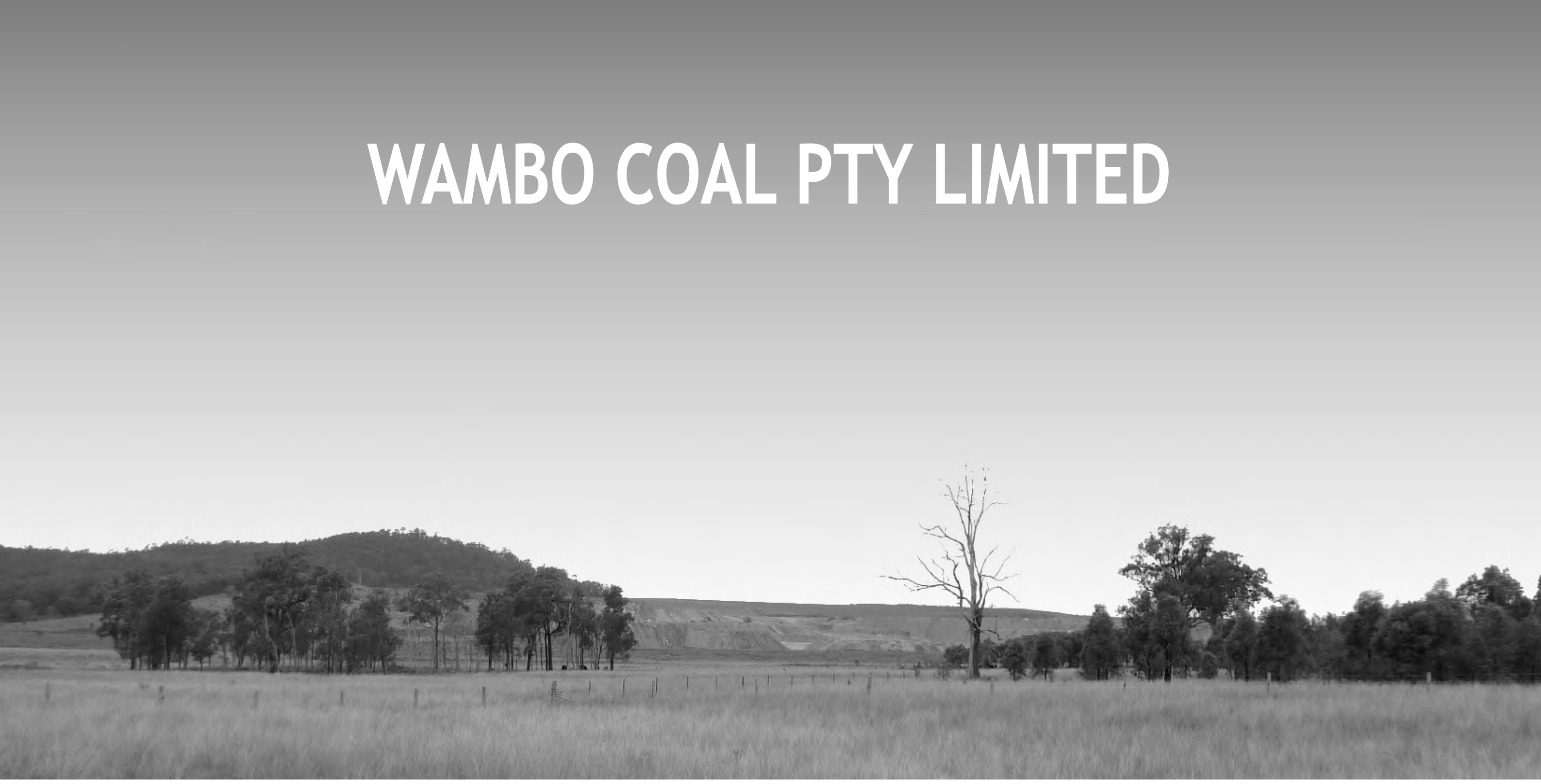
WAMBO COAL PTY LIMITED



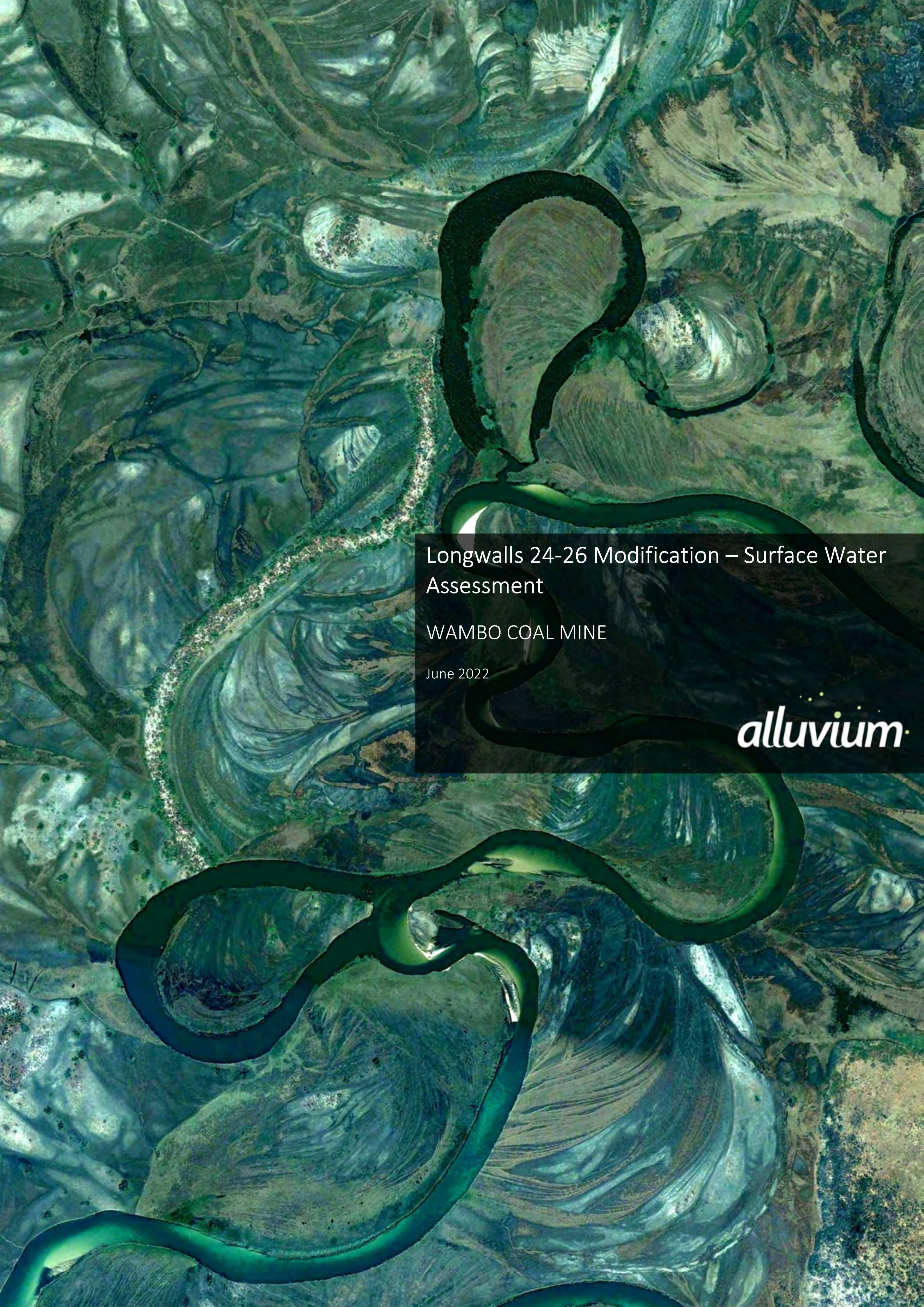
WAMBO COAL MINE
LONGWALL 24 TO 26 MODIFICATION

MODIFICATION REPORT

For the Modification of DA 305-7-2003 (MOD 19)
Optimisation and Continued Operation
of the Approved South Bates Extension Underground Mine

APPENDIX C
Surface Water Assessment

Peabody



Longwalls 24-26 Modification – Surface Water Assessment

WAMBO COAL MINE

June 2022

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

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Version:	4.0
Date issued:	27/6/2022
Issued to:	Wambo Coal Pty Ltd (WCPL)
Citation:	Alluvium, 2022, Wambo Longwalls 24-26 Modification – Surface Water Assessment, report prepared by Alluvium Consulting Australia for the Wambo Coal Pty Ltd (WCPL)
Cover image:	abstract river image, Shutterstock

Contents

Figures

Tables

1 Introduction

The Wambo Coal Mine (Figure 1-1) is situated approximately 15 kilometres (km) west of Singleton, near the village of Warkworth, New South Wales (NSW), and is operated in accordance with Development Consent (DA 305-7-2003). The Wambo Coal Mine is owned and operated by Wambo Coal Pty Limited (WCPL), a subsidiary of Peabody Energy Australia Pty Limited.

The South Bates Extension Underground Mine is a component of the approved Wambo Coal Mine comprising LW 17 to LW 25 (Figure 1-2) in the Whybrow Seam. The South Bates Extension Underground Mine was approved in December 2017 (as part of DA 305-7-2003 Modification 17) and operations commenced in LW 17 in 2018. WCPL is currently mining LW 22 and developing first workings for LW 23 and 24.

WCPL is seeking to modify Development Consent (DA 305-7-2003) under section 4.55(2) of the NSW *Environmental Planning & Assessment Act 1979* to allow for the reorientation of the approved LW 24 and LW 25, and the addition of LW 26 (the Modification) (Figure 1-1 and Figure 1-2).

This Surface Water Assessment outlines the pre (pre LW 21 to LW 26) and post subsidence environment for the modified South Bates Extension Underground Mine area (as shown in Figure 1-2), addresses potential impacts on surface water as a result of the Modification, and proposes mitigation, monitoring and reporting.

1.1 Scope

This Surface Water Assessment covers surface water aspects that interface with the approved and modified South Bates Extension Underground Mine plan. This includes North Wambo Creek, the North Wambo Creek Diversion (NWCD), its tributaries and surrounding landscape and the headwater tributaries of Waterfall Creek to the north.

The impact assessment of subsidence upon waterways and surface water generally is undertaken in the structure developed during the *Isaac River Cumulative Impact Assessment of Mine Developments* (Alluvium, 2008), a project jointly funded by Anglo American and BHP Billiton undertaken in collaboration with Queensland Government. Although not directly applicable to NSW regulation, the findings assisted the development of the *Watercourse Subsidence – Central Queensland Mining Industry* guideline (DERM, 2011). The framework for assessing impacts on watercourses by subsidence was developed into the following hierarchy, which has been adopted for this study:

- 1st order – direct physical effects of subsidence
- 2nd order – geomorphic response to subsidence
- 3rd order – changes to water quantity and quality
- 4th order – biological response

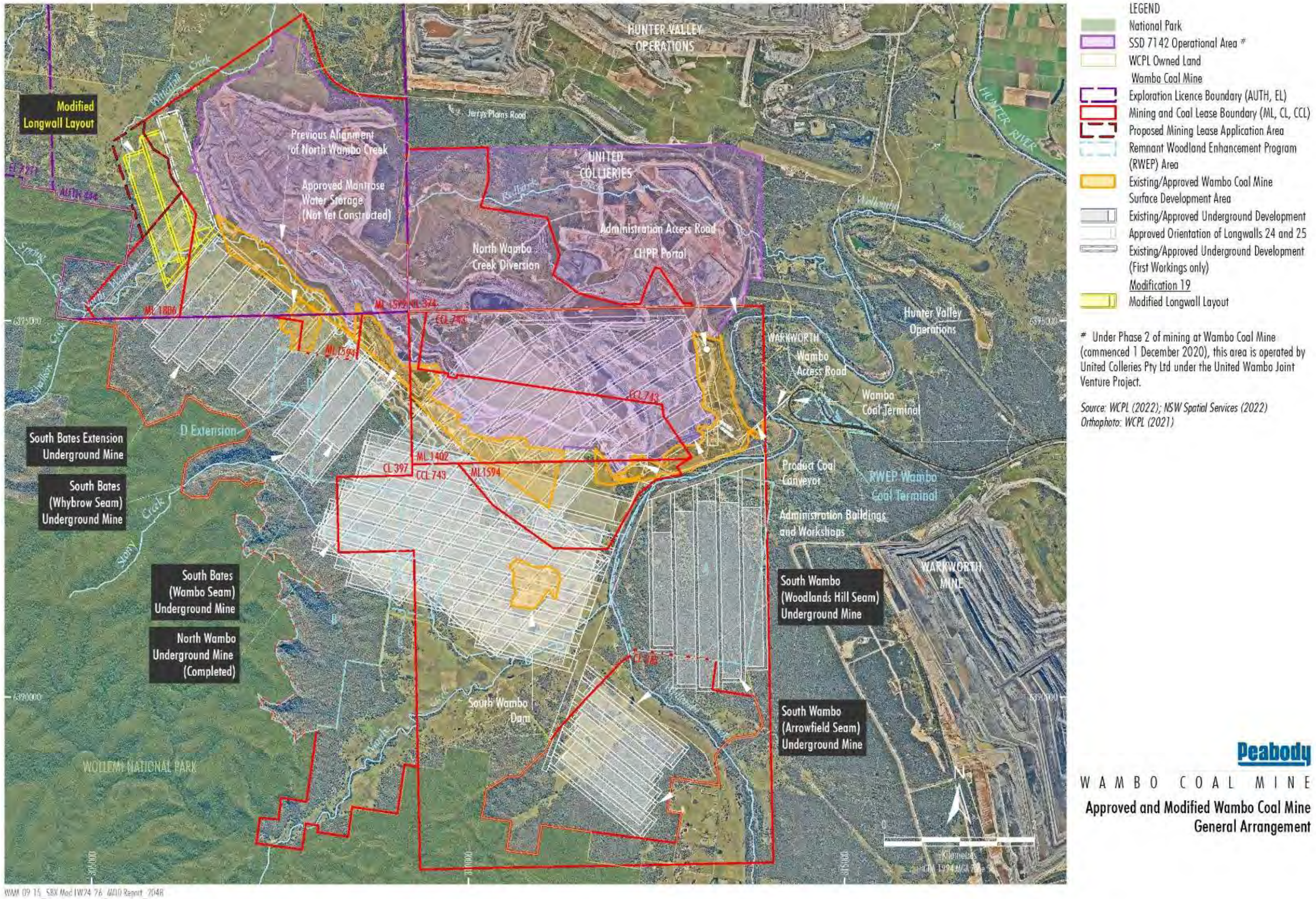

Figure 1-1. *Approved and Modified Wambo Coal Mine General Arrangement*

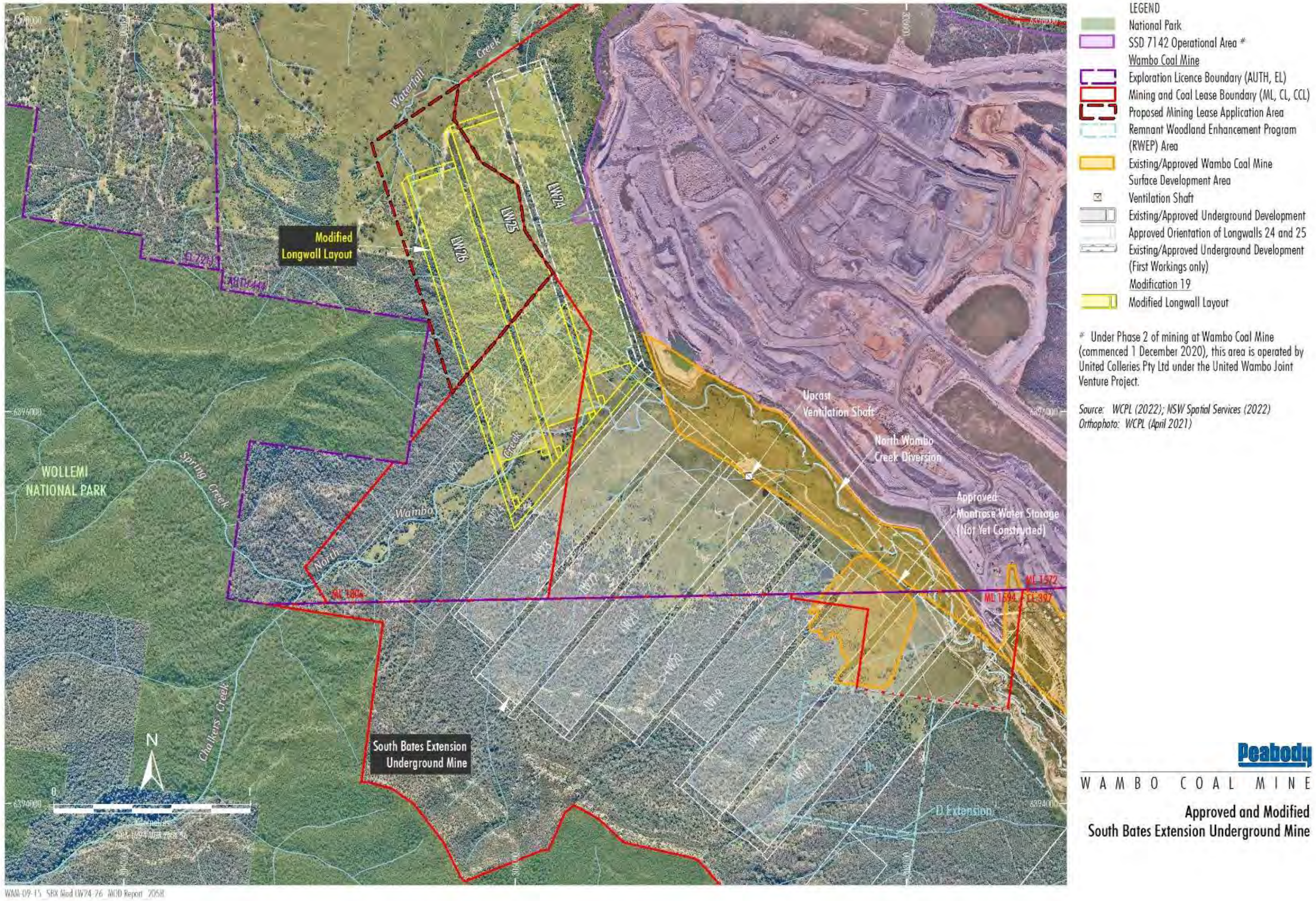

Figure 1-2. *Approved and Modified South Bates Extension Underground Mine General Arrangement*

2 Description of Existing Surface Water Values

A snapshot of the existing condition of the landscape and surface water environments interacting with the approved and modified South Bates Extension Underground Mine plan is provided to inform the impact assessment and any mitigation strategies that may be required. For the purposes of this Surface Water Assessment, the surface water environment interacting with the approved and modified South Bates Extension Underground Mine has been divided into the following areas (Figure 2-1):

- Upstream Reach –the section of North Wambo Creek upstream of the NWCD and its tributaries Spring and Chalkers Creeks. The Modification would result in a reduction in the length of the upstream reach that would be undermined.
- NWCD Stage 2 – the upstream half (approx.) of the NWCD that was constructed prior to NWCD Stage 3. Only LW 18 intercepts the NWCD Stage 2 and the modified LW 24 to LW 26 are located upstream of the NWCD Stage 2.
- NWCD Stage 3 – the downstream half (approx.) of the NWCD that was constructed to replace the now mined-out NWCD Stage 1. The modified LW 24 to LW 26 are located upstream of the NWCD Stage 3.
- Downstream Reach – the section of North Wambo Creek downstream of the NWCD. Although the South Bates Extension Underground Mine is located upstream of the downstream reach, this section of North Wambo Creek has been subsided by previous mining activities at the Wambo Coal Mine.
- Southern Tributaries – the North Wambo Creek and NWCD tributaries located to the south of North Wambo Creek and NWCD in the vicinity of the South Bates Extension Underground Mine. The Modification would result in a reduction in the length of the southern tributaries that would be undermined.
- Northern Tributaries – the North Wambo Creek and NWCD tributaries located to the north of North Wambo Creek and NWCD in the vicinity of the South Bates Extension Underground Mine. The Modification would result in an increase in the length of the northern tributaries that would be undermined.
- Waterfall Creek – Waterfall Creek and its tributaries in the vicinity of the South Bates Extension Underground Mine. The Modification would result the undermining of sections of Waterfall Creek and its tributaries that would not be undermined otherwise.

The snapshot of the existing condition based on several previous point in time condition assessments from 2015-2022 and the NWCD monitoring from 2017-2021. These assessments and monitoring were all undertaken during the period when mining of LWs 17-20 at the South Bates Extension Underground Mine was taking place.

A monitoring program for NWCD was established in November 2017 in response to recommendations in the Extraction Plan for LW 11 to LW 16 (Alluvium, 2016) (see Section 4.1). The monitoring results are detailed in Alluvium's (2022) *North Wambo Creek Diversion Operations Monitoring 2021*. The latest monitoring of NWCD and North Wambo Creek was completed in early 2022 (due to wet weather delaying the 2021 monitoring field inspections), the details of which are found in *North Wambo Creek Diversion Operations Monitoring 2021* (Alluvium, 2022). As well as the NWCD monitoring, information from a NWCD performance review (Alluvium, 2015) and other historical information were used to inform this assessment.

Further baseline assessment of the upstream reaches of North Wambo Creek and its tributaries Spring and Chalkers Creeks was completed in February 2018. The results of that assessment are detailed in Alluvium's (2018) *North Wambo Creek – Baseline assessment geomorphic context statement*.

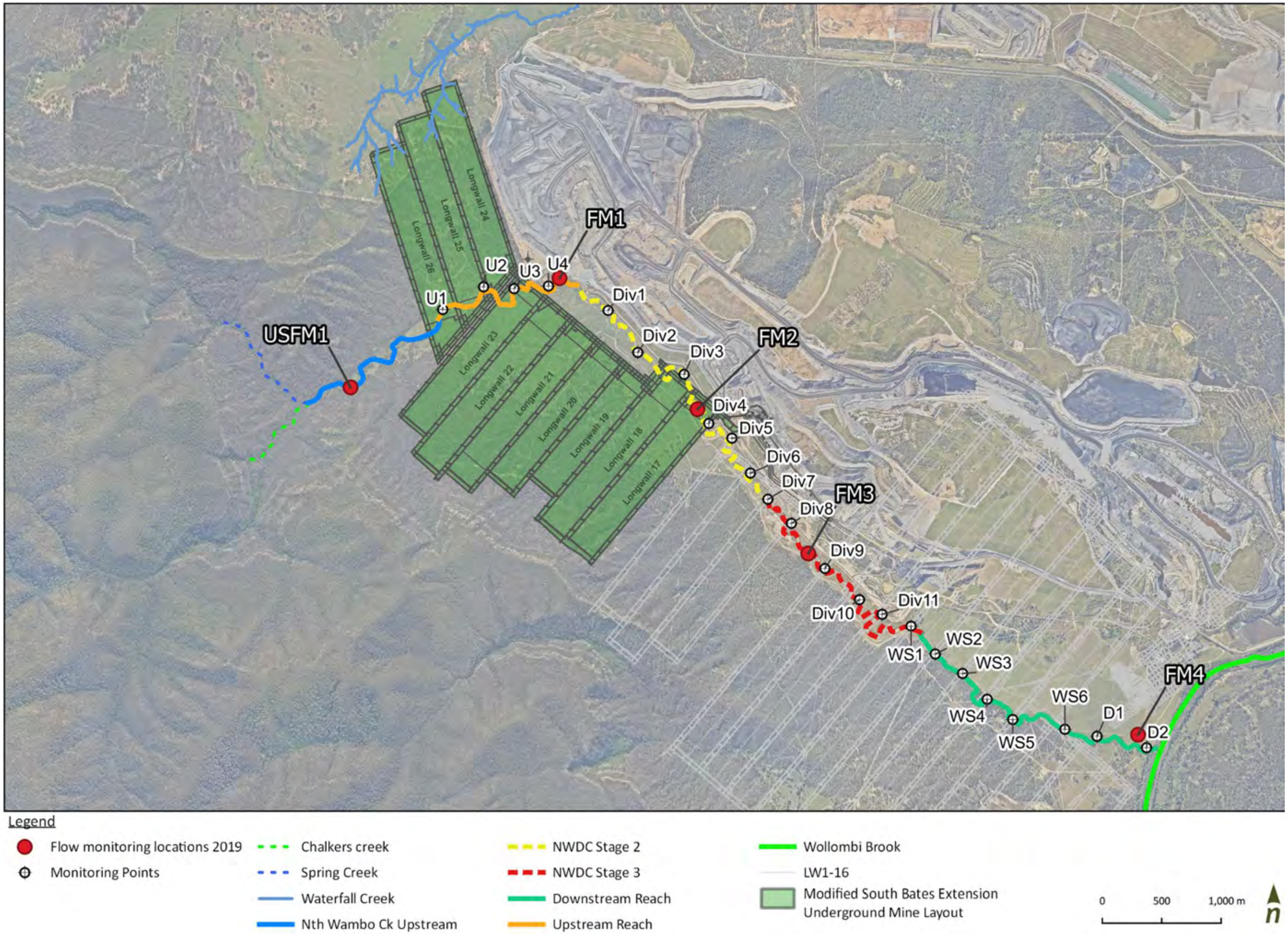

Figure 2-1. *Study Area*

2.1 Character, behaviour and condition of waterways

Upstream Reach

The upstream reach includes the section of North Wambo Creek upstream of the NWCD and its tributaries Spring and Chalkers Creeks.

