Environmental & Social Consultants

FLOOD IMPACT ASSESSMENT

Mandalong Southern Extension Project
Modification 9

FINAL

September 2020

FLOOD IMPACT ASSESSMENT

Mandalong Southern Extension Project
Modification 9

FINAL

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Centennial Coal

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This report was prepared using Umwelt's ISO 9001 certified Quality Management System.

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	Name	Date	Name	Date
1	G. Mounser	12/02/2020	G. Mounser	12/02/2020
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3	G. Mounser	17/09/2020	G. Mounser	17/09/2020

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1.0 Introduction

1.1 Background

Mandalong Mine (Mandalong) is an existing underground coal mine near Morisset, approximately 35 kilometres (km) south-west of Newcastle predominantly within the Lake Macquarie local government area (LGA) of New South Wales (NSW) (refer to **Figure 1.1**). The mine is operated by Centennial Mandalong Pty Limited (Centennial Mandalong). Centennial Mandalong has approval to extract run-of-mine (ROM) coal from the West Wallarah and Wallarah-Great Northern (WGN) seams using a combination of longwall and continuous mining methods.

Mandalong operates under State significant development (SSD) consent SSD-5144 (the consent), which was granted on 12 October 2015 by the NSW Planning Assessment Commission (PAC) under Part 4, Division 4.1 of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act).

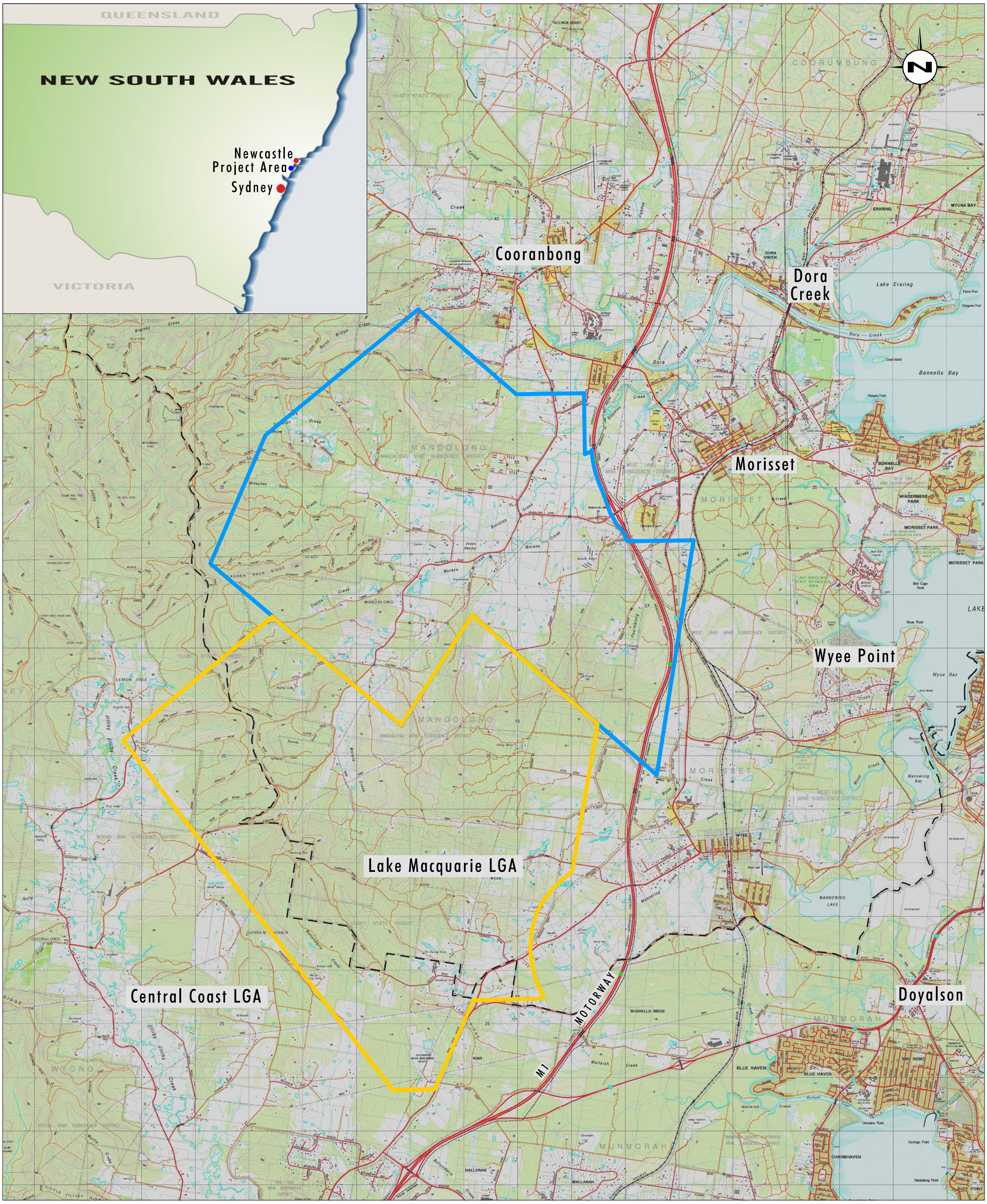
The Mandalong Southern Extension Project (the Project) extends Mandalong Mine's existing underground mining operations into the area covered by Mining Leases ML1722 and ML1744 in order to access, develop and extract the additional coal reserves identified within the West Wallarah Seam and WGN Seam at a rate of up to 6.5 Mtpa of ROM coal. The Project also allows for the continued utilisation of existing surface infrastructure integral to the mining operation in terms of coal delivery, handling and transport (refer to **Figure 1.2a**).

Within the original Centennial Mandalong operations, longwalls are numbered LW1 to LW24A, and underground coal extraction has been completed with the final coal extracted from LW24A in early 2019. Within the Mandalong Southern Extension Project, longwall numbering commences at LW25 and increases sequentially to LW64. Mining is currently occurring in LW27.

Umwelt prepared the Surface Water Assessment for the Project in August 2013 (Umwelt, 2013). Approval for the Project was granted in October 2015 (State Significant Development - SSD 5144). Since the 2015 approval, several modifications to SSD 5144 have been approved including Modifications 4 and 5 for which flood impacts were reassessed for LW23 to LW24A. The most recent Flood Impact Assessment was prepared for the Extraction Plan for LW25 to 31 (Umwelt, 2018).

Centennial Mandalong is seeking to modify SSD-5144 (Modification 9), pursuant to Section 4.55(2) of the EP&A Act, to change Mandalong's approved mine plan, including reorientating some of the approved longwall panels, removing longwalls that will not be developed and renumbering the longwalls accordingly as discussed in **Section 1.1**.

This Flood Impact Assessment (FIA) has been prepared by Umwelt (Australia) Pty Limited (Umwelt) to support the Modification 9 mine layout and the Extraction Plan for LW30-33. For the purpose of this FIA, the assessment of flood impacts will be based on a comparison of approved impacts as of SSD 5144 Modification 5 and Extraction Plan LW25-31 with the predicted impacts of Modification 9.



Source: LPMA (2006), Centennial Mandalong (2012)

Legend
- Project Area
- Existing Centennial Mandalong Operations
- Local Government Area (LGA)

FIGURE 1.1

Locality Map

1.2 Modification 9 Mine Layout

The approved Mandalong Southern Extension Project covers an area of approximately 4,500 ha, with the land being privately owned rural land as well as Olney State Forest, Jilliby State Conservation Area and Crown Land (Commonwealth) (refer to **Figure 1.2a** and **Figure 1.2b**). This FIA has been developed to support a proposed Section 4.55(1A) modification (Modification 9) to the Mandalong Southern Extension Project development consent (SSD 5144) to:

- Delete project approved longwalls 30, 31 and 37
- Reorientate project approved longwalls 32 to 36
- Re-name project approved longwalls 32 to 36 to longwalls 30 to 34, and then delete longwall 34.
- Increase the chain pillar widths between the re-orientated longwalls to be consistent with the pillar factor of safety and predicted subsidence assessed for the approved mining layout.

Following the public exhibition period of the Modification 9 Report, further analysis was undertaken regarding the extent of the geological sill and re-orientation layout. This has resulted in the final location of the re-orientated longwalls shifting 35 metres (m) towards the existing main headings to ensure an adequate barrier pillar size between the longwall panels and the main headings for operational safety reasons. The prospect of this shift was highlighted in Section 4.1 of the Modification Report. Further, due to the extent of the sill, LW34 has been removed and no longer forms part of the modification.

Relative to the previous revision of this report (Rev. 2, March 2020), there has been a minor shift of longwalls LW30-33 by 35 m to the east. The new mine plan and predicted subsidence contours incorporating the shifted longwalls LW30-33 have been reviewed, and Umwelt has determined that:

- The new mine plan for LW30-33 has changed slightly relative to the mine plan in the earlier revision of this report (Rev. 2, March 2020), but does not materially impact the RMA-2 model mesh
- The change to subsidence in the region of LW30-33 is such that the impacts on the RMA-2 hydrodynamic modelling results and watercourse stability (long section) analysis for Morans Creek and Buttonderry Creek would be negligible, and
- RMA-2 model results for this latest report revision (Rev. 3, September 2020) can be based on the model mesh prepared for the original mine plan (Rev. 2, March 2020).

1.3 Potential Surface Water Impacts

This FIA has been undertaken for a portion of the Mandalong Southern Extension Project Area (the Project Area) that will be subject to potential impacts from the Modification 9 (refer to **Figure 1.2a**).

The key feature of the Modification 9 that can potentially impact on flood behaviour within the catchment is subsidence resulting from underground mining. The potential subsidence impacts on surface water resources in the Project Area relate to vertical subsidence displacement (i.e. differential settlement/ movement) (refer to the Subsidence Assessment Report; Ditton Geotechnical Services (DgS), 2020b and subsidence contours presented in DgS, 2020a). The aim of this FIA is to define the potential impacts on flooding and drainage as a result of the Modification 9.

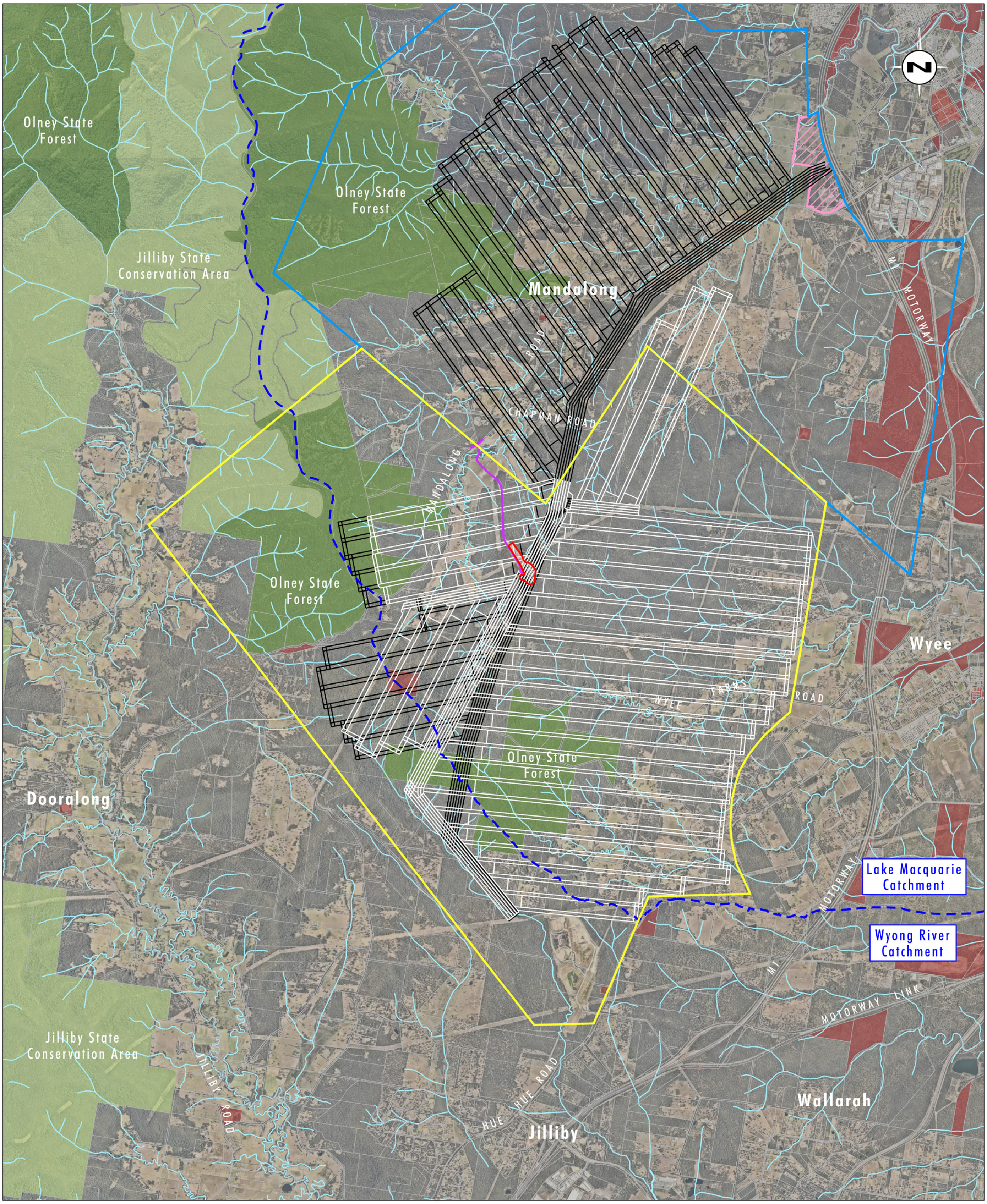


Image Source: Nearmap (Dec 2020)
Data Source: Centenial Mandalong (2020), LPI (2020)

0 1 2 3km
1:70 000

Legend

- Project Area
- Existing Centennial Mandalong Lease Area
- Existing Mandalong Mine Access Site Surface Infrastructure
- Surface Infrastructure
- Approved Longwalls
- Proposed Longwalls
- Access Road
- Cadastre
- Drainage Line
- State Forest
- Conservation Area
- Crown Land
- Catchment Boundary

FIGURE 1.2a

Approved and Proposed Centennial Operations

File Name (A4): R01/20091_002.dgn
20200731 14.58

umwelt

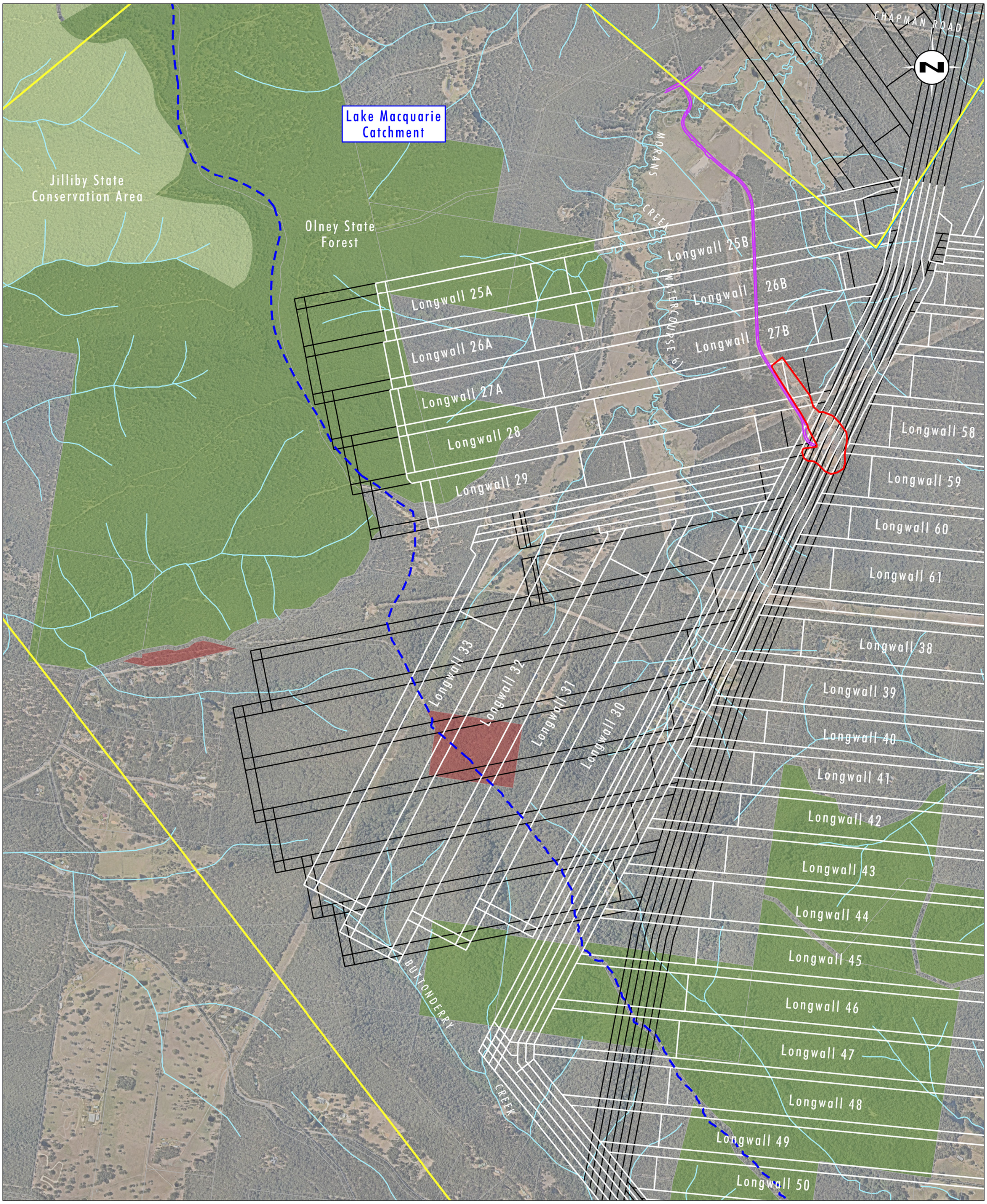


Image Source: Nearmap (Dec 2020)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Existing Centennial Mandalong Lease Area
- Surface Infrastructure
- Approved Longwalls
- Proposed Longwalls
- Access Road
- Drainage Line
- Cadastre
- State Forest
- Conservation Area
- Crown Land
- Catchment Boundary

FIGURE 1.2b

Approved and Proposed Centennial Operations

File Name (A4): R01/20091_003.dgn
20200731 14.57

1.4 Structure of the Report

This FIA has been prepared for Centennial Mandalong to support the Modification 9 mine layout and the Extraction Plan for LW30-33. For the purpose of this FIA, the assessment of flood impacts and watercourse stability impacts will be based on a comparison of approved impacts as of SSD 5144 Modification 5 and Extraction Plan LW25-31 with the predicted impacts of Modification 9.

The report is structured as follows:

- **Section 2.0** outlines the surface water planning context for the Project and the Modification 9
- **Section 3.0** provides information on the existing surface water resources within the Project Area
- **Section 4.0** presents the potential impacts to flooding of the Modification 9 and proposed management strategies
- **Section 5.0** provides a discussion of the monitoring and reporting requirements for the Project.

2.0 Planning Context

This FIA has been prepared to support the Modification Report being prepared as part of a Proposed Modification (Modification 9) to the Project development consent. The relevant planning instruments and guidelines for surface water, and in particular flooding, are summarised below.

2.1 Planning Instruments and Guidelines

The Modification 9 is subject to the relevant requirements of the following water planning policies/plans and legislation regarding flood impacts associated with the Project:

- *Water Management Act 2000*
- *Water Act 1912*
- *Protection of the Environment Operations Act 1997* (POEO Act)
- State Water Management Outcomes Plan (SWMOP) (Department of Natural Resources (DNR), undated)
- Hunter-Central Rivers Catchment Action Plan (CAP)
- Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region (Department of Infrastructure Planning and Natural Resources (DIPNR), 2005)
- River Hydrology and Energy Relationships - Design Notes for the Mining Industry (DWE 2007)
- Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
- Water Sharing Plan for the Central Coast Unregulated Water Sources 2009
- Water Sharing Plan for the Jilliby Creek Water Source 2003.

The relevant requirements of these plans and regulations regarding this FIA are addressed in this report.

3.0 Existing Surface Water Environment

This section provides information on the existing surface water environment within the Project Area, including catchment areas, watercourses and existing flood regimes to be modelled.

