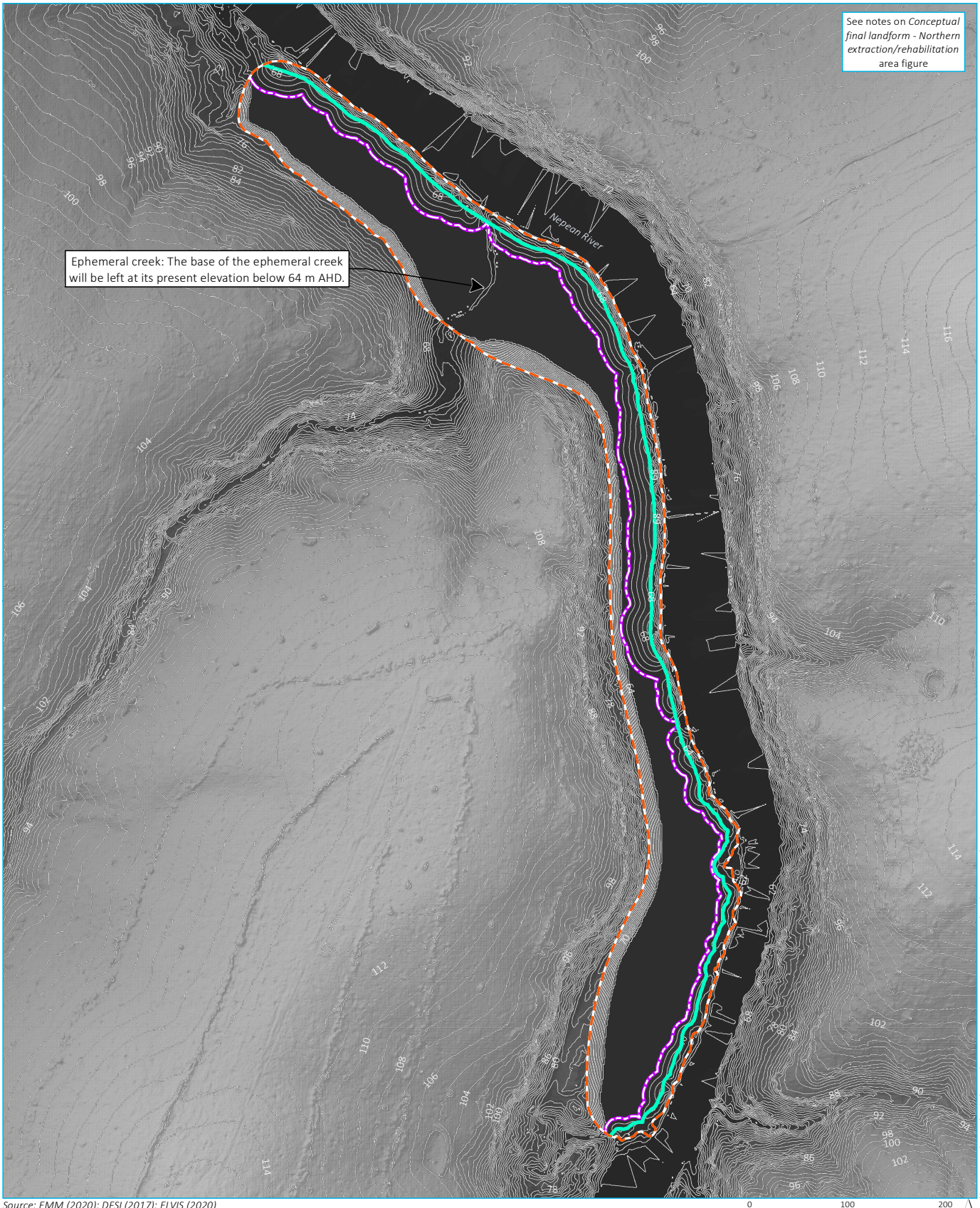
KEY

- Stage 8 - extraction/rehabilitation area
- Inland extent of horizontal setback (10 m)
- Infiltration swale/toe of riverside 1:5 permanent batter
- Contour (1 m)
- Major road

Conceptual final landform 10 m setback
Northern extraction/rehabilitation area

Menangle Quarry Extension
Figure 2.9

EMM
creating opportunities



Source: EMM (2020); DFSI (2017); ELVIS (2020)