Spring and Chalkers Creek tributaries originate from the sandstone capped ranges to the west of the Wambo Coal Mine. These ranges have massive sandstone beds that form plateau on the crest with angle of repose slopes beneath. Consequently, these ranges can generate substantial quantities of sand as input to North Wambo Creek valley. Near the confluence of Spring and Chalkers Creek, which forms North Wambo Creek, much of the sedimentary bedrock is conglomerate, providing cobbles and gravels as bedload to the waterway (Figure 2-2). Both these waterways have a steep gradient and are horizontally confined by bedrock in hillslopes with only minor floodplain pockets.

Downstream of the confluence of the confined Spring and Chalkers Creeks, North Wambo Creek becomes progressively less confined before becoming completely alluvial prior to the NWCD (Figure 2-2). The extents of North Wambo Creek assessed have been subject to a long period of adjustment in response to land clearing and agricultural use (livestock grazing). The farming settlement of the valley appears to have comprised several smaller allotments and land use is likely to have been intensive. Grazing occurred in the valley and along the subject reaches up until 2019.

Prior to development of the Wambo Coal Mine, North Wambo Creek has undergone a number of adjustments. It is probable that the watercourse was a discontinuous alluvial channel with swamp like features, potentially a chain of ponds. With complete clearing of the valley floor it appears that a channel incised, widened and meandered in the sandy alluvials. There is no longer an active channel present for much of North Wambo Creek immediately upstream of the NWCD, it has infilled and exhibits very little fluvial bed form activity (Figure 2-2). This section appears to be returning to a discontinuous alluvial form, inset below the former surface.

It is likely in this setting that much of the flow generated in the range to the west in lower intensity and magnitude rainfall events was as base flow in the alluvial sediments. The current open cut operation adjacent to the offtake of NWCD influences the flow regime locally, in NWCD and downstream.

Riparian vegetation in the reach immediately upstream of NWCD is limited to ground cover, which has been dense at the times of inspection 2015-2021. The reasons for limited regeneration of woody species in this reach are not known. The reach appears no longer subject to cattle grazing however kangaroo numbers in the area are significant. Changes in the saturation of alluvials due to a steeper hydraulic gradient to the open cut may also be a factor in limiting woody regeneration.

NWCD Stage 2

The upstream half (approx.) of NWCD is known as NWCD Stage 2. This was constructed prior to Stage 3 which replaces the mined-out NWCD Stage 1. NWCD Stage 2 is constructed initially in the floodplain of North Wambo Creek then gradually into foot slopes of the range to the west (transitioning from an alluvial setting to fully bedrock controlled). A low capacity low flow channel, typically 2-3 metres (m) deep and up to 10m top width has been cut into a constructed floodplain that decreases from around 80m wide to 30m wide moving downstream as depth of cut increases (to about 8m below natural ground surface at the interface with NWCD Stage 3) (Figure 2-3).

At the upstream end of NWCD Stage 2, overland flow entry has been managed adequately and with a lower gradient and broader cross section the diversion is in similar condition to the upstream reach. Hydraulic energy conditions increase with the depth of cut and the narrower floodplain, moving downstream. This has resulted in deepening and widening of the low flow channel that is likely to continue in the alluvial/colluvial sediments present (Figure 2-3). This process is occurring in the zone over LW 11 to LW 17 and immediately upstream.

NWCD Stage 2 is known to have had substantial rehabilitation effort in the form of revegetation largely with a pasture seed mix and some tube stock patches and other remedial works in 2011 and again in 2013. In response to the limited success of these initial rehabilitation works, a program of shallow ripping (including treatment of subsidence cracks) and seeding has progressed since early 2019. With wet conditions across 2020-21 (in 2021 the rainfall gauge at Bulga (South Wambo) experienced its wettest year on record), this program is showing signs of success with greatly improved vegetation coverage (Figure 2-3). In addition, a number of mitigation works such as rock chutes on diversion batters have been undertaken in accordance with the existing North Wambo Creek Detailed Rehabilitation Plan (Alluvium, 2021) during 2020-21 to mitigate erosion on the batters associated with overland flow entry from the west.

NWCD Stage 3

The downstream half (approx.) of NWCD is known as NWCD Stage 3. NWCD Stage 3 is largely constructed in foot slopes with much of the channel boundaries being weathered sandstone and conglomerate bedrock. Where not bedrock, the weathered sediments are generally highly dispersive and prone to erosion on the surface and sub-surface (Figure 2-3).

This section of NWCD had, until recent years, limited vegetation establishment and overland flow entry management issues. Mitigation works have been designed and implemented to manage these issues in accordance with the existing North Wambo Creek Detailed Rehabilitation Plan (Alluvium, 2021). Based on 2021-2022 monitoring, the works are proving successful. The sandstone boundaries of the channel remain relatively sound in the majority, with only a few instances of bedrock weathering to the extent of it breaking down to constituent sediments.

Elevated energy conditions in NWCD Stage 3 and the limited finer sediment supplied to the reach under current sediment supply conditions means there is little prospect of deposition and that any fine sediment topsoil in the channel is likely to be stripped in larger flow events. Combined, these conditions constrain longer term vegetation establishment potential from regeneration/self-seeding processes. With the shallow bedrock in the reach, vegetation is at further risk of removal due to potential barriers to root penetration where sandstone beds are massive.

The downstream extents of NWCD Stage 3 were constructed over terrain that was already subsided by earlier longwall mining.

Downstream Reach

Downstream of NWCD through to the confluence with Wollombi Brook, the remaining alignment of North Wambo Creek has been subsided by five longwalls in the 2000's. This reach of North Wambo Creek is relatively low sinuosity and is increasingly incised as it cuts down to the level of Wollombi Brook. Channel migration is limited by consolidated Wollombi Brook terrace sediments. Bedrock controls are occasionally present in the channel bed.

Riparian vegetation remains minimally cleared for much of the downstream reach, however clearing has occurred to the top of bank along the north eastern side for much of the reach. What remains, exhibited clear signs of water stress during the monitoring period prior to 2020 likely due, at least in part, to the dry climatic conditions in this area of NSW over that time, but also due to the reduction in flows from upstream reaches of North Wambo Creek. The wet conditions from 2020 onward have seen dense growth of ground cover, predominantly weeds, evidence of overstorey regeneration is yet to be observed.

Subsidence pools are present in the downstream reach, providing pool habitat that is otherwise not presently common in North Wambo Creek, although these were all found to be dry in November 2019. There has been limited erosion response in the downstream reach, such as incision through pillars, to date.

A notable threat to the condition of the downstream reach exists in the form of a significant drop through culverts of a track crossing shortly upstream of the Wollombi Brook confluence. Sediment has accumulated upstream of the culverts and has been colonised by vegetation. Should the culverts fail through undermining or outflanking it is likely a considerable amount of deepening would occur through the accumulated sediments.


Typical Spring Creek reach (2018 baseline)


Typical Chalkers Creek reach (2018 baseline)


Partly confined North Wambo Creek, downstream of confluence of Spring and Chalkers Creeks (2018)


Partly confined North Wambo Creek, downstream of confluence of Spring and Chalkers Creeks (2018)


Upstream view in fully alluvial reach (2019) at monitoring point US3


Upstream view in alluvial reach (2021) at US3 to contrast ground cover and first return of surface flow in >7 years

Figure 2-2. *North Wambo Creek Upper Reach Photographs*


Upstream end of NWCD – Stage 2 near Div 1 (2022) | *Mid NWCD – Stage 2 near Div 2 (2022)*


Mid NWCD – Stage 2 near Div 5 (2022) | *Mid NWCD – Stage 2 near Div 5 (2022)*


NWCD – Stage 3 near Div 7 dry conditions (2022) | *NWCD – Stage 3 near Div 8 – some rock bank erosion (2022)*

Figure 2-3. *North Wambo Creek Diversion Stage 2 and Stage 3*

Western Tributaries

Several tributaries flow from the sandstone escarpment of the range to the west into North Wambo Creek and NWCD in the vicinity of the South Bates Extension Underground Mine (Figure 2-4). These tributaries transition from steep deeply incised bedrock-controlled gullies to broad alluvial flood-outs with no defined channel progressing downstream before entry to North Wambo Creek and NWCD. These systems are all presently in dynamic equilibrium with relative stability. Riparian vegetation is near intact throughout the steeper upper reaches then cleared for grazing where they flood out onto the flatter valley base. There are small fam dams on some of these tributaries and the nature of their inflow to NWCD has been altered by works implemented with the diversion.

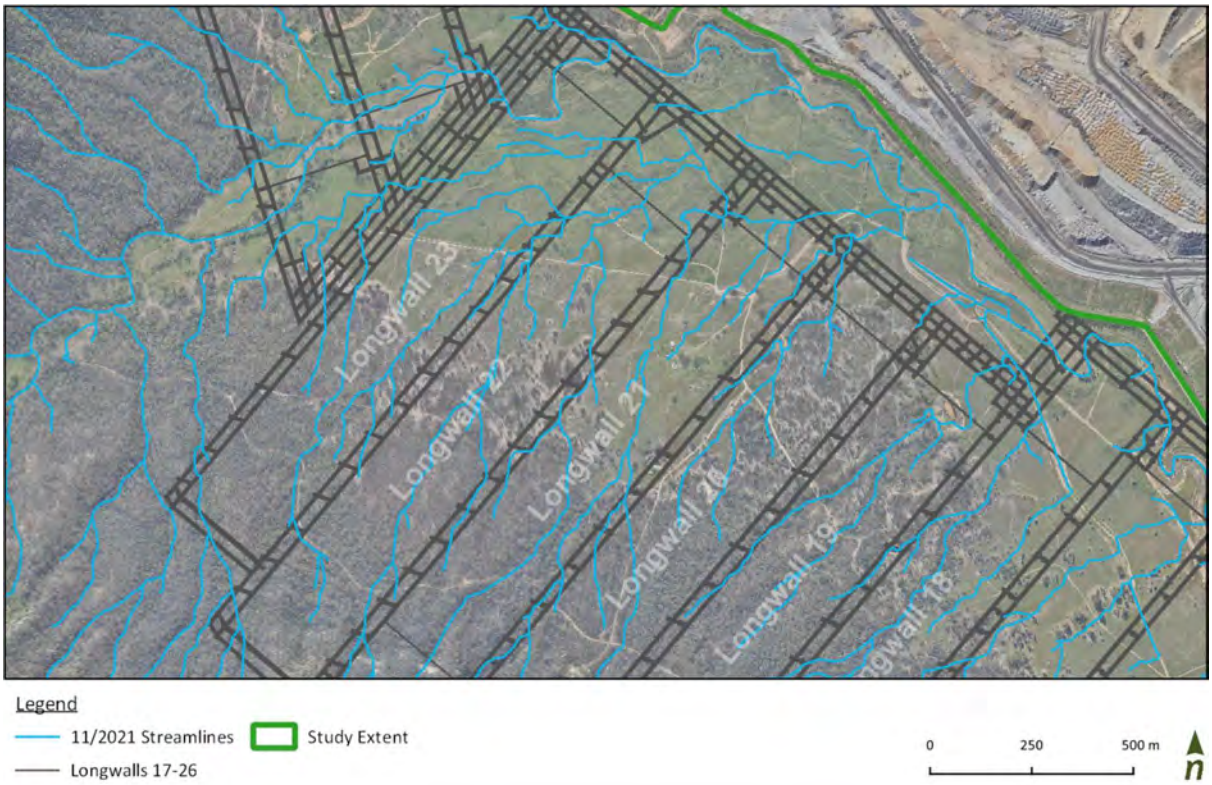

Figure 2-4. *Western tributaries of North Wambo Creek*

Northern Tributaries

To the north of North Wambo Creek in the vicinity of the South Bates Extension Underground Mine several tributaries flow from the ridge towards the upstream reach of North Wambo Creek. These tributaries transition from steep deeply incised gullies to broader gullies but do not become alluvial flood-outs as observed with the Western Tributaries. In the 2022 inspection, the riparian vegetation was dense in the upper catchment with significant tree and ground cover (Figure 2-5). In the lower end of the tributaries the tree cover became less dense however dense ground cover remained (Figure 2-5). These systems appear to be in dynamic equilibrium with relative stability.

Upper catchment on Northern Tributaries within LW 26. Incised channel with dense vegetated cover (2022)

Lower catchment on Northern Tributaries within LW 24. Broad channel with light vegetated cover (2022)

Figure 2-5. *Northern tributaries of North Wambo Creek*

Waterfall Creek

Over the ridge from the Northern Tributaries the Waterfall Creek tributaries are steep and relatively incised gullies which run though the northern side of LW 24 to LW 26, with similar characteristics to those seen in the northern tributaries. Downstream of the panel extents, the tributaries broaden but with an incised main channel. The WCPL-owned land in the vicinity of this area is currently leased for cattle grazing. These systems have undergone some adjustment post clearing and some localised instabilities remain, though extents are limited by bedrock. Photographs of the Waterfall Creek tributaries are provided in Figure 2-6.

Upstream Waterfall Creek tributaries within LW 26. Incised channel with vegetated cover (2022)

Waterfall Creek tributaries downstream of LW 26. Incised channel and beginnings of a headcut (2022)

Waterfall Creek tributaries downstream of LW 25 & 26. Incised channel with some bed erosion (2022)

Waterfall Creek tributaries in upper catchment within LW 24. Wide channel with vegetated bed (2022)

Figure 2-6. *Waterfall Creek tributaries*

3 Impact Assessment

This section provides an assessment of the potential surface water impacts associated with the modified South Bates Extension Underground Mine relative to the surface water impacts associated with the approved South Bates Extension Underground Mine outlined in the Surface Water Assessment prepared by Advisian (2016) for Modification 17.

One of the effects of underground longwall mining is that after coal is mined, the roof strata falls into the void (goaf) causing the natural ground surface to subside. As the Modification would involve the reorientation of the approved LW 24 and LW 25, and the addition of LW 26 (Figure 1-1 and Figure 1-2), the watercourses, adjacent floodplains and hill slopes that exist over the area of the modified LW 24 to LW26 that would be affected by subsidence are the subject of this Surface Water Assessment.

3.1 1st Order – Direct Effects of Subsidence

Subsidence Modelling

Mine Subsidence Engineering Consultants (MSEC) have undertaken subsidence modelling for this Modification. The Subsidence Assessment includes subsidence predictions for the modified South Bates Extension Underground Mine layout as well as comparison with the subsidence predictions for the approved South Extension Underground Mine layout.

A comparison of the maximum predicted total subsidence effects for the approved and modified South Bates Extension Underground Mine layout is provided in Table 3-1. The values represent the maximum predicted accumulated movements within the South Bates Extension Underground Mine subsidence area due to the extraction of all longwalls for the respective layouts. The modified maximum predicted subsidence effects are the same or lower than the approved layout predicted subsidence effects.

Table 3-1. Comparison of maximum predicted total subsidence effects

Layout	Longwalls	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Approved Layout	LW 17 to LW 25	1950	90	> 3.0	> 3.0
Modified Layout	LW 17 to LW 26	1950	80	> 3.0	> 3.0

Source: MSEC (2022)

MSEC's (2022) subsidence predictions for the modified LW 21 to LW 26 are shown on Figure 3-1 and Figure 3-2. The subsidence predictions are for maximum subsidence expressed at the surface of 1.95m with chain pillar subsidence of up to 0.2m.

Figure 3-3 shows 1m and 5m contours derived from the post-subsidence topography generated by subtracting the predicted subsidence depth from the LiDAR captured in November 2021 (which included subsidence up to LW20). The LiDAR provided for this study was captured in November 2021, and is considered to have captured the majority of subsidence which has occurred between LW 17 and LW 20. Therefore the predictions provided by MSEC (2022) have only been applied to LW 21 and LW 26.

Figure 3-1. *Predicted Post Subsidence Surface Contours – Modified LW 21 to LW 26*

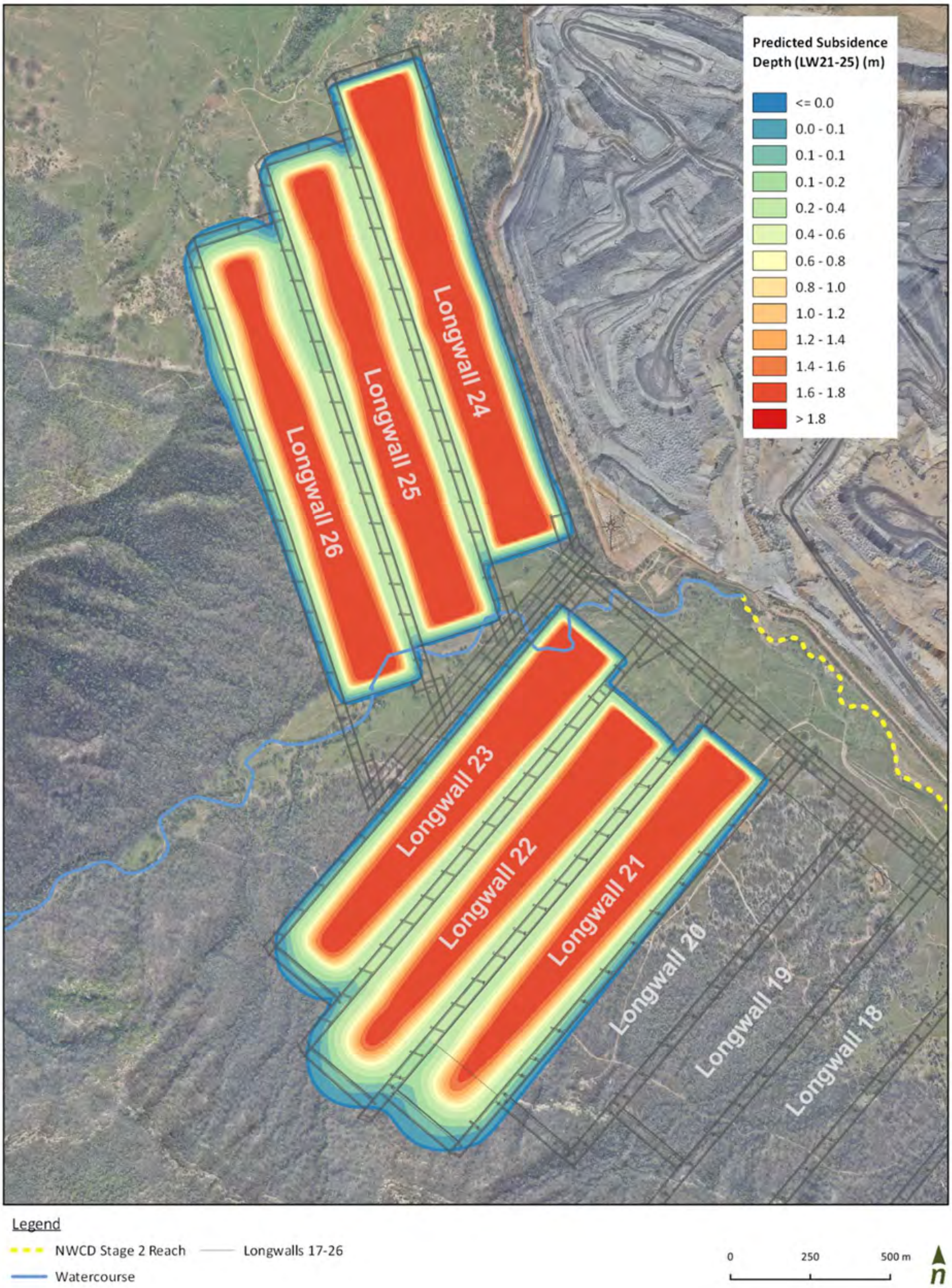

Figure 3-2. *Predicted Subsidence Depths – Modified LW 21 to LW 26*

Figure 3-3. *Predicted Post Subsidence Surface Contours – Modified Layout*

Surface tensile cracking and compressional buckling

Longwall mining can result in surface cracking and buckling at the surface. The extent and severity of these mining-induced ground deformations are dependent on several factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near-surface geological structures (MSEC, 2022).

Cracking has been observed above the existing component of the South Bates Extension Underground Mine (LW 17 to LW 20). As part of the Subsidence Assessment, MSEC has mapped the surface cracking across Wambo Mine for LW 17 to LW 20 (Figure 3-4). The largest surface deformations occurred adjacent to the maingates and tailgates, towards the finishing (i.e. north-eastern) ends of the longwalls, due to the shallower depths of cover. Less extensive cracking was recorded towards the commencing (i.e. south-western) end of the longwalls due to the higher depths of cover and possibly because the less accessible terrain limited inspection and mapping of the surface. Examples of cracking above LW 17 are provided in Figures 3-5 to 3-6.

Where these cracks occur in colluvial and alluvial sediments, surficial and sub surface erosion response can be expected. The sediments across this terrain can be dispersive, which makes them prone to changes in rates of erosion with changes in landscape dynamics.

The areas of greatest risk would be where cracks open in erodible sediments with an orientation down slope or where flow entry may be concentrated, or ponding occurs. These may be prone to enlargement should the volume of the crack be sufficient that local inputs of sediment don't infill it nor do the clays swell sufficiently to seal it. In these instances, some rill/gully erosion may develop. This had not been observed to the end of 2019 as insufficient rainfall had occurred since mining. Further inspection post the wet conditions of 2020-21 should be undertaken when safe to do so as cracks such as those shown in Figure 3-6 have the potential to undergo substantial enlargement due to runoff.

Where local ponding occurs in the same location as cracking, dispersive sediments are likely to flow down cracks with water, enlarging the crack at surface, which may develop into considerable tunnel erosion.

Subsurface cracking of overburden strata

An increase in hydraulic connectivity between the surface and the workings, particularly under waterways, can result in significant (third order) surface water impacts. Observations in the downstream extents of North Wambo Creek (downstream of where the North Wambo Underground Mine panels LW 1 to LW 10 intercept the creek) indicate that flows reaching this part of the waterway are limited to high intensity rainfall events or following extended wet conditions. Base flow conditions are likely to have altered because of underground mining, alluvial drawdown associated with open cut extraction, the removal of alluvium upstream for the construction of the NWCD and excision of catchment by the open cut. Observations of vegetation indicate that base flow conditions have been altered by a combination of the above factors, including death of aquatic plants and increasing colonisation by terrestrial vegetation. In the fully subsided sections of North Wambo Creek, subsidence pools have developed over several panels. This may indicate that loss of base flow is most likely through tensile cracking along the boundaries of the pillars and not compression buckle cracks across the panel.

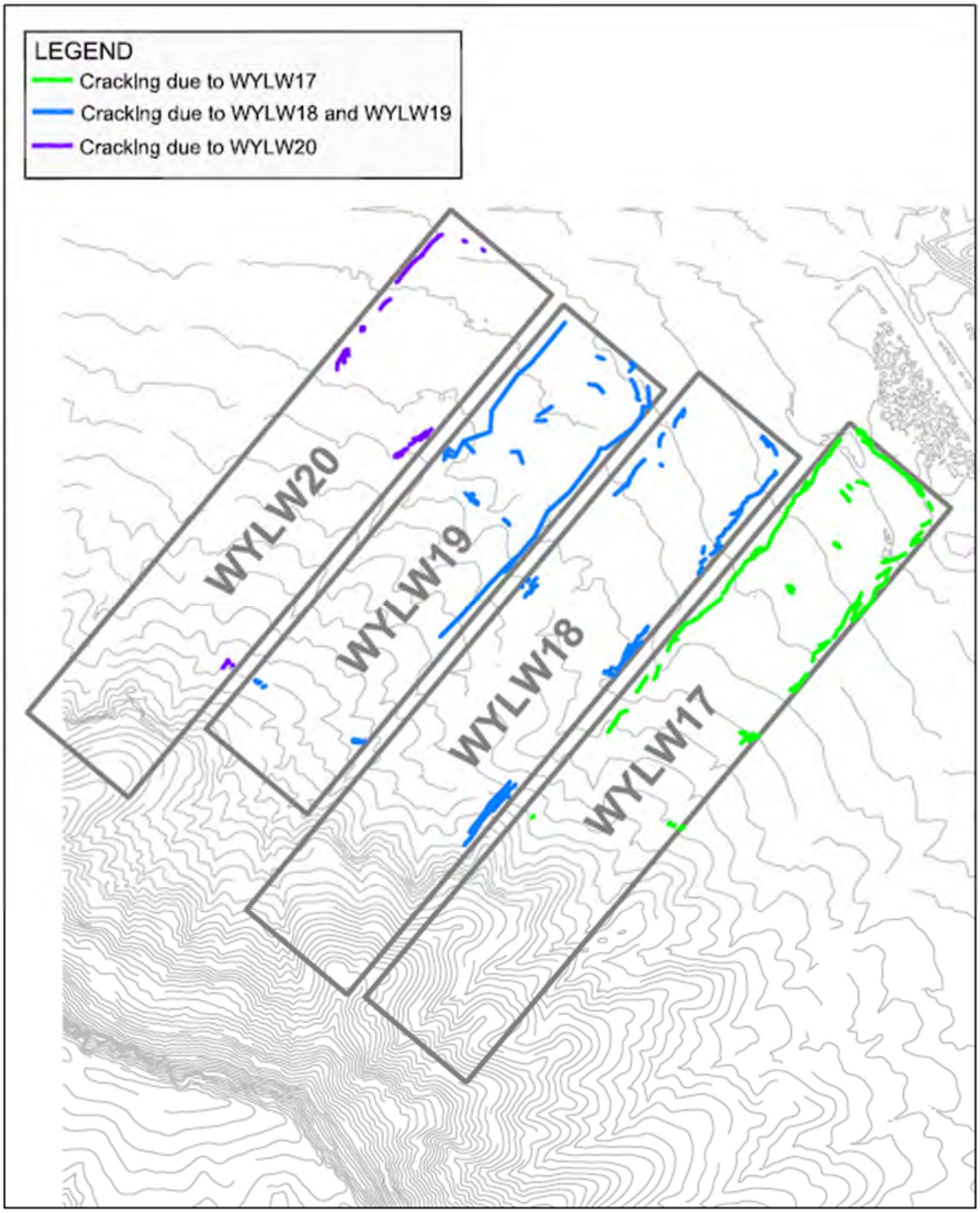

Figure 3-4. *Mapped Surface Cracking above LW 17 to LW 20 (MSEC, 2022)*

Figure 3-5. *Cracking at Surface Over LW 17 (MSEC, 2022)*

Figure 3-6. *Large Crack Development Example Over LW 17 (MSEC, 2022)*

Predicted subsidence of panel catchments and waterways

North Wambo Creek

A comparison of the maximum predicted total subsidence effects for North Wambo Creek based on the approved and modified South Bates Extension Underground Mine layout is provided in Table 3-2. The magnitude of the predicted subsidence effects would generally remain unchanged.