3.1 Strahler Stream Ordering

In characterising the watercourses in the Project Area, consideration was given to the Strahler watercourse ordering system presented in DIPNR guideline documents (DIPNR 2005b, DIPNR undated) (DIPNR is now the NSW Department of Planning, Industry & Environment - DPIE)). Watercourse ordering is a hierarchical numbering system based on the degree of branching within a waterway system and provides an indication of the branching or complexity of creek and river systems.

The Strahler watercourse ordering system begins at the origin of a waterway, the initial watercourse being a first order watercourse. The watercourse remains first order until joining another watercourse. The confluence of two first order waterways results in a second order watercourse and the watercourse remains second order until joining a second order or higher order watercourse. After the confluence of two second order watercourses, the subsequent downstream waterway is designated a third order watercourse and so on moving downstream. Where lower order watercourses join higher order watercourses, the higher order numbering is unaffected, i.e. the watercourse resulting from the confluence of a first or second order watercourse with a third order watercourse will remain a third order watercourse.

The DIPNR guideline documents (DIPNR 2005b, DIPNR undated) classify waterway orders into three schedules linked to their stream ordering. The schedules are as follows:

- Schedule 1 – usually intermittent and consisting of first or second order waterways
- Schedule 2 – third and higher order waterways that drain into primary catchment rivers
- Schedule 3 – these watercourses are major rivers, including their primary tributaries and associated alluvial groundwater zones.

3.2 Catchment Areas and Watercourses

The majority of the Project Area lies within the broader catchment of Lake Macquarie, with the southern portion of the Project Area within the Wyong River catchment (refer to **Figure 3.1**).

The Project Area intersects five sub catchment areas: Morans Creek, Wyee Creek and Mannering Creek catchments which flow to Lake Macquarie; and Buttonderry Creek and Jilliby Creek catchments which flow to the Wyong River (refer to **Figure 3.1**). The Modification 9 will predominantly impact the Project Area within the Morans Creek Catchment (identified as Watercourse 6 in the 2013 Surface Water Assessment (Umwelt, 2013) and referred to as such for this assessment for continuity), and a small portion of the upstream catchment of Buttonderry Creek – refer to **Figure 1.2b** and **Figure 3.2**. Buttonderry Creek is identified as Watercourse 5 in the 2013 Surface Water Assessment (Umwelt, 2013) and referred to as such for this assessment for continuity.

The upper reaches of three first order watercourses within the Jilliby Creek catchment extend into the area of Longwall LW34. As LW34 has now been deleted, this further supports the view that Modification 9 will have a negligible (if any) impact on Jilliby Creek.

Watercourses of third order (as defined in Schedule 2) and higher with the potential to be impacted by the Modification 9 were modelled with a 2D hydrodynamic model. For the Modification 9 this includes Morans Creek, and the modelling employs the same flood model developed for the Surface Water Assessment (Umwelt, 2013).

Morans Creek joins Stockton Creek about 0.3 km upstream of the Pacific Motorway (M1). The downstream boundary of the hydraulic model domain is on Stockton Creek at the M1 motorway (refer to **Figure 3.1**). This downstream boundary is approximately 1 km downstream of the most downstream longwall (LW1). The upstream model boundary terminates at the northern end of the re-orientated LW30 (on Morans Creek).

As the upper reaches of Buttonderry Creek are typically first and second order watercourses (as defined in Schedule 1) within the vicinity of the Modification 9 (refer to **Figure 3.1**), Buttonderry Creek was not included in the hydraulic modelling. However, assessment of watercourse impacts for Buttonderry Creek was completed based on the subsidence predictions. A similar approach was used for Buttonderry Creek within the EIS prepared in 2013.

Key characteristics of each of the catchment areas impacted by the Modification 9 within the Project Area are summarised within **Section 3.2.1** for Morans Creek and **Section 3.2.2** for Buttonderry Creek.

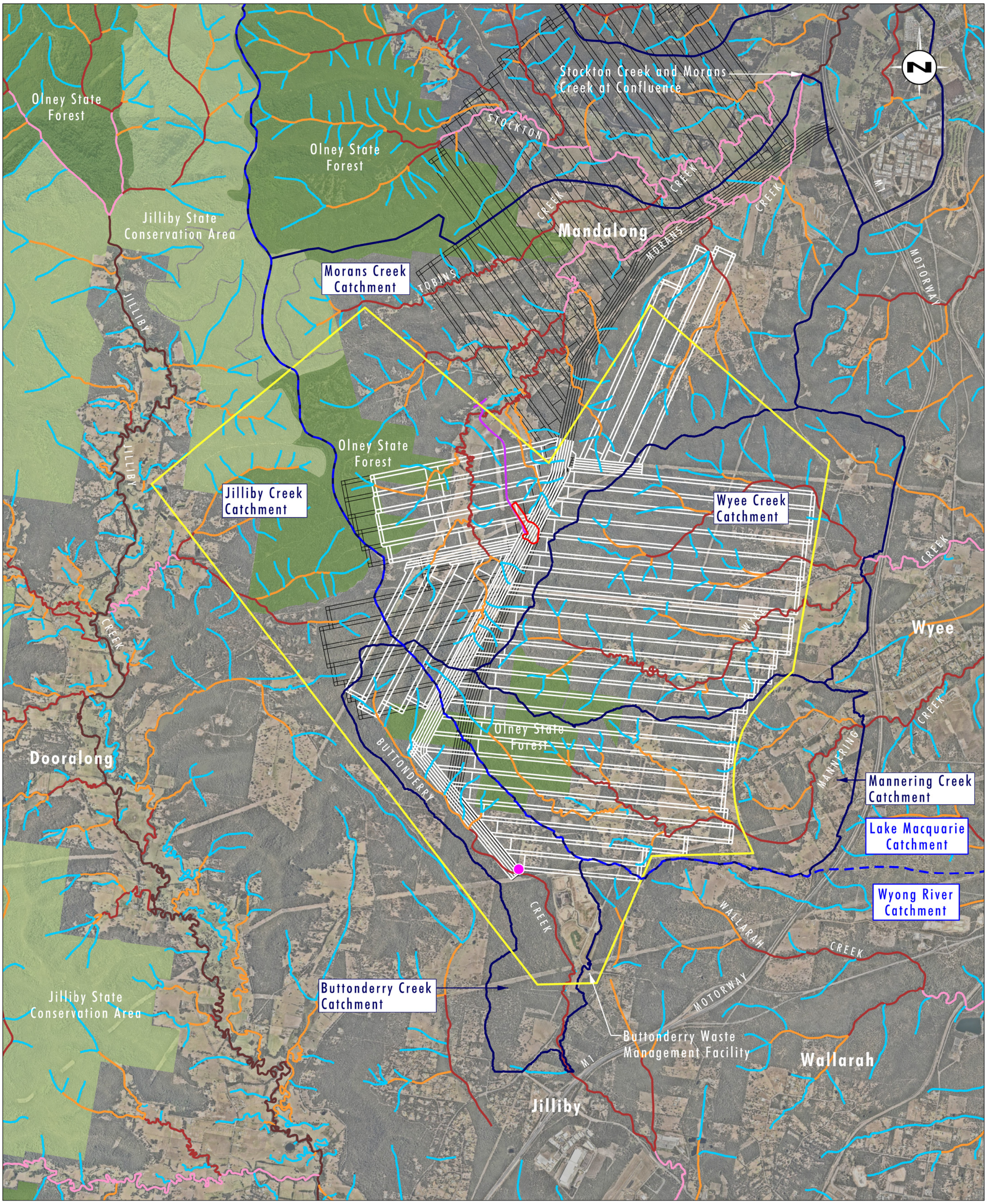


Image Source: Nearmap (Mar 2019)
Data Source: Centennial Mandalong (2019), LPI (2016, 2018)

0 1 2 3km
1:70 000

Legend

- Project Area
- Sub-catchment Boundary
- Approved Longawalls
- Proposed Longwalls
- Surface Infrastructure
- Access Road
- State Forest
- Conservation Area
- Catchment Boundary
- Approximate Location of Observed Ponding
- Stream Order:
  - 1st Order
  - 2nd Order
  - 3rd Order
  - 4th Order
  - 5th Order

FIGURE 3.1

Watercourses and Catchments

File Name (A4): R01/20091_004.dgn
20200731 15.03

3.2.1 Morans Creek

Morans Creek, a third order watercourse within the Project Area (refer to **Figure 3.1** and **Figure 3.2**; Watercourse 6), is located in the Lake Macquarie catchment and flows in an approximately north-easterly direction through the Project Area, before flowing into Stockton Creek approximately 4 km north of the Project Area and 0.3 km upstream of the Pacific Motorway (M1). Stockton Creek flows into Dora Creek west of Morisset, which flows into Lake Macquarie.

Approximately 1274 ha (43% of the total catchment area) of Morans Creek lies within the Project Area (Umwelt, 2013). Catchment elevations range from 260 metres Australian Height Datum (mAHD) within the southern sections of the catchment to 30 mAHD at the northern end of the Project Area.

Ponding areas, which occur after prolonged rainfall and/or flooding, were observed during a field survey in June 2011, primarily within second order tributaries of Morans Creek (refer to Umwelt, 2013 for further information). No scouring was observed along surveyed sections of Morans Creek during the June 2011 survey conducted by Umwelt as preparation for the 2013 EIS.

In contrast to the sections of Morans Creek in the vicinity of the approved Mandalong Mine to the north of the Project Area, the portion of the Morans Creek catchment area within the Project Area is predominantly well forested, with sandy soils and some rocks ranging in size up to approximately 200 mm in diameter (refer to Umwelt, 2013 for further information). Soil landscapes for Morans Creek are discussed further in **Section 3.3**.

3.2.2 Buttonderry Creek

Buttonderry Creek is a second order watercourse within the Project Area, (refer to **Figure 3.1** and **Figure 3.2**; Watercourse 5). Within the Project Area Buttonderry Creek flows in a southerly direction to the west of the Buttonderry Waste Management Facility, and then flows into the Wyong River approximately 6 km south of the Project Area. Approximately 505 ha (80% of the total catchment area) of Buttonderry Creek lies within the Project Area (Umwelt, 2013).The Buttonderry Creek catchment ranges in elevation from approximately 260 mAHD in the north to approximately 20 mAHD at the southern boundary of the Project Area, adjacent to the Buttonderry Waste Management Facility. Within the Project Area, the catchment is predominantly forested with a thick canopy of medium sized trees with minimal underbrush (refer to Umwelt, 2013 for further information).

Sections of Buttonderry Creek displayed evidence of scouring, including bank erosion and deposition of sandy sediments within the creek bed during the field survey in June 2011 conducted by Umwelt. Ponding was also observed within the main channel of Buttonderry Creek in the south of the Project Area during the June 2011 survey (refer to Umwelt, 2013 for further information). Soil landscapes for Buttonderry Creek are discussed further in **Section 3.3**.

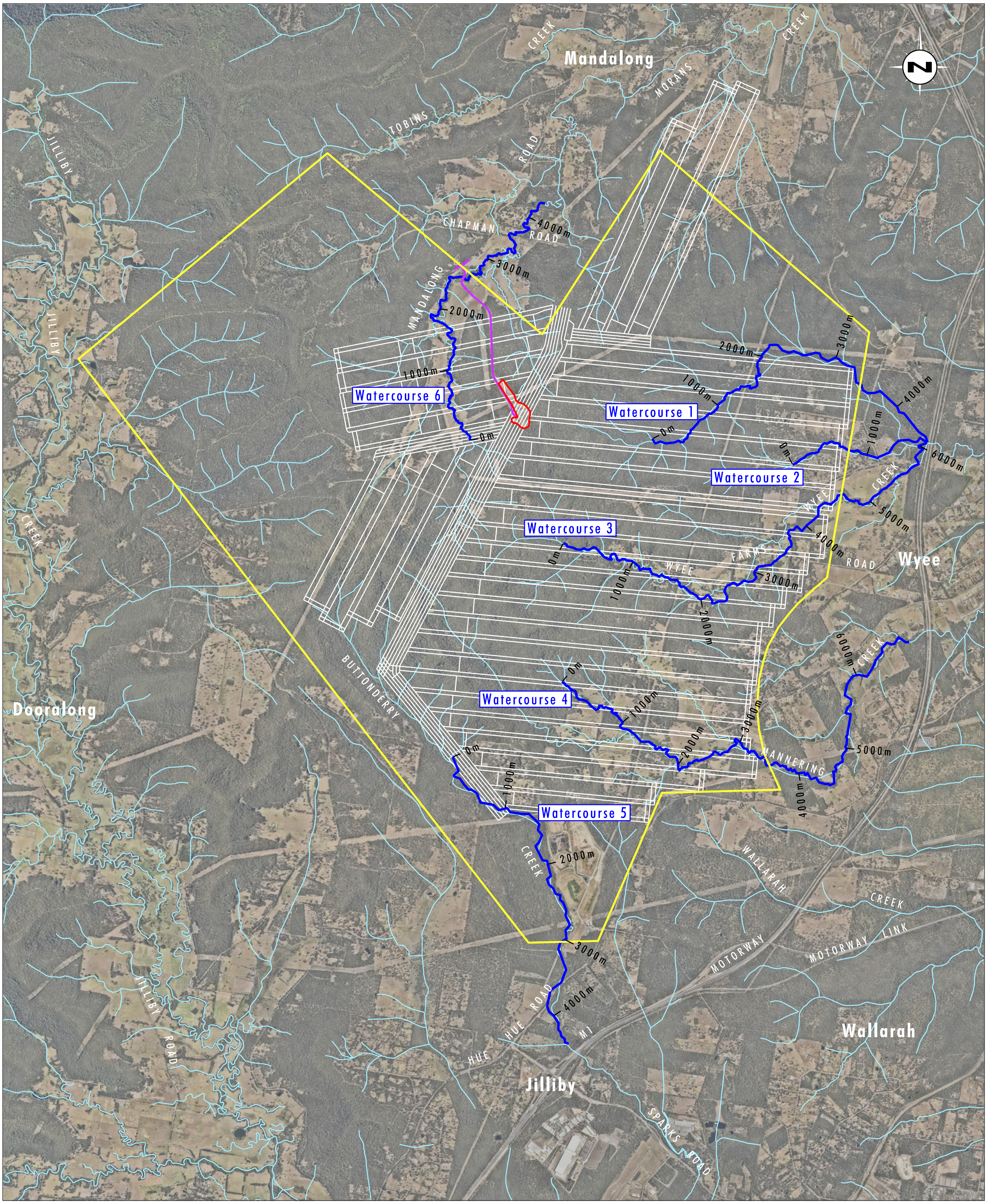


Image Source: Nearmap (Dec 2020)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 1.0 2.0 2.5km
1:60 000

Legend

- Project Area
- Surface Infrastructure
- Proposed Longwalls
- Access Road
- Subsidence Affected Area
- Drainage Line
- Watercourse Longsection Locations

FIGURE 3.2

Watercourse Extents and Locations within the Project Area

File Name (A4): R01/20091_010.dgn
20200915 18.29

3.3 Soil Landscapes

The Project Area typically includes seven soil landscapes (Department of Land and Water Conservation (DLWC) 1993), with the extents shown in **Figure 3.3** and the typical soil landscape properties summarised in **Table 3.1**. The upper slopes of the Project Area are predominantly Mandalong and Woodburys Bridge soil landscapes, with the footslopes predominantly Gorokan soil landscapes. The floodplain areas are typically Yarramalong, Wyong and Doyalson soil landscapes. All of the soils landscapes within the Project Area typically exhibit between moderate and very high erodibility, with a corresponding erosion hazard between slight to moderate and extreme (refer to **Table 3.1**). Erodibility describes the susceptibility of soil to mobilise as a result of rainfall and runoff, while erosion hazard describes the likelihood for erosion to occur within a given area.

Table 3.1 Soil Landscapes in the Mandalong Southern Extension Project Area

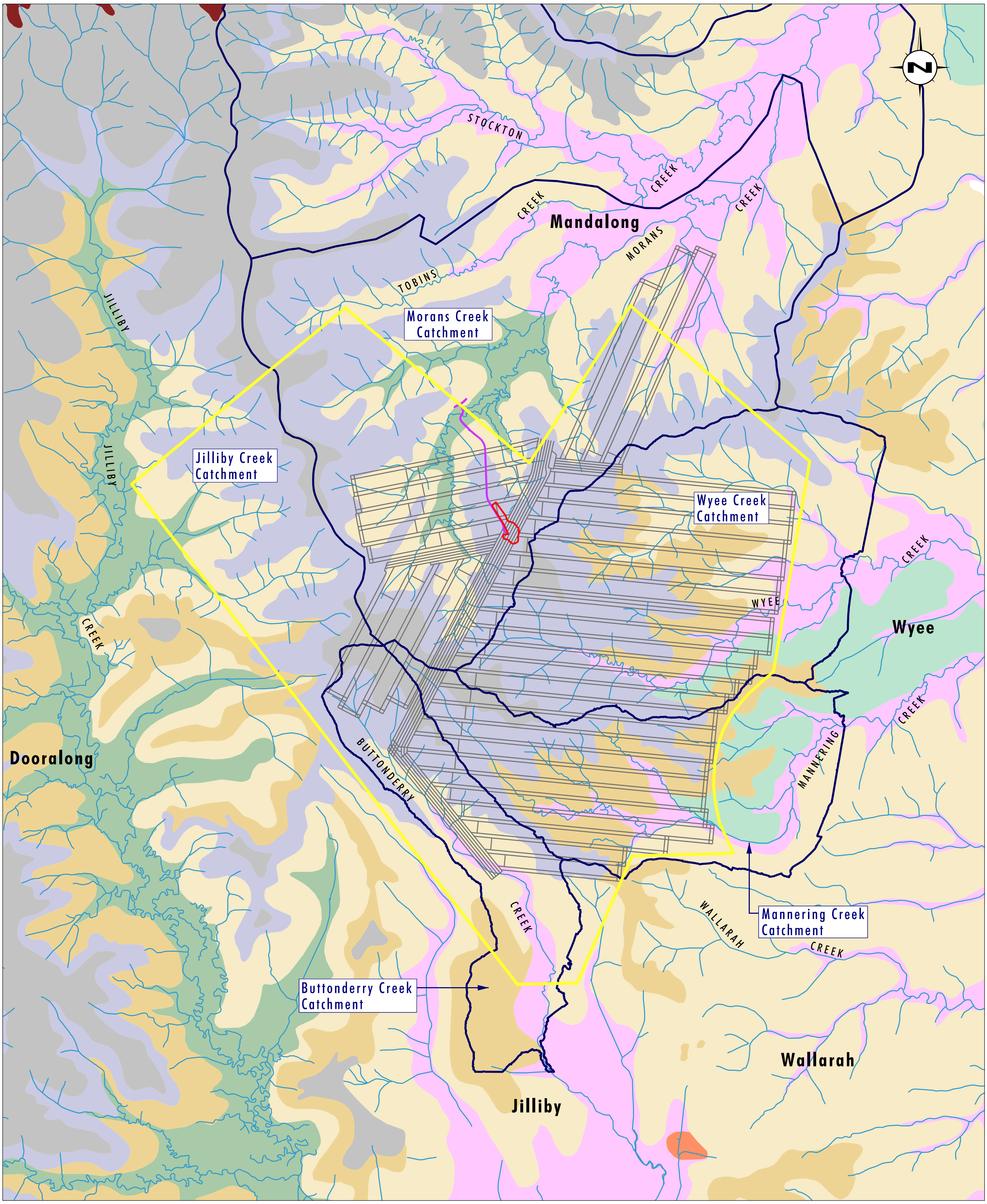
Soil Landscape	Typical Terrain	Dominant Topsoil	Erodibility	Erosion Hazard[1]
Watagan	Hill tops	Friable dark brown loam (WN1[2]) Hardsetting yellowish brown sandy clay loam (WN2[2])	Very high	Extreme
Mandalong	Upper slopes	Hardsetting stony brown sandy clay loam (ML1[2])	Moderate to High	Very High
Woodburys Bridge		Dark brown pedal fine sandy loam (WO1[2])	Moderate	Moderate
Gorokan	Footslopes	Loose dark brown loamy sand (GK1[2])	High	Moderate to High
Yarramalong	Floodplains	Loose brown sands (YA1[2])	Moderate to High	Slight to High
		Brown pedal loam (YA2[2])	Moderate	Slight to High
Wyong		Brownish black pedal loam (WY1[2])	Moderate	Slight to Moderate
Doyalson		Brown loose loamy sand (DO1[2])	Moderate to High	Moderate

Note: [1]Erosion Hazard category for grazing conditions

[2] Source: Soil Landscapes for Gosford – Lake Macquarie, DLWC (1993)

The soil landscapes within the Morans Creek catchment include Watagan and Mandalong soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Yarramalong and Wyong soil landscapes within the floodplain area (refer to **Figure 3.3**).