0 100 200 m

GDA 1994 MGA Zone 56

N

KEY

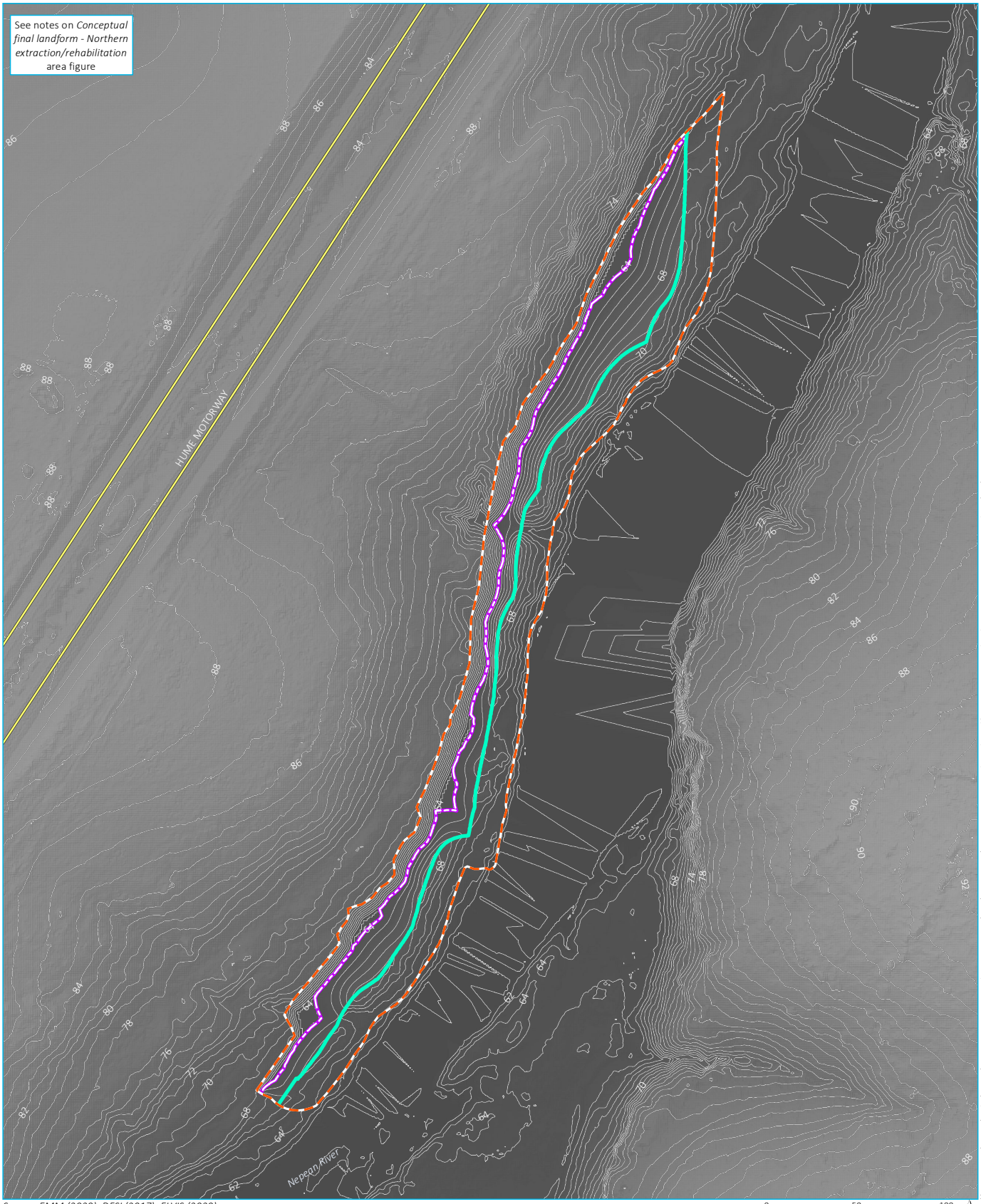
- Stage 8 - extraction/rehabilitation area
- Inland extent of horizontal setback (10 m)
- Infiltration swale/toe of riverside 1:5 permanent batter
- Contour (1 m)

Conceptual final landform 10 m setback
Southern extraction/rehabilitation area

Menangle Quarry Extension
Figure 2.10

\\emmsvr1\emm\Jobs\2019\J190166 - Menangle Quarry LEC\GIS\02_Maps\G028_ConceptualFinalLandform_10mSetback_SE_20200515_02.mxd 15/05/2020

EMM creating opportunities



Source: EMM (2020); DFSI (2017); ELVIS (2020)