Table 3-2. Comparison of maximum predicted total subsidence effects for North Wambo Creek

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Approved Layout	1950	80	> 3.0	> 3.0
Modified Layout	1950	70	> 3.0	> 3.0

Source: MSEC (2022)

Although the Modification would not significantly change the magnitude of the predicted subsidence effects along North Wambo Creek, the length of North Wambo Creek that would located directly above the South Bates Extension Underground Mine would reduce from approximately 2.7km to 0.6km (i.e. a 2.1km reduction).

Details of the predicted maximum subsidence as a result of the modified South Bates Extension Underground Mine within North Wambo Creek and its catchment are shown in Table 3-3 below. A visual representation of the maximum subsidence depth for each longwall panel is shown in Figure 3-7 and Figure 3-8.

Table 3-3. Maximum predicted subsidence depth along North Wambo Creek by modified longwall panel

Longwall Panel	Panel Length (km)	Maximum Depth of Subsidence (m)
21	1.5	0
22	1.4	0
23	1.4	1.95
24	1.58	0
25	1.58	0.09
26	1.58	1.8

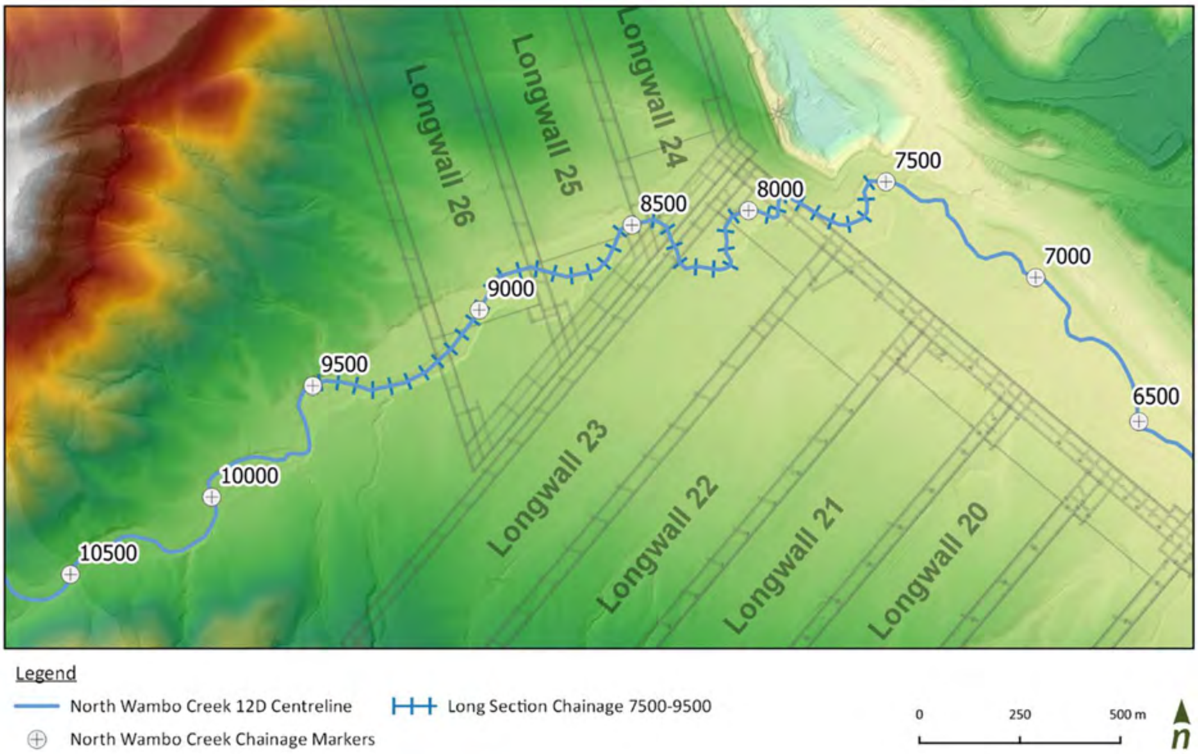

Figure 3-7. *Predicted Post Subsidence Surface over LW 23, LW 24 and LW 25. Note the extents of macro channel and orientation of the channel in relation to the LW 23, LW 24 to 25 panel alignment*

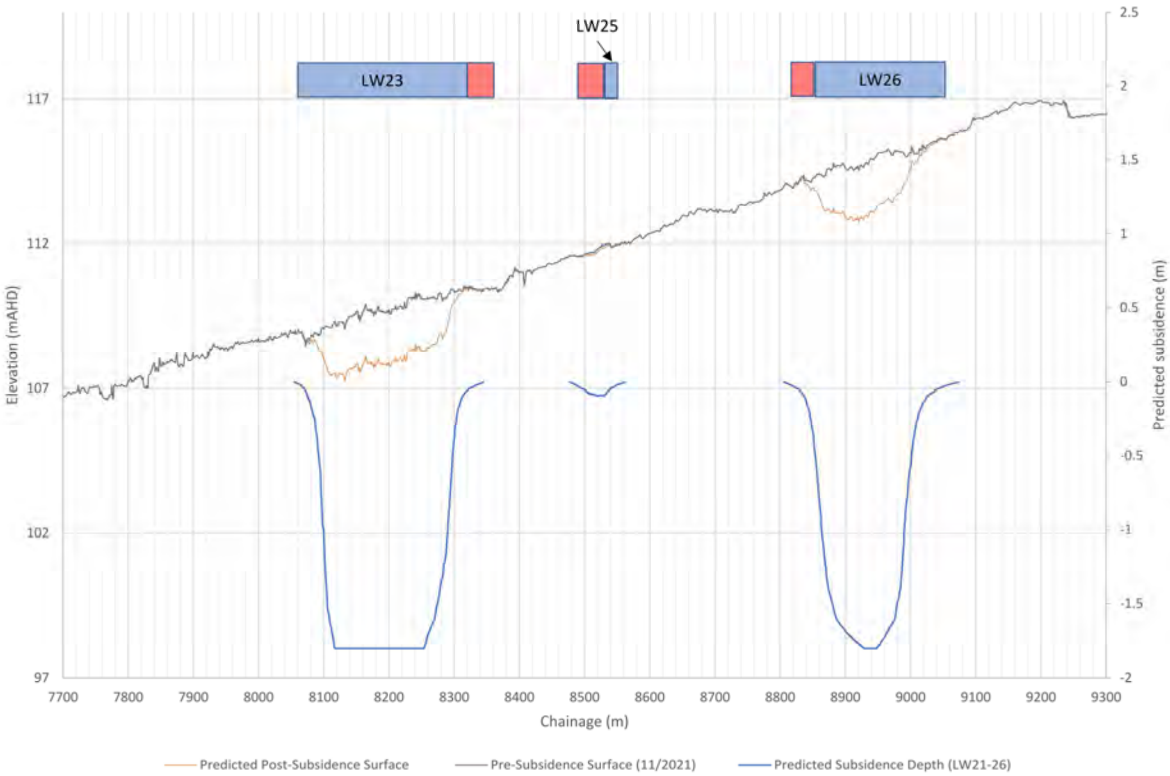

Figure 3-8. *Pre and Post Subsidence Longitudinal Profile of North Wambo Creek through LW 23, LW 24 & LW 25*

The predicted subsidence void (or pool) volume estimates within the North Wambo Creek channel are summarised in Table 3-4. These assume static channel boundaries (no erosion or deposition or management intervention), which would not be the case when flows occur that are capable of eroding the channel boundaries (2nd order response). Such response would change the pool volumes over time. Volumes are calculated from top of bank to top of bank of the macro channel, which includes the inset floodplain/bench and the low flow channel. The predicted subsidence void volume for LW 23, LW 25 and LW 26 (LW 24 does not overlap) is 57,978m^3 which is comparable to the predicted subsidence void volume of the previous South Bates Underground Mine LW 11 to LW 16) subsiding NWCD which had a total subsidence void volume of 64,225m^3. This is also significantly lower than the approved arrangement of LW 24 where the panel was aligned almost in parallel with North Wambo Creek creating void volumes within this panel of over 89,000m^3.

Table 3-4. Subsidence void volumes North Wambo Creek

Longwall Panel	Subsidence Void Volume (m^3)
23	15,335
25	13,828
26	28,815
Total	57,978

Waterfall Creek

Waterfall Creek is not located above the approved South Bates Extension Underground Mine layout. The Modification would result in the undermining of approximately 0.2km of Waterfall Creek (LW 26). The predicted subsidence effects for Waterfall Creek based on the modified layout are therefore greater than those based on the approved layout (Table 3-5).

Table 3-5. Comparison of maximum predicted total subsidence effects for Waterfall Creek

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Approved Layout	< 20	< 0.5	< 0.01	< 0.01
Modified Layout	450	13	0.45	0.40

3.2 2nd Order – Predicted Geomorphic Response of Surface Water Systems

North Wambo Creek

Up to 1.95m of subsidence (1.95m cumulative when other longwalls subside) over approximately 220m of North Wambo Creek channel over LW 23 is likely to initiate erosion response upstream through the unconsolidated alluvial sediments in the channel over the extents of the main headings and the margins of LW 25. This would be in the form of incision of the channel bed, followed by widening and potentially meander migration with the channel trying to reduce its grade. This incision is likely to link with that in LW 26 in the future. The erosion would serve to mobilise sediments into the LW 23 subsidence void/pool, resulting in overall lowering of the stream bed locally. A full sediment supply and transport analysis would be required to determine the potential maximum depth and duration of such deepening. However, in the long term (dependent on timing of flows capable of mobilising sediment), sediment supply from upstream (see Figure 3-9 and Figure 3-10), which appears relatively high, hence the infilling of the previous post settlement incision, would overwhelm the subsidence void created by LW 23 and LW 26.

Given the current channel infill that followed initial phases of incision in response to land use change over the last 200 years is unconsolidated and relatively broad (15-50m), the risk of bank erosion subsequent to incision is low, there should simply be a redistribution of the mobile bed load. Only very localised extents of banks over pillars and at drops into panels may require management.

The subsidence of LW 26 would initiate a similar response in the immediate few hundred metres of channel upstream of it and undergo infilling with locally sourced coarse sediment.

In-channel one dimensional hydraulic assessment (Figure 3-11 and Figure 3-12) indicates that the reach impacted by LW 21 to LW 26 is relatively low energy with stream power, shear stress and velocity being mostly within current best practice design criteria for diversions in Australian mining. Following subsidence there are some areas (particularly across the panels) where hydraulic parameters decrease and some areas (particularly across the pillars) where they extend within the range where instability for alluvial channel boundaries is expected and may require management (Section 4).

The capture of any bedload sediment transported to this point in North Wambo Creek, which is presently negligible, in LW 23 and LW 26 means that flows downstream of the panels are effectively clear and would look to mobilise material from the channel bed. Downstream within the NWCD where potential for deposition is already limited due to diversion configuration, surfaces are likely to remain as bare bedrock, limiting potential for vegetation establishment on lower channel boundaries.

With the substantial decrease in length of North Wambo Creek subsided in the Modification, the extent severity and duration of impacts described above would be greatly reduced. The previous LW 24 alignment would have created a lengthy pond that would have trapped all bedload input to the reach for a substantial period of time (decades likely with the exception of current multi year wet conditions) that would have increased incision and meander migration downstream of it and into NWCD.

NWCD

There is no predicted subsidence within NWCD caused by the extraction of the modified LW 21 to LW 26. Due to the decrease in volume of subsidence trough created on North Wambo Creek, geomorphic impacts would be reduced as a result of the Modification as there is less impact on flow and bedload sediment transport.

Figure 3-9. *Downstream view in channel near monitoring point US1, over LW 26, of unconsolidated sands and gravels (2019 in dry conditions)*

Figure 3-10. *Sands and gravels dominate at monitoring point US3 near where LW 23 would subside the NWC (under dry conditions in 2019, hence wombat presence in channel bed)*

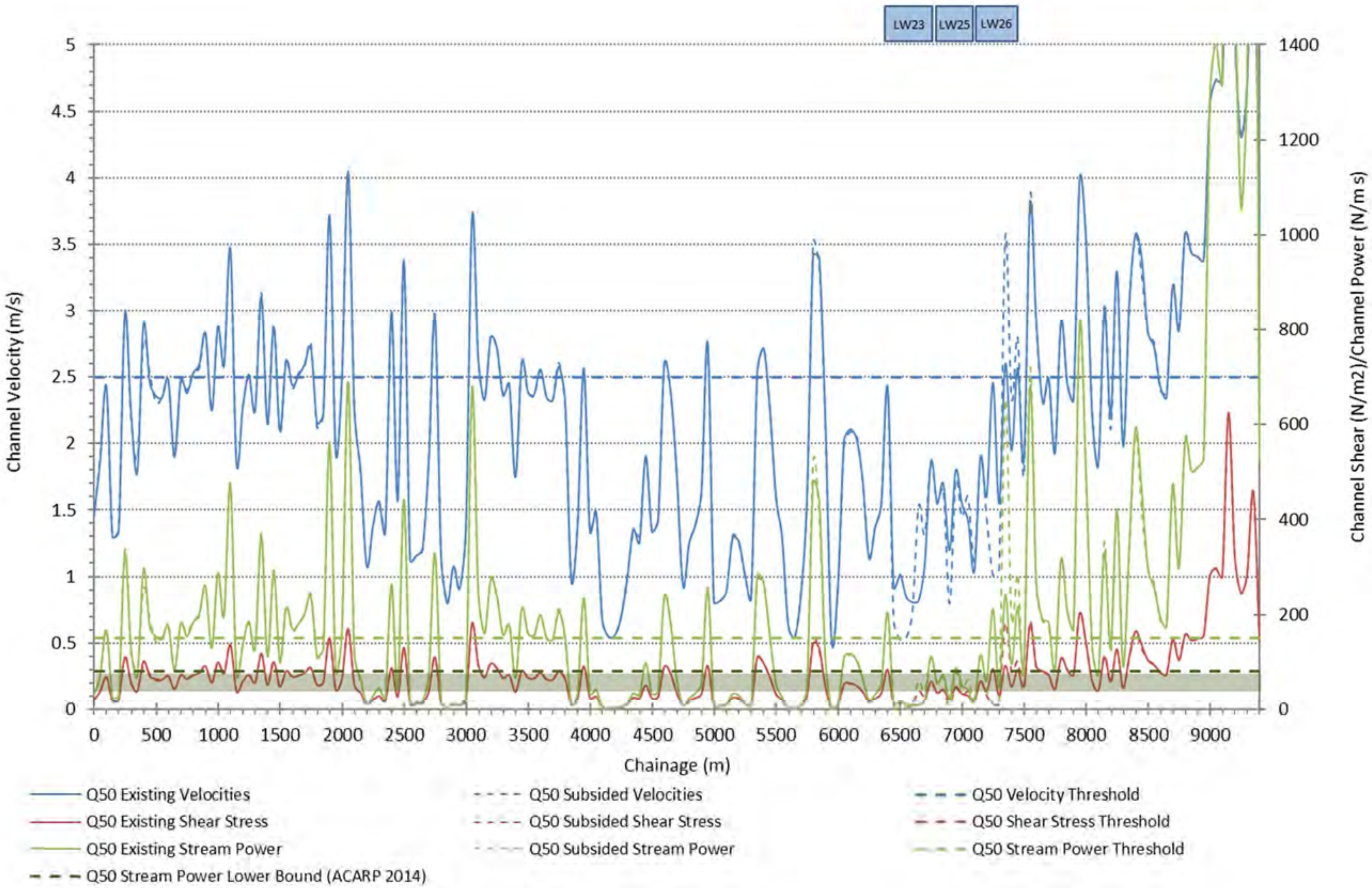

Figure 3-11. *Existing and Post Subsidence Hydraulic Conditions for 2% AEP*

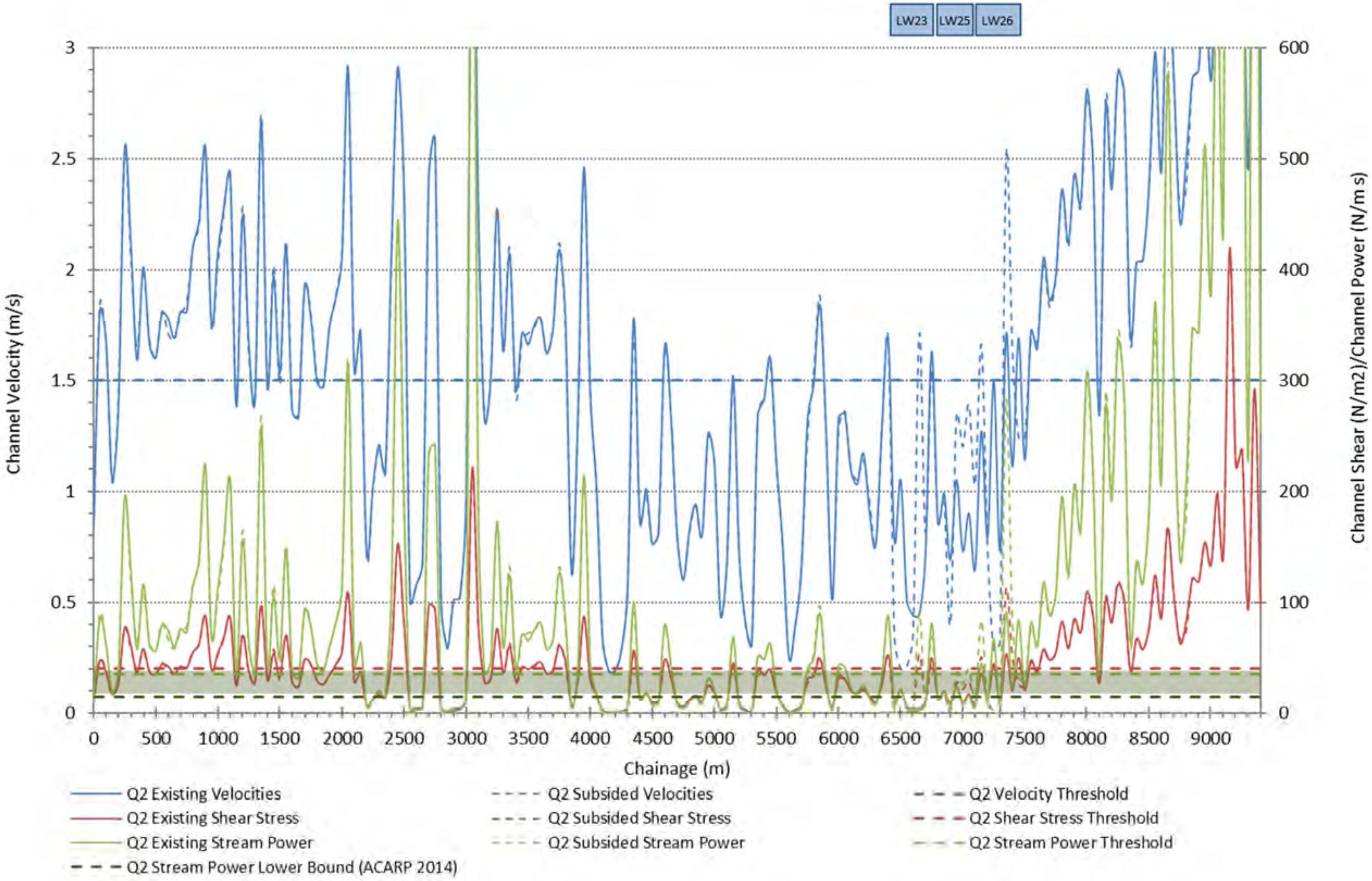

Figure 3-12. *Existing and Post Subsidence Hydraulic Conditions for 0.5EY Event (1 in 2 AEP)*

Western Tributaries

The flow paths from the range to the west into North Wambo Creek are also likely to undergo change following subsidence of the approved/modified LW 21 to LW 23 (noting that the Modification would not change LW 21 to LW 23). This is due to the geometry of these flow paths relative to magnitude of subsidence.

The predicted changes in flow paths are presented in Figure 3-13. The streamlines shown are those predicted by the software CatchmentSIM using the existing and predicted subsidence digital terrain models (DTM). It is important to note that the predicted flow path changes are completely reliant on the accuracy of the DTM and subsidence predictions, particularly as changes in flow paths occur with relatively small changes in elevation.

The existing streamlines are shown as light blue dashed lines with the predicted post subsidence streamlines shown as solid red sitting underneath them. Hence where a blue dashed streamline is shown on the map with no underlying red, that section of stream is abandoned post subsidence.

Over LW 21 the major change for the existing streamlines following subsidence would occur towards the centre of the panel where the predicted subsidence depths are greatest. The flow path is predicted to shift slightly further to the east, directing more flow paths within LW 21 instead of flowing to LW 22. This would result in some slight shortening of this tributary which would increase the grade and therefore lead to possible instabilities.

The main tributary flowing down LW 22 previously converged with the smaller tributaries from LW 23 over what would become the LW 22/LW 23 pillar zone. The predicted flow path for this tributary is now down the centre of LW 22 before again converging with the LW 23 tributaries further downstream.

Following subsidence, LW 23 would now capture one of the main southern tributaries that currently flows north over the approved LW 22 and LW23 to the approved location of LW24. Previously this tributary would have flowed north before flowing east, back across LW 23 and into the NWCD. Following subsidence, the flow path of this tributary, along with another main tributary would shift towards the centre of LW 23 and flow down the panel to the north east. The results of the hydraulic modelling have shown that at the northern extent of the panel ponding occurs on North Wambo Creek. Once the ponded area fills it would overflow into North Wambo Creek to the east as the elevation of the pillar zone would be higher than the right bank of North Wambo Creek following subsidence. This area should be monitored as the new flow entry point would potentially lead to erosion (headcut) where it enters North Wambo Creek.

The modified location of LW 24 would result in a reduction in the number of the minor tributaries that would be subsided by the South Bates Extension Underground Mine. Overall, there is less subsidence of this group of tributaries compared to the approved case.

Northern Tributaries

Similar subsidence behaviour to LW 23 would occur on North Wambo Creek where it intersects with LW 25 and LW 26 and the northern tributaries.

The predicted changes in flow paths are presented in Figure 3-13. The steepness of the northern tributaries means that the subsidence in LW 24 to LW 26 would not result in significant changes to the flow paths. Where these flow paths meet North Wambo Creek, there would be some migration to parallel flow paths typically within 50m of the baseline.

Similar to LW 23, LW 25 and LW 26 retain some storm volume within the subsided panel within North Wambo Creek just upstream of the pillars. These pillar locations should be monitored as they may lead to increased erosion of the pillars within North Wambo Creek.

This assessment does not include an evaluation of whether or not seepage into the sands that are dominant in the sediments allow for seepage to reduce the occurrence of overtopping from these subsidence troughs.