The soil landscapes within the Buttonderry Creek catchment include Watagan, Mandalong and Woodburys Bridge soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Wyong soil landscapes within the floodplain area (refer to **Figure 3.3**).



Data Source: Centennial Mandalong (2020) DLWC (1993), LPI (2016)

0 1 2 3km
1:70 000

Legend

- Project Area
- Sub-catchment Boundary
- Surface Infrastructure
- Proposed Longwalls
- Access Road
- Drainage Line

Soil Landscapes:

- Disturbed Terrain
- Doyalson Soil Landscape
- Gorokan Soil Landscape
- Mandalong Landscape
- Sydney Town Landscape
- Watagan Landscape
- Woodburys Landscape
- Wyong Landscape
- Yarramalong Landscape

FIGURE 3.3

Soil Landscapes

File Name (A4): R01/20091_005.dgn
20200731 15.07

3.4 Flood Regimes and Approved Impacts

Hydrodynamics is the study of fluids in motion, and for this FIA a two-dimensional (2D) hydrodynamic flood model (also referred to as a 2D hydraulic flood model) has been employed to model flood behaviour, for several design storm events (refer to **Appendix 1**). The flood modelling approach in this assessment is the same as used in the 2013 Surface Water Assessment (Umwelt, 2013), subsequent Flood Impact Assessments for the Mandalong South Modifications 4 (Umwelt, 2016) and 5 (Umwelt, 2017) associated with changes to longwalls 22 to 24A, and the most recent Flood Impact Assessment that was prepared for the Extraction Plan for LW25 to 31 (Umwelt, 2018). As such, only watercourses of third order (Schedule 2) and higher (refer to **Figure 3.1**) that would be potentially impacted by the Modification 9 were modelled (i.e. Morans Creek only). As the upper reaches of Buttonderry Creek are typically first and second order watercourses (i.e. Schedule 1) within the vicinity of the Modification 9 (refer to **Figure 3.1**), Buttonderry Creek was not included in the hydraulic modelling. However, assessment of watercourse impacts for Buttonderry Creek was completed based on the subsidence predictions.

Based on the adopted 2D hydrodynamic model, **Figure 3.4** illustrates the modelled peak 100 year Average Recurrence Interval (ARI) flood depths for pre-mining conditions in Morans Creek and **Figure 3.5** illustrates the modelled peak 1 year ARI flood depths for pre-mining conditions in Morans Creek. Flood hazard categories for pre-mining conditions within Morans Creek for the 100 year ARI flood event are included in **Figure 3.6**.

For the purpose of this FIA, the assessment of the proposed Modification 9 landform impacts is based on a comparison with approved impacts as of SSD 5144 Modification 5 and Extraction Plan LW25-31.

The pre-mining landform serves as a reference for the approved and proposed landforms where appropriate. For the Mandalong Southern Extension Project (the Project), the pre-mining landform is defined as mining being completed for the original Centennial Mandalong operation (Longwalls 1 to 24A) and prior to mining in the Project Area (Longwalls LW25 to 64). Completed mining for the original Centennial Mandalong operation has been based on observed subsidence (LIDAR) where available and predicted subsidence otherwise.

umwelt

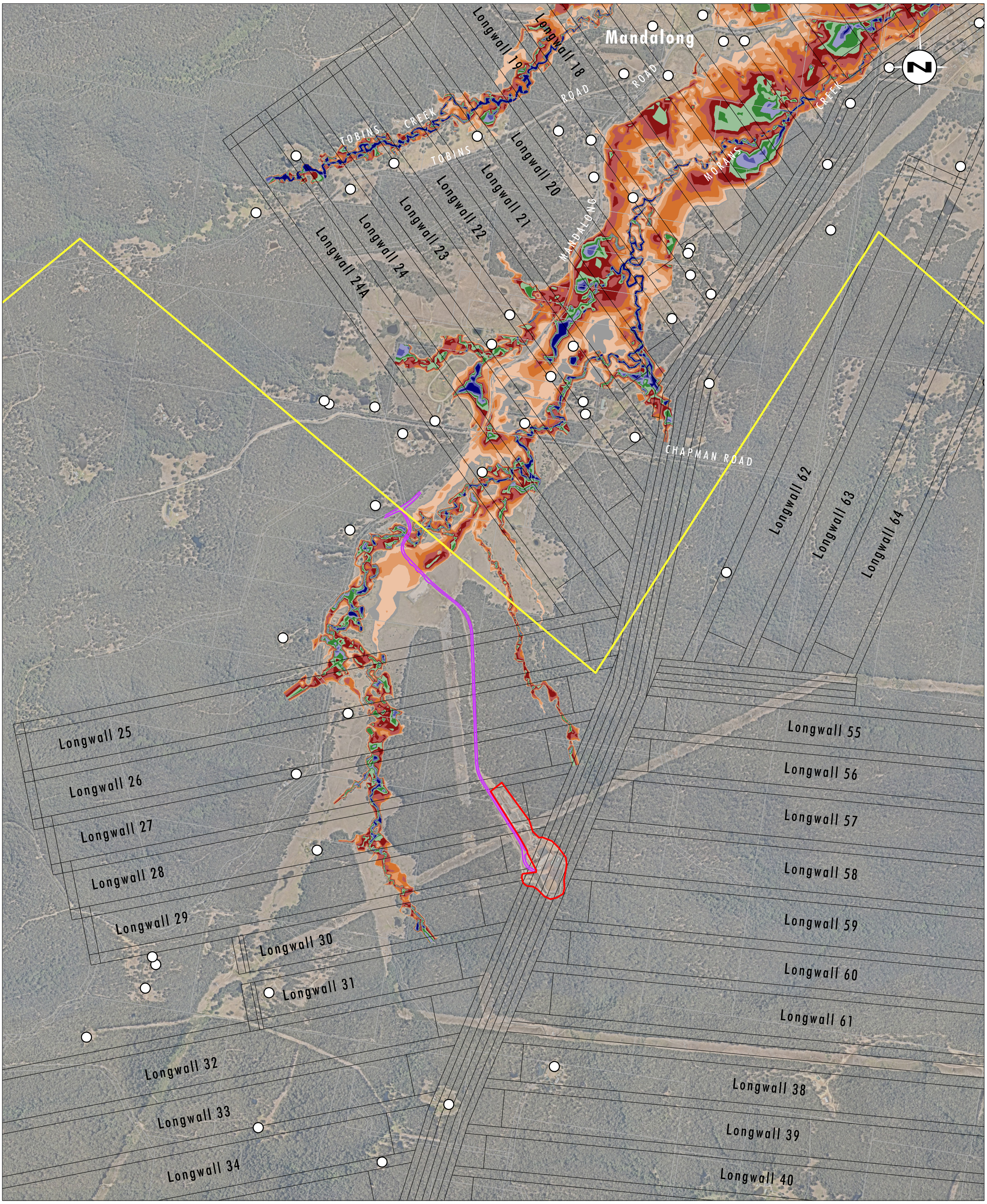


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend
- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Water Depth (metres)
- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 3.4

100 year ARI Storm Event
Maximum Flood Depths for Morans Creek
(Pre-mining Landform)

File Name (A4): R01/20091_007.dgn
20200731 15.12

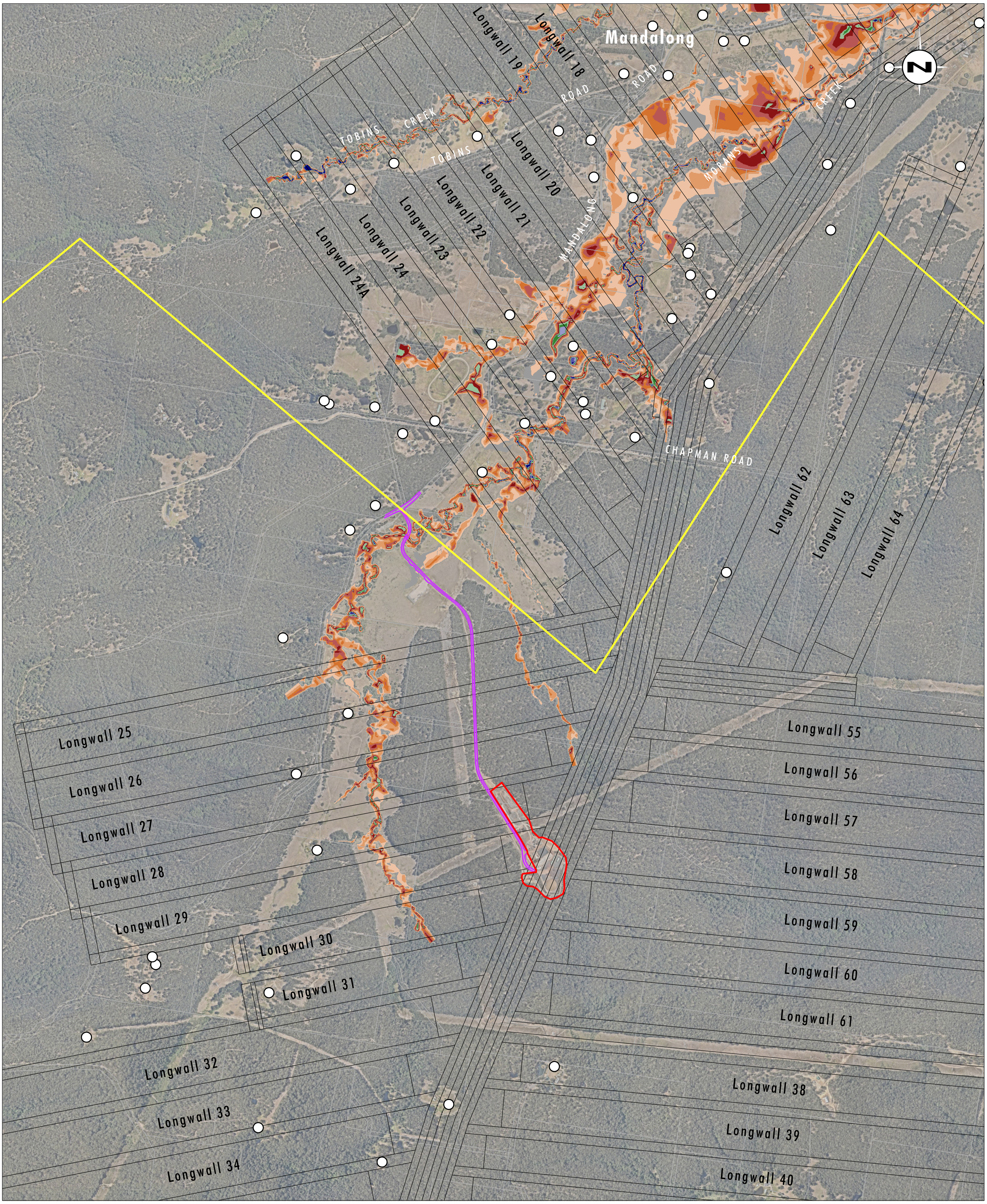


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 3.5

1 year ARI Storm Event
Maximum Flood Depths for Morans Creek
(Pre-mining Landform)

File Name (A4): R01/20091_008.dgn
20200731 15.10

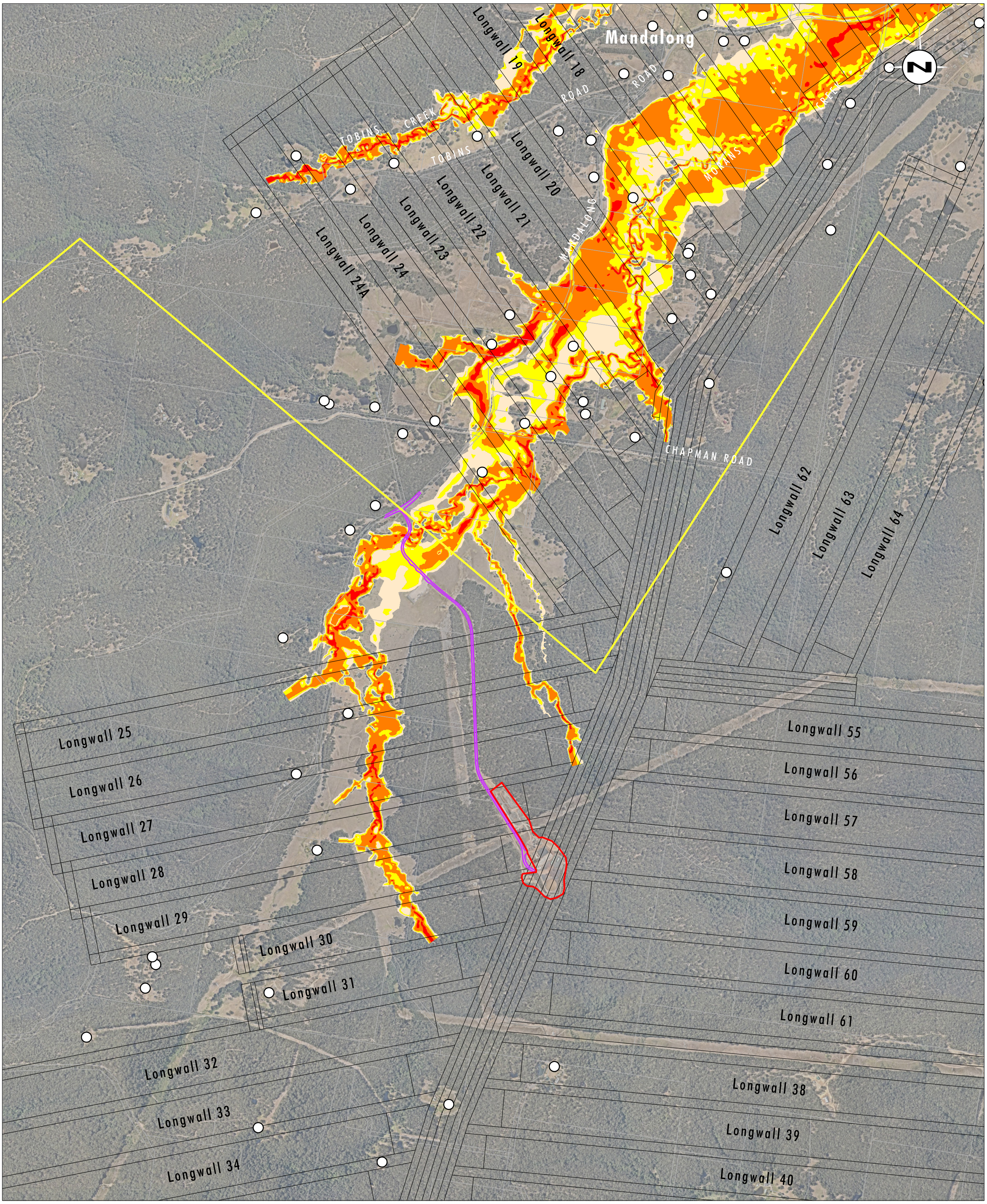


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Hazard Category

- Low Hazard - Unclassified hazard
- Low Hazard - Vehicles unstable
- High Hazard - Wading unsafe
- High Hazard - Damage to light structures

FIGURE 3.6

100 year ARI Storm Event
Maximum Flood Hazard Categories for Morans Creek
(Pre-mining Landform)

File Name (A4): R01/30091_009.dgn
20200731 15.13

4.0 Surface Water Impacts and Management Methods

This section of the FIA reviews the potential impacts of the Project on surface water resources and the proposed management of any identified potential impacts. The assessment approach and methodology are discussed in **Appendix 1**.

The proposed landform has the potential to impact on the following:

- catchment area boundaries
- watercourse stability and associated water quality
- remnant ponding
- flood regimes.

The potential of each of these impacts and any proposed management methods are outlined in **Sections 4.1** to **4.4**.

Relative to the previous Rev 2 report, the new mine plan now includes a lateral 35 m shift to the east for longwalls LW30 to 33. As shown in **Figure 4.1**, the limit of subsidence (20 mm subsidence contour) for these shifted longwalls is outside the RMA-2 hydraulic model domain. Hence, the 35 m shift for these longwalls will not materially change the previous (Rev. 2, March 2020) Modification 9 subsidence impacts for the hydraulic model domain. As such, the previous (Rev 2, March 2020) flood modelling and long section analysis are still relevant and are adopted for this latest report revision (Rev 3, September 2020).

On the other hand, the 35 m shift for these longwalls can potentially change the previous (Rev. 2) predicted impacts to catchment boundaries and remnant ponding and theses two matters have been re-examined as part of this latest report revision (Rev. 3, September 2020).

The three landforms (pre-mining, approved and proposed) addressed in the Rev. 2 report are maintained with adjustment for the change in predicted subsidence related to the 35 m shift in longwalls LW30-33, as follows:

1. *Pre-mining landform* – refers to completed mining within the original Centennial Mandalong operations (longwalls LW1 to 24A) and prior to mining commencing in the Project Area (Mandalong Southern Extension Project). The pre-mining landform watercourse stability assessment as discussed in **Section 4.2** and the pre-mining landform remnant ponding analysis as discussed in **Section 4.3** reflects the pre-mining scenario from the Rev 2 report.

   NOTE: The pre- mining landform is based on observed subsidence for Longwalls 1 to 17 (captured in 2015 LiDAR) and predicted subsidence for Longwalls 18 to 24A. No subsidence for longwalls LW25 to 64 within the Project Area.

2. *Approved landform* – refers to approved predicted subsided landform for the Project Area applicable to SSD 5144 Modification 5 and Extraction Plan LW25-31, i.e. the pre-mining landform with predicted subsidence for the Project Area (longwalls LW25 to LW64) as approved. The approved landform watercourse stability assessment as discussed in **Section 4.2** and the approved landform remnant ponding analysis as discussed in **Section 4.3** reflects the approved scenario from the Rev 2 report.

NOTE: The approved mining landform is based on observed subsidence for longwalls LW1 to 17 (using 2015 LIDAR) and predicted subsidence for Longwalls LW25 to 64 within the Project Area.

3. *Proposed landform* – refers to the predicted subsided landform as a result of the Modification 9, i.e. the approved subsidence impacts as of SSD 5144 Modification 5 and Extraction Plan LW25-31 revised to include the longwall modifications listed in **Section 1.1**. The proposed landform watercourse stability assessment as discussed in **Section 4.2** reflects the proposed scenario from the Rev 2 report. This is because the proposed changes to Longwalls LW 30 to 33 since the Rev 2 report (35 m lateral shift to east) result in predicted subsidence contours that do not impact the identified watercourse stability long sections for Morans Creek and Buttonderry Creek. On the other hand, the proposed changes to Longwalls LW 30 to 33 since the Rev 2 report (35 m lateral shift to east) will modify the remnant ponding in the area under investigation. As part of the process of modifying the proposed landform remnant ponding for this Rev 3 report, as discussed in **Section 4.3**, the latest 2020 LIDAR has been employed.

NOTE: The proposed mining landform is based on observed total subsidence for Longwalls LW1 to 25 (using 2020 LIDAR). As the 2020 LIDAR reflected partial subsidence for Longwalls LW26 to 29, the pre-mining scenario was modified with predicted subsidence for these longwalls. As the 2020 LIDAR reflected a non-subsided landform for Longwalls LW30 to 33, the 2020 LIDAR was modified with the predicted subsidence for these longwalls. For areas outside the longwalls, the 2020 LIDAR was used to define the proposed landform.

4.1 Catchment Areas

The predicted subsidence associated with the proposed landform has the potential to alter catchment boundaries that overlap the predicted subsidence area. Subsidence predictions for the Project (Ditton Geotechnical Services, 2020a, 2020b) indicate that the proposed underground mining will result in maximum predicted vertical subsidence of approximately 1.3 m in areas above longwalls LW25 to 33.

Catchment analysis for the proposed subsided landform indicates that the catchment boundaries of the creek systems to be undermined will not change significantly relative to the approved subsided landform.