0 50 100 m
GDA 1994 MGA Zone 56

KEY

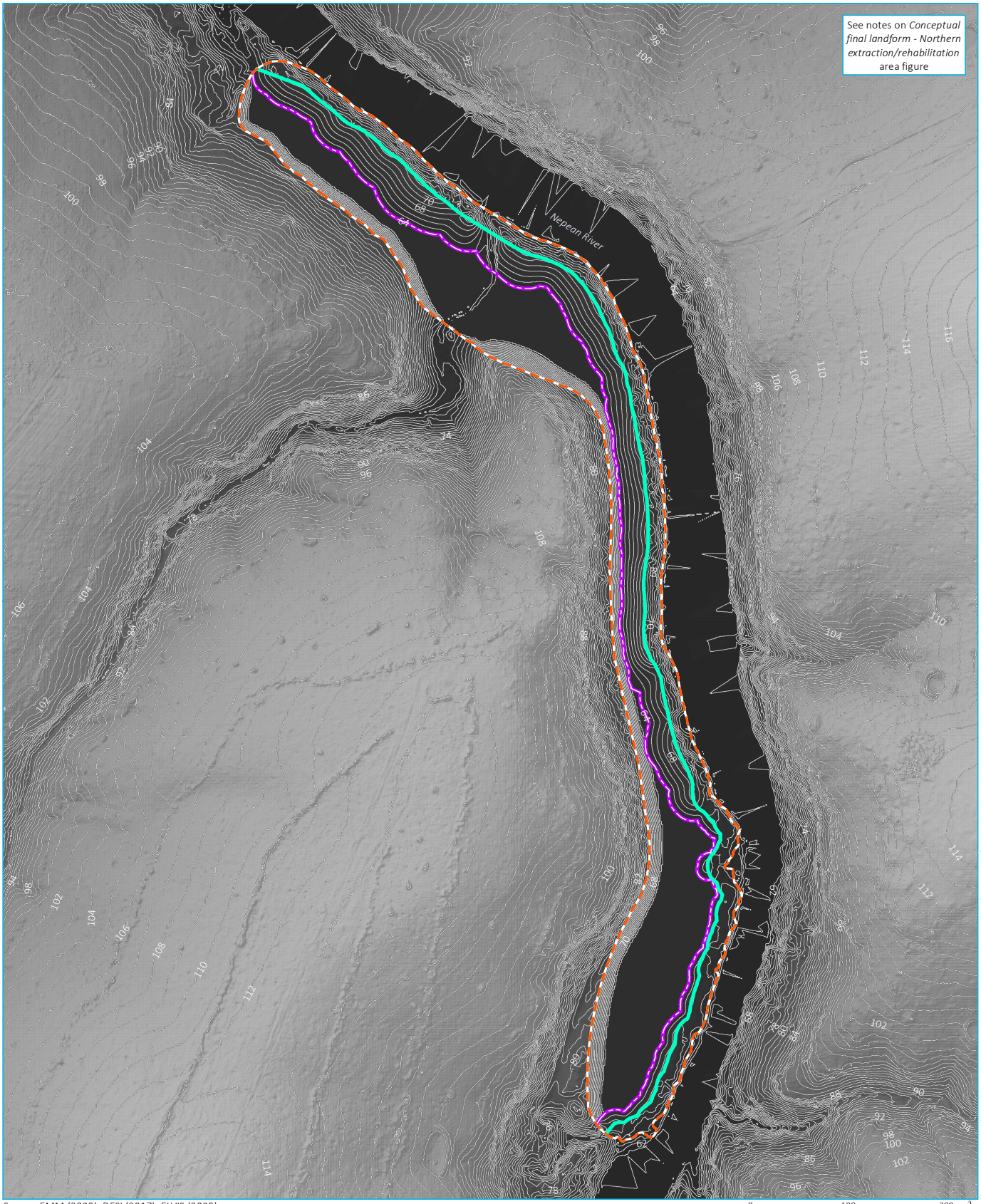
- Stage 8 - extraction/rehabilitation area
- Inland extent of horizontal setback (17.5 m)
- Infiltration swale/toe of riverside 1:5 permanent batter
- Contour (1 m)
- Major road

Conceptual final landform 17.5 m setback
Northern extraction/rehabilitation area

Menangle Quarry Extension
Figure 2.11

\\emmsvr1\emm\Jobs\2019\J190166 - Menangle Quarry LEC\GIS\02_Maps\G025_ConceptualFinalLandform_17_5mSetback_NE_20200515_03.mxd 15/05/2020

EMM creating opportunities



Source: EMM (2020); DFSI (2017); ELVIS (2020)

0 100 200 m

GDA 1994 MGA Zone 56

N

KEY

- Stage 8 - extraction/rehabilitation area
- Inland extent of horizontal setback (17.5 m)
- Infiltration swale/toe of riverside 1:5 permanent batter
- Contour (1 m)

Conceptual final landform 17.5 m setback
Southern extraction/rehabilitation area

Menangle Quarry Extension
Figure 2.12

\\emmsvr1\emm\Jobs\2019\J190166 - Menangle Quarry LEC\GIS\02_Maps\G026_ConceptualFinalLandform_17_5mSetback_SE_20200515_03.mxd 15/05/2020

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