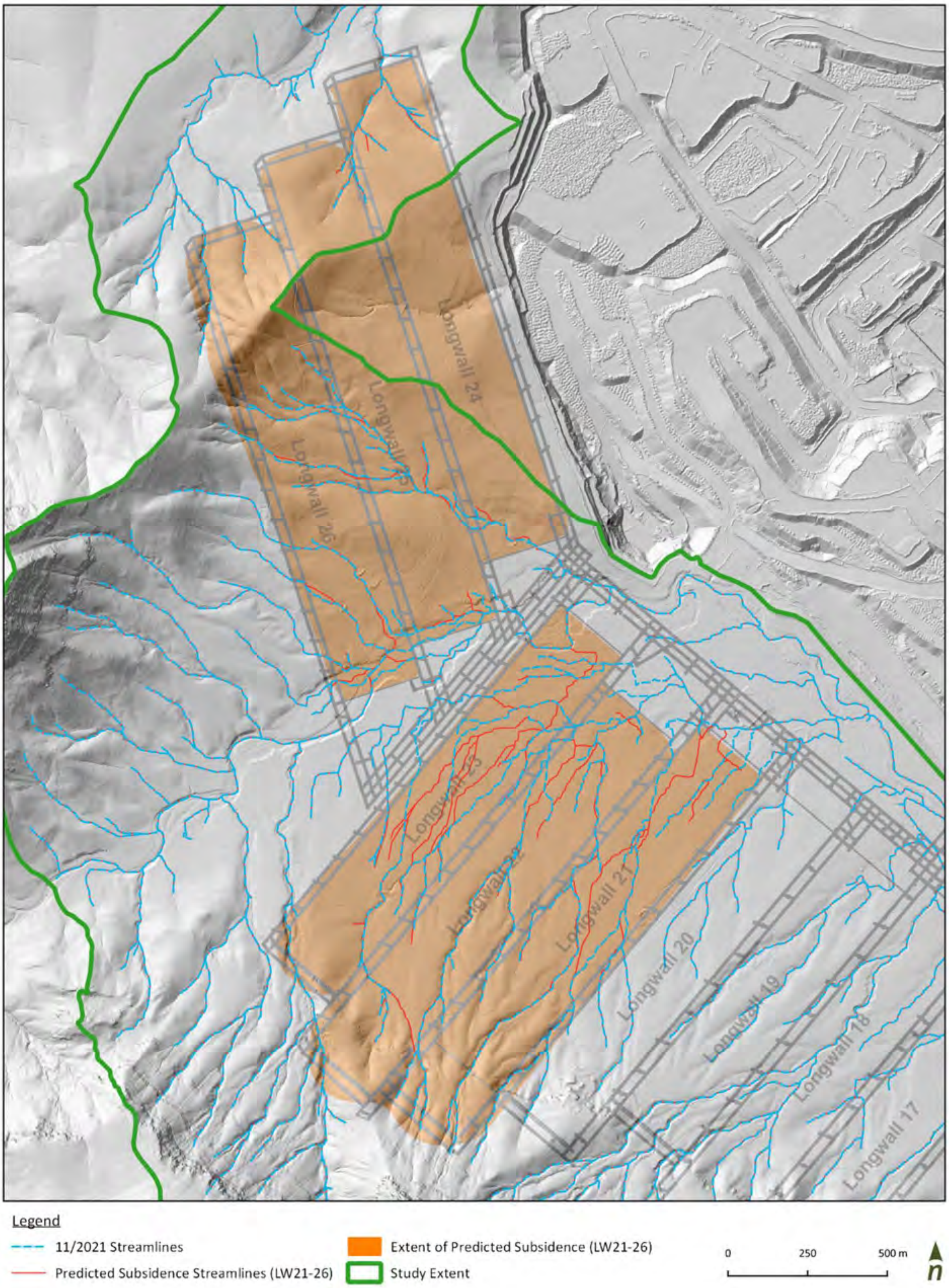

Figure 3-13. *Pre and Post Subsidence Flow Paths for Western and Northern Tributaries*

The northern tributaries would not have been subsided under the approved South Bates Extension Underground Mine, the Modification would therefore increase the length of minor tributaries subsided. The Modification would reduce the potential for channel bed incision to migrate into these tributaries from North Wambo Creek in comparison to the approved South Bates Extension Underground Mine.

Waterfall Creek
The impact of subsidence of the flow paths in the Waterfall Creek catchment would be minor with only small changes in alignment, typically less than 10m, towards the centre of the panel. The small impacts would be primarily due to the relatively smaller extent of the panels within the catchment and due to their position in the steeper upper catchment. This is an increase over the approved South Bates Extension Underground Mine, as no subsidence of these flow paths occurred in that case.

3.3 3rd Order – Predicted Impacts to Water Quantity and Quality

Changes to Water Quantity
The impact of subsidence on flow rate and storage in the western tributaries was assessed using 2D hydraulic modelling. Using the existing (November 2021) and post subsided topographic surfaces, the 2D model was used to determine how the subsidence from the modified LW 21 to LW 26 would impact on the stream and surface water flow passing through the site. The models were run longer than the duration of the storm events to determine the volume of water remaining ponded across the site.

The hydrology used in this project in North Wambo Creek built on the RORB hydrologic model developed to assess LW 21 to LW 24 which was updated to meet the recent update to the 2019 Australian Rainfall and Runoff (ARR 2019).

Previous version of the hydrologic model built for this site in 2016, utilised 25mm as the initial loss. Subsequent work in 2018 revised this with a higher loss of 65.9mm based on advice from 2017 and 2018 site visits. Following the 2016 ARR update the modelling for this report utilised the Australian Rainfall and Runoff Datahub's initial loss value of 50mm and a continuing loss of 3.4. The continuing loss value was multiplied by a factor of 0.4 down to 1.36mm/h on advice provided by the ARR Data Hub. This advice suggested that flows estimated using the data hub losses were underpredicting design flows in NSW. Table 3-6 shows the effect of these changes on the peak design flows across the four storm events.

Table 3-6. RORB Peak Design Flows: 2016 estimates, 2018 estimates and 2022 estimates

	2016 estimates	2018 estimates	2022 estimates
Upstream catchment (km^2)	34	34	34
Event	Peak Discharge (m^3/s)	Peak Discharge (m^3/s)	Peak Discharge (m^3/s)
0.5EY	43	10.5	21.6
2% AEP	154	57.6	102.3
1% AEP	180	75.4	119.6
0.1% AEP	324	93	225.8

Subsidence of the modified LW 21 to LW 26 would increase in-channel storage by more than 16 times when compared to existing conditions (Table 3-7). However, these volumes of residual ponding are far less than the approved South Bates Extension Underground Mine as LW 24 does not run parallel with and subside a substantial length of North Wambo Creek in the Modification.

Table 3-7. Residual Ponding Volume Estimates North Wambo Creek and Waterfall Creek (2% AEP)

Longwall	Existing (m^3)	Subsided (m^3)	Difference (m^3)
21	75.0	368.7	293.7
22	16.9	3,098.3	3,081.4
23	419.0	4,793.6	4,374.6
24	40.2	503.3	482.82
25	12.4	1,194.3	1,181.9
26	319.5	4,584.2	4,264.7
TOTAL	883.0	14,542.5	13,659.4

As well as increasing in-channel storage, the subsidence of the modified LW 21 to LW 26 would result in ponding of water at the lower ends of the panels. The predicted ponding following subsidence is depicted in greater detail in Figure 3-14 and Figure 3-15, for the 2% AEP. It should be noted that the ponding due to subsidence occurs almost completely in North Wambo Creek. In Waterfall Creek no ponding is shown in the existing case and a ponding volume of 20 cubic metres (m^3) in the subsided case in the 2% AEP.

While the impact to the amount of ponding is significant, these volumes are smaller in terms of the overall runoff volumes estimated in North Wambo Creek. Table 3-8 shows the largest change in volume is a reduction of 0.5EY event. The impact on volume decreases as the magnitude of the total design storm volume increases relative to the storage capacity of the subsided terrain.

Table 3-8. Predicted volume changes to North Wambo Creek stream flow post subsidence

Event	Existing (m^3)	Subsided (m^3) after LW21-24	Difference (%)
0.5EY	667,041	645,952	-3.2%
2% AEP	1,214,274	1,199,797	-1.2%
1% AEP	1,167,799	1,153,807	-1.2%
0.1% AEP	3,248,209	3,233,816	-0.4%

Subsidence impacts on water quantity on Waterfall Creek were smaller again due to there being very little additional storage created by the subsidence in LW 24 to LW 26. Table 3-9 shows the overall impact on volumes.

Table 3-9. Predicted volume changes to Waterfall Creek stream flow post subsidence

Event	Existing (m^3)	Subsided (m^3) after LW21-24	Difference (%)
0.5EY	19,510	19,444	-0.3%
2% AEP	31,841	31,754	-0.3%
1% AEP	35,144	35,075	-0.2%
0.1% AEP	51,833	51,756	-0.1%

The impacts of the subsidence on the design event hydrographs through North Wambo Creek are shown in Figure 3-16 to Figure 3-19. Figure 3-20 shows the volume impacts in the 2% AEP event.

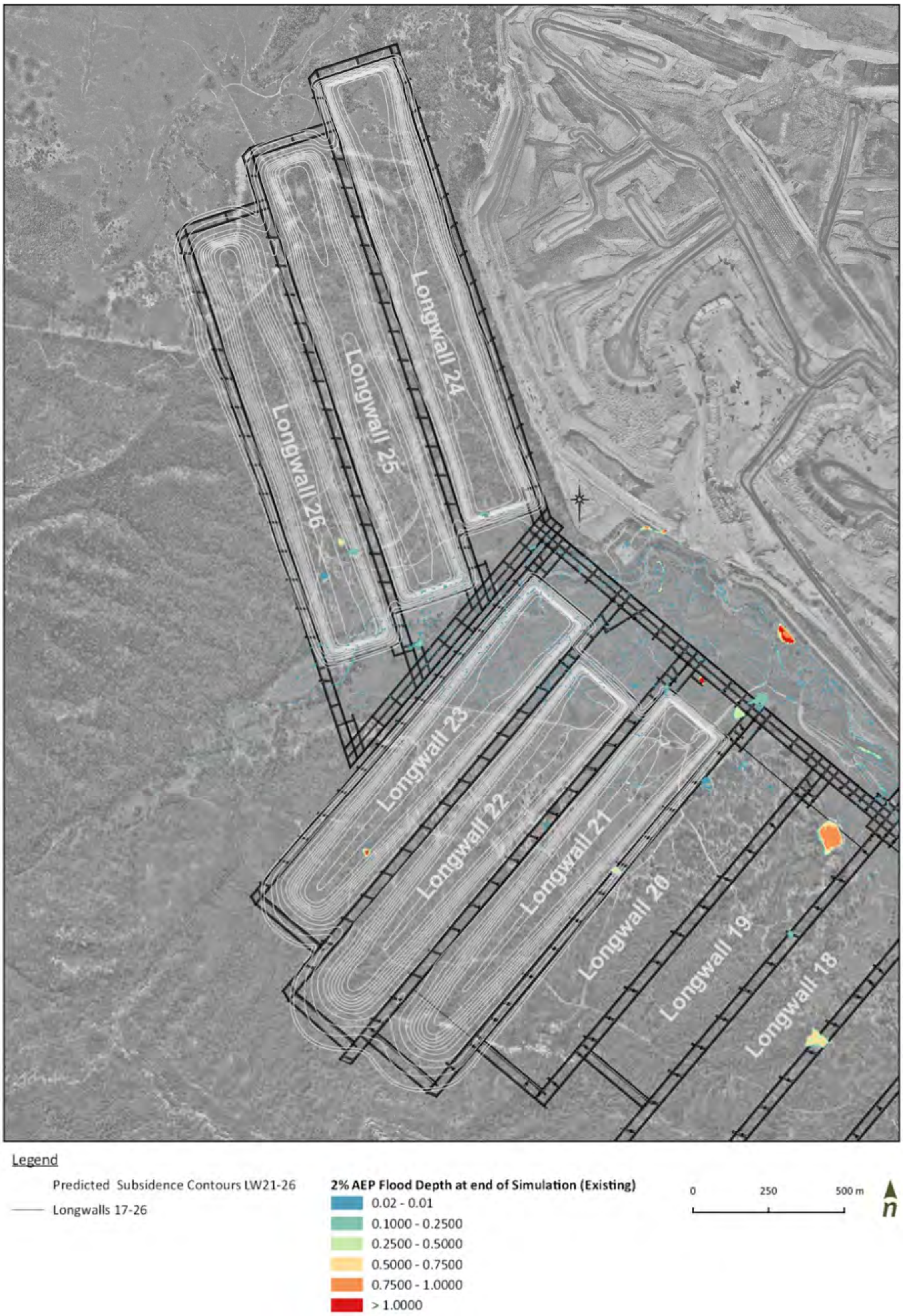

Figure 3-14. *2% AEP Residual Ponding – Existing Conditions*

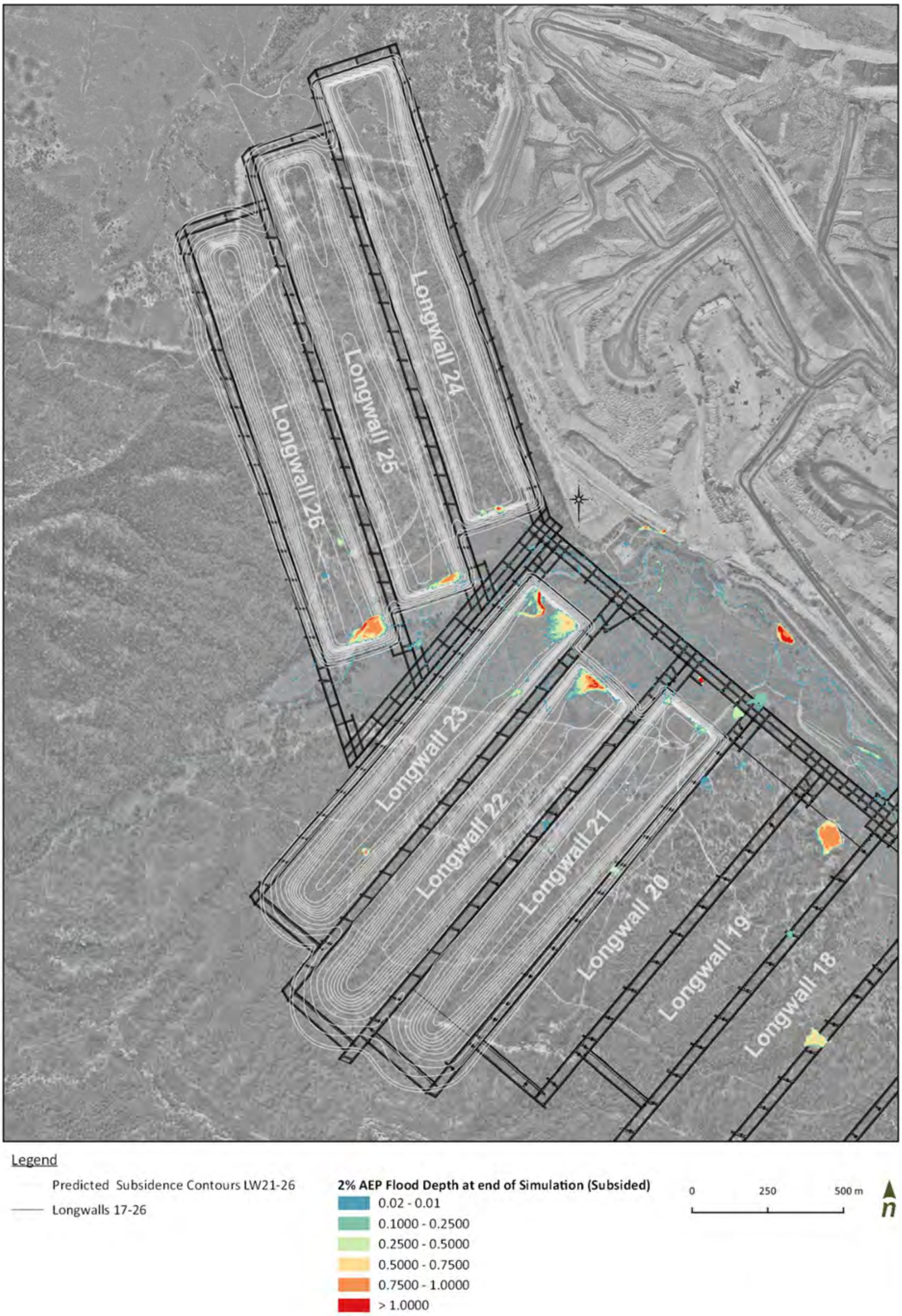

Figure 3-15. *2% AEP Residual Ponding – Subsided Conditions*

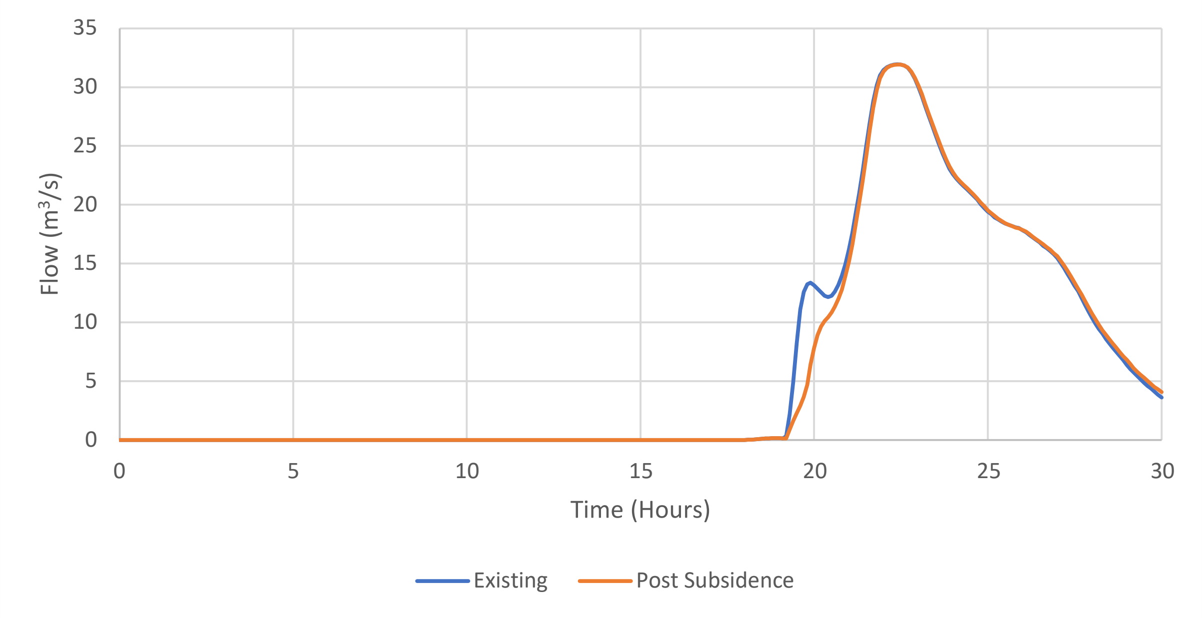

Figure 3-16. *North Wambo Creek Hydrograph at FM2 - Pre and Post Subsidence (0.5EY Event)*

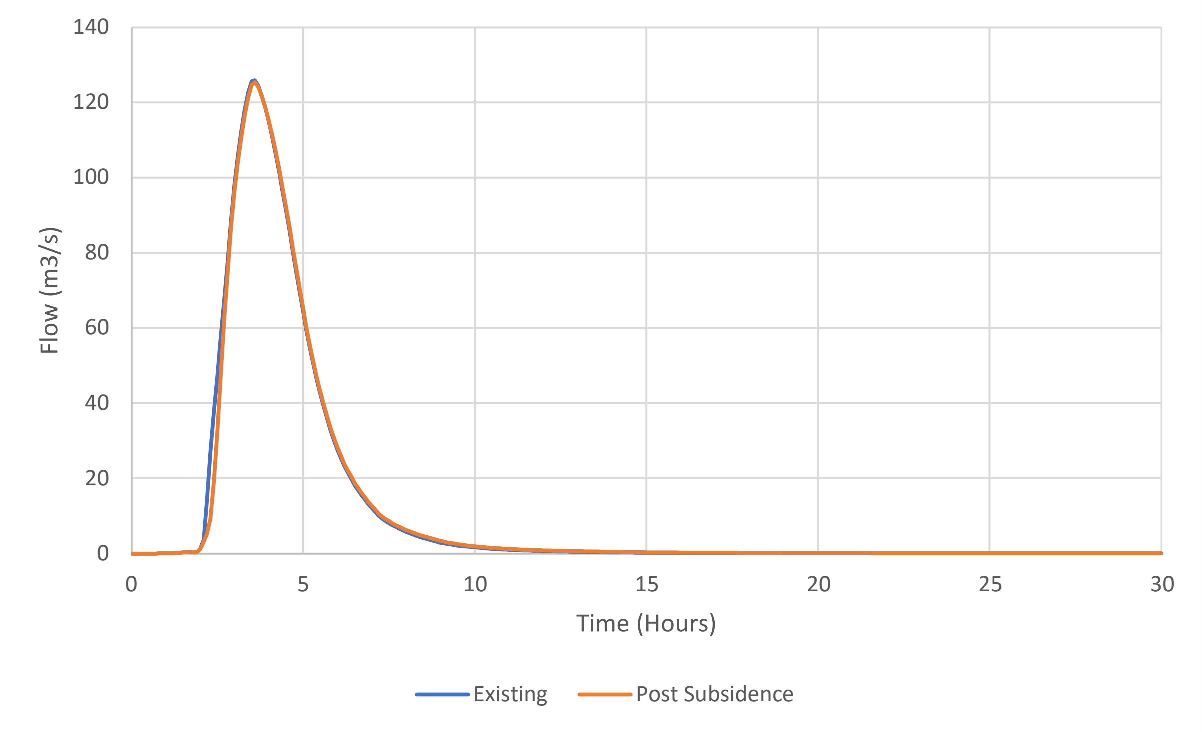

Figure 3-17. *North Wambo Creek Hydrograph at FM2 - Pre and post Subsidence (2% AEP Event)*

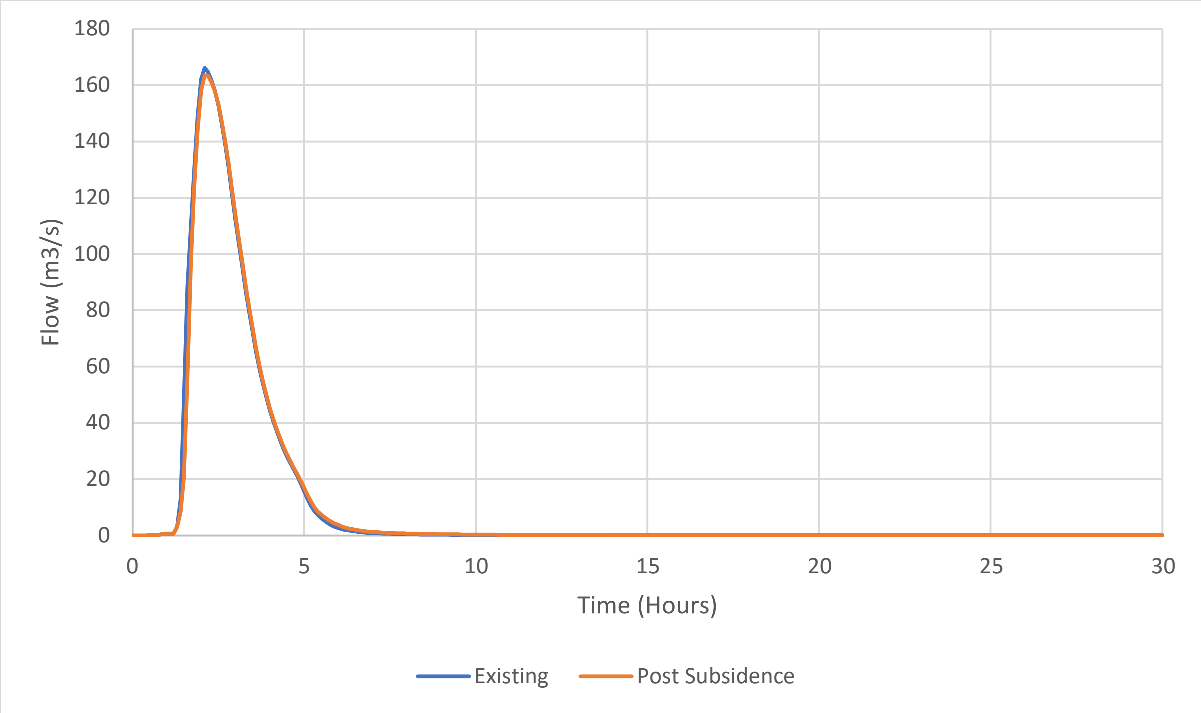

Figure 3-18. *North Wambo Creek Hydrograph at FM2 - Pre and Post Subsidence (1% AEP Event)*