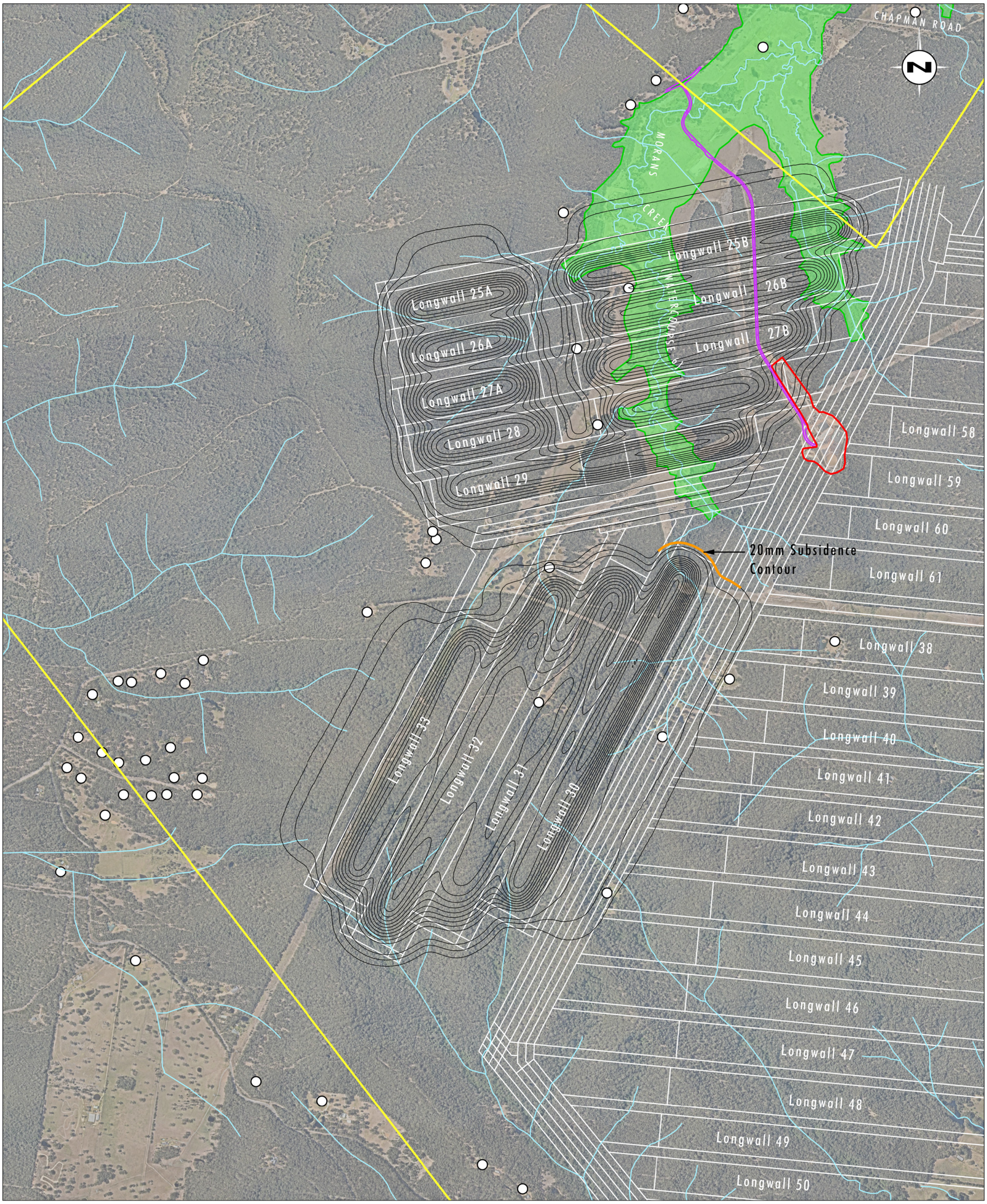


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Proposed Longwalls
- Access Road
- Predicted Subsidence Contours
- Drainage
- RMA2 Model Extent

FIGURE 4.1

Predicted Subsidence Extent

File Name (A4): R01/20091_018.dgn
20200803 10.28

4.2 Watercourse Stability

Longwall subsidence within the Project Area has the potential to impact the physical characteristics and hydraulic response of flows within a watercourse. Subsidence can cause changes to the longitudinal grades which can impact flow velocities and tractive stresses at various locations. Changes to flow velocity and tractive stress during flood events can impact the stability of a watercourse, causing scouring, changes to channel geometry and/or rerouting of the watercourse. The potential for changes to velocity and tractive stress within the Project Area therefore need to be examined to identify locations that may require monitoring and ongoing management as mining progresses.

The assessment of potential impacts on watercourse stability considers changes to longitudinal grades by long section analysis (refer to **Section 4.2.1**) and changes to bank full velocities and tractive stresses (refer to **Section 4.2.2**). A summary of watercourse impacts is given in **Section 4.4**.

4.2.1 Long Section Analysis

Long section analysis can provide an initial indication of locations along the watercourse where subsidence could impact longitudinal grades of the proposed landform relative to the pre-mining and approved landforms. An increase in longitudinal grade in the direction of flow (i.e. steeper grade) has the potential to promote scouring while a decrease in grade has the potential to promote ponding.

Figure 4.2 shows the location of the third order section of Morans Creek within the Project Area and a distance downstream, as used in the long section analysis. **Graph 4.1** shows the Morans Creek long section for each of the pre-mining landform, approved landform and proposed landform.

Graph 4.2 shows a long section of the third order section of Buttonderry Creek, as used in the long section analysis, for the pre-mining landform, approved landform and proposed landform. This third order section of Buttonderry Creek is within the Project Area and extends a distance downstream, and can be seen in **Figure 3.2.**

Viewing the approved subsided landform against the pre-mining landform in **Graph 4.1** and **Graph 4.2** provides a base to compare how the proposed landform may differ to the approved landform. For the proposed landform, potential scouring and ponding locations are marked on the long section where subsidence is expected to significantly impact longitudinal grades.

The analysis indicates changes in Morans Creek longitudinal grade (in the direction of flow) for the proposed landform relative to the approved landform, at the following locations:

- An increase in longitudinal grade in the direction of flow (i.e. steeper grade) is likely between chainage 100 to 300 m (southern chain pillar of Longwall 29), which could result in increased scouring in this region for the proposed landform relative to both the approved landform and the pre-mining landform.
- An increase in longitudinal grade in the direction of flow (i.e. increasing grade sloping upward in the direction of flow) is likely between chainages 350 to 450 m (over Longwall 29) and near chainages 1550 to 1650 m (over Longwall 25B), which could result in increased ponding near those sites relative to both the approved landform and the pre-mining landform.

The approximate locations of these potential scouring and ponding locations are illustrated on **Figure 4.2**.

The changes in Morans Creek longitudinal grade for the proposed landform near Longwalls 25B and 26B astride the chain pillar (near chainage 1350 m), are reductions in grade in the direction of flow. As such, at Longwall 26B there is less potential for remnant ponding compared to the approved landform, and at Longwall 25B there is less potential for scouring compared to the approved landform.

The location of potential scouring and ponding should be included in any ongoing watercourse monitoring program and may require remediation works (refer to **Sections 4.8** and **5.0**).

The analysis indicates that changes in Buttonderry Creek longitudinal grade for the proposed landform are negligible compared to the approved landform.

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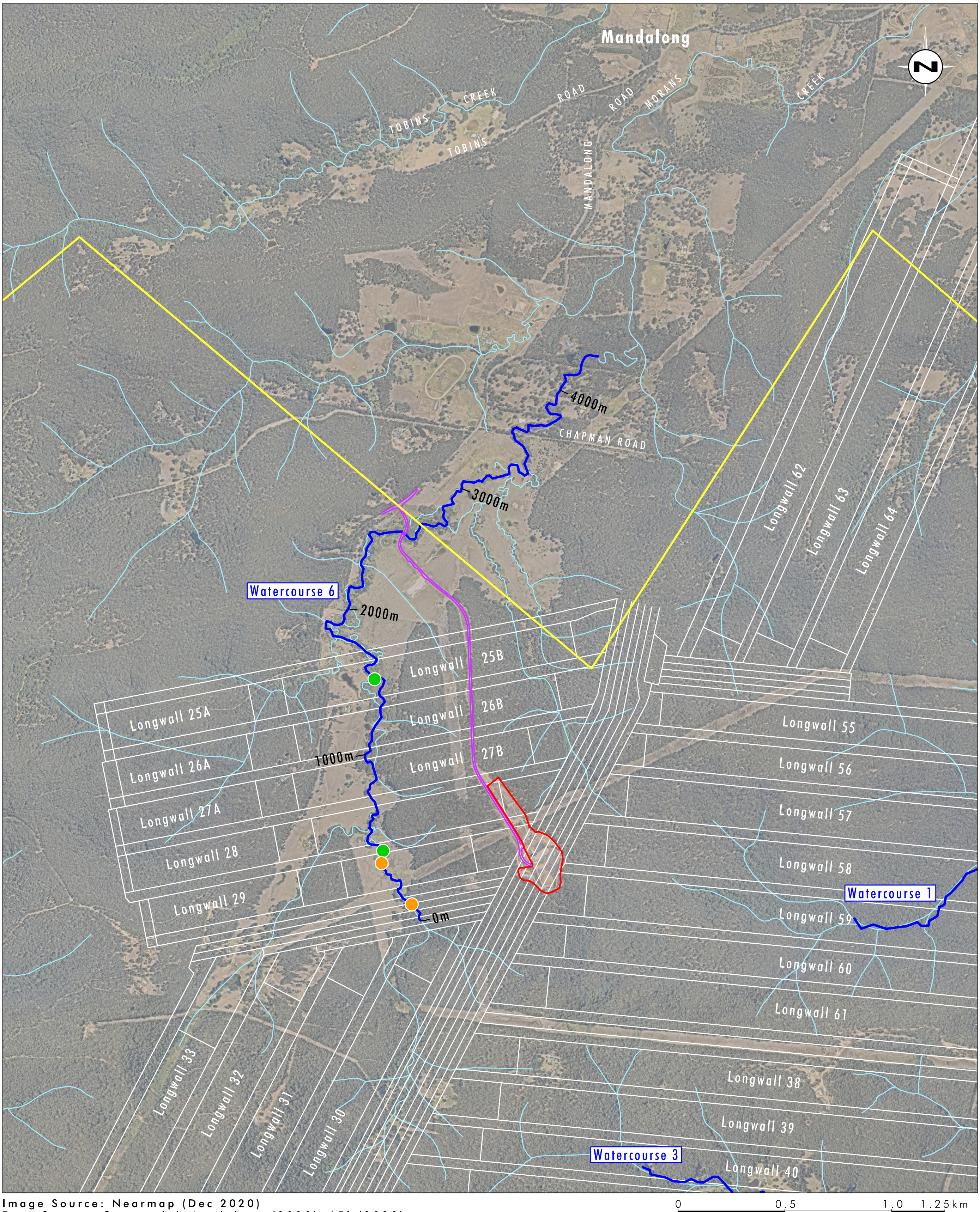


Image Source: Nearmap (Dec 2020)
Data Source: Centennial Mandalong (2020), LPI (2020)

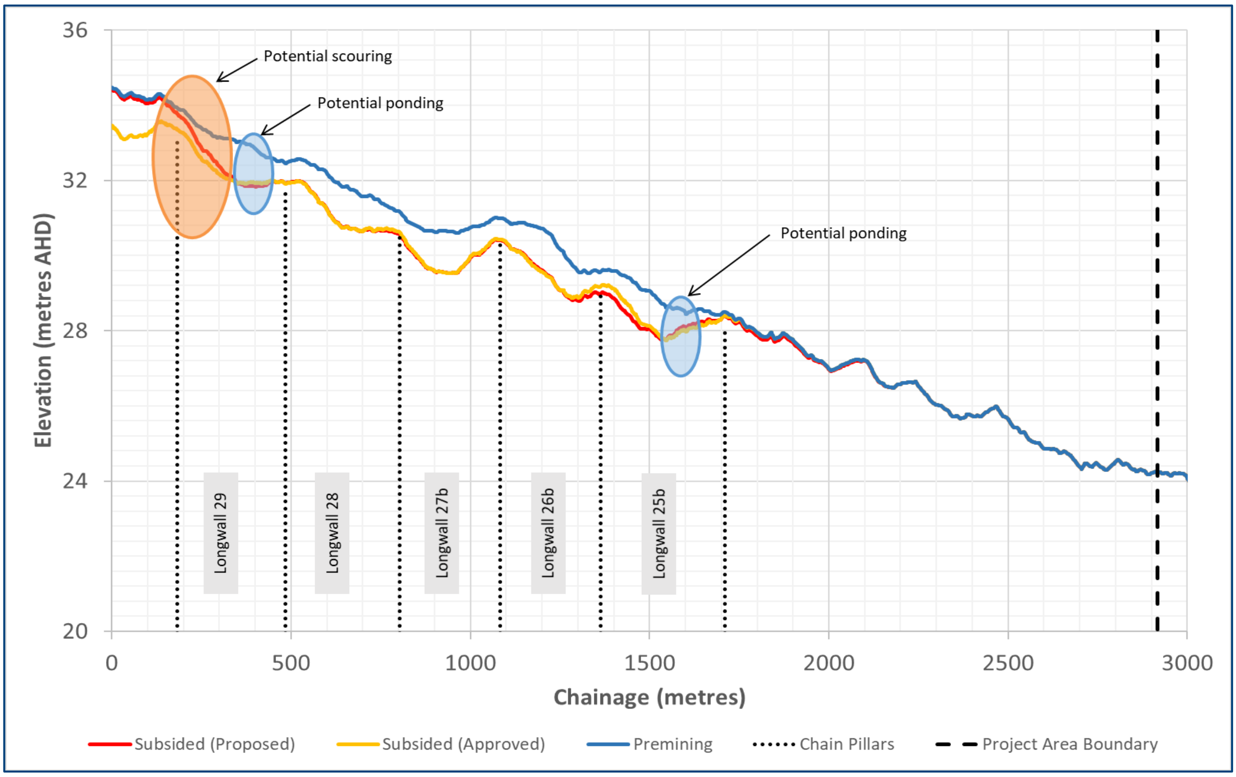
Legend

- Project Area
- Surface Infrastructure
- Proposed Longwalls
- Access Road
- Drainage Line
- Watercourse Longsection Locations
- Predicted Scouring Location (whole section between dots)
- Predicted Ponding Location

FIGURE 4.2

Long Section Locations and Monitoring Points

File Name (A4): R01/20091_006.dgn
20200731 15.08



Graph 4.1 Long section of Morans Creek for pre-mining, approved and proposed scenarios

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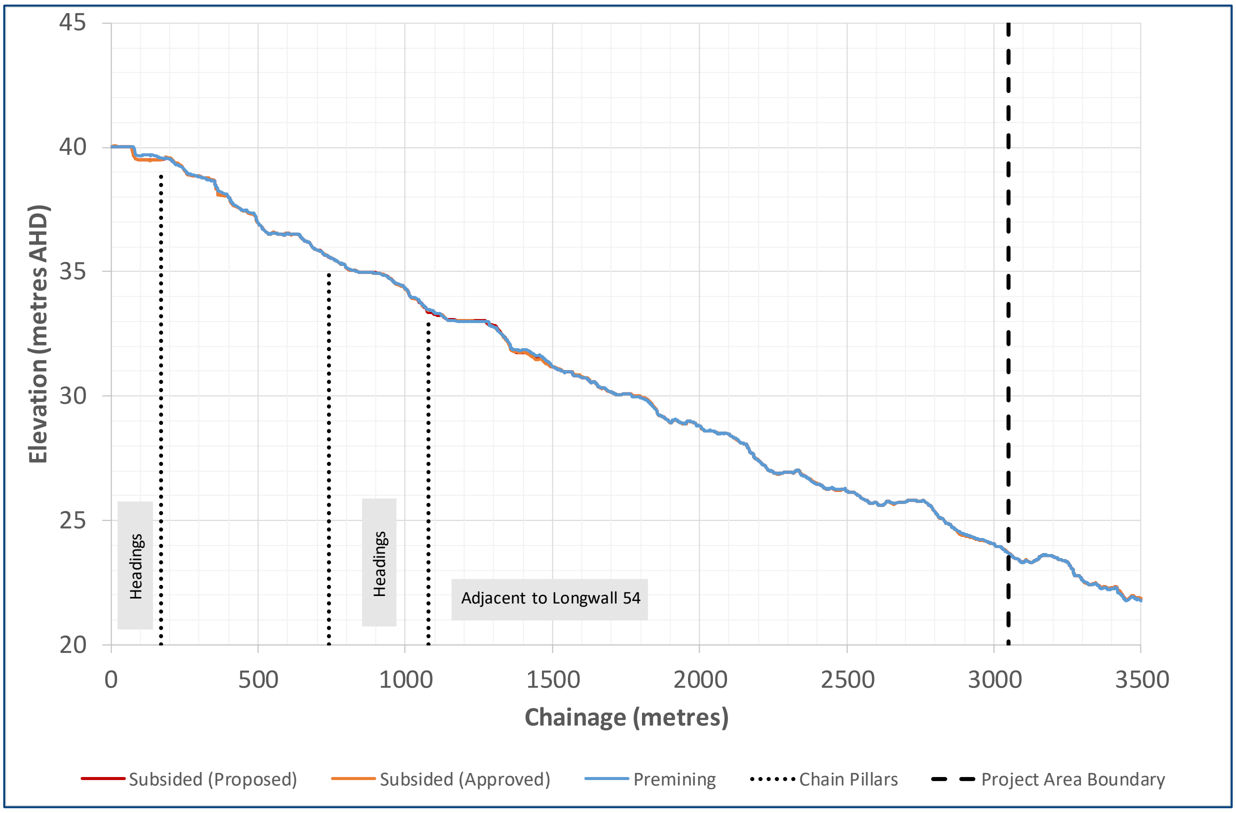

Graph 4.2 Long section of Buttonderry Creek for pre-mining, approved and proposed scenarios

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4.2.2 Velocities and Tractive Stresses

The long-term stability of the bed and banks of a watercourse are influenced by the flow energy within the watercourse. The flow energy is typically estimated using modelled flow velocities and tractive stresses (i.e. the shearing force of the water against the bed and banks) within the watercourse in response to a bankfull flow event. The bankfull flow event is classified as the design event that results in flow depths being approximately equal to the top of the banks of the watercourse, which typically corresponds to the 1 year or 2 year ARI design event.

4.2.2.1 Approach

The potential impacts on watercourse stability as a result of the predicted subsidence for Modification 9 (i.e. the proposed landform) were assessed using modelled changes in the approximate bankfull flow velocity and tractive stress (refer to **Appendix 1**) and results of the longitudinal gradient analysis (refer to **Section 4.2.1**).

The potential impact of changes to modelled velocities and tractive stresses on the stability of a watercourse were estimated using stability thresholds. The stability thresholds allow for flows to be categorised as *stable, marginally stable* or *unstable*. The thresholds depend on bed and bank material and vegetation coverage. The stability of a watercourse refers to how it accommodates itself to inflowing water and sediment load (Fischenich, 2001). Typically, stable watercourses may adjust their boundaries but do not exhibit changes to their geometric character (Fischenich, 2001). When the stability thresholds (refer to **Table 4.1**) for the material forming the bank of a channel are exceeded (i.e. fall into the *Unstable* category), erosion occurs (Fischenich, 2001).

Based on the observations from the field inspections conducted as part of the 2013 Surface Water Assessment (Umwelt, 2013), bed materials appear to range from graded loam to fine gravels and cobbles. The thresholds for tractive stress and flow velocity shown in **Table 4.1** have been selected as indicative thresholds for determining the stability state of Morans Creek.

Table 4.1 Tractive Stress and Velocity Thresholds for graded loam to fine gravels to cobbles (Adapted from Fischenich (2001))

Flow Metric	Stable	Marginally Stable	Unstable
Velocity	< 0.75 m/s	0.75 m/s to 1.15 m/s	> 1.15 m/s
Tractive Stress	< 3.6 N/m^2	3.6 N/m^2 to 18.2 N/m^2	> 18.2 N/m^2

Using the 2D hydrodynamic modelling results for Morans Creek, the estimated bankfull velocity and tractive stress (based on the 1 year ARI design event) for the pre-mining, approved and proposed landform are included in **Graph 4.3** and **Graph 4.4** respectively. These charts also show indicative stability thresholds (adapted from Fischenich (2001), refer to **Table 4.1**) and the approximate location of the longwalls and the boundary of the Project Area.

Morans Creek was modelled using a 2D hydrodynamic model (refer to **Appendix 1**), and the tractive stress plotted in **Graph 4.4** represents the tractive stress *per metre width of channel* at the stream centre line. This measure provides an estimate of the maximum tractive stress within the watercourse profile (i.e. at the centreline) and has been used to assess the potential impact of tractive stresses.