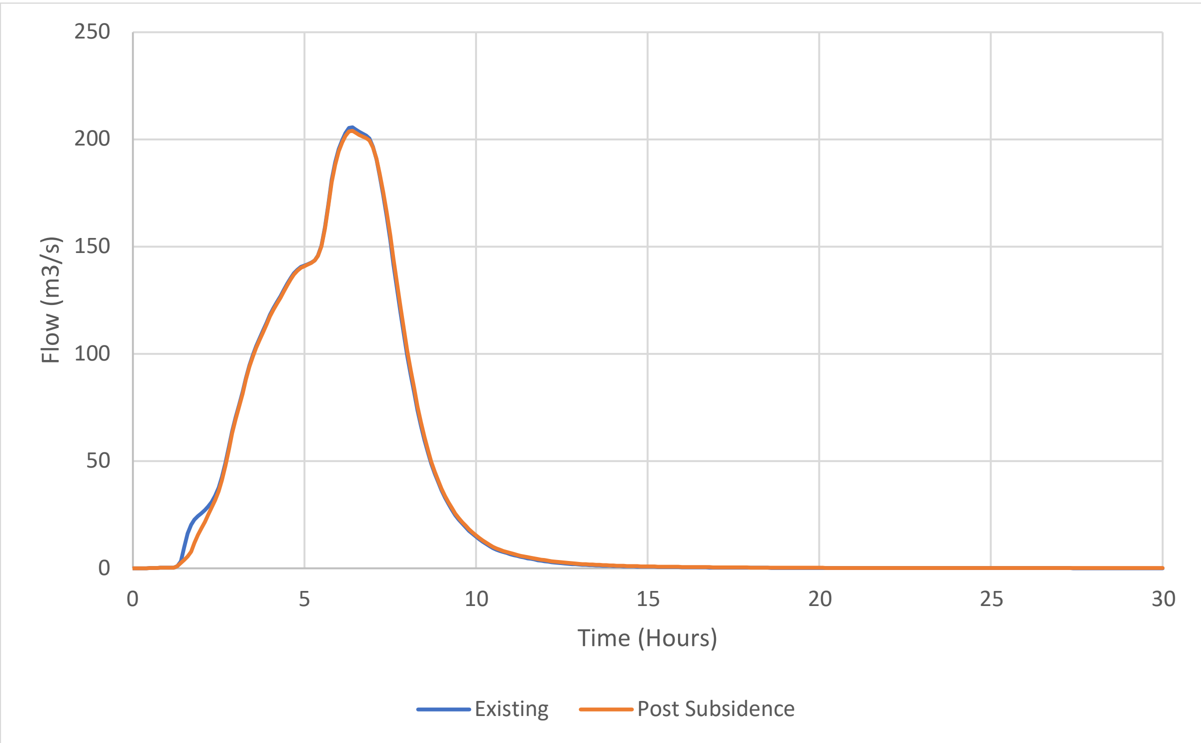

Figure 3-19. *North Wambo Creek Hydrograph at FM2 - Pre and Post Subsidence (0.1% AEP Event)*

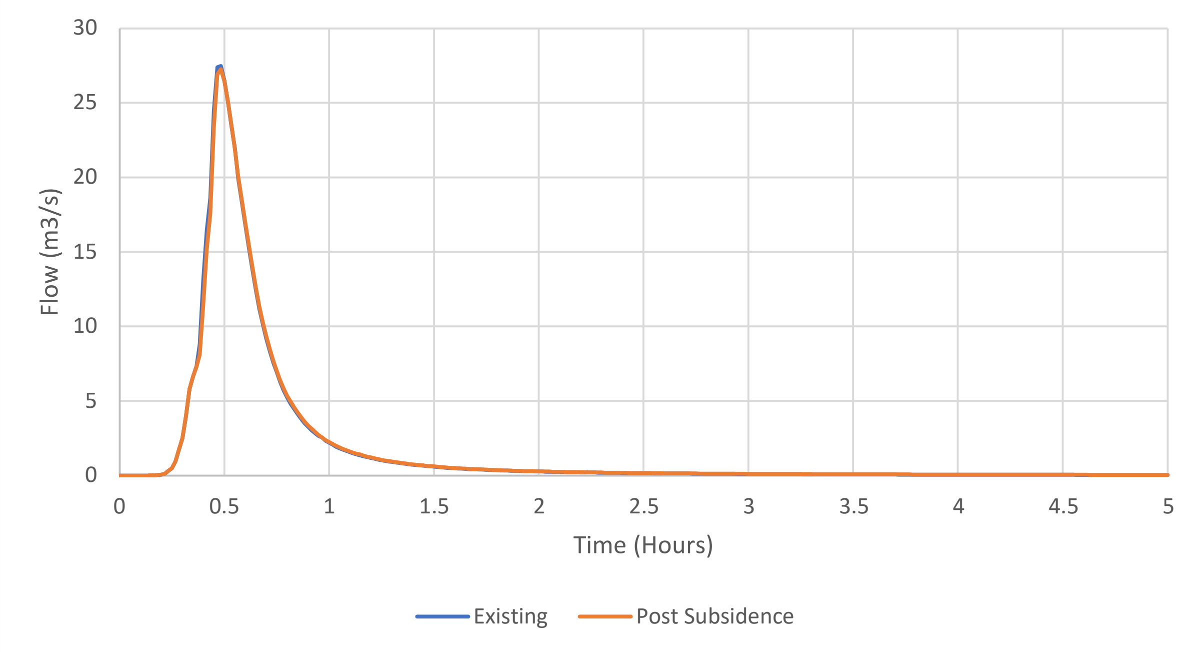

Figure 3-20. *Waterfall Creek Hydrograph at Downstream of Model Extent - Pre and Post Subsidence (2% AEP Event)*

It should be noted that this assessment has only considered the topographical impacts resulting from subsidence and has not assessed the potential for losses to the alluvial aquifer, losses to the underground workings or changes to topography by erosion/deposition or management intervention. It is likely that such losses would increase with ponding in these areas unless fine sediment decreases the hydraulic conductivity of the base of the pools or there is management intervention. As the Modification would however reduce ponding in North Wambo Creek and the NWCD relative to the approved South Bates Extension Underground Mine plan, the Modification would reduce these losses relative to the approved South Bates Extension Underground Mine plan.

The Modification is not expected to result in additional flow impacts in the Wollombi Brook and or the Hunter River. Given residual ponding volumes will be less in North Wambo Creek, flow impacts to Wollombi Brook and the Hunter River would be less.

Changes to Water Quality

An increase in suspended sediments in Waterfall Creek and North Wambo Creek and the NWCD is possible from increased erosion. The suspended sediments in North Wambo Creek and the NWCD would however be less than the approved South Bates Extension Underground Mine plan. Management measures can be put in place to mitigate the risk.

Due to a predicted decrease in flows (water quantity) through Waterfall Creek, North Wambo Creek and NWCD, it is possible that any negative impacts to water quality would be exacerbated as there would be less dilution occurring. However, reduced flows also mean reduced potential to transport sediments downstream of site, hence potential for offsite impacts to water quality is low. Once again, the Modification would however reduce these impacts in North Wambo Creek and the NWCD relative to the approved South Bates Extension Underground Mine plan.

The Modification is not expected to result in additional water quality impacts in the Wollombi Brook and or the Hunter River. Due to the change in LW24 orientation, potential for erosion in several locations is less, hence potential for water quality impacts should be less.

3.4 4th Order – Predicted Impacts to Flora and Fauna

The consequences for ecology associated with impacts described above should be considered by WCPL's ecology specialists. The changes in behaviour of water in the landscape due to subsidence provide potential for both positive and negative impacts, depending on current ecological conditions and the extent of change. The primary change of note is alteration of flow paths in the western tributaries may alter the species composition along the zones that currently receive flows and similarly for those areas that would receive flows post subsidence. There is also the possibility of pools forming over LW 21 to LW 26 which may provide ecological habitat for some flora and fauna yet impact negatively on others.

In comparison to the approved South Bates Extension Underground Mine plan, ephemeral ponded area would decrease, resulting in less change from existing condition and less potential for wetland area establishment over the LW 24 to LW 26 footprint. Conversely, with reduced potential for seepage loss via the alluvial aquifer to the backfilled open cut, more surface water would be available in NWCD and downstream, maintaining ecological function in those reaches.

4 Subsidence Management

Subsidence management involves monitoring the impacts of subsidence to identify issues or the need for mitigation activities. Monitoring involves establishing baseline data against which future monitoring can be compared. Monitoring of waterways intersected by the panels extends upstream and downstream of the mine footprint to determine if observed changes are the result of subsidence or other factors. The monitoring program implemented at the Wambo Coal Mine is described below.

4.1 Existing Surface Water Monitoring Program

Surface water-related monitoring at the Wambo Coal Mine is conducted in accordance with the Water Management Plan prepared as part of a component of the Extraction Plan in accordance with Condition B7, Schedule 2 of Development Consent (DA 305-7-2003).

The monitoring program is a combined approach to diversion and subsidence impacts on North Wambo Creek. This includes:

- Index of Diversion Condition (including establishment of reaches and monitoring points) collected in the first round of operational monitoring
- Assessment of performance against risks identified in the Extraction Plan by expert fluvial geomorphic assessment
- Aerial photography analysis of changes relative to subsidence in the monitoring period
- Vegetation of geomorphic features in the monitoring area (referencing previous LFA monitoring)
- Analysis of flow event information for frequency and duration
- Analysis of long and cross-section survey for future comparison
- Summary of baseline condition and recommendations for mitigation of risks

A series of upstream, diversion and downstream monitoring transects were completed for North Wambo Creek and NWCD. The current monitoring sites for subsidence are shown in Figure 4-1.

The Index of Diversion Condition provides a rapid assessment of the diversion and adjoining reaches of interest along the watercourse(s) and is designed to flag potential management issues rather than provide a detailed scientific assessment of the waterway. It is an integrated suite of indicators that measures the geomorphic and riparian condition of a diversion (Geomorphic Index and Riparian Index, respectively) and its upstream and downstream reaches. Observations are recorded at monitoring points, spaced at regular intervals, within each reach to determine an average score for the reach. To provide a consistent approach at each monitoring point, observations are recorded within a limited area known as a transect. IDC monitoring locations are established in WCPL's Surface Water Monitoring Program.

For details on the most recent round of monitoring at Wambo refer *North Wambo Creek Diversion Operations Monitoring 2021* (Alluvium, 2022).

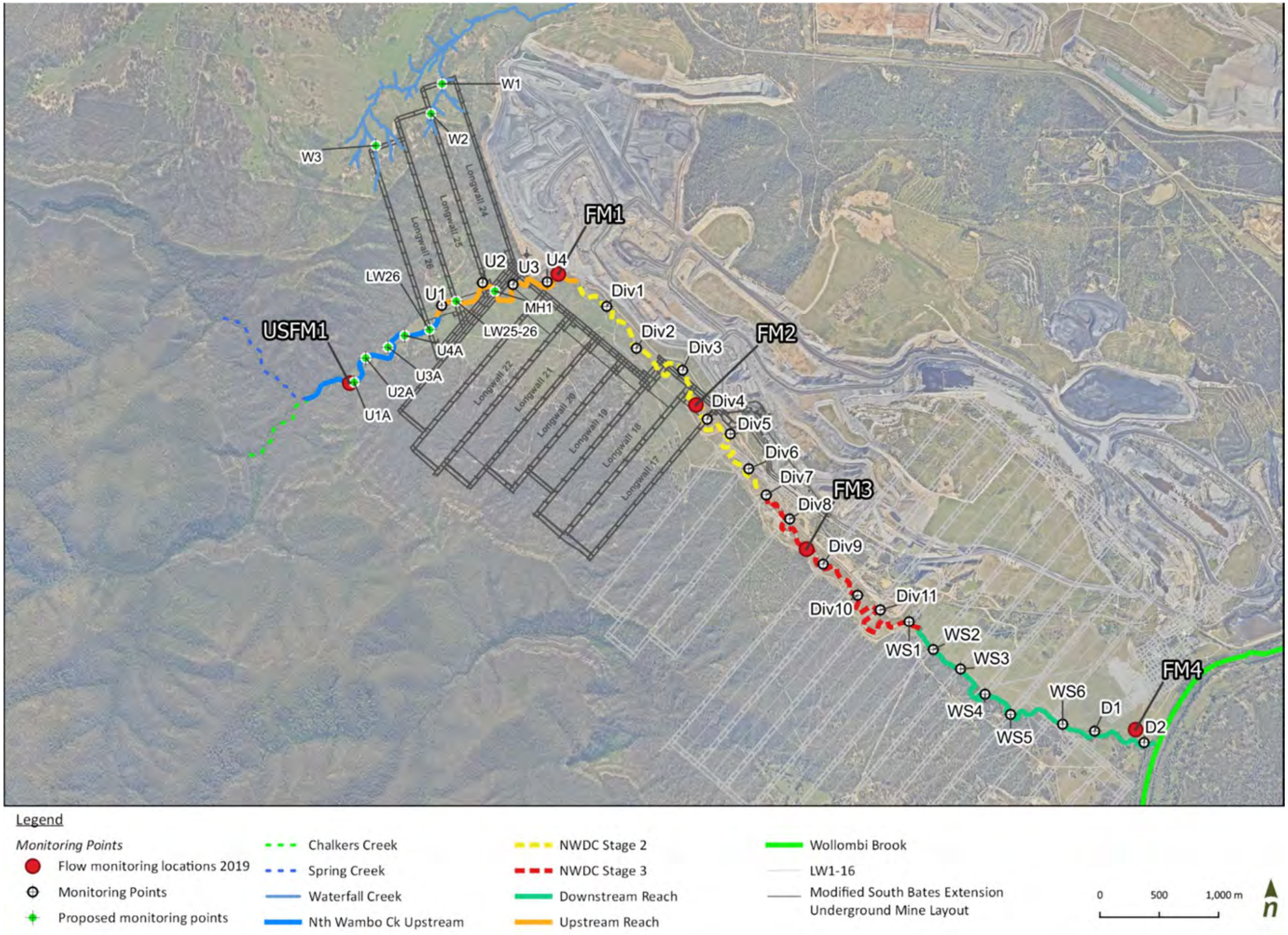

Figure 4-1. *Monitoring Locations for NWCD and Subsidence Monitoring Program including Proposed Monitoring Points*

Proposed amendment to monitoring

The proposed amendment would involve establishment of monitoring points where North Wambo Creek crosses pillars and the main headings arrangement for LW 24 to LW 26 (sites LW 26, LW 25 to LW 26 and MH1) and the addition of four new monitoring points upstream of the modified mine footprint (U1A to U4A) to have a monitoring reach comprised of points that are not directly impacted by mining activity (as shown on Figure 4-1).The existing upstream reach monitoring points U1 to U4 in place since 2017 should continue to be used as photo points to enable assessment of condition trajectory at those locations within the new LW 24 to LW 26 panels and immediately downstream.

New monitoring points are also proposed where headwater tributaries of Waterfall Creek cross the boundaries of longwall panels (W1 to W3) to monitor change at the major gradient change on these tributaries.

4.2 Recommendations for Mitigation Works

The zone where works are recommended for North Wambo Creek and the western tributaries associated with the subsidence of modified LW 21 to LW 26 are shown on Figure 4-3. Based on the predicted subsidence and landscape response, a number of mitigation measures are proposed. These measures are indicative only and purely relate to potential geomorphic response associated with surface water flows. Any mitigation works would need to be coordinated with any works associated with alluvial groundwater management that may be proposed as part of meeting rehabilitation targets for NWCD and North Wambo Creek through to its confluence with Wollombi Brook.

It is important to note that all the mitigation works mentioned are based on predicted subsidence modelling and final mitigation works would be dependent on actual subsidence.

North Wambo Creek

Instabilities are likely to develop at the drop into LW 24 (and upstream), the LW 23 to LW 24 pillar and potential bedload sediment starvation downstream of LW 23 in response to stream flows. Based on stream flow gauging over the last decade, the magnitude of stream flows being gauged are less than the 0.5EY design flow estimated through the 2016 ARR. This may be simply related to an extended dry period, technical issues associated with gauging or changes in alluvial aquifer saturation associated with losses to the open cut. North Wambo Creek currently exhibits limited fluvial activity in channel bed forms over LW 23 to LW 26. The combination of these observations may mean that the potential for instabilities is limited, however the observation period on stream flows is too short to draw that conclusion and we note the wet period through 2020 to early 2022 has generated more stream flow than observed 2015-2020.

On the assumption that stream flows of sufficient magnitude would occur, indicative mitigation measures for the predicted geomorphic responses would involve a combination of vegetation management and channel stabilisation through measures such as timber pile field alignment training, armouring and/or channel reconfiguration.

Due to the revised arrangement of LW 24 to 26, the subsidence is predicted to create online ponded storages within LW 25 and LW 26. Flows out of these ponded areas may increase the likelihood of erosion of the LW 24 to 25 pillar as shown in Figure 4-2.

Western Tributaries

It is recommended that the western tributaries be monitored as subsidence occurs. Comparison of modelled streamlines for existing and post subsidence conditions (Figure 3-13) indicate that the length of some of the western tributaries could decrease which could initiate incision that would propagate upstream as headcuts.

Erosion mitigation measures such as revegetation in combination with channel realignment (to increase length and reduce grade) or structural bed works such as rock chutes may be required.

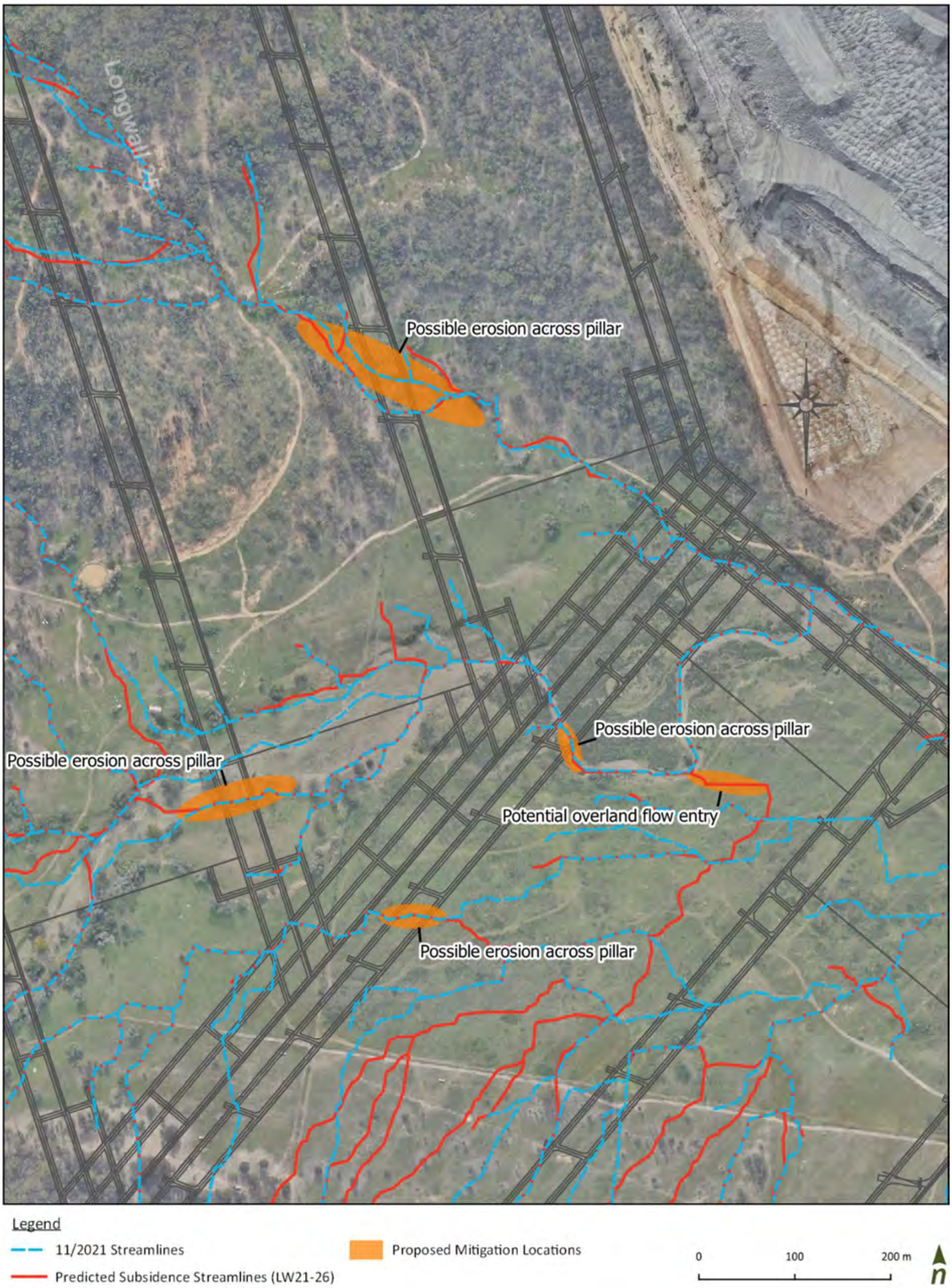

Figure 4-2. *North Wambo Creek - Location where mitigation measures are likely required following subsidence*

The modelling indicates that the overland flow entry location of at least one of the western tributaries would now be further upstream within North Wambo Creek over LW 23 rather than downstream in the NWCD (Figure 3-13). Some form of mitigation measure would be required to manage this new overland flow entry point in order to prevent a headcut forming at this location. Mitigation measures would depend on the actual location and severity of the erosion and could range from revegetation to channel realignment and lengthening or the construction of a rock chute.

Northern Tributaries

It is recommended that the northern tributaries to North Wambo Creek be monitored as subsidence occurs. Within LW 26 the post subsidence flow paths show some lengthening of the primary gully before entering North Wambo Creek. The post subsidence flow paths also show that between LW 25 and LW 26 there are no significant changed in alignment of the gullies.

Waterfall Creek

Comparison of the modelled streamlines shows that large changes are not anticipated due to the predicted subsidence in LW 24 to LW 26. Given the lack of historic observations, however, it is recommended that the Waterfall Creek tributaries be monitored as subsidence occurs.

While there are no significant changes in the gullies upstream of Waterfall Creek some mitigation measures may be required where gullies cross pillars as shown in Figure 4-3. Where needed the mitigation measures may involve a combination of vegetation management and channel stabilisation through measures such as timber pile field alignment training, armouring and/or channel reconfiguration.

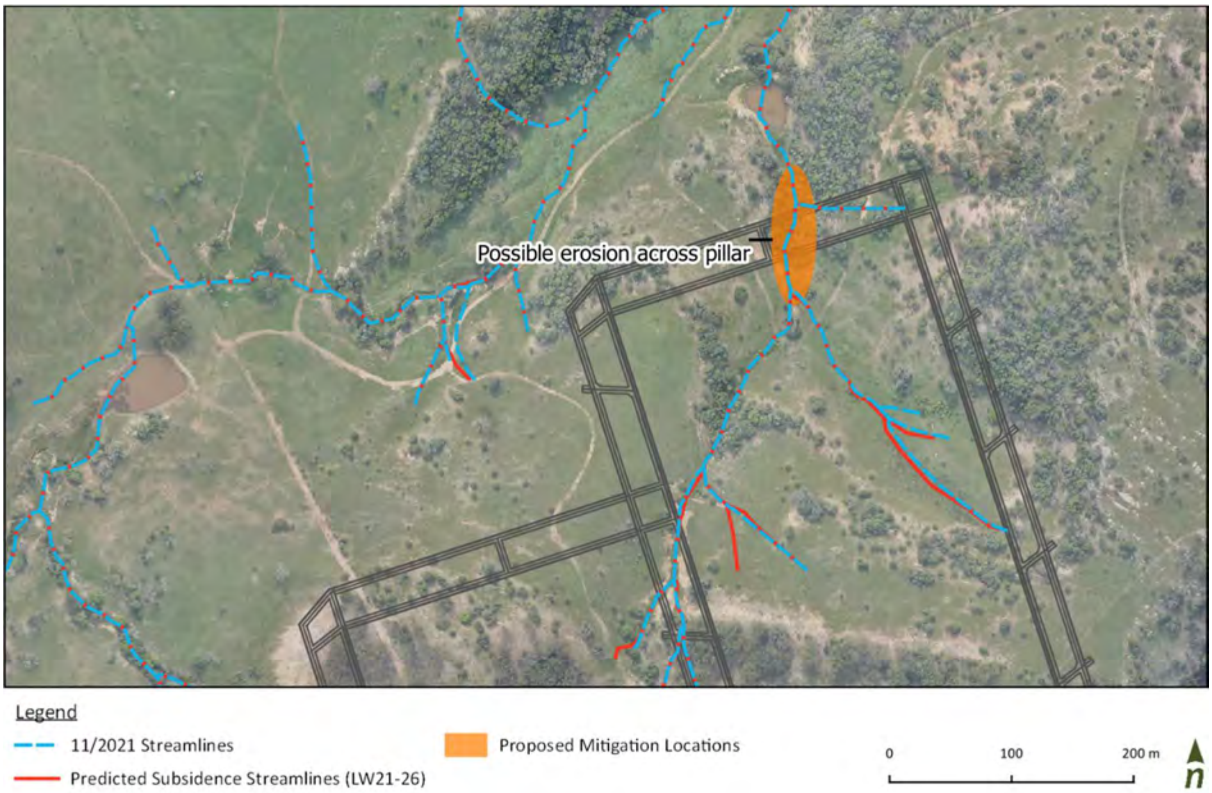

Figure 4-3. *Waterfall Creek - Location where mitigation measures may be required following subsidence*

5 Conclusion

The Modification would result in a substantial reduction in the length and hence volume of subsidence pool created in North Wambo Creek. This would result in less potential for loss of surface water to the alluvial aquifer and potentially into the open cut backfill which in turn means a greater proportion of flows reporting to the NWCD and downstream. The potential for localised instability remains where North Wambo Creek and other minor flow path tributaries experience steepening of channel bed grade into subsided terrain. These can be managed with established successful techniques including targeted vegetation establishment, rock grade control chutes or similar.

The subsidence troughs would capture all bedload input into the section intersected by LW 24 to LW 26 for a period of time, however given observed hydrology and geomorphology of the system, where limited bedload transport occurs, this would result in negligible change to current sediment transport processes.

Some headwaters of Waterfall Creek would be subject to subsidence under the Modification where localised steepening of channel bed gradients would potentially need to be managed with established successful grade control techniques.

Additional monitoring locations are proposed on North Wambo Creek on pillar and main headings intercepts, a known point of potential instability. A new upstream monitoring reach (4 monitoring points) should be established upstream of any mining footprint and the existing upstream monitoring points for North Wambo Creek diversion should be continued as part of monitoring potential impacts across LW 24 to LW 26 and through to the NWCD.

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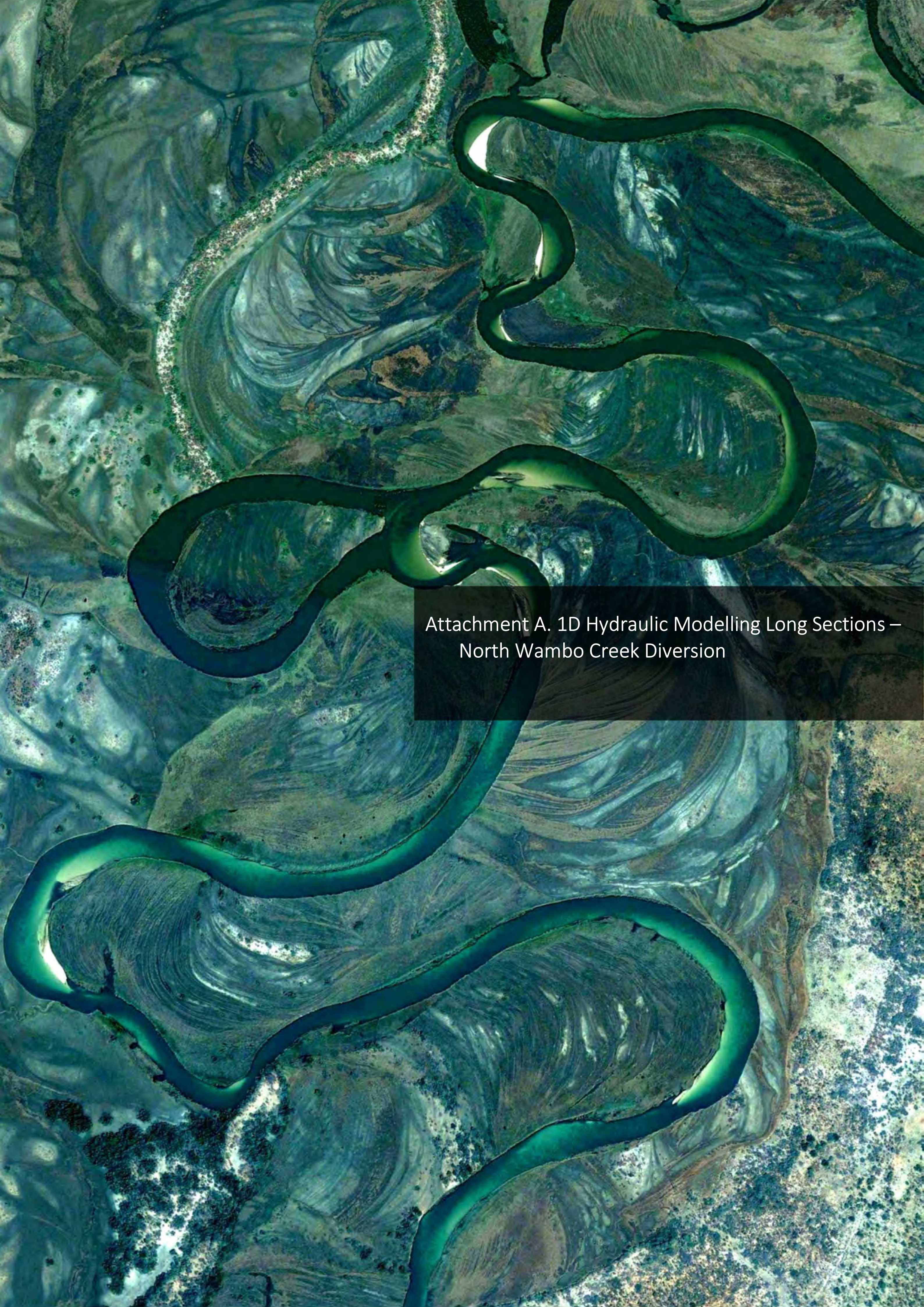

Attachment A. 1D Hydraulic Modelling Long Sections – North Wambo Creek Diversion

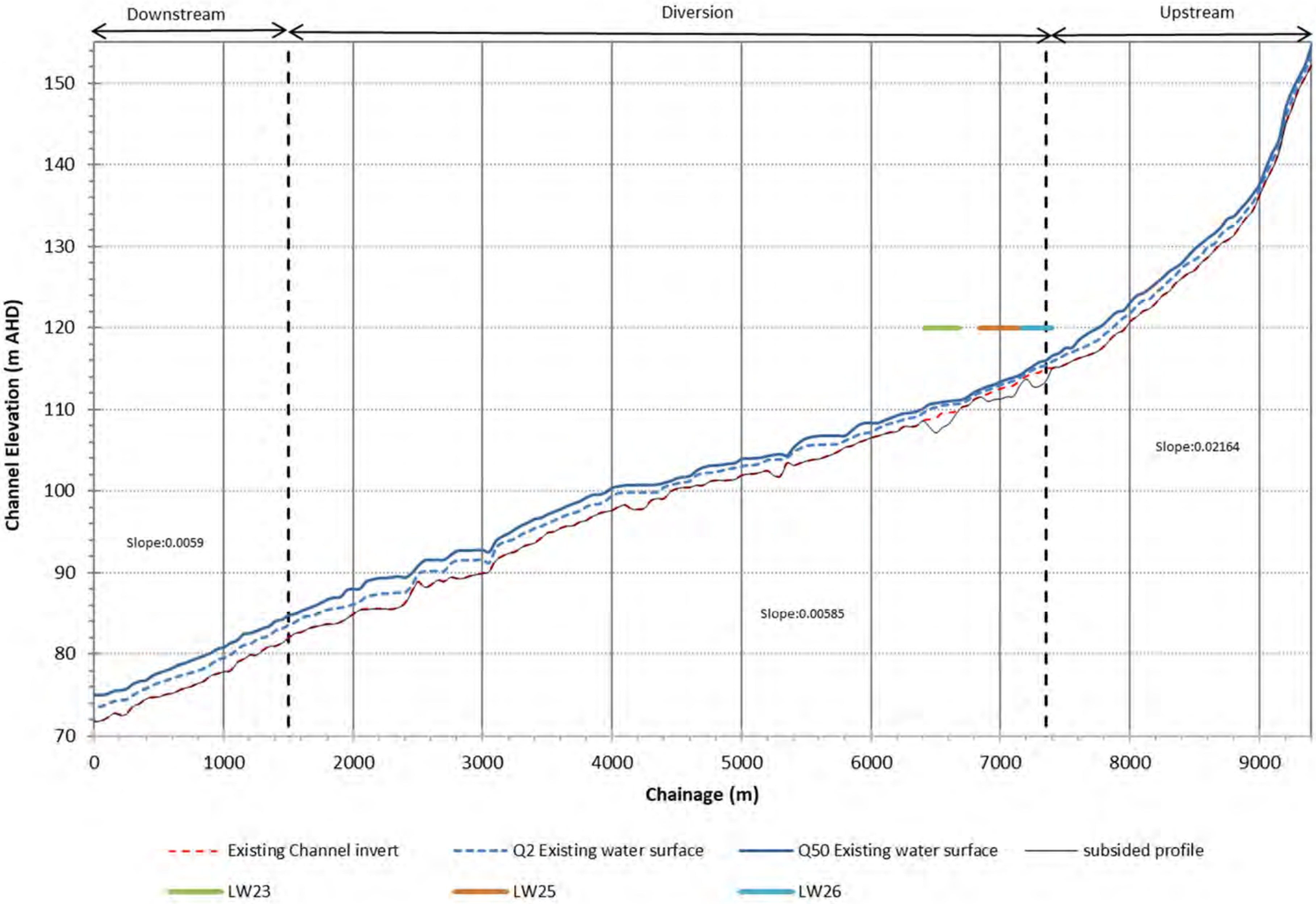

Figure A 1. North Wambo Creek – Pre and Post Subsidence bed levels and water surface elevations – 0.5EY and 2% AEP Events

Attachment B. Hydrologic Modelling Updates

1 Hydrologic Modelling of the Modified South Bates Extension Underground Mine

Hydrologic modelling was undertaken to develop inflow for the hydraulic models developed for North Wambo Creek and Waterfall Creek. The hydraulic models were developed to assess the changes in flood behaviour in the area impacted by the planned longwall mining panels (LWs 21-26) at the Wambo Coal Mine. This includes the rearrangement of LW24-26 from their previously approved locations. The catchment, as defined for the study, covers an area of approximately 39.5km^2 and is shown in Figure B**1-1**

For North Wambo Creek, the hydrologic model used in this study is a RORB model and is based on the RORB model developed for the previous assessment of the South Bates Extension[1]. The hydrologic model has not been directly calibrated as no reliable long-term flow data was available on North Wambo Creek (short term data records have been used to further develop understanding of losses). Hydrologic outputs for the catchment have been derived at locations to facilitate the hydraulic modelling of existing mining operations.

In Waterfall Creek a direct rainfall approach has been adopted across the whole catchment area. The process of deriving IFDs has been described in this report but the application of the rainfall to the hydraulic model is covered in Attachment C discussing the hydraulic modelling.

For this study flow estimates have been generated for the 0.5EY, 2% AEP, 1% AEP and 0.1% AEP events.

1.1 RORB Model Description

The hydrologic modelling software used in this study is RORBWin version 6.45, a Windows version of the industry accepted RORB program (Laurenson et al 2007).

A RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing the runoff through the catchment system, combining flows at channel junctions; and
- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of stream flow, and the slow response or base flow component has not been included in the model.

Setting up the model comprises:

- Determining the catchment boundary and dividing the catchment into sub-catchments;
- Calculating the area of each sub-catchment;
- Placing model nodes at sub-catchment inflows and junctions;
- Placing reach storages between nodes; and

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[1] Alluvium, (2020) *Surface Water Technical Report for South Bates Extension Underground Mine (Longwalls 21- 24)*

- Measuring the length of reach between adjacent nodes.

The RORB model requires four parameters to be specified which include k_c, m, initial loss (IL) and continuing loss (CL). The k_c and m parameters are factors in the storage discharge relationship.

The storage discharge relationship for the reach storages in the model has the general form:

$$S = 3600k\,Q^m$$

Where:

S is the volume of water in storage (m^3);
k is related to travel time of a particular reach and the characteristics of the whole catchment;
Q is outflow rate from the reach storage; and

m is a dimensionless exponent representing the non-linearity of catchment response. m varies in the range 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a value of 0.8.

The relationship between k and k_c is given by the equation:

$$k = k_{ri}\,k_c$$

Where:

k_{ri} is the relative delay time of reach i; and
k_c is an empirical coefficient applicable to the catchment and is a constant for the whole catchment.

The two rainfall loss parameters of initial loss and continuing loss are used in the generation of the rainfall excess hyetograph for the model. Initial loss is the rainfall at the start of a storm event which fills soil and groundwater storage, is intercepted by vegetation, or is lost by another process and does not contribute to runoff. Continuing loss is the ongoing portion of rainfall that falls after the initial loss that does not produce surface runoff. This could be due to deep soil storage, vegetation interception or evaporation. The loss parameters used in the model can be storm and catchment specific.

1.2 Catchment Delineation

The catchment delineation developed in the previous study has been carried over for this analysis. For inflows to the hydraulic model only the subcatchments upstream of the Spring Creek-Chalkers Creek confluence were required. These are considered to be sufficiently upstream of the area subject to the subsidence to warrant any review of the subcatchment delineation.

1.3 Model Parameters

Due to the lack of long-term stream flow data for the catchment, it was not possible to directly calibrate the hydrologic model. Therefore, it was necessary to investigate what options were available to develop the parameters required for modelling.

Kleemola Regional Relationship Method

Australian Rainfall and Runoff (ARR) outlines, in section 3.6.2, the regional relationships developed to calculate k_c for ungauged catchments. For eastern New South Wales, the relevant method was derived by Kleemola and takes the form:

$$k_c = 1.18*Area^{0.46}$$

Table B1-1, below, lists the Kleemola-derived k_c value.

Table B1-1. Calculated Kleemola value

Scenario	Catchment Area (km^2)	Kleemola k_c Value*
Existing Conditions	39.5	6.40

*Note, that the underlying assumption is that m = 0.8.

Other modelling parameters

The initial loss-continuing loss (IL/CL) model was used. ARR 2019 provides regional estimates of loss parameters for whole storm loss and continuing losses. Initial losses were adjusted based on median pre-burst depths for events of varying AEP. The initial and continuing loss values for the 0.1% AEP were linearly interpolated using a log-log of losses versus AEP as described in Book 8 of ARR 16. The adopted loss values are presented in Table B1-2.

Table B1-2. Adopted model parameters for initial loss and continuing loss prior to pre-burst

Parameter	0.5EY to 0.5%AEP	0.1% AEP
Initial Loss	50 mm	14.4 mm
Continuing Loss	1.36 mm/hr*	1.28 mm/hr

* Note: For events up to the 1% AEP the data hub continuing loss of 3.4 mm/hr was multiplied by 0.4 as per recommendation for catchments in New South Wales where other catchment specific losses aren't available.

1.4 Design Rainfall

Design rainfall depths were generated for events up to the 0.1% AEP event for this study. The IFD table for the North Wambo Creek catchment is presented in Table B1-3 and the Waterfall Creek IFD is presented in Table B1-4. The design rainfalls were determined using the ARR method inbuilt in RORB (with site specific parameters determined from ARR (2019)).

Table B1-3. IFD Table for the North Wambo Creek catchment, total rainfall depth in mm (includes ARF)

Event	0.5EY	2% AEP	1% AEP	0.1% AEP
15 min	11.5	23.9	27.1	37.9
30 min	16.8	34.3	38.7	54.3
1 hour	22.6	43.9	49.2	68.8
3 hours	33.3	60.5	67	91.4
6 hours	43	80.2	89.4	124.6
12 hours	56.6	109.7	123.5	174
18 hours	66.9	133.6	150.6	215.3
24 hours	75.4	154.2	175.7	252.5
48 hours	97.1	207.9	236.3	361.4

Table B1-4. IFD Table for the Waterfall Creek catchment, total rainfall depth in mm (includes ARF)

Event	0.5EY	2% AEP	1% AEP	0.1% AEP
15 min	12.3	26.2	29.9	52
30 min	17.7	36.8	41.7	69.5
1 hour	23.3	46.4	52.1	84.3
3 hours	33.7	62.6	69.6	110.1
6 hours	42.7	80.9	90.5	136.4
12 hours	55.1	108.2	122.3	178.5
18 hours	63.8	129.6	146.9	212.6
24 hours	70.9	147.5	168.2	241.7
48 hours	89.1	194.4	221	331.7

Temporal patterns

The temporal patterns were taken from the Datahub with the majority of data originating from the East Coast (South) region.

In Waterfall Creek the full set of temporal patterns were run TUFLOW model. From the processed outputs GIS techniques were used to determine the relevant temporal patterns for the area of interest.

For North Wambo Creek, the full set of temporal patterns were not run in the TUFLOW. Instead, the ensemble of temporal patterns was narrowed down to the most critical by the Storm Injector program. Storm Injector is a software product that can take a hydrologic model created in RORB and automatically create and analyse derivative versions of the model in accordance with ARR 2016.

The existing and diverted catchments of North Wambo creek catchment were analysed. Storm injector provided the critical durations and the temporal pattern that produced it. Table B1-5 summarises the AEP and temporal patterns selected for 2D hydrodynamic modelling.

Table B1-5. North Wambo Creek - AEP, duration and corresponding temporal patterns

Durations (min)	Durations (hour)	AEP			
		0.5EY	2%	1%	0.1%
90	1.5			5	
180	3		5		
360	6				1
1440	24	1			

1.5 RORB Model Output

The RORB model outputs for North Wambo Creek are presented in Table B1-6. The output locations are downstream of the predicted extent of subsidence from LW21-26 on North Wambo Creek. Note this is the located that was used to determine the critical storm duration but a different location to inflow point into the TUFLOW model (at the confluence of Spring Creek and Chalkers Creek). Downstream of the inflow point, direct rainfall is applied to the 2D model.

Note that the peak flow rates did not all coincide on the same duration storm event – overall the critical duration varied from as long as the 24 hour for the 0.5EY event to as short as the 1.5 hour for the 0.1%AEP event, depending on location within the catchment.

Table B1-6. Design flow estimates from RORB analysis

	Downstream of LW-21-26 (Catchment 23)
Upstream catchment (km^2)	28.8
ARI/AEP	Peak Discharge (m^3/s)
0.5EY	29
2%	113
1%	143
0.1%	230

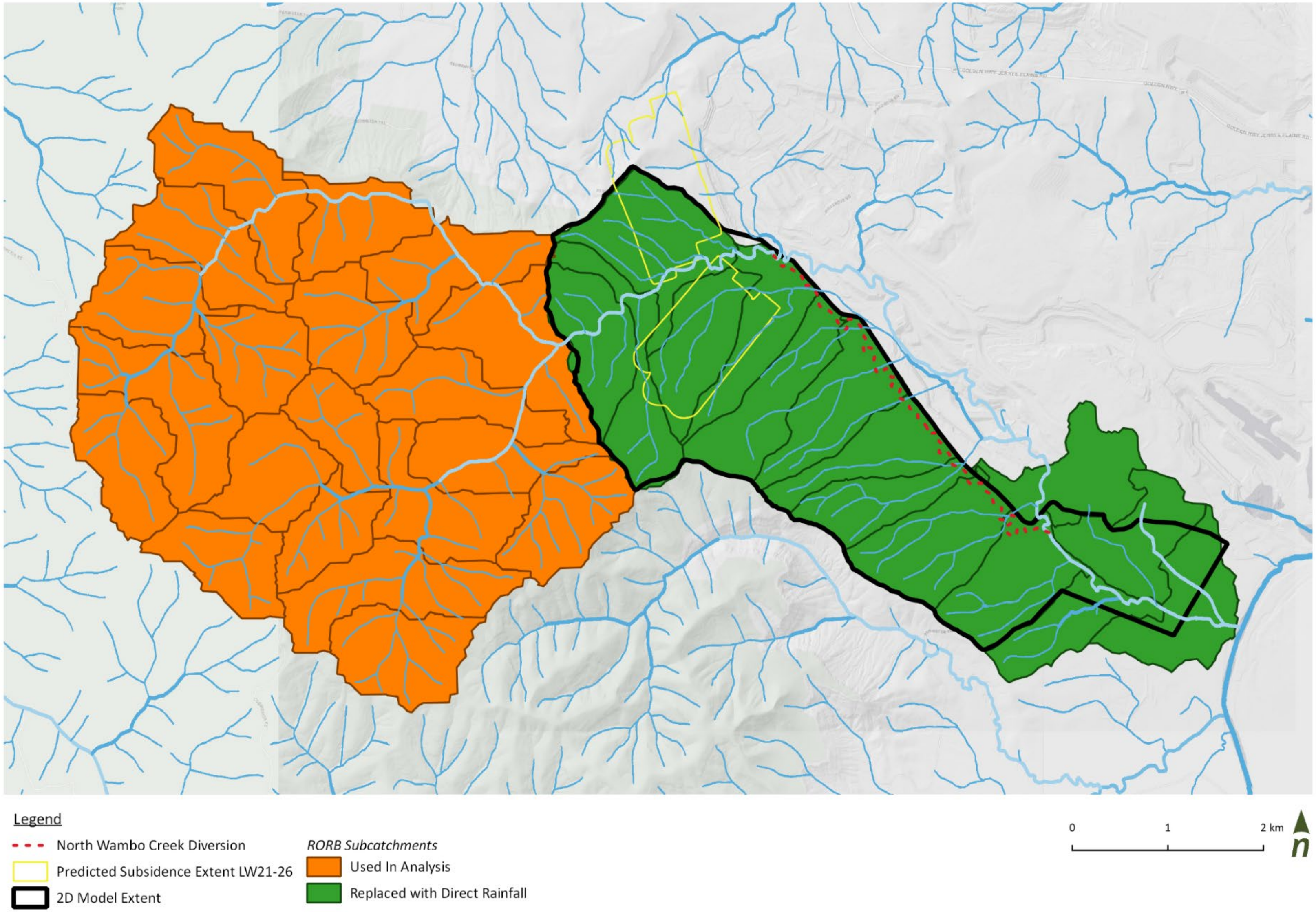
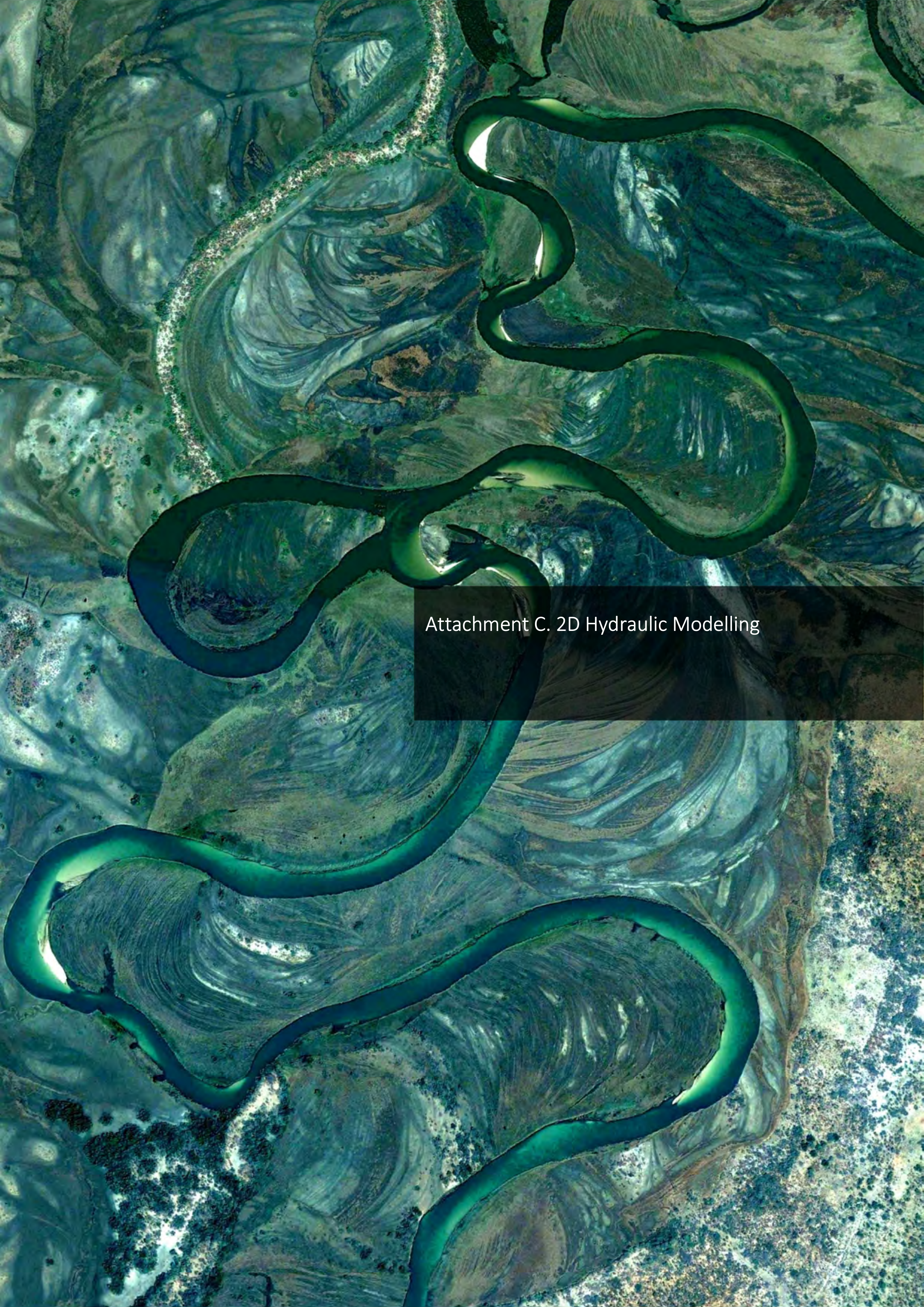


Figure B1-1. *RORB Model Overview*

Attachment C. 2D Hydraulic Modelling



1 Hydraulic Modelling of the Modified South Bates Extension Underground Mine

Hydraulic modelling was undertaken to assess the changes in flood behaviour in the area impacted by the planned longwall mining panels (LWs 21-26) at the Wambo Coal Mine. This includes the rearrangement of LW24-26 from their previously approved locations.

1.1 Model Extent

A 2D hydraulic model of North Wambo Creek and Waterfall Creek catchments was developed in TUFLOW HPC (Build 2020-10-AC). The model has two separate 2D model domains; one for each watercourse.

The hydraulic model outfalls on North Wambo Creek, approximately 2km downstream of the North Wambo Creek diversion. The upstream model extent on North Wambo Creek is the confluence of Spring Creek and Chalkers Creek. In the Waterfall Creek model domain the entire catchment adjacent to the long walls has been modelled. The extent of the model is shown in Figure C1-1.

1.2 Topography

LiDAR

LiDAR was provided by Wambo Coal Pty Limited (WCPL). The limited metadata provided indicates the LiDAR was flown on the 15th of November 2021. The point data provided was triangulated into a TIN and exported to ASCII grid format with a 1m grid cell size for use in the TUFLOW model.