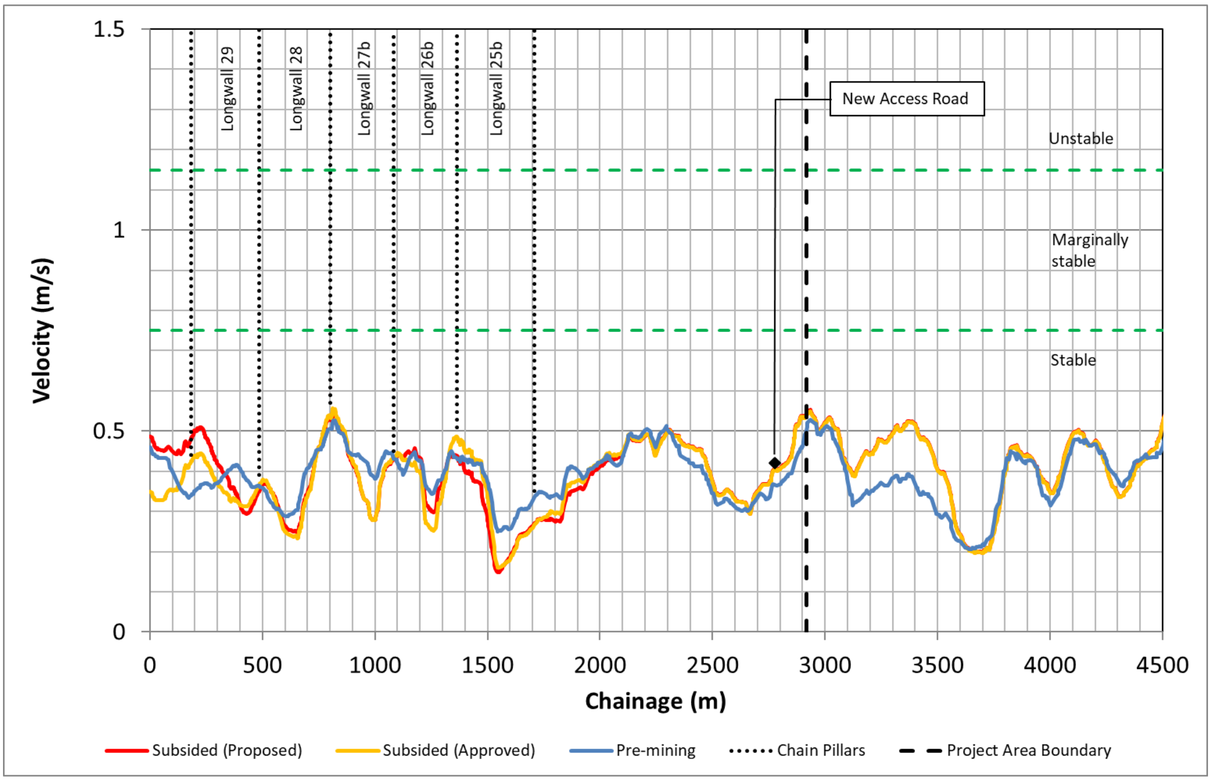
4.2.2.2 Potential Impacts of Velocities and Tractive Stresses

Modelled bankfull velocities for Morans Creek in **Graph 4.3**, show:

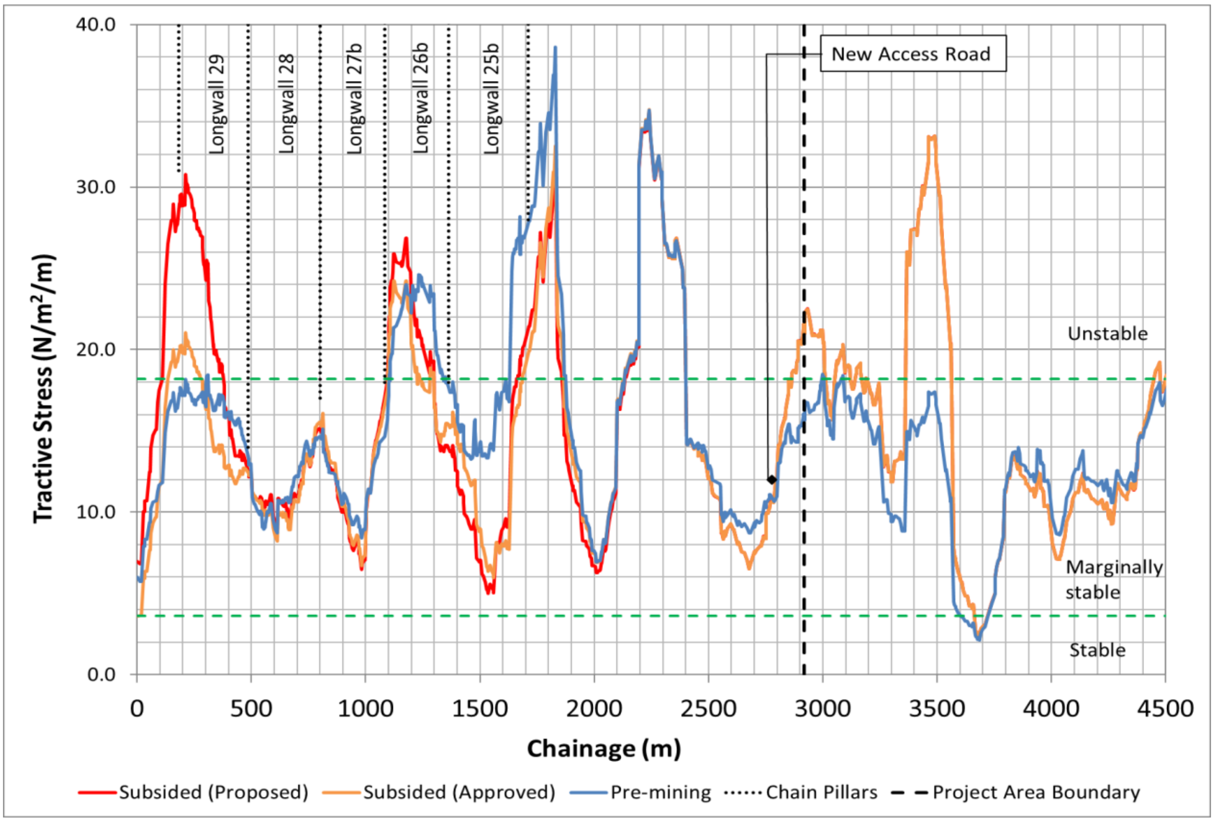
- the greatest increases in velocity for the proposed landform relative to the approved landform are predicted to occur between chainages 100 to 400 m (southern chain pillar Longwall 29)
- smaller increases in velocity for the proposed landform relative to the approved landform are predicted to occur between chainages 1100 to 1200 m (centre of Longwall 26B)
- minor decreases in velocity for the proposed landform relative to the approved landform are predicted to occur between chainages 400 to 500 m and near chainage 1550 m and at 1800 m
- no changes in velocity for the proposed landform relative to the approved landform are predicted to occur downstream of chainage 2100 m
- all bankfull velocities in Morans Creek are predicted to be within the “stable” range.

Modelled bankfull tractive stresses for Morans Creek are presented in **Graph 4.4** and show:

- for the proposed landform substantial increases in tractive stress within the “unstable” zone are predicted to occur between chainages 100 to 400 m (southern chain pillar Longwall 29) relative to the approved landform where increased tractive stress in the “unstable” zone occurred for chainages 130 to 280 m
- the maximum tractive stress is predicted to occur at chainage 212 m, increasing to 30.7 $N/m^2/m$ for the proposed landform compared to 21.0 $N/m^2/m$ for the approved landform at that location
- by comparison the pre-mining landform is predicted to be within the “marginally stable” zone for chainages 100 to 400 m, therefore the greatest impacts to watercourse stability are likely to be observed around Longwall 29 (chainages 100 to 400 m)
- increases in tractive stress for the proposed landform relative to the approved landform are predicted to occur near chainages 1100 to 1200 m (Longwall 26B), with an increase from 24.0 to 27.8 $N/m^2/m$ observed around chainage 1177 m
- decreases in tractive stress for the proposed landform relative to the approved landform are predicted to occur between chainages 1300 to 1550 m and 1870 to 1960 m
- no changes in tractive stress for the proposed landform relative to the approved landform are predicted downstream of chainage 2100 m.



Graph 4.3 Morans Creek – Modelled Velocity (1 Year ARI Design Storm Event)



Graph 4.4 Morans Creek – Modelled Tractive Stress (1 year ARI Design Storm Event)

4.3 Remnant Ponding

The proposed landform has the potential to cause or increase remnant ponding (ponding that occurs after prolonged rainfall and/or flooding) within the area affected by subsidence. **Figure 4.3** shows remnant ponding for the proposed landform compared to the approved landform and the pre-mining landform.

> *NOTE: In **Figure 4.3**, the proposed scenario is the bottom layer in the drawing, with the pre-mining scenario being on a layer above, and the approved scenario is the top layer.*

Remnant ponding for the proposed landform is based on the predicted subsided landform associated with the new mine plan that includes re-orientated longwalls LW30 to LW33, and a shift 35 m east relative to the earlier (Rev 2) mine plan. As discussed in **Section 4.0**, subsidence impacts to remnant ponding for the proposed landform use observed total subsidence for Longwalls LW1 to LW25 (based on recent LIDAR dated 5 April 2020) and the latest predicted subsidence for longwalls LW26-33 (DGS, 2020a, 2020b).

> *NOTE: Mining of longwall LW25 was completed on 17 September 2019, and recent LIDAR captured on 5 April 2020 will reflect full subsidence for all longwalls LW1 to LW25. Longwall LW26 mining was completed on 6 March 2020 and the recent LIDAR will exhibit partial subsidence for LW26, hence predicted subsidence has been used for longwalls LW26 to LW33. Previously predicted subsidence for the higher numbered longwalls within the Project Area is unchanged.*

Analysis of remnant ponding for the proposed landform compared with remnant ponding for the approved landform indicates:

- Remnant ponding is typically confined to existing flow paths (refer to **Figure 4.3**)
- Minor increases in remnant ponding:
  - Along the third order section of Morans Creek near Longwall 25B (consistent with long section analysis in **Graph 4.1**).
  - Along the first and second order tributaries of Morans Creek near Longwall 26A.
  - Along a second order section of Morans Creek at the northern end of Longwall 30
  - Along Morans Creek to the north of Longwall 25B near the Project Area boundary.
    *NOTE: Relative to the earlier Rev 2 report this proposed landform remnant ponding has increased relative to the approved landform in some areas and decreased in other areas. This is due to 2020 LIDAR being used for the proposed landform remnant ponding, whereas the approved landform has retained the 2015 LIDAR data. However, the total area of remnant ponding for the proposed landform has decreased relative to the both the pre-mining and approved landforms (refer to **Table 4.2** below).*
- minor increases along Buttonderry Creek and a second order watercourse to the north of Buttonderry Creek.

> *NOTE: Relative to the earlier Rev 2 report this proposed landform remnant ponding has increased relative to the approved landform in some areas and decreased in other areas. This is due to 2020 LIDAR being used for the proposed landform remnant ponding, whereas the approved landform has retained the 2015 LIDAR data. However, the total area of remnant ponding for the proposed landform has decreased relative to both the pre-mining and approved landforms (refer to **Table 4.2** below).*

As discussed in Umwelt (2013), analysis indicates that the total remnant ponding area for the pre-mining landform within the Project Area is approximately 128 ha. Of this total area, the remnant ponding area for the pre-mining landform within the catchments of Morans Creek and Buttonderry Creek is 16 ha. Within Longwalls LW30 to 33 the remnant ponding for the pre-mining landform is 2.25 ha. **Table 4.2** presents a comparison of the remnant ponding within the subsidence affected area for the pre-mining, approved and proposed landforms.

Table 4.2 Changes in remnant ponding for Morans Creek and Buttonderry Creek within the subsidence affected area

Landform	Total area of predicted remnant ponding (ha)	Change in area from Pre-mining (ha)	Total area of predicted remnant ponding within LW30-33 (ha)	Change in area from Pre-mining (ha) – within LW 30-33
Pre-mining (2015 LiDAR)	16.0	-	2.25	-
Approved (2015 LIDAR)	17.5	1.5 (+9.4%)	2.31	0.06 (+2.7%)
Proposed - Modification 9 (2020 LIDAR)	10.2	-5.8 (-36.2%)	0.73	-1.52 (-67.6%)

As can be seen in **Table 4.2**, an assessment of the proposed landform indicates changes to remnant ponding in the area to be undermined as follows:

- Compared to the pre-mining scenario, a decrease in total remnant ponding area of 5.8 ha is predicted (i.e. a decrease of 36.2%)
- Compared to the pre-mining scenario, a decrease of 1.52 ha in remnant ponding within Longwalls LW 30-33 (i.e. a decrease of 67.6%)
- Compared to the approved mining scenario, a decrease in total remnant ponding area of 7.3 ha is predicted
- Compared to the approved mining scenario, a decrease of 1.58 ha in remnant ponding within Longwalls LW30-33.

The analysis indicates that potential impacts on remnant ponding are confined to existing flow paths, with no predicted impact on access routes to, or within, properties (and residences) within the Project Area. Where potential increases to remnant ponding are predicted (refer to **Figure 4.3**) or subsequently observed, local drainage works may be required to alleviate the increased ponding (refer to **Section 4.8**).

The locations of proposed monitoring points for potential changes in remnant ponding are included in **Figure 4.2** and discussed in **Section 5.0**.

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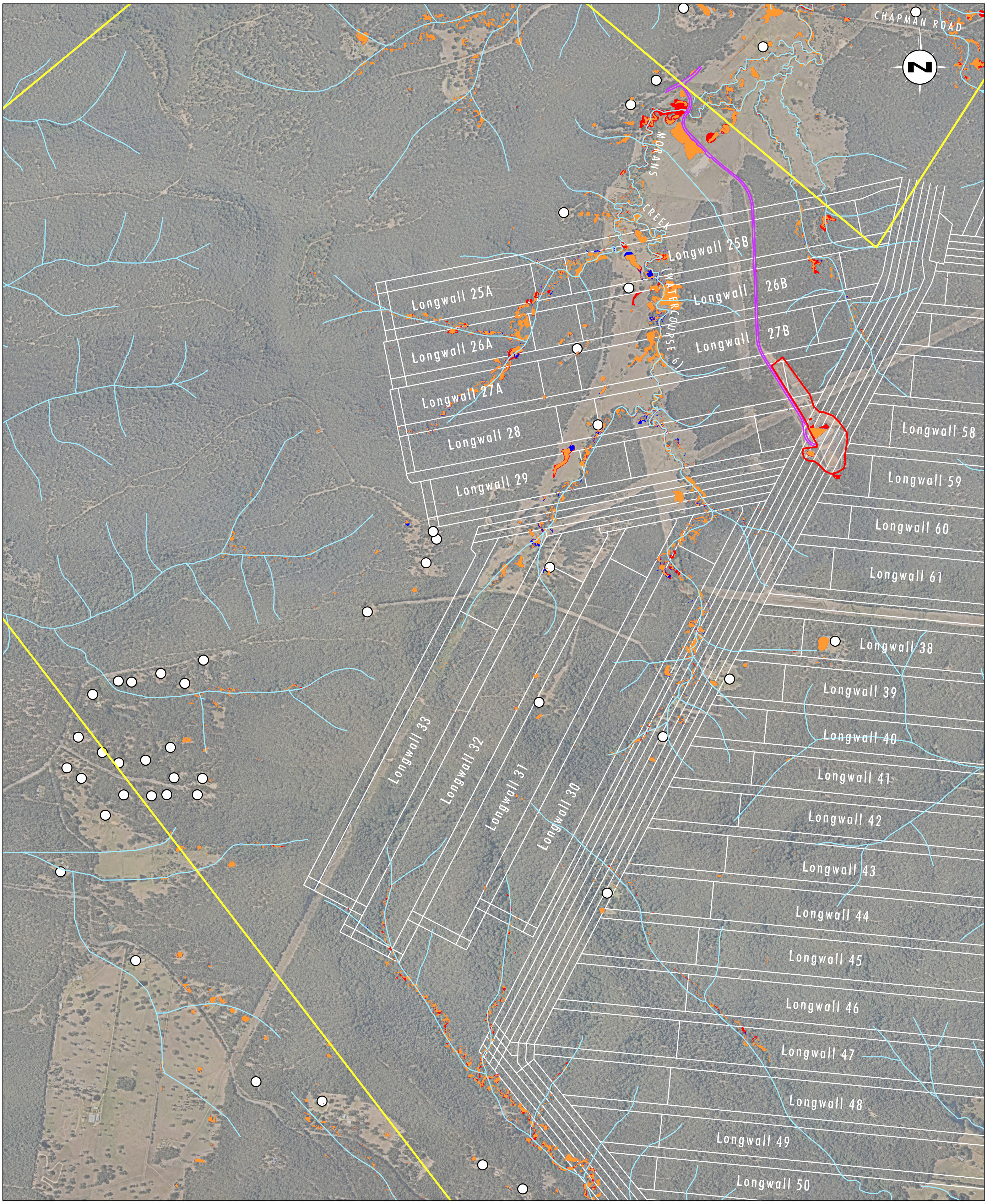

Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Proposed Longwalls
- Access Road
- Drainage
- Ponding Areas (Approved Mining Scenario)
- Ponding Areas (Pre-mining Scenario)
- Ponding Areas (Proposed Mining Scenario)

FIGURE 4.3

Proposed Remnant Ponding (Modification 9)

File Name (A4): R01/20091_011.dgn
20200803 10.08

4.4 Summary of Watercourse Impacts

1. Analysis of the Morans Creek long section, velocities and tractive stresses for pre-mining, approved and proposed landforms indicates that key impacts for the Modification 9 include: Steeper downward grades in the direction of flow between chainages 100 to 400 m of Morans Creek (near the southern chain pillar of Longwall 29) are observed for the proposed landform as a results of longwall mining.

2. Analysis of the Buttonderry Creek long section for the proposed landform indicates a negligible change in longitudinal grade compared to the approved landform.

3. Steep downward grades result in increased flow velocities and tractive stresses on the bed material between chainages 100 to 400 m for the proposed landform.

4. Since predicted tractive stresses are "marginally stable" for the pre-mining landform and "unstable" for the proposed landform, it is likely that scouring will occur between chainages 100 to 400 m.

5. The most likely location for increased scouring for the proposed landform is near chainage 212 m where the greatest increase in predicted tractive stress occurs relative to the pre-mining and approved landforms.

6. Increased ponding between chainages 350 to 450 m (over Longwall 29) and near chainages 1550 to 1650 m (over Longwall 25B) is likely due to steeper upwards slopes in the direction of flow relative to the approved landform and the pre-mining landform.

Watercourse stabilisation works should be undertaken if increased bed and bank scouring is observed during monitoring of subsidence and watercourse stability (refer to **Sections 5.1** and **5.2**).

For the proposed subsided landform, compared to the approved landform there are areas where remnant ponding increases and areas where remnant ponding decreases. Overall the total area of remnant ponding is predicted to decrease by 7.3 ha relative to the approved landform, and over Longwalls LW31 to 33 there is a predicted to be a decrease in remnant ponding of 1.58 ha – refer to **Table 4.2**. Areas where there are predicted to be minor increases in remnant ponding include on Morans Creek along the third order section near Longwall 25B, along the first and second order tributaries near Longwall 26A, along a second order section at the northern end of Longwall 30, along a third order section to the north of Longwall 25B near the Project Area boundary, and minor increases along Buttonderry Creek and a second order watercourse to the north of Buttonderry Creek.

Compared to the pre-mining scenario a decrease in total remnant ponding area of 5.8 ha is predicted, and a 1.52 ha decrease is predicted within the subsidence affected area of Longwalls LW30 to 33.

Drainage mitigation works should be undertaken if increases in remnant ponding are identified during monitoring of subsidence and watercourse stability (refer to **Sections 5.1** and **5.2**).

4.5 Flood Regime

A potential consequence of the predicted subsidence is a change to the flood regime (flood behaviour and flood extent), both within the Project Area and the surrounding areas. This section presents the results of 2D hydrodynamic flood modelling and potential impacts as a result of the proposed landform, by examining predicted changes in modelled peak flood depths and flood hazard categories, in accordance with the *'NSW Floodplain Development Manual, The Management of Flood Liable Land'* (DIPNR 2005a) - refer to **Appendix 1** for a description of the modelling approach.

The potential impacts of the proposed landform on the flood regime within the modelled floodplain of Morans Creek has been assessed using the 2D hydrodynamic model. This process was aided by comparison to the modelled flood regimes for the pre-mining and approved landforms. **Section 3.4** describes the pre-mining flood regime, while this section describes the flood regimes for the approved landform and the proposed landform.