Due to it being captured in November 2021 this dataset is considered to have captured actual subsidence up to the completion of LW20. Subsidence from LW21-26 will be represented in this study using the subsidence predictions provided.

Subsidence Predictions

Subsidence modelling has been undertaken by Mine Subsidence Engineering Consultants (MSEC) in 2022. The subsidence predictions were provided and contours covering the extents from LW17 to LW26 which covers the rearrangement of LW24-26.

The subsidence prediction contours were clipped to only include LW21 to LW26 because the LiDAR has captured actual subsidence up to this point. Subsidence contours along this cut line were modified slightly to prevent a sharp step in the topography which is considered unrealistic.

A final fully subsided surface was created by subtracting the predicted subsidence depths from the LiDAR discussed above.

1.3 Model Parameters

Both 2D domains adopted a 4m grid cell size. Running in TUFLOW HPC, the model has an adaptive timestep.

1.4 Roughness

Manning's n roughness coefficient for the model was set by assessing aerial imagery and site photographs. Depth-varying coefficients have been used where higher coefficients are adopted up to a depth of 30mm which transition to smaller coefficients at a depth of 100mm. Table C1-1 shows the depth-varying roughness coefficients applied in the North Wambo Creek and Waterfall Creek models.

Table C1-1. Manning's 'n' Coefficients

Depth 1	n1	Depth 2	n2	Description
-	0.02	-	-	Water bodies
0.03	0.03	0.1	0.03	Unpaved roads
0.03	0.03	0.1	0.035	Waterway minimal vegetation
0.03	0.03	0.1	0.06	Moderate dense vegetation
0.03	0.03	0.1	0.1	Dense Vegetation
0.03	0.03	0.1	0.04	General Topography

1.5 Boundary Conditions

North Wambo Creek

Inflow hydrographs were applied to the upstream model boundary and the confluence between Spring Creek and Chalkers Creek as shown in Figure C1-1. On North Wambo Creek rainfall was applied downstream of this confluence using a 2d_rf rainfall boundary. This approach allows for a better representation of the surface water flow paths on the mining panels allows for simple quantification of the impacts to these flow paths due to subsidence.

Two downstream boundaries were adopted on North Wambo Creek; one stage-discharge (HQ) boundary on the main channel of North Wambo Creek and a separate stage-discharge (HQ) boundary for the overbank flow on the left bank of North Wambo Creek.

Waterfall Creek

On Waterfall Creek rainfall was applied to the entire model domain using a 2d_rf rainfall boundary as shown in Figure C1-1. The downstream boundary applied in this domain is a stage-discharge (HQ) boundary applied using a 2d_bc layer.

1.6 Limitations

It should be noted that the TUFLOW does not simulate erosion and sediment transport. Dam and other embankment failure scenarios have not been modelled in this assessment and therefore results are based on stable topography over the full length of the modelled events – which is unlikely to occur during a large magnitude event.

It should also be noted that this assessment has focussed solely on the impact that the topographical changes resulting from subsidence have had on storage and flow in North Wambo Creek and Waterfall Creek. The assessment does not consider the potential for losses to cracking in the subsided surface in the vicinity of the longwall panels.

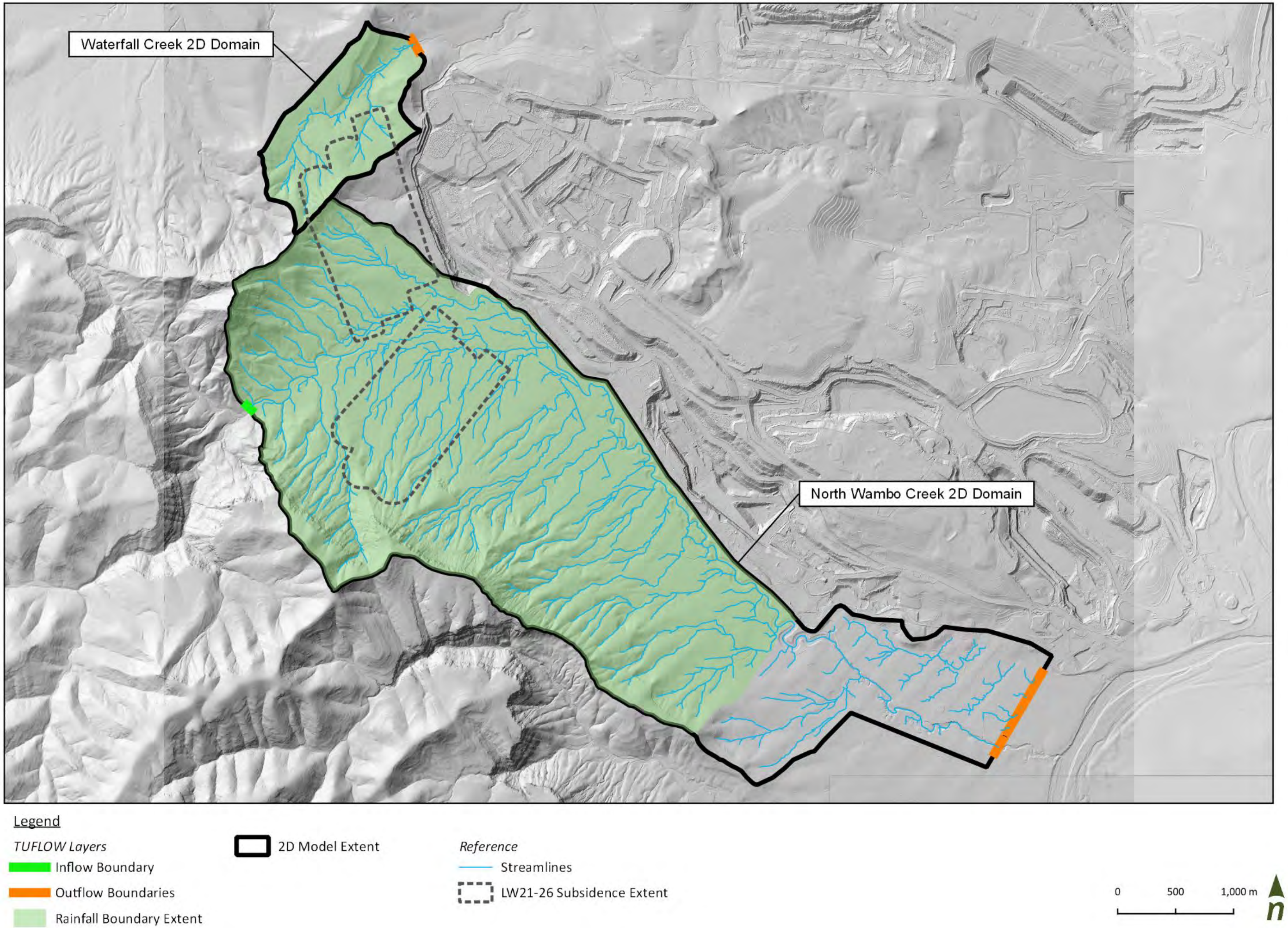


Figure C1-1. *TUFLOW Model Setup*

2 Modelling Results

The figures below are presented in the following order:

- Existing Flood Depth (Figure C2 to Figure C5)
- Existing Flood Velocity (Figure C6 to Figure C9)
- Subsided Flood Depth (Figure C10 to Figure C13)
- Subsided Flood Velocity (Figure C14 to Figure C17)

Within each group, the figures are presented in order of design flood event; 0.5EY, 2% AEP, 1% AEP and 0.1% AEP for both existing and subsided surface conditions.

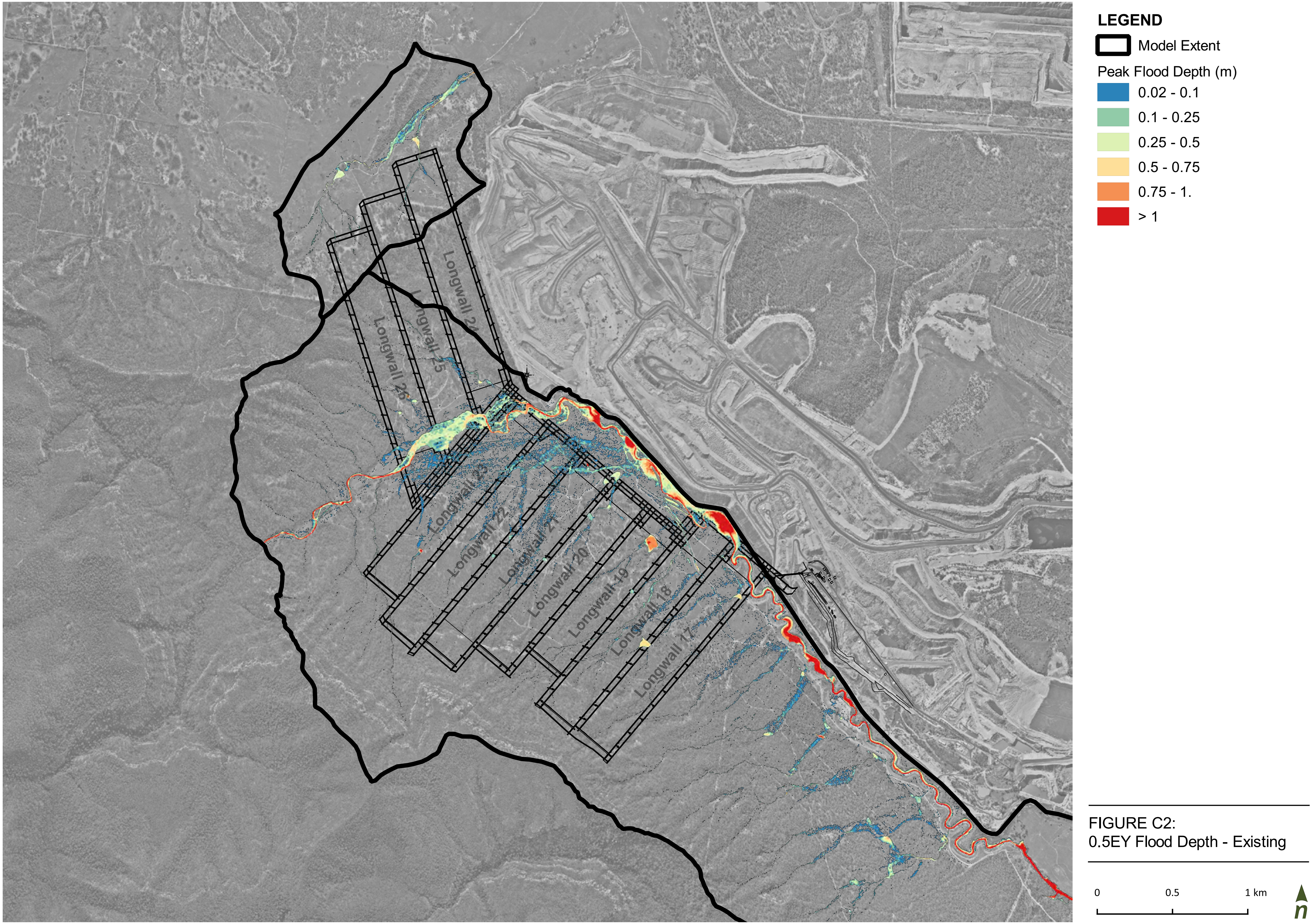
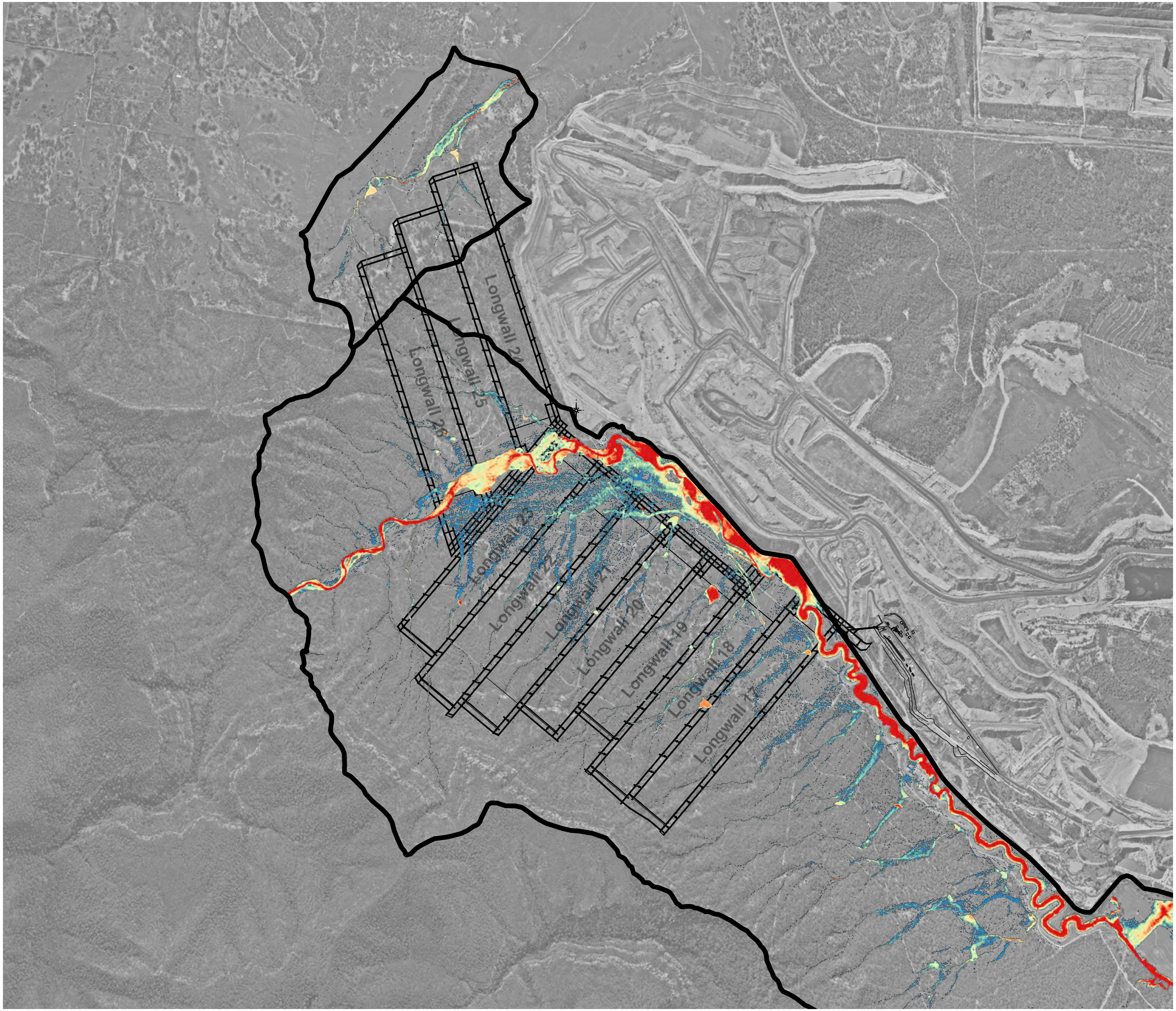


FIGURE C2:
0.5EY Flood Depth - Existing



LEGEND

Model Extent

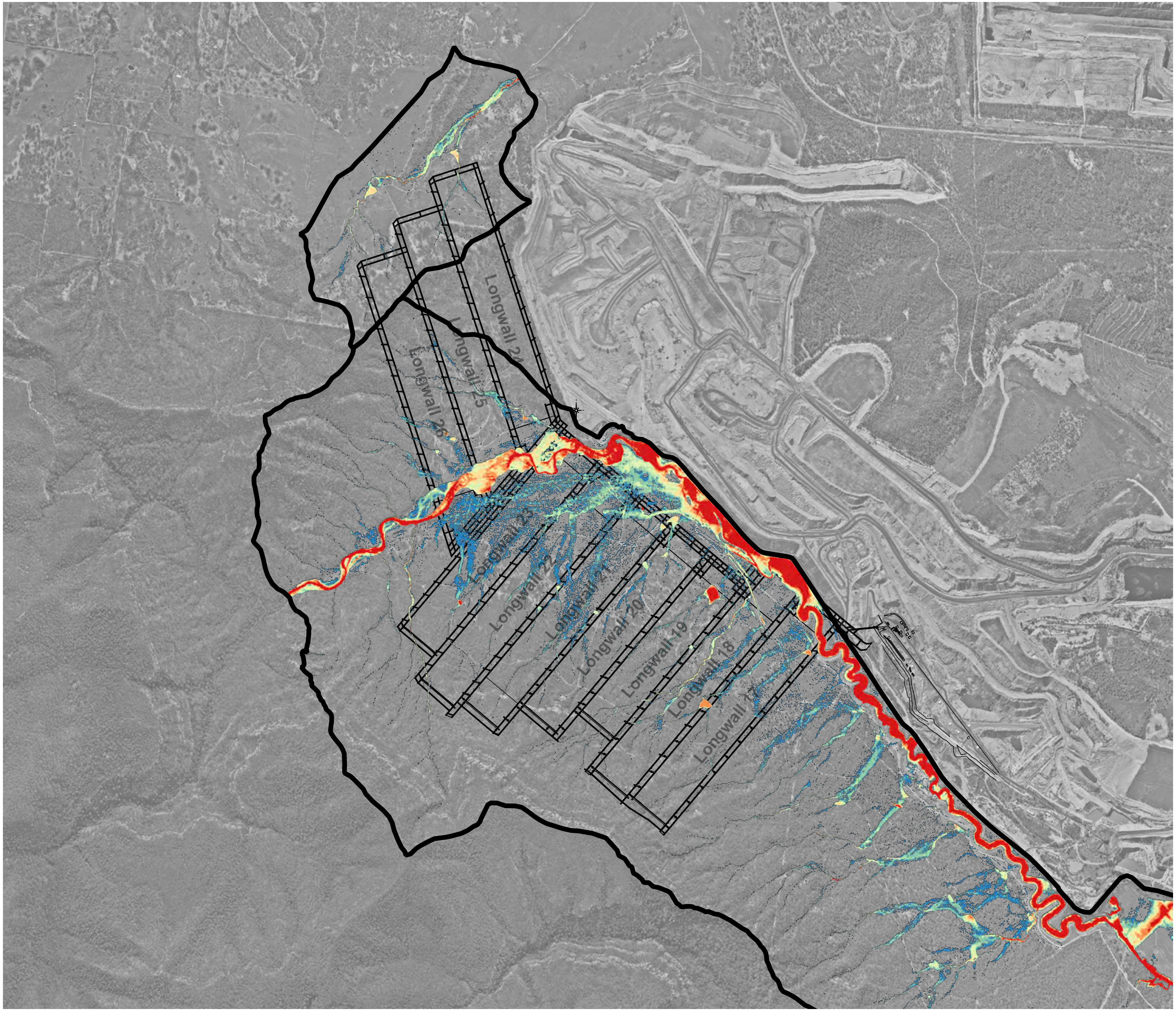
Peak Flood Depth (m)

- 0.02 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C3:
2% AEP Flood Depth - Existing

0 0.5 1 km

n



LEGEND

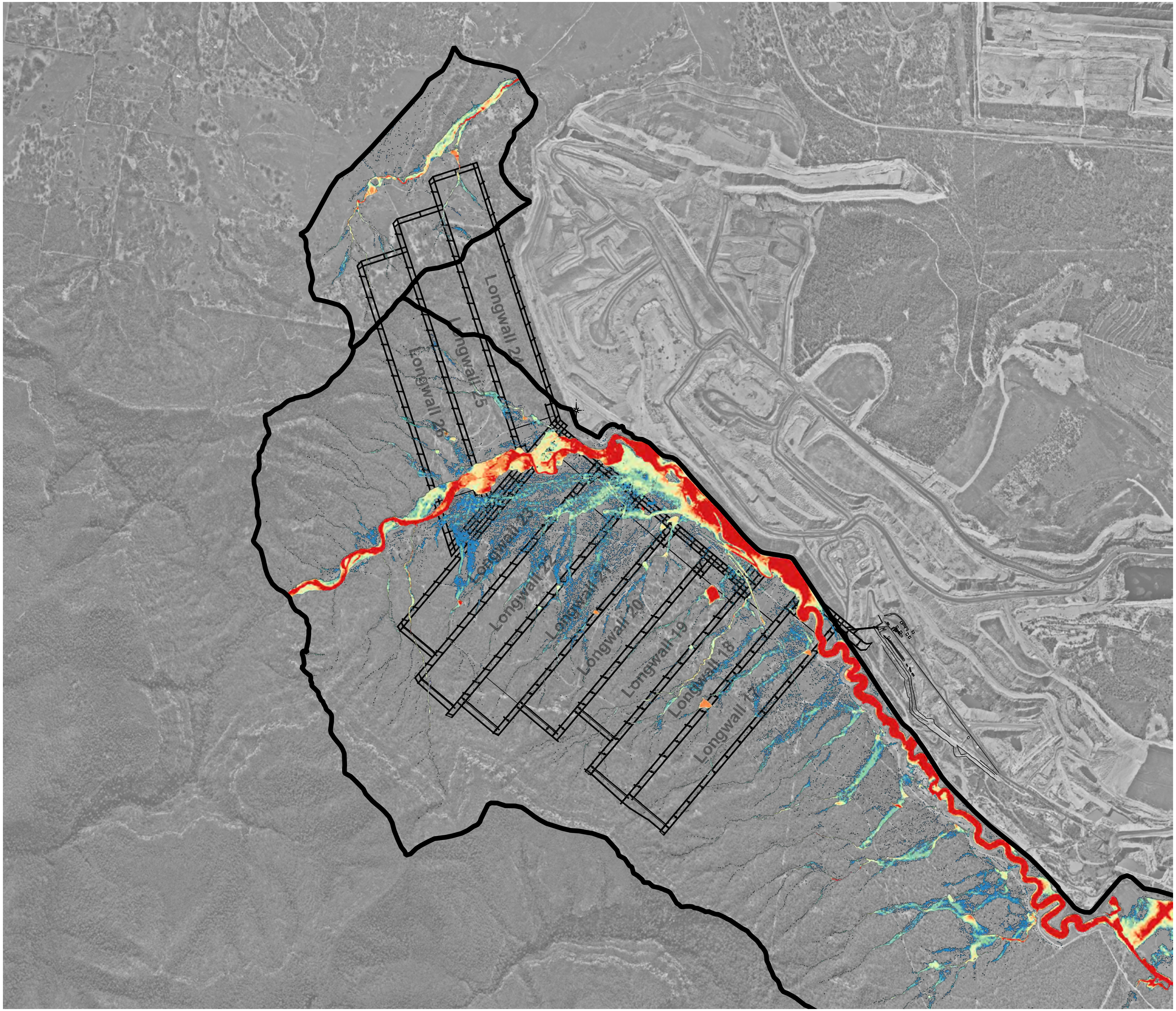
Model Extent

Peak Flood Depth (m)

- 0.02 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C4:
1% AEP Flood Depth - Existing

0 0.5 1 km



LEGEND

Model Extent

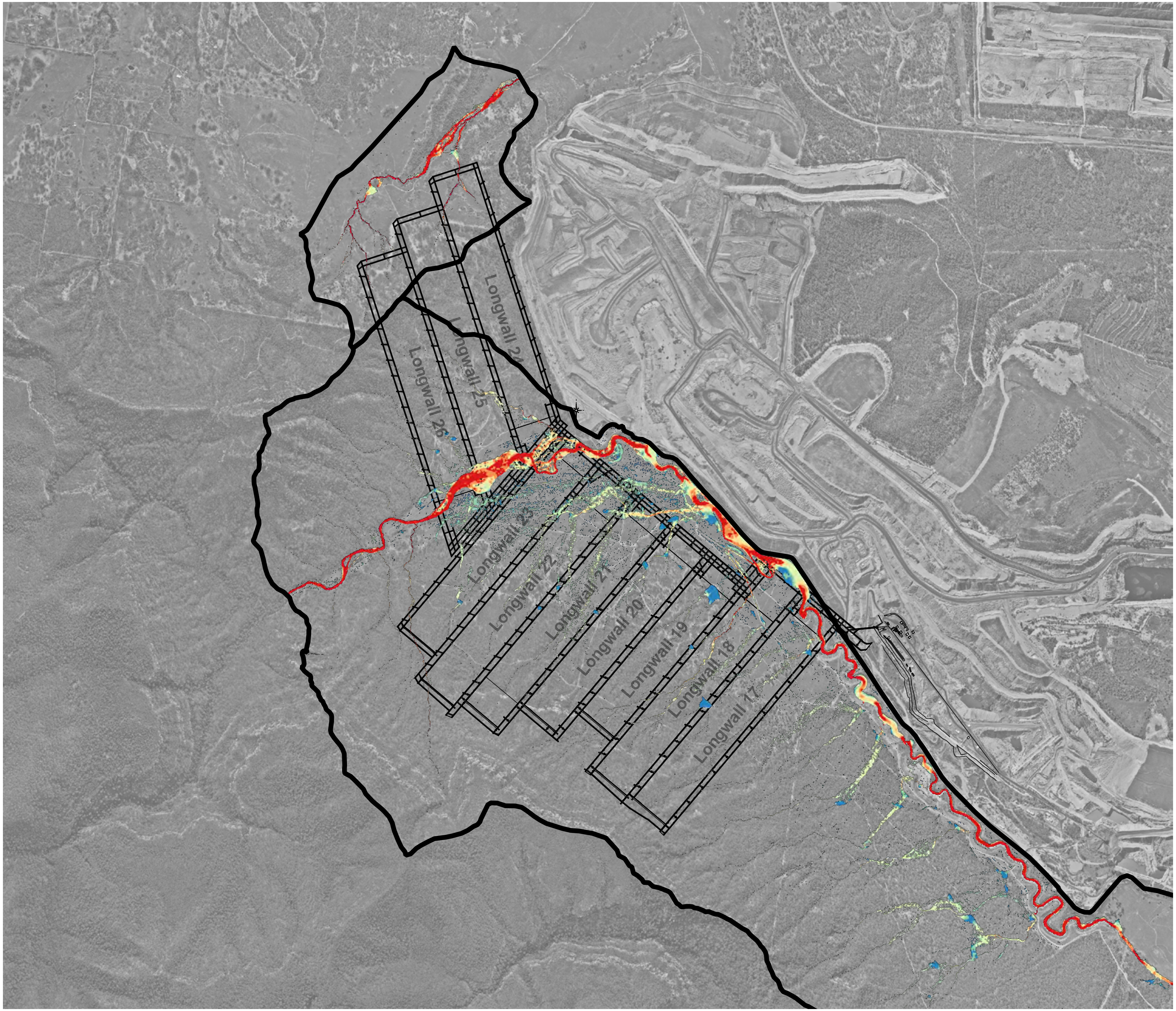
Peak Flood Depth (m)