The Morans Creek modelled peak flood depths for the 100 year ARI event for the pre-mining landform are shown in **Figure 3.4**. The modelled peak flood depths for the 100 year ARI event for the approved landform in Morans Creek are shown in **Figure 4.4**, which includes zoomed-in views of dwellings that lie wholly or partially within the extent of the 100 year ARI event. The modelled peak flood depths for the 1 year ARI event for the approved landform in Morans Creek are shown in **Figure 4.5**.

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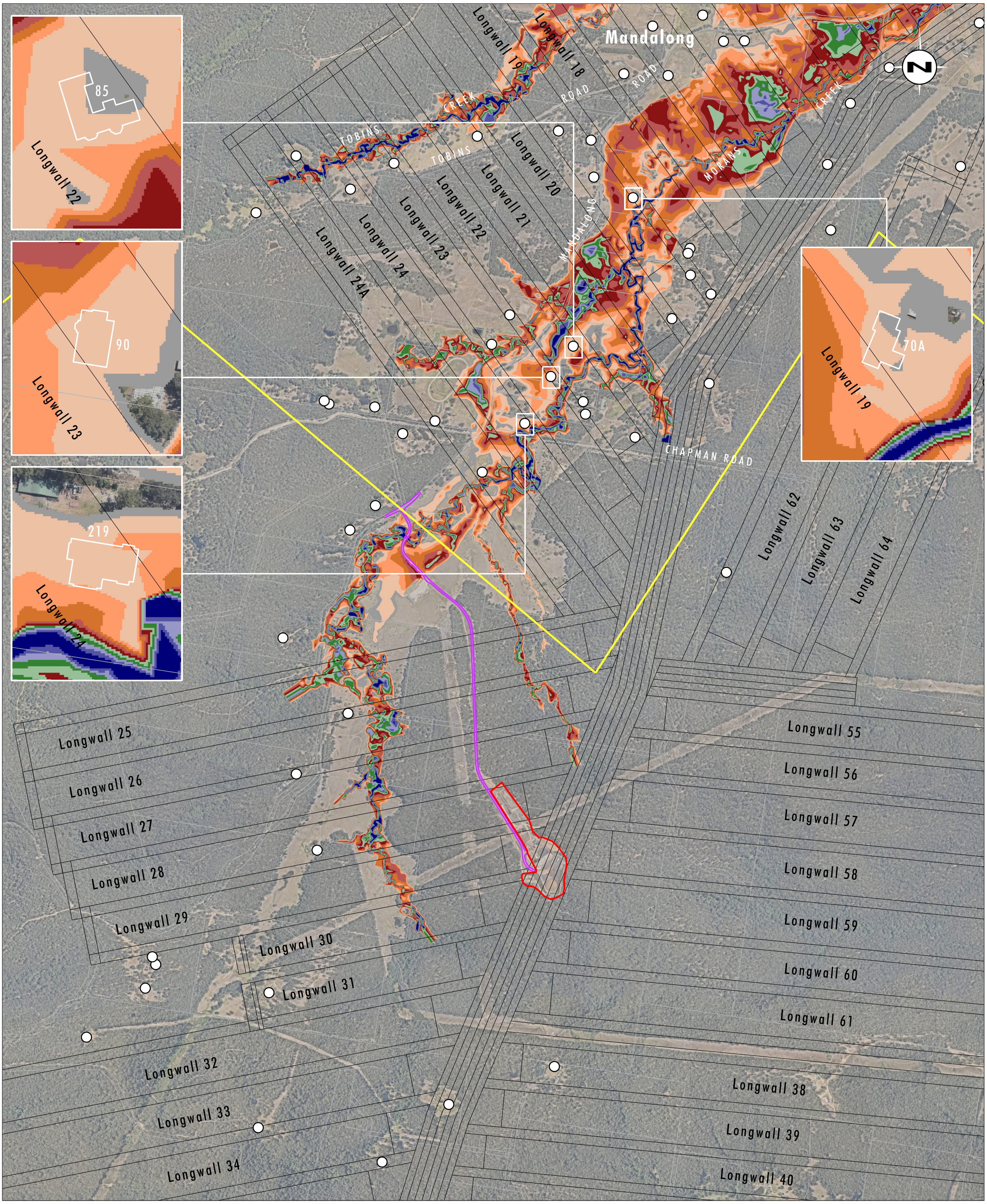


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.4

100 year ARI Storm Event
Maximum Flood Depths for Morans Creek
(Approved Landform)

File Name (A4): R01/20091_012.dgn
20200731 15.38

umwelt

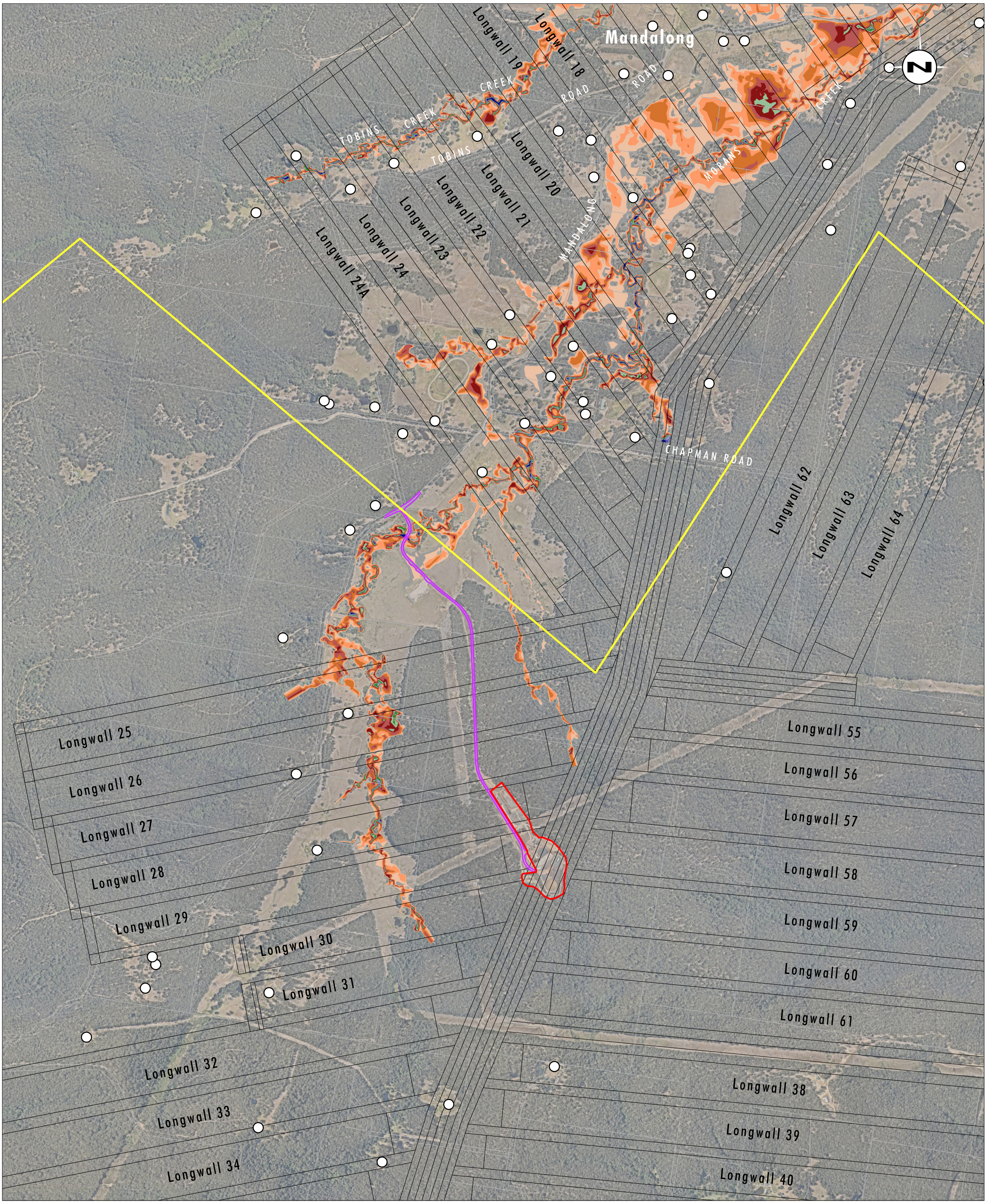


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.5

1 year ARI Storm Event Maximum Flood Depths for Morans Creek (Approved Landform)

File Name (A4): R01/20091_013.dgn
20200731 15.45

Figure 4.6 shows the modelled peak flood depths for the 100 year ARI design event for the proposed landform in Morans Creek, which includes zoomed-in views of dwellings that lie wholly or partially within the extent of the 100 year ARI event. **Figure 4.7** shows the modelled peak flood depths for the 1 year ARI design event for the proposed landform in Morans Creek.

Modelled flood hazard categories within Morans Creek for the 100 year ARI design flood event are shown on **Figure 4.8** for the approved landform, and **Figure 4.9** for the proposed landform.

4.5.1 Dwellings and Freeboard for Habitable Floor Levels

For the purposes of this study, where the 100 year ARI flood event inundates the habitable floor(s) of a dwelling, that dwelling is deemed 'flood liable'. Further, where subsidence results in the 100 year ARI event inundating the habitable floor(s) where this was not previously the case or subsidence causes an increase in the inundation depth of the habitable floor(s), then the flood liability of the dwelling has been adversely impacted.

Review of 100 year ARI flood depths shows four (4) dwellings with a footprint that is wholly or partially within the 100 year ARI flood extent. Comparing the modelled 100 year ARI flood levels for the proposed landform (**Figure 4.6** refers) to that of the approved landform (**Figure 4.4** refers), indicates there are no adverse impacts on the four subject dwellings, as summarised in **Table 4.3** and discussed below.

Table 4.3 shows that three dwellings (Nos. 70A, 90, 219) are not flood liable, having freeboard above the 100 year ARI flood level for the approved landform. For two of these dwellings (70A, 219) the freeboard remains unchanged for the proposed landform, and for one dwelling (90) the freeboard increases by 0.001 m.. One dwelling (No. 85) is flood liable for the approved landform with a habitable floor level 0.29 m below the 100 year ARI flood level), however for the proposed landform there is no change in the 100 year ARI flood level and hence no change in the flood liability.

Table 4.3 100 year ARI flood levels and freeboard for subject dwellings[1]

Dwelling ID	100 yr ARI Flood Level – Approved mAHD	100 yr ARI Flood Level – Proposed mAHD	Approved Freeboard[2] m	Change in Freeboard for Proposed m
70A	17.323	17.323	0.48	0.0
85	20.607	20.607	-0.29	0.0
90	21.259	21.258	0.59	+0.001
219	22.932	22.932	0.42	0.0

Note [1]: The approved and proposed mining landforms for assessing flood regime impacts are unchanged from the Rev 2 report. The approved mining landform is based on observed subsidence for longwalls LW1 to 17 (using 2015 LIDAR) and predicted subsidence for Longwalls LW25 to 64 within the Project Area in accordance with SSD 5144 Modification 5 and Extraction Plan LW25-31. The proposed mining landform is based on observed subsidence for Longwalls LW1 to 17 (using 2015 LIDAR) and predicted subsidence for Longwalls LW18 to 34 (LW34 now deleted).
Note [2]: 'Approved' freeboard is from Umwelt (July 2018).

As can be seen in **Table 4.3**, there is essentially no change in the 100 year ARI flood level for the approved and proposed landforms (proposed landform has 1 mm decrease in 100 year ARI flood level for Dwelling 90). Hence, it is evident that in the vicinity of each dwelling and relative to the approved landform there is no change in 100 year ARI flood depth over the ground including the access routes to the dwellings.

umwelt

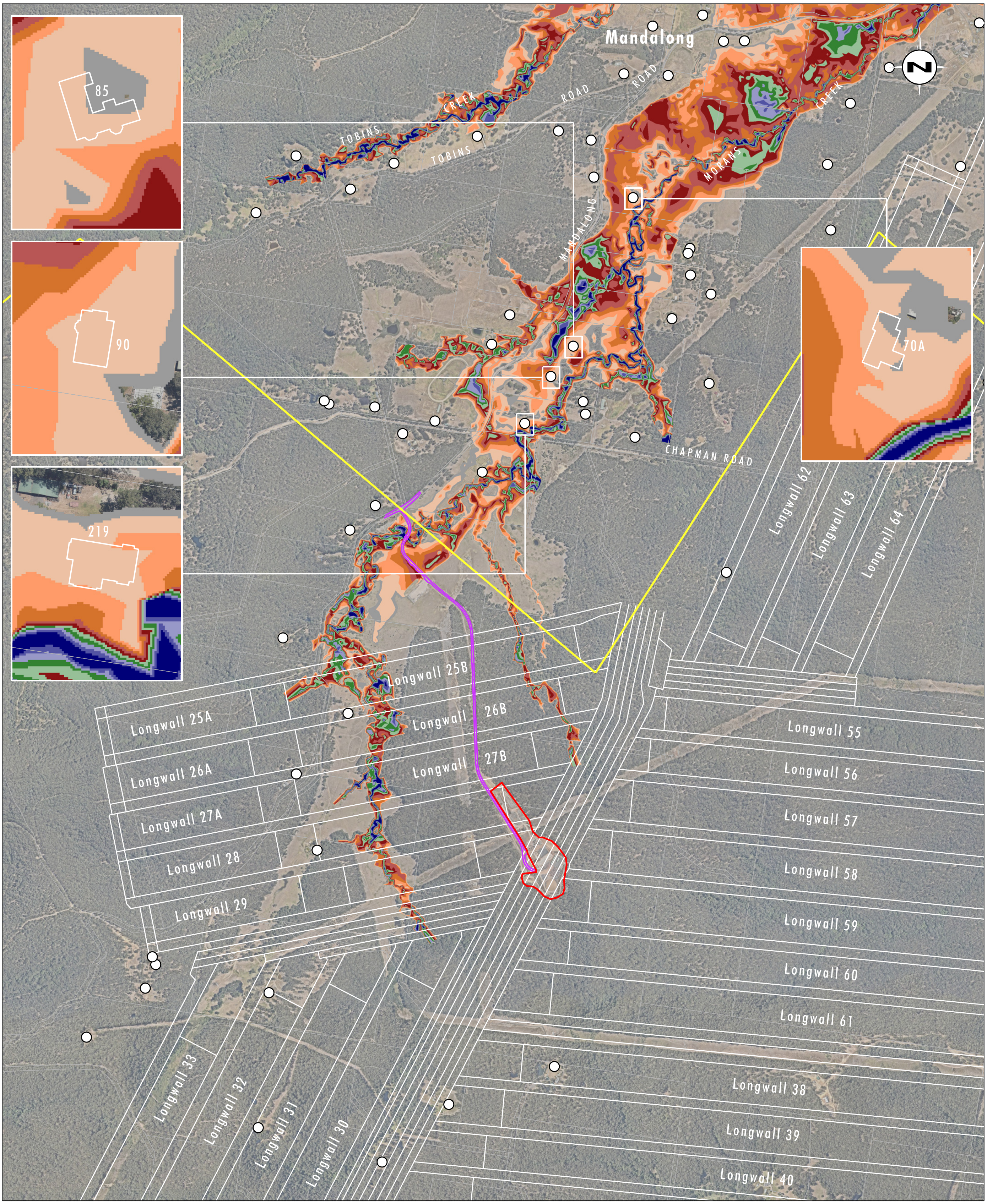


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend
- Project Area
- Dwellings
- Surface Infrastructure Site
- Proposed Longwalls
- Access Road
- Cadastre

Water Depth (metres)
- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.6

100 year ARI Storm Event Maximum Flood Depths for Morans Creek (Proposed Landform)

File Name (A4): R01/20091_014.dgn
20200731 15.48

umwelt

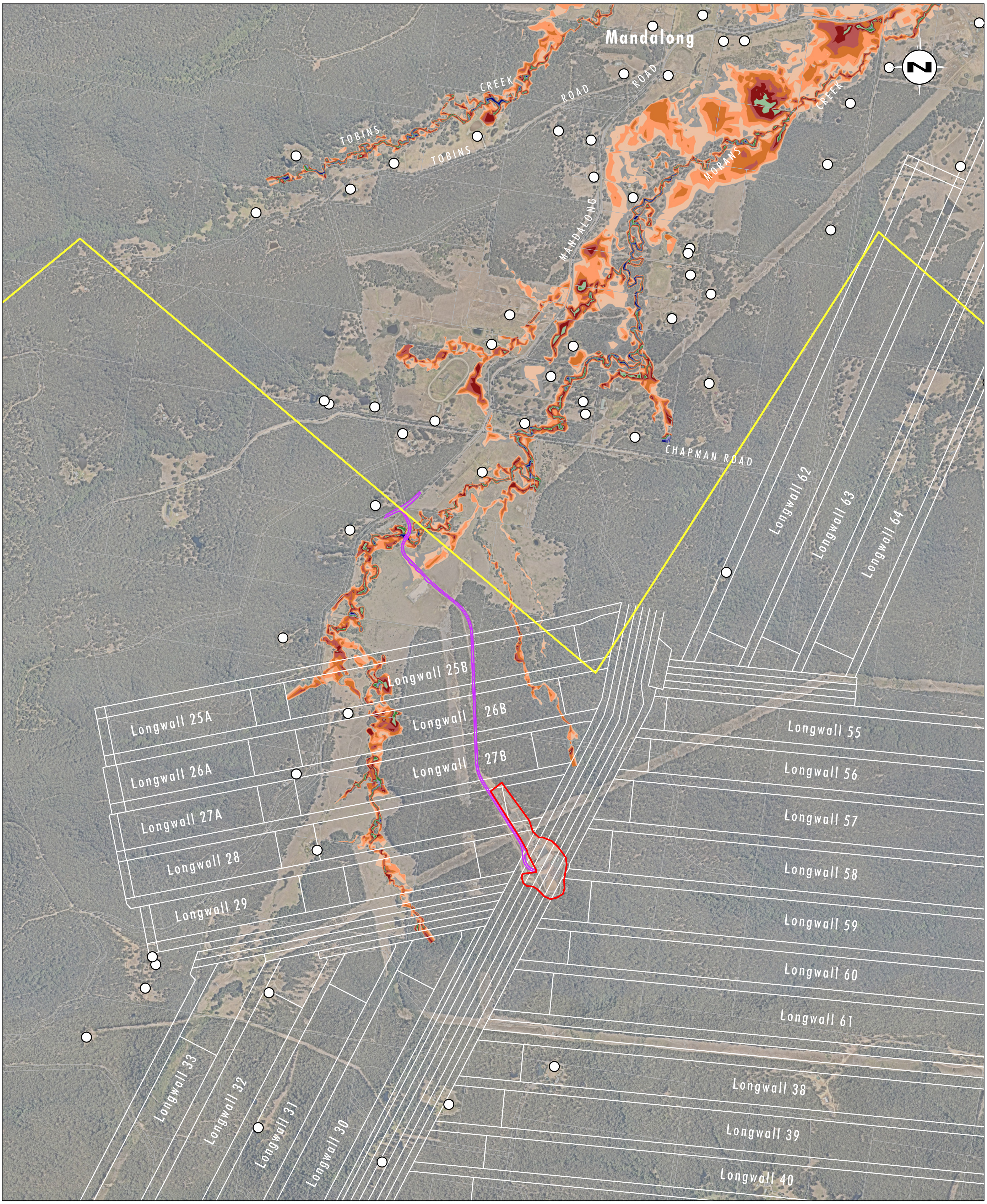


Image Source: Nearmap (Dec 2020)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend

- Project Area
- Dwellings
- Surface Infrastructure Site
- Proposed Longwalls
- Access Road
- Cadastre

Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.7

1 year ARI Storm Event
Maximum Flood Depths for Morans Creek
(Proposed Landform)

File Name (A4): R01/20091_015.dgn
20200731 15.52

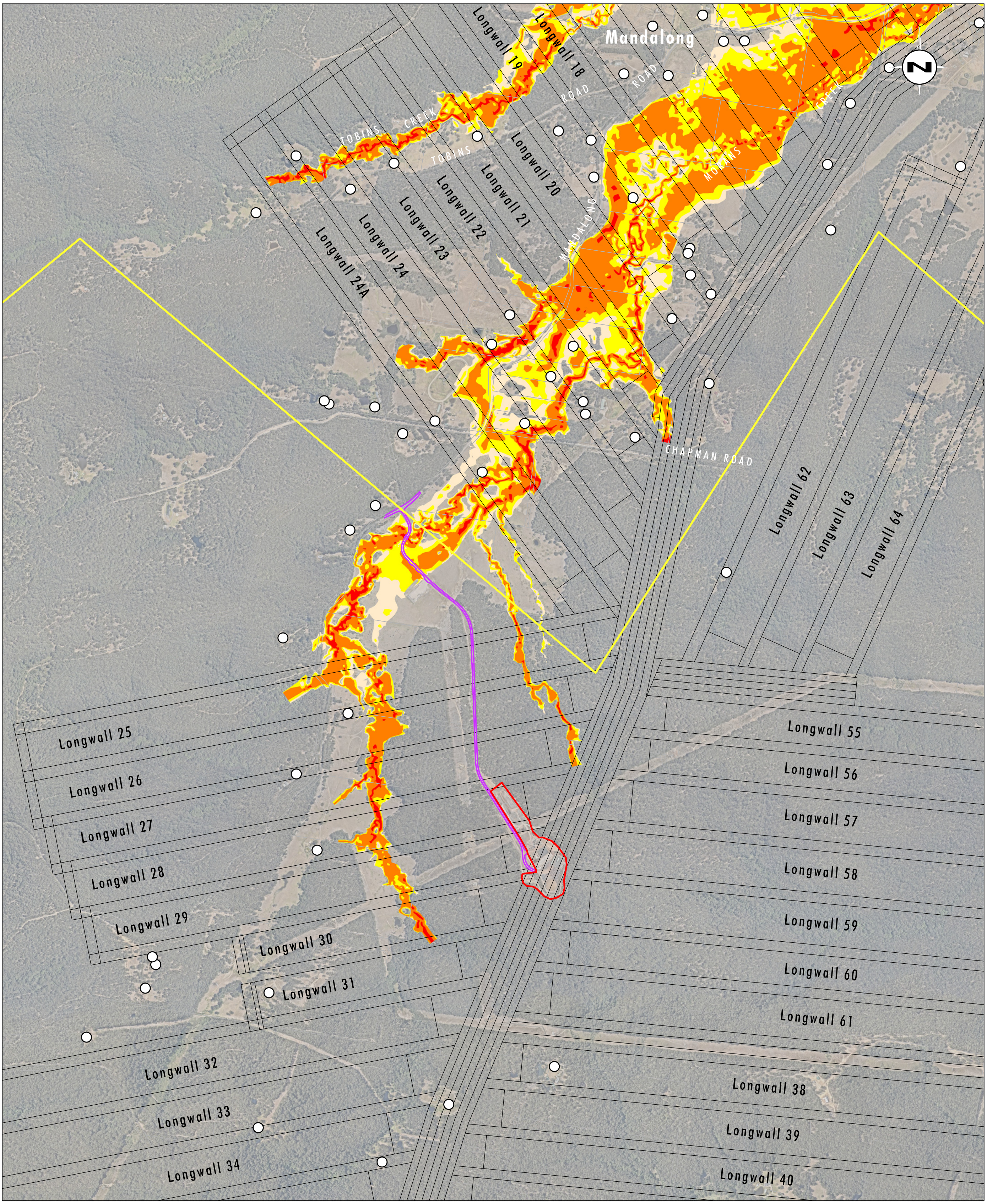


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2019), LPI (2020)

Legend

- Project Area
- Dwelling
- Surface Infrastructure Site
- Approved Longwalls
- Access Road
- Cadastre

Hazard Category

- Low Hazard - Unclassified hazard
- Low Hazard - Vehicles unstable
- High Hazard - Wading unsafe
- High Hazard - Damage to light structures

FIGURE 4.8

100 year ARI Storm Event
Maximum Flood Hazard for Morans Creek
(Approved Landform)

File Name (A4): R01/20091_016.dgn
20200731 16.00

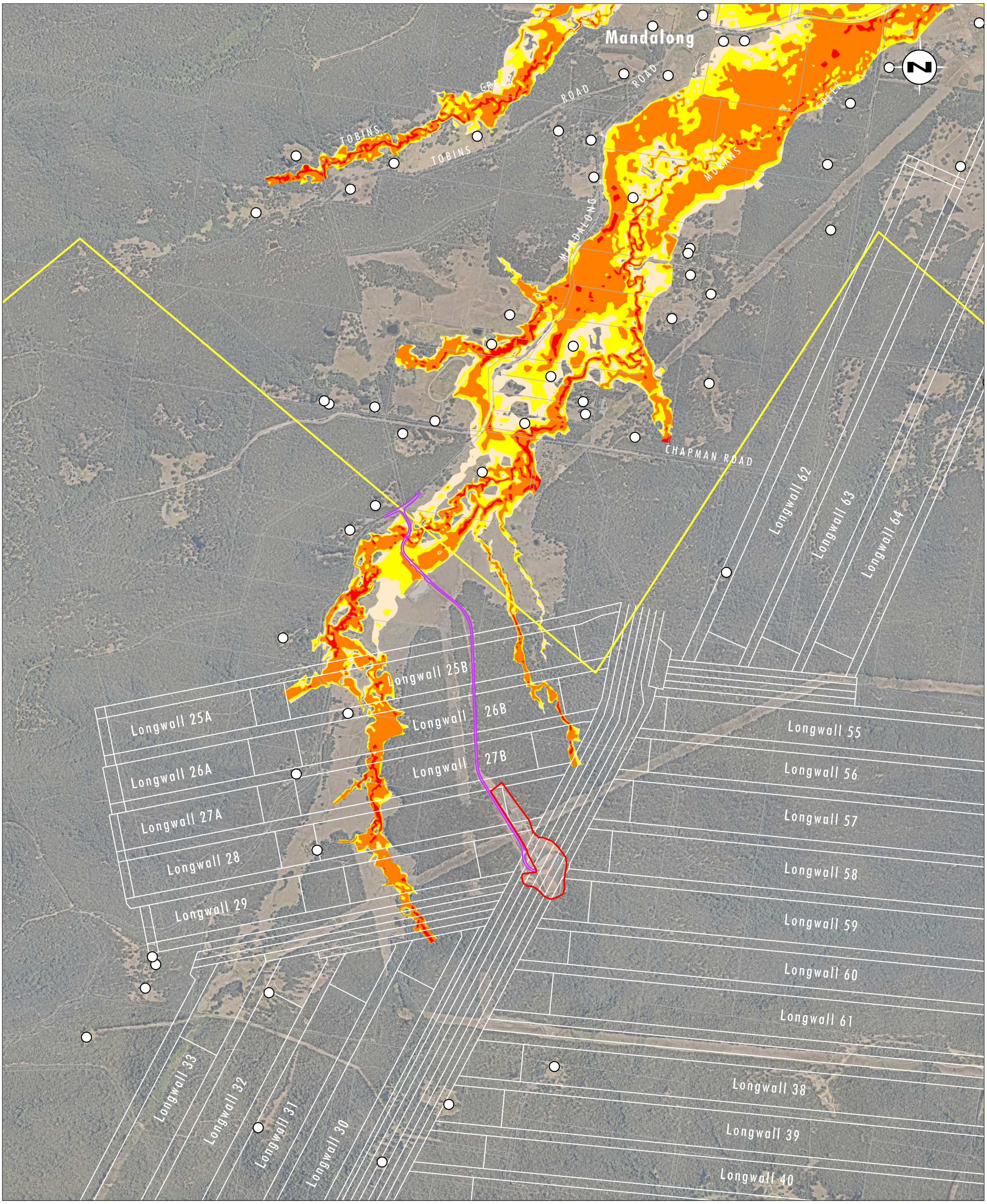


Image Source: Nearmap (Dec 2019)
Data Source: Centennial Mandalong (2020), LPI (2020)

0 0.5 1.0 1.25km
1:25 000

Legend
- Project Area
- Dwellings
- Surface Infrastructure Site
- Proposed Longwalls
- Access Road
- Cadastre

Hazard Category
- Low Hazard - Unclassified hazard
- Low Hazard - Vehicles unstable
- High Hazard - Wading unsafe
- High Hazard - Damage to light structures

FIGURE 4.9

100 year ARI Storm Event Maximum Flood Hazard for Morans Creek (Proposed Landform)

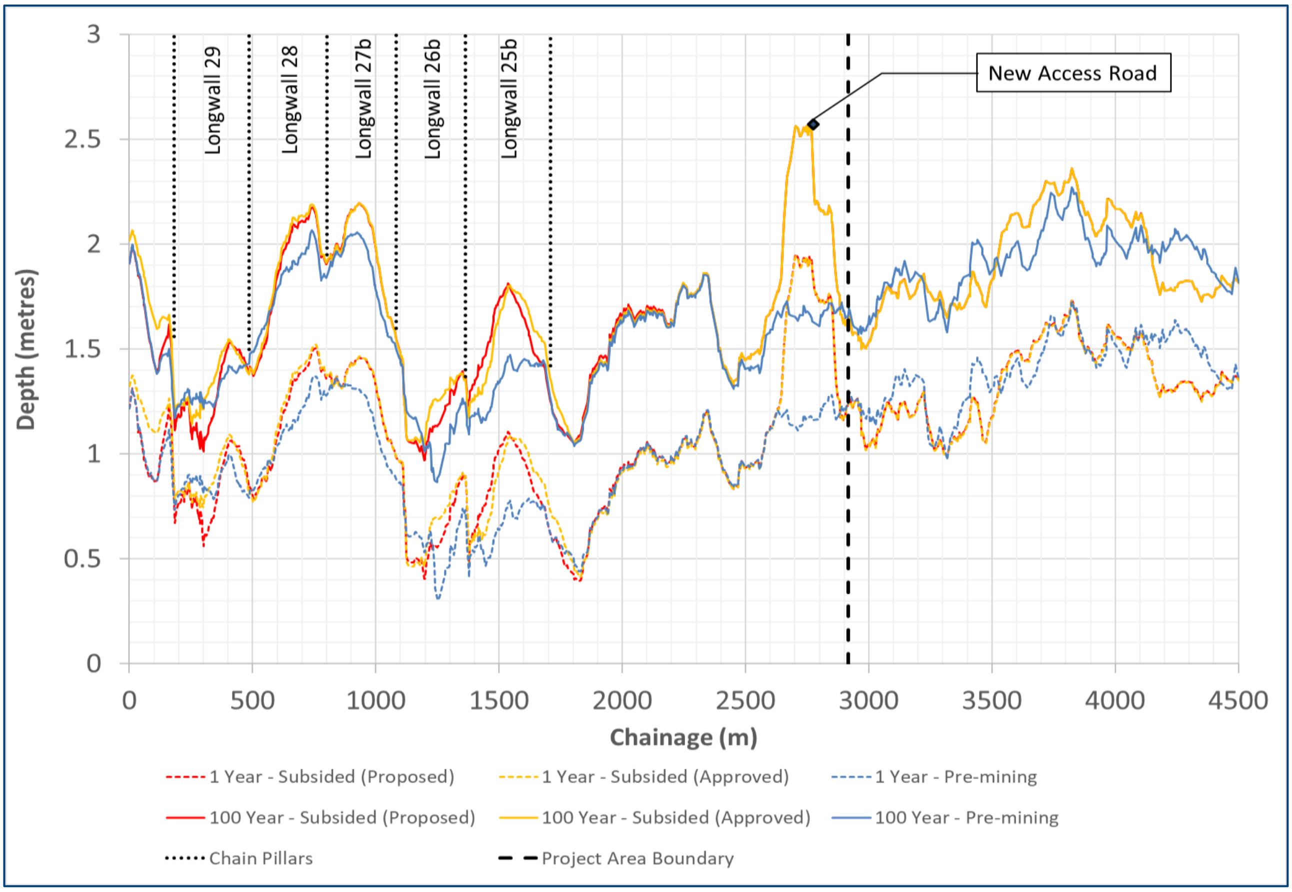
4.5.2 Morans Creek

4.5.2.1 Flood Depths

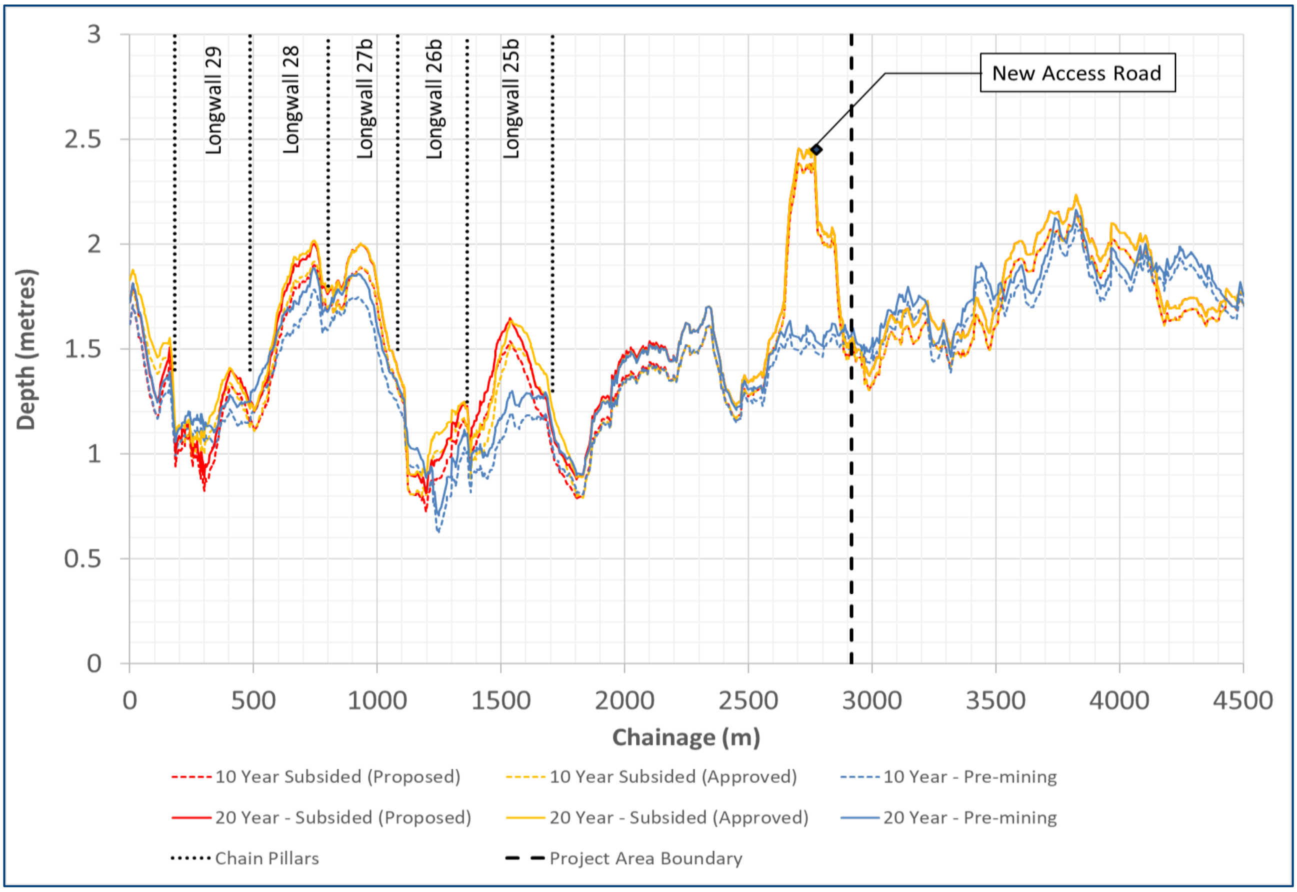
Graph 4.5 presents the modelled peak flood depths for the third order section of Morans Creek within the Project Area and for a distance downstream (Watercourse 6), for the 1year and 100 year ARI design storm events. The modelling indicates the following for the proposed landform and the 100 year ARI design storm event:

- relative to the approved landform, modelled peak flood depths for the proposed landform exhibit increases in depth between chainage 1400 and 1550 m (peak increase 0.13 m at chainage 1430 m). However, this appears to be attributed to a shift in flood behaviour that occurs between chainages 1400 to 1700 m (Longwall 25B), as it can be seen that between chainage 1550 and 1700 m modelled peak flood depths for the proposed landform decrease (peak reduction 0.15 m at chainage 1680 m relative to the approved landform.
- at all other locations modelled, peak flood depths for the proposed landform relative to the approved landform do not increase more than 0.05 m within the Morans Creek channel, with similar scale reductions also occurring.
- a similar pattern of changes to the modelled peak flood depths for other design storm events occurs, as can be seen for the 1 year ARI design event in **Graph 4.5**, and for the 10 year and 20 year ARI design events in **Graph 4.6**.
- for chainages coinciding with Longwalls 25B to 29, the maximum increase in peak 100 year ARI flood depth for the approved landform relative to the pre-mining landform is 0.3 m at Longwall 25B (refer **Graph 4.5**), with no significant increase (≤ 0.05 m) occurring at this location for the proposed landform relative to the approved landform.
- for chainages beyond the Longwalls 25B to 29 modelled peak flood depths for the approved landform show a maximum increase for the 100 year ARI flood depth compared to the pre-mining landform of 0.8 m near the new access road (refer **Graph 4.5**), with no further change in the flood level at this location for the proposed landform relative to the approved landform.

Given the modelled increases in 100 year ARI flood depths for the proposed landform relative to the approved subsided landform are no more than 0.13 metres, with similar scale reductions, means there are only negligible changes to the 100 year ARI flood extent (refer to **Figure 4.6** and **Figure 4.4** for comparison). For the 10 year and 20 year ARI design events, there are similar negligible changes to flood extent for the proposed landform relative to the approved landform, and for the minor 1 year ARI flood event, the small modelled increases in flood depth remain predominantly in channel (refer to **Figure 4.7** and **Figure 4.5** for comparison).



Graph 4.5 Morans Creek (Watercourse 6) – Modelled Flood Depths (1 year and 100 year ARI events)

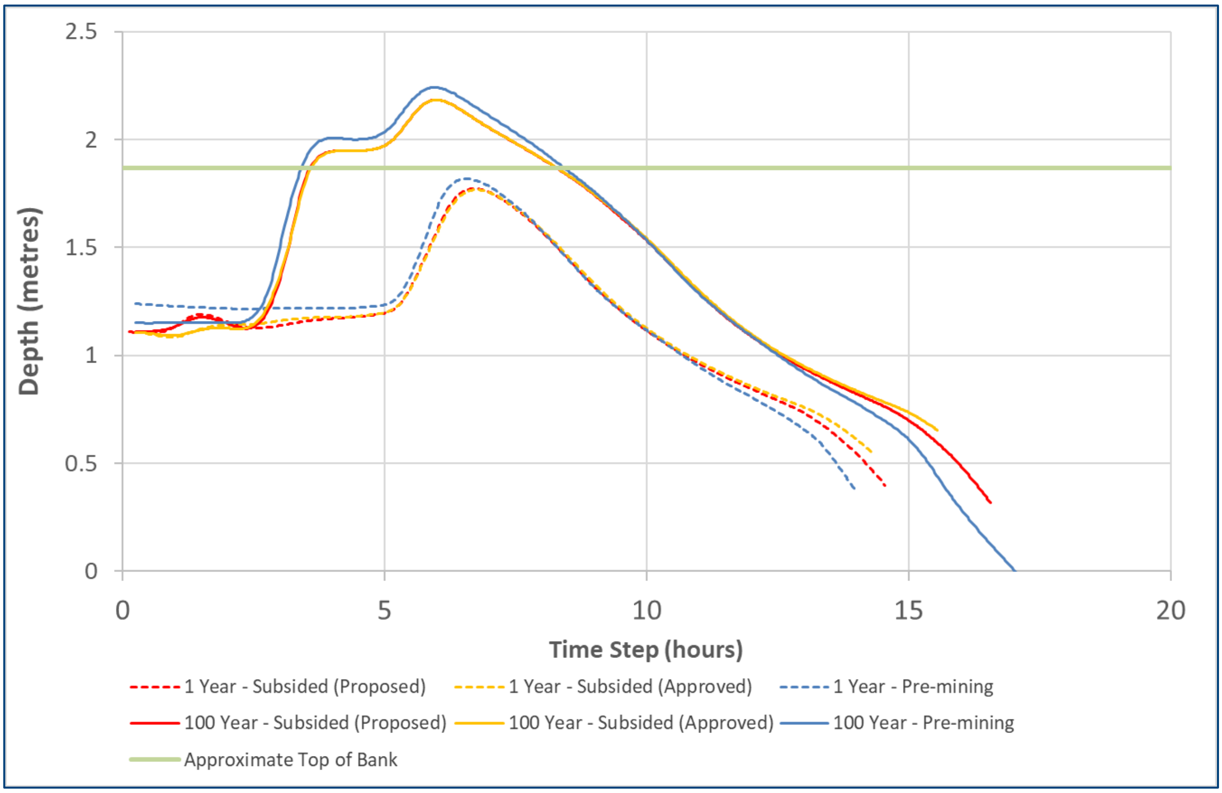


Graph 4.6 Morans Creek (Watercourse 6) – Modelled Flood Depths (10 year and 20 year ARI events)

4.5.2.2 Flood Duration

Graph 4.7 presents the depth hydrograph for Morans Creek at the northern boundary of the Project Area (chainage 2917 m).

For the 1 year ARI storm event, no out-of-channel flows are expected for the proposed landform, consistent with the pre-mining and approved landforms. For the 100 year ARI storm event, out of channel flows are predicted to remain at approximately 4.5 hours for the proposed landform, consistent with the pre-mining and approved landforms (refer to **Graph 4.7**). This indicates that the predicted subsidence associated with the proposed landform will have minimal impacts on access to and agricultural use of the land surrounding the Project Area.



Graph 4.7 Morans Creek (Watercourse 6) – Modelled Depth Hydrograph (1 year and 100 year ARI events)

4.5.2.3 Flood Hazard Categories

Modelled flood hazard categories for Morans Creek (Watercourse 6) during the 100 year ARI flood event for pre-mining, approved and proposed landforms are mapped in **Figure 3.6**, **Figure 4.8** and **Figure 4.9**, respectively. The flood hazard category at any location is based on the maximum value of the 'velocity x depth' (V x D) product during the flood event.

Comparing 100 year ARI flood hazard for the pre-mining landform to the approved landform (refer to **Figure 3.6** and **Figure 4.8**), it is evident that at numerous locations around Morans Creek where there are increases to the area covered by a particular flood hazard category. However, there do not appear to be areas where there is a significant increase in the flood hazard level. Interestingly, there are some areas for the approved landform where the area of a particular hazard category reduces (including the highest category level) relative to the pre-mining landform.

Comparing 100 year ARI flood hazard for the proposed landform to the approved landform shows very minor (essentially negligible) change in flood hazard between the two scenarios (refer to **Figure 4.9** and **Figure 4.8** respectively for comparison).

The majority of identified dwellings within the Project Area and their access routes are outside of the modelled flood extent for the 100 year ARI design flood event for both the approved subsided landform and for the proposed subsidence landform. There are four (4) dwellings (downstream of the Project Area, as identified in **Figure 4.6**) within the 100 year ARI flood extent, however there is no discernible difference in 100 year ARI flood hazard between the approved landform and the proposed landform (refer to **Figure 4.8** and **Figure 4.9** respectively for comparison).

4.6 Regional Infrastructure

The modelling indicates that for the Modification 9 no significant impacts to the functionality of roads and transport are expected as a result of the proposed landform.

4.7 Annual Flows, Environmental Flows and Downstream Users

Modelling shows very minor impacts to flood regimes and remnant ponding areas associated with the proposed landform relative to the approved landform.

Relative to the earlier Rev 2 report the proposed landform remnant ponding has increased relative to the approved landform in some areas and decreased in other areas. This is due to 2020 LIDAR being used for the proposed landform remnant ponding, whereas the approved landform has retained the 2015 LIDAR data. However, the total area of remnant ponding for the proposed landform has decreased relative to the both the pre-mining and approved landforms (refer to **Table 4.2**).

Impacts on the flow rates and annual flow volumes in Morans Creek would be negligible (or non-existent). Further, the watercourses within the Project Area do not have a long-term persistent baseflow. Their ephemeral nature is reflected in small flows during dry periods and cease to flow during drought periods. Any impacts to baseflows are expected to have negligible impacts on the streamflow conditions within these watercourses.

As a result of the limited potential for changes to water quantities, including annual flow volumes, baseflows and environmental flows, downstream users are unlikely to experience significant changes to water availability due to the Modification 9.

Overall, it is considered that the Modification 9 will not result in adverse cumulative impacts on water use or flows in the areas surrounding the Project Area.

4.8 Proposed Monitoring and Remediation Protocols

Taking into consideration the existing surface water regime, associated topography and previous experience at the existing Mandalong Mine, it is considered likely that only minor remediation works will be required consisting essentially of erosion protection/remediation measures. However, a comprehensive monitoring regime should be implemented to monitor major drainage lines and those locations identified in **Figure 4.1** for potential subsidence impacts. Particular attention should be given to Morans Creek between chainages 100 to 400 m as shown on **Figure 4.1** and **Graph 4.1**, where there is potential for scouring (between the two predicted scouring locations marked on **Figure 4.1**) as a result of a predicted increase in longitudinal grade (i.e. the watercourse becomes steeper in the direction of flow).

The required controls and protocols should utilise standard erosion and sediment control techniques to manage surface water during any remediation (refer to **Section 4.8.1**).

Similarly, due to the steepness of the catchment areas and surrounding topography, as well as the substantial vegetation, it is not considered practical to divert runoff from upstream catchment areas around potentially impacted areas of streams. As such, it is proposed that all remediation works are managed in stream.

Remediation measures and procedures for drainage lines within the Project Area will be detailed in the Subsidence Management Plan and will be implemented as required and refined where necessary based on performance experience. These measures and procedures may include, but are not be limited to:

- monitoring of vertical and horizontal subsidence along second and third order drainage lines as determined in consultation with the DPIE, formerly Department of Industry (Water) (DOI - Water)
- visual inspection and recording (including photographic records at least every 50 m) of stream bed and bank condition and riparian vegetation along second and third order drainage lines, including collection of baseline data and monitoring during mining and in the post- mining phase
- erosion and sediment controls
- soil stabilisation measures, where appropriate
- revegetation techniques and maintenance
- velocity reduction controls

4.8.1 Erosion and Sediment Controls

Any necessary subsidence remediation works will require suitable erosion and sediment controls, both as remediation and as future protection. All erosion and sediment control measures should be carried out in accordance with the relevant guidelines for erosion and sediment control, including:

- Managing Urban Stormwater Soils and Construction (the Blue Book) Volume 1 (Landcom, 2004) and Volume 2C Unsealed Roads (Department of Environment and Climate Change (DECC) 2008)
- where relevant, to a standard consistent with Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Mine Sites in the Hunter Coalfields (DIPNR, undated).

The general erosion and sediment control principles proposed to be incorporated into the construction of mitigation works during the Project include:

- construction of erosion and sediment controls prior to the commencement of any substantial construction works
- construction and regular maintenance of sediment fences downslope of disturbed areas
- use of soil amelioration/stabilisation methods where appropriate
- repair to or replacement of riparian vegetation along second and third order drainage lines where required
- seeding and controlled fertilising of disturbed areas to provide for rapid grass cover. Areas will be seeded with a grass mix specific to the needs of the area to be grassed
- regular inspection of all works and immediately following rainfall events of a magnitude sufficient to generate runoff to ensure erosion and sediment controls are performing adequately
- provision for the immediate repair or redesign of erosion and sediment controls which are identified as not performing adequately.

In addition to the above erosion and sediment control measures, construction plans will detail the specific inspection, maintenance and revegetation requirements for each work area where subsidence remediation works are required.

4.9 Summary of Impacts

The potential impacts of the Mandalong Southern Extension Project on flooding have been minimised by the iterative process Centennial Mandalong has undertaken over time to develop mine designs that minimise potential impacts on surface waters, including catchment areas, watercourse impacts, flood regimes, regional infrastructure and annual flows.

An assessment of the predicted subsidence impacts, as described in **Section 4.1**, indicates that the catchment boundaries of the creek systems to be undermined will not change significantly for the proposed landform relative to the approved landform.

The existing environment has already undergone scouring and sediment transport as a result of constructed features, including culverts and bridges, however any further scouring may further increase sediment transport and degrade water quality. Monitoring of watercourses within the impacted area and the implementation of appropriate mitigation measures are proposed to reduce the potential for additional scouring. If subsidence remediation works are required, erosion and sediment control measures should be included to assist in remediation and to minimise impact to downstream water quality.

Also, the potential for change to remnant ponding or storage of surface runoff is considered minimal. Relative to the earlier Rev 2 report the proposed landform remnant ponding has increased relative to the approved landform in some areas and decreased in other areas. This is due to 2020 LIDAR being used for the proposed landform remnant ponding, whereas the approved landform has retained the 2015 LIDAR data. However, the total area of remnant ponding for the proposed landform has decreased relative to the both the pre-mining and approved landforms (refer to **Table 4.2**).

A series of monitoring points have been identified to monitor potential drainage grade changes and remnant ponding (refer to **Sections 4.2** and **4.3**, **Figure 4.2** and **Graph 4.1**). Within Morans Creek there are two remnant ponding monitoring locations and one scouring monitoring location (refer to **Figure 4.2**). These locations should be monitored in addition to those identified within the 2013 Surface Water Assessment for all six watercourses within the Project Area (Umwelt, 2013). Long section analysis of Buttonderry Creek indicates a negligible change in longitudinal grade for the proposed landform when compared to the approved landform and therefore no additional monitoring points for Buttonderry Creek are recommended.

Relative to the approved landform, modelled 100 year ARI peak flood depths for the proposed landform exhibit increases in depth between chainage 1400 and 1550 m (peak increase 0.13 m at chainage 1430 m). However, this appears to be attributed to a shift in flood behaviour that occurs between chainages 1400 to 1700 m (Longwall 25B), as it can be seen that between chainage 1550 and 1700 m modelled peak flood depths for the proposed landform decrease (peak reduction 0.15 m at chainage 1680 m relative to the approved landform.

Given there are some small modelled increases in 100 year ARI flood depths for the proposed landform relative to the approved subsided landform, with similar scale reductions, means there are only negligible changes to the 100 year ARI flood extent (refer to **Figure 4.6** and **Figure 4.4** respectively for comparison). For the 10 year and 20 year ARI design events, there are similar negligible changes to flood extent for the proposed landform relative to the approved landform, and for the minor 1 year ARI flood event, the small modelled increases in flood depth remain predominantly in channel.

Based on a representative location on Morans Creek near the northern boundary of the Project Area, for the 1 year ARI storm event no out-of-channel flows are expected for the proposed landform, consistent with the pre-mining and approved landforms. For the 100 year ARI storm event, out of channel flows are predicted to remain at approximately 4.5 hours for the proposed landform, consistent with the pre-mining and approved landforms (refer to **Graph 4.7**). This indicates that the predicted subsidence associated with the proposed landform will have minimal impacts on access to and agricultural use of the land surrounding the Project Area.

The majority of identified dwellings within and surrounding the Project Area, including access routes, are outside of the modelled flood extent for the 100 year ARI design flood event, for both the approved landform and the proposed landform. There are four (4) dwellings within the 100 year ARI flood extent (downstream of the Project Area, as identified in **Figure 4.6**).

Comparing the modelled 100 year ARI flood levels for the proposed landform (**Figure 4.6** refers) to that of the approved landform (**Figure 4.4** refers), indicates there are no adverse impacts on the four subject dwellings, as summarised in **Table 4.3**. This in includes no change in 100 year ARI flood depth over the ground including the access route to each dwelling

Modelling shows minor impacts to flood regimes and remnant ponding areas associated with the proposed landform relative to the approved landform. Impacts on the flow rates and annual flow volumes in Morans Creek would be negligible (or non-existent). Further, the watercourses within the Project Area do not have a long-term persistent baseflow. Their ephemeral nature is reflected in small flows during dry periods and cease to flow during drought periods. Any impacts to baseflows are expected to have negligible impacts on the streamflow conditions within these watercourses.

As a result of the limited potential for changes to water quantities, including annual flow volumes, baseflows and environmental flows, downstream users are unlikely to experience significant changes to water availability due to the Modification 9.

Overall, it is considered that the Modification 9 will not result in adverse cumulative impacts on water use or flows in the areas surrounding the Project.

5.0 Monitoring, Licensing and Reporting

5.1 Subsidence Monitoring

Centennial Mandalong has an established subsidence monitoring program and management plans for the existing approved Mandalong Mine. The established subsidence monitoring program will be continued within the Project Area, with inspections of second order and higher watercourses proposed to be undertaken on a regular basis to assess whether watercourses within the subsidence affectation zone are adversely impacted by remnant ponding and scouring, and to thereby determine appropriate remediation works.

Relative to the approved landform, it is considered that the proposed subsided landform will have only a minor impact on remnant ponding or drainage realignment within the Project Area. As the proposed scenario remnant ponding areas have been estimated using the latest available 2020 LIDAR data and predicted subsidence, the remnant ponding predictions differ to the Rev 2 report in some areas. However, overall, the total remnant ponding area for the proposed scenario has decreased relative to the Rev 2 report and relative to the approved scenario and the pre-mining scenario.

There are locations where drainage line grades will increase relative to the pre-mining landform, and monitoring locations have been identified based on the watercourse stability (long section) analysis (refer to **Section 4.2**). If monitoring identifies that remediation works are required, remediation works should consider channel characteristics, including channel grades and channel stabilities.

If remediation works are necessary, they have the potential to generate short term impacts on water quality while the remediation works are being undertaken and stable vegetated landforms are being established. Potential water quality impacts for downstream water users and ecosystems relate to increased sediment generation and export of sediment off site. To mitigate the potential impact, erosion and sediment control measures should be implemented as required (refer to **Section 4.8.1**), as part of the ongoing monitoring and remediation works.

5.2 Watercourse Stability Monitoring

Based on the predicted subsidence impacts on watercourses within the Project Area, Centennial Mandalong proposes to monitor watercourses within and near to the undermined area. A particular focus will be a location identified with potential for scouring, as addressed in **Section 4.2** and shown in **Figure 4.2** and **Graph 4.1**.

Monitoring will commence immediately prior to the undermining of the areas and continue through the post-mining period, with additional inspection of the monitoring locations following rainfall events of a magnitude sufficient to generate runoff (an appropriate rainfall trigger will be identified during the preparation of the monitoring program). Annual watercourse stability reports are to be prepared with the key findings reported in the Annual Review for the Project. Monitoring will include:

- monitoring of any bed control points
- monitoring of areas where subsidence may increase the erosive potential above the determined threshold limits potentially causing channel erosion/instability
- the use of long section and cross section surveys, photographic records and/or methods outlined in Australian Rivers Assessment System (AUSRIVAS) (eWater CRC, 1994).

5.3 Erosion and Sediment Controls for Remediation Works

Where subsidence remediation works are required, the design and implementation of such works should incorporate erosion and sediment controls that will be monitored during the works period in accordance with the Blue Book (Landcom 2004 and DECC 2008), including regular inspections and inspection after rainfall events causing runoff (refer to **Section 4.8.1**).

5.4 Reporting

Results from the proposed monitoring programs (refer to **Sections 5.1** to **5.3**) are to be reported in the Annual Review and made available to the public on the Centennial Mandalong website.

6.0 References

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Water Management (General) Regulation 2018 (NSW), p 92, No 480

APPENDIX 1

Assessment Approach

A1.1 Subsidence Predictions

Subsidence predictions for the mine plan applicable to the proposed modification (Modification 9) were provided by Ditton Geotechnical Service Pty Ltd. The predicted subsidence was used to 'subside' the digital terrain model (DTM) that was developed for the Project Area using aerial LiDAR survey (ALS) data. The subsided DTM then reflects the potential subsidence for the local terrain (proposed landform). Similarly, relevant subsidence predictions and DTMs reflect the local terrain for the approved landform and pre-mining landform. Relevant DTMs incorporate total observed (actual) subsidence where suitable LIDAR topographic data is available for previously undermined areas.

A1.2 Modelling Methodology

Two dimensional (2D) hydrodynamic modelling (RMA-2 software) was used to estimate the potential surface water impacts of the Modification 9 within the Morans Creek floodplain. The modelling compared flood behaviour for the pre-mining landform, approved landform and proposed landform.

The 2D hydrodynamic RMA-2 model uses a finite element mesh to describe the terrain of the modelled area at a variable resolution, suitable to capture the hydraulically important details. The finite element mesh typically consists of nodes (points) that describe a detailed network of triangular elements. The nodes are locations where the various 2D hydraulic equations are computed for each time step, which can then be interpolated across the mesh elements to provide a highly detailed estimate of the flood response of a floodplain. The RMA-2 software package is typically applied to large and broad floodplains.

A 2D hydrodynamic RMA-2 model was previously developed for Morans Creek as part of the *Mandalong Valley Flood Study* (Hughes Truman 2004). That 2D model has been used for subsequent surface water assessments and ongoing subsidence management plans, covering Morans Creek (e.g. Umwelt 2012, 2013, 2016, 2017 and 2018). The 2D model has been further developed to model the potential subsidence impacts on the flood flows within Morans Creek for the Modification 9.

A high resolution DTM provides the essential information to define the topography across the model mesh for the different landform scenarios (i.e. pre-mining, approved and proposed). The 2D hydrodynamic model was used to estimate the flood response for pre-mining conditions and to also predict the flood response for the approved subsided landform and the proposed subsided landform.

Specifically, the 2D hydrodynamic model was used to estimate the flood response of watercourses within the Project Area and to identify any potential downstream impacts for four design flood events, including:

- approximate bank-full event, typically the one (1) year or two (2) year average recurrence interval (ARI) design event (1 year ARI event used);
- 10 year ARI design event;
- 20 year ARI design event; and
- 100 year ARI design event.

ARI refers to the long term average interval (in years) between occurrences of a design storm of a specific magnitude or greater. For example, a 10 year ARI storm is expected to occur on average every 10 years assuming a sufficiently long observation period (of the order of several hundred years). This does not mean the event will occur once every 10 years, and in fact such events tend to cluster within flood dominated periods as a result of large-scale climate cycles.

The bank full flood event, defined as the design flood event that results in flow depths that are approximately equal to the top of bank of a watercourse, are used for the estimation of the potential changes to velocities and tractive stresses (largely dependent on velocity) within the main watercourse channel sections. The estimation of tractive stress within the modelled watercourses allows for the determination of locations which have the potential to undergo increased erosion or scouring as a consequence of the changes to the watercourses.

The outputs of the flood model were used to generate flood maps and graphs, which allow for comparison of the pre-mining, approved and proposed landform flood depths, velocities and flood hazard categories. The flood model also allows for the estimation of potential changes to tractive stresses within each watercourse during approximately bank full flows.

A1.2.2 Remnant Ponding

Remnant ponding refers to the areas which retain surface water for an extended period following a rainfall event. They are typically local depressions which do not gravity drain, i.e. not free draining. Subsidence has the potential to alter the existing pattern of remnant ponding, potentially impacting on the existing amenity of properties, including farm dams, pasture areas and access routes. The changes to remnant ponding can also impact existing ecosystems.

The potential changes to the pattern of remnant ponding were estimated using the high resolution DTM and predicted subsidence for the Modification 9, and Geographic Information System (GIS) tools that identify areas within the DTMs that are not free draining. It should be noted that the remnant ponding analysis does not include minor drainage structures, such as subsurface drains, that may be in place to alleviate local ponding issues.

A1.2.3 Watercourse Stability

The 2D hydrodynamic model results provide information to assess potential changes to the bed and bank stability of the modelled watercourses in response to the predicted subsidence. Changes to the landform as a result of predicted subsidence can result in changes to flow velocities and tractive stresses within a watercourse, which can change the existing pattern of erosion and deposition within a watercourse.

The potential impact of changes to modelled velocities and tractive stresses on the stability of a watercourse are estimated using stability thresholds. The stability thresholds allow for flows to be categorised as stable, marginally stable or unstable. The thresholds depend on bed and bank material and vegetation coverage.

Based on the observations from previous field inspections (Umwelt. 2013), bed materials appear to range from graded loam to fine gravels and cobbles. The thresholds for tractive stress and flow velocity shown in **Table A1.2** have therefore been selected as indicative thresholds for determining the stability state of each watercourse.

Table A1.2 Permissible Tractive Stress and Velocity Thresholds for graded loam to fine gravels to cobbles, Adapted from Fischenich (2001)

Flow Metric	Stable	Marginally Stable	Unstable
Velocity	< 0.75 m/s	0.75 m/s to 1.15 m/s	> 1.15 m/s
Tractive Stress	< 3.6 N/m^2	3.6 N/m^2 to 18.2 N/m^2	> 18.2 N/m^2

The results from a 2D hydrodynamic model allowed the tractive stress to be plotted *per unit width,* typically at the channel centre line.

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