- 0.02 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C5:
0.1% AEP Flood Depth - Existing

0 0.5 1 km

n



LEGEND

Model Extent

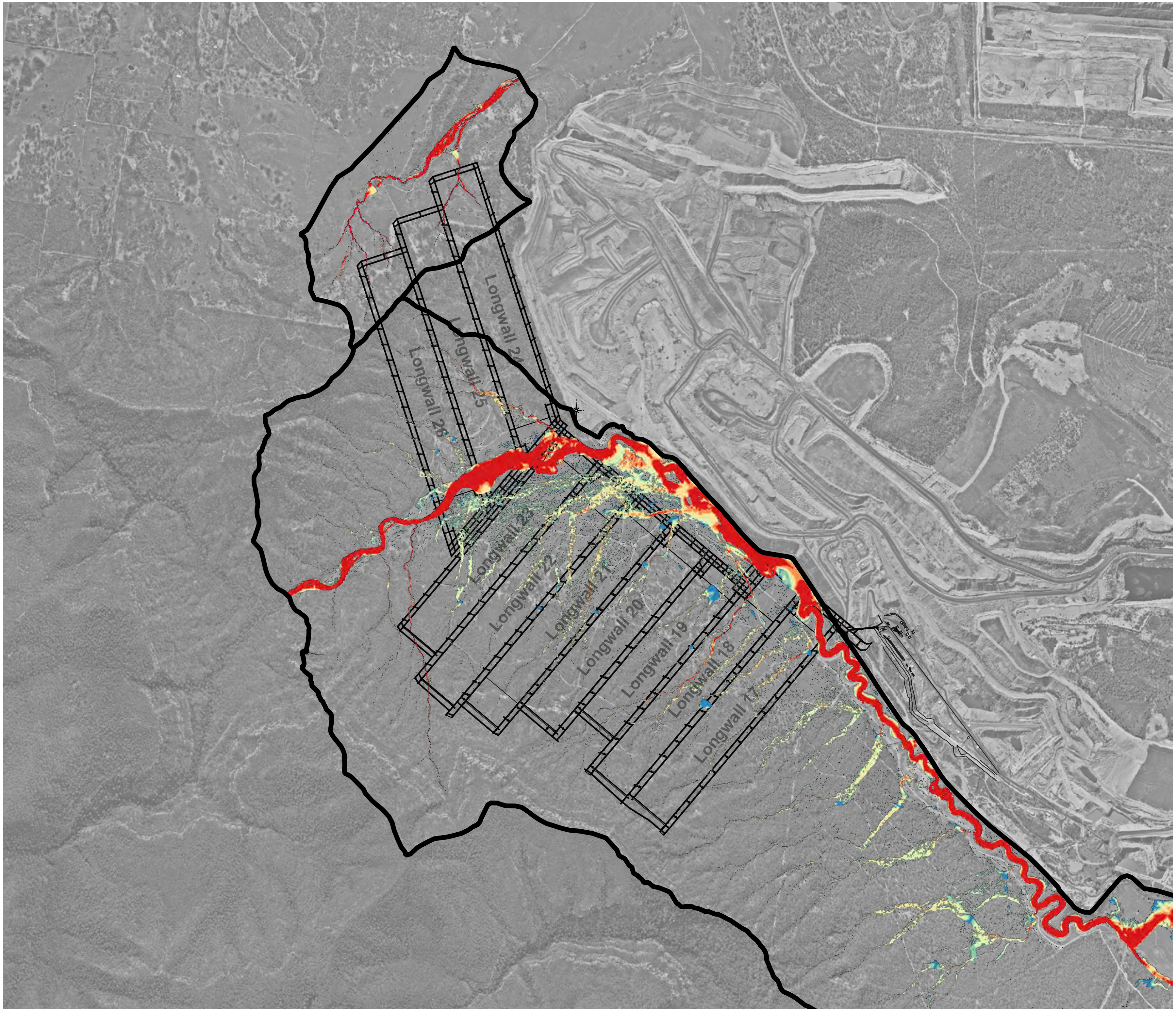
Peak Flood Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C6:
0.5EY Flood Velocity - Existing

0 0.5 1 km

n



LEGEND

Model Extent

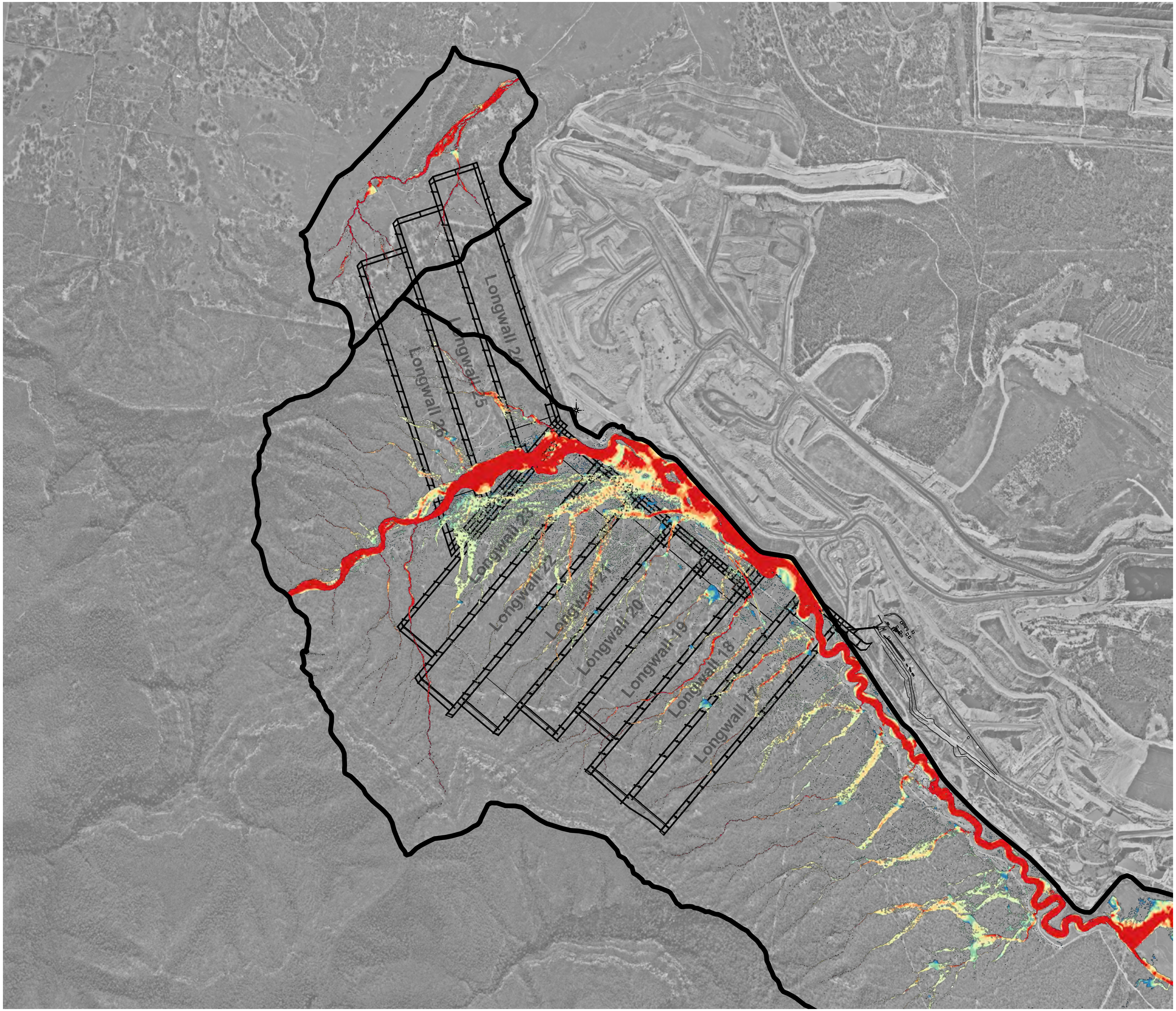
Peak Flood Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C7:
2% AEP Flood Velocity - Existing

0 0.5 1 km

n



LEGEND

Model Extent

Peak Flood Velocity (m/s)

0 - 0.1

0.1 - 0.25

0.25 - 0.5

0.5 - 0.75

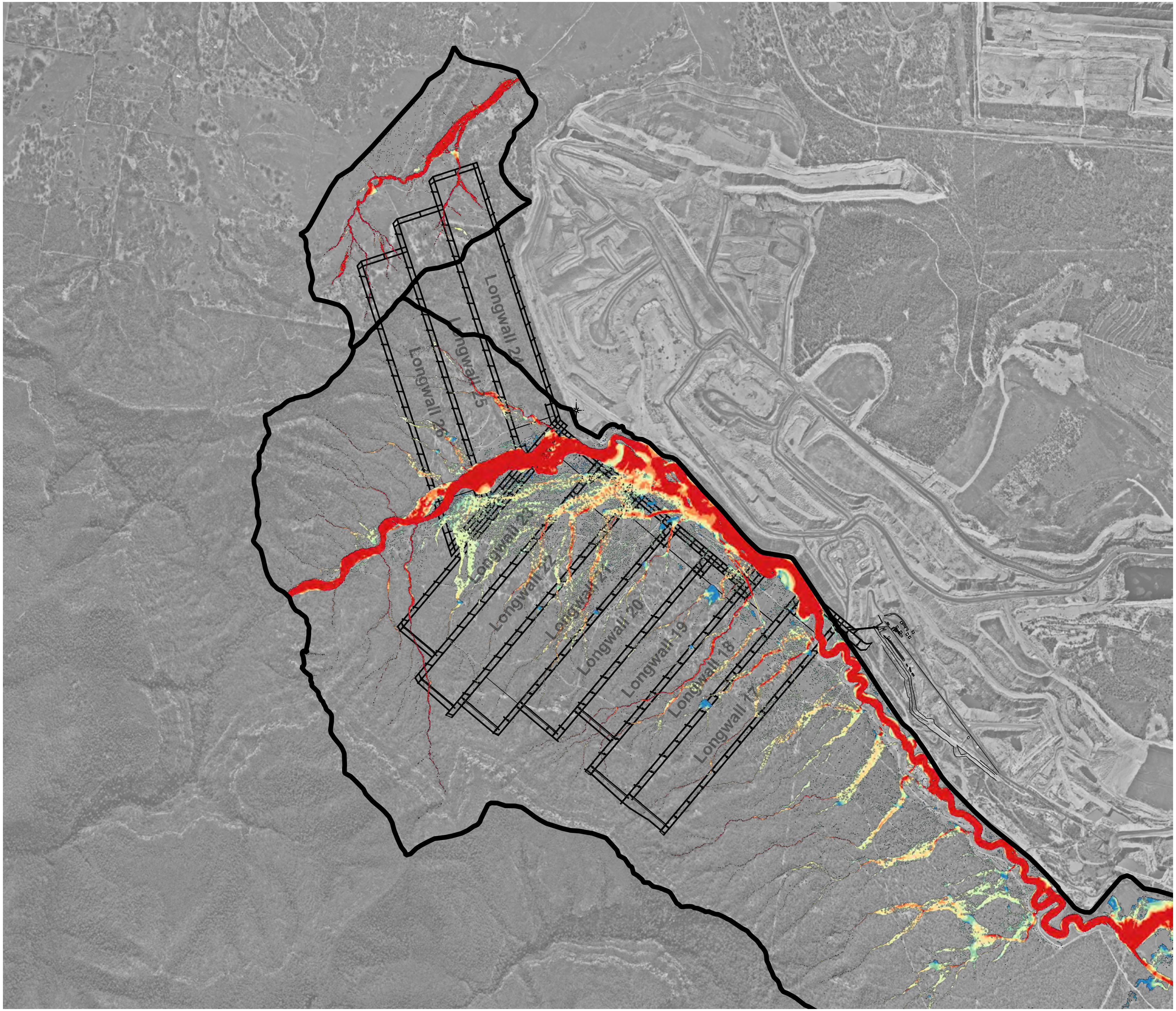
0.75 - 1.

> 1

FIGURE C8:
1% AEP Flood Velocity - Existing

0 0.5 1 km

n



LEGEND

Model Extent

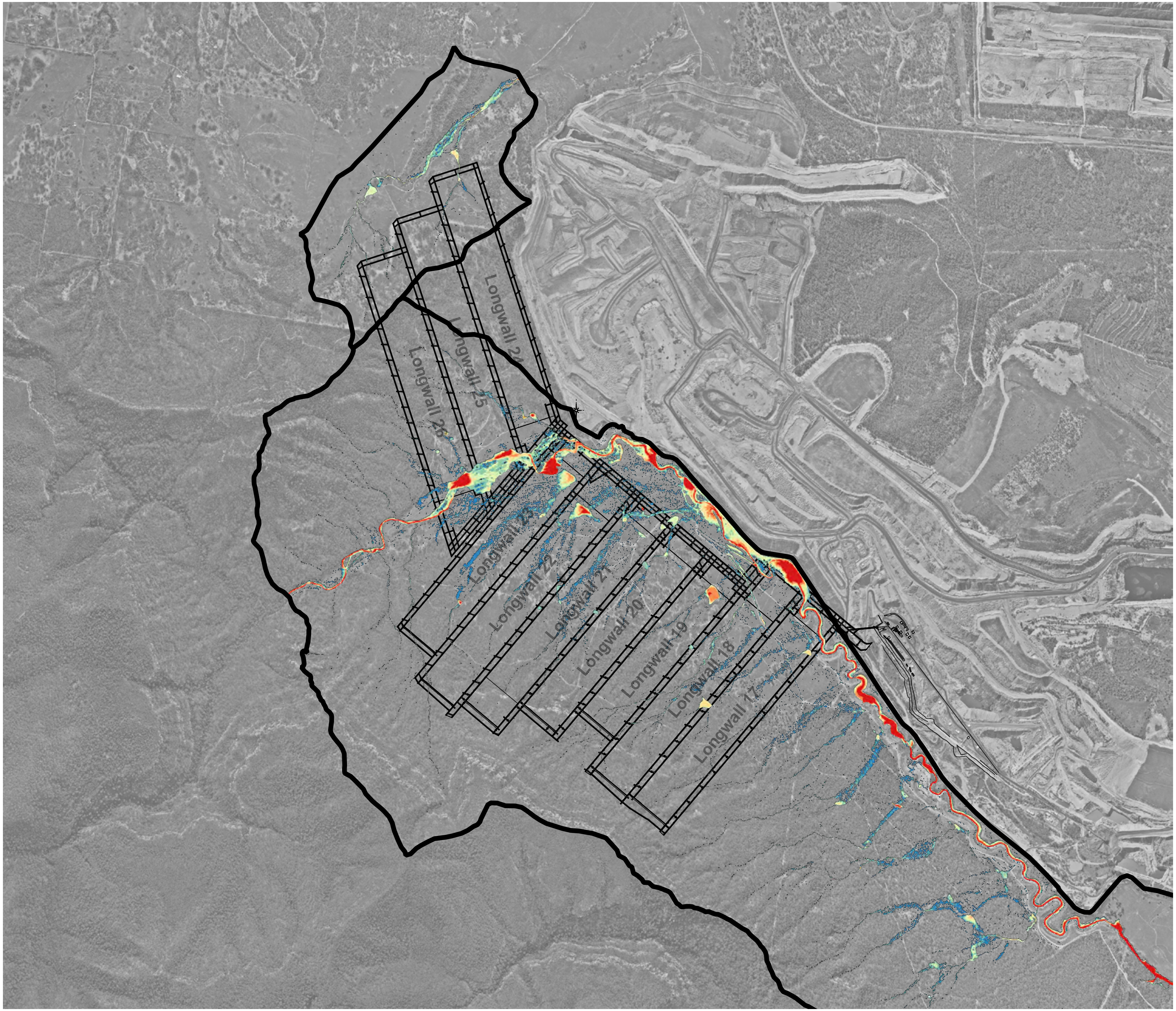
Peak Flood Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C9:
0.1% AEP Flood Velocity - Existing

0 0.5 1 km

n



LEGEND

Model Extent

Peak Flood Depth (m)

0.02 - 0.1

0.1 - 0.25

0.25 - 0.5

0.5 - 0.75

0.75 - 1.

> 1

FIGURE C10:
0.5EY Flood Depth - Subsided

0 0.5 1 km

n

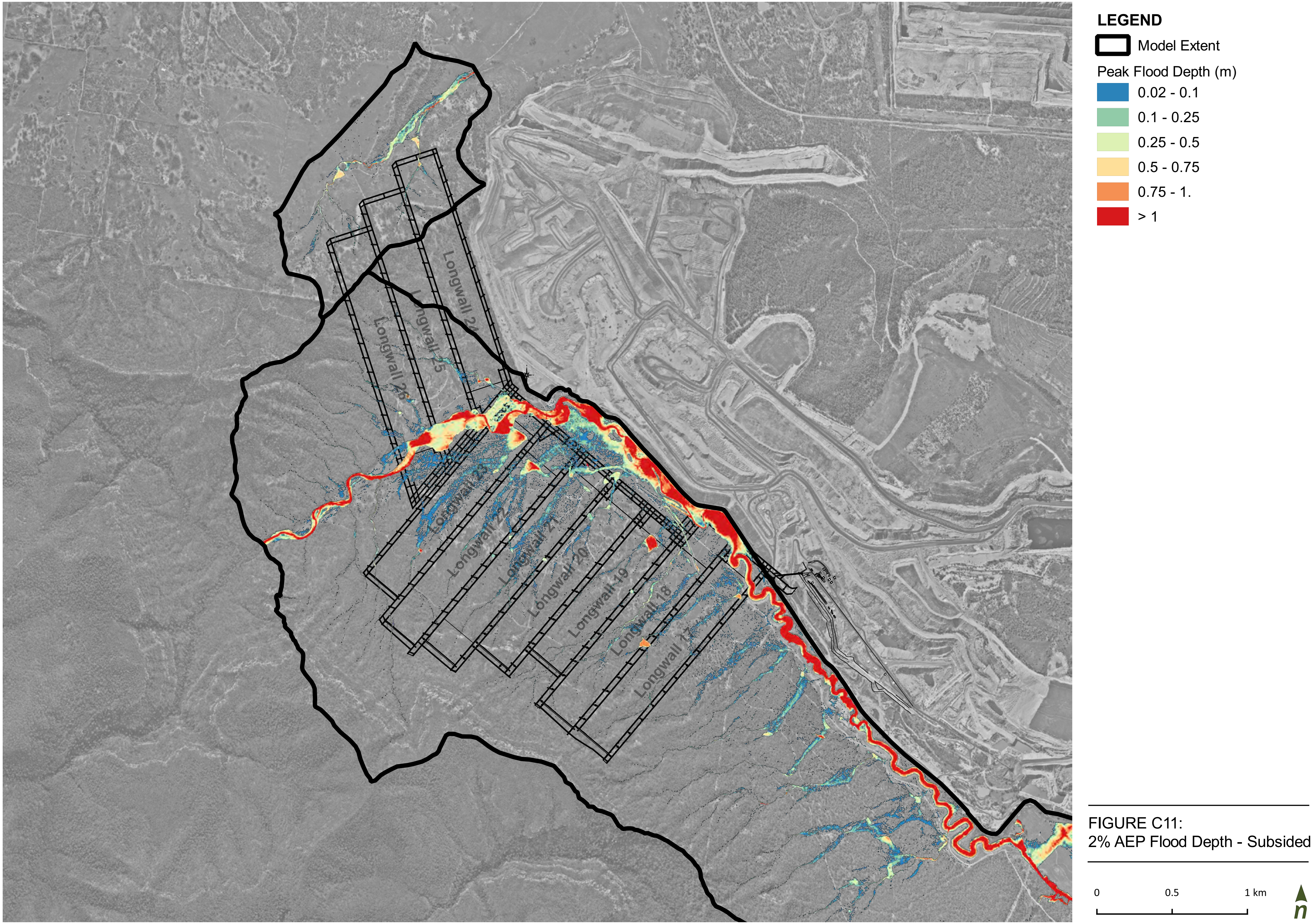
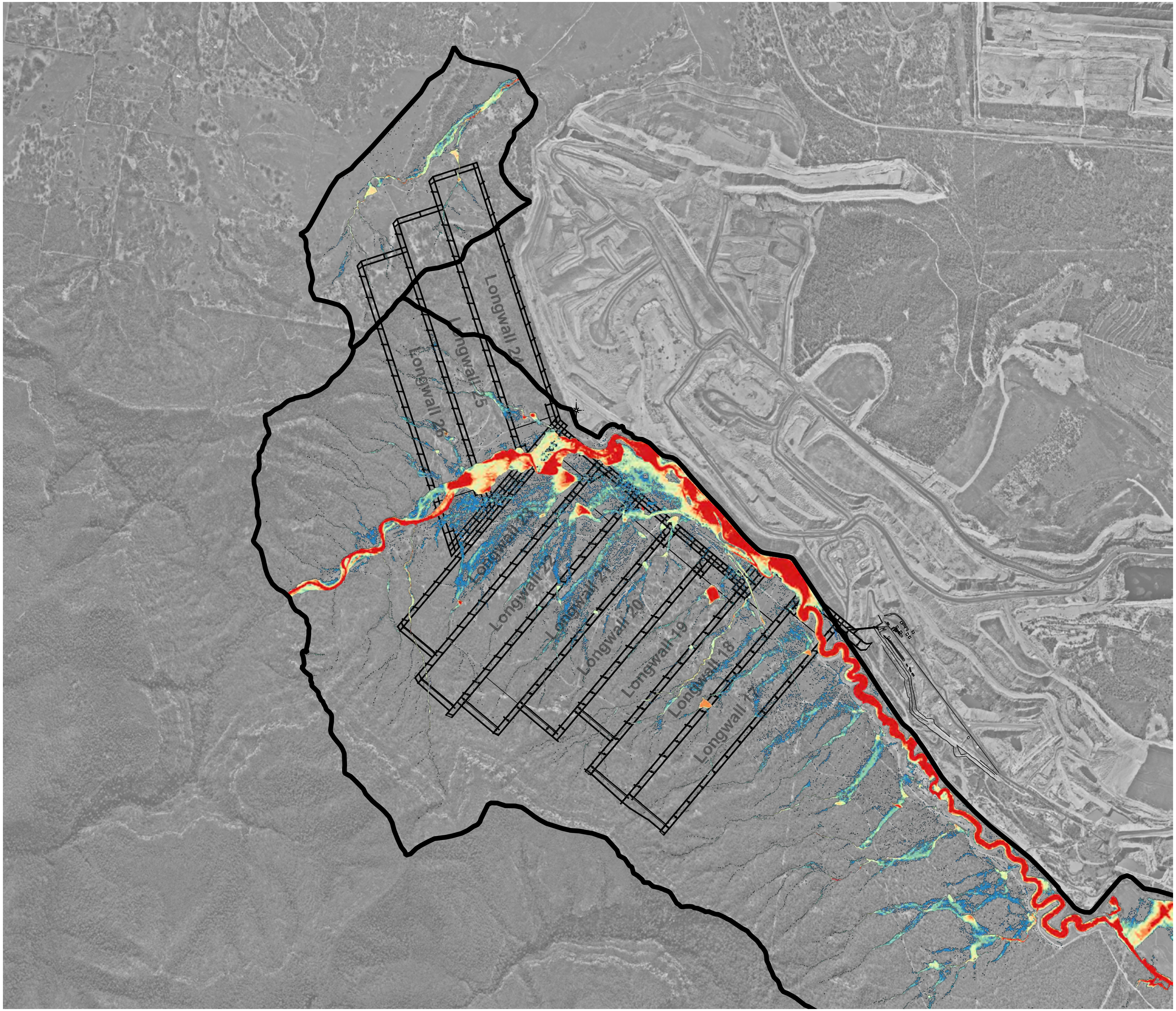


FIGURE C11:
2% AEP Flood Depth - Subsided



LEGEND

Model Extent

Peak Flood Depth (m)

- 0.02 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C12:
1% AEP Flood Depth - Subsided

0 0.5 1 km

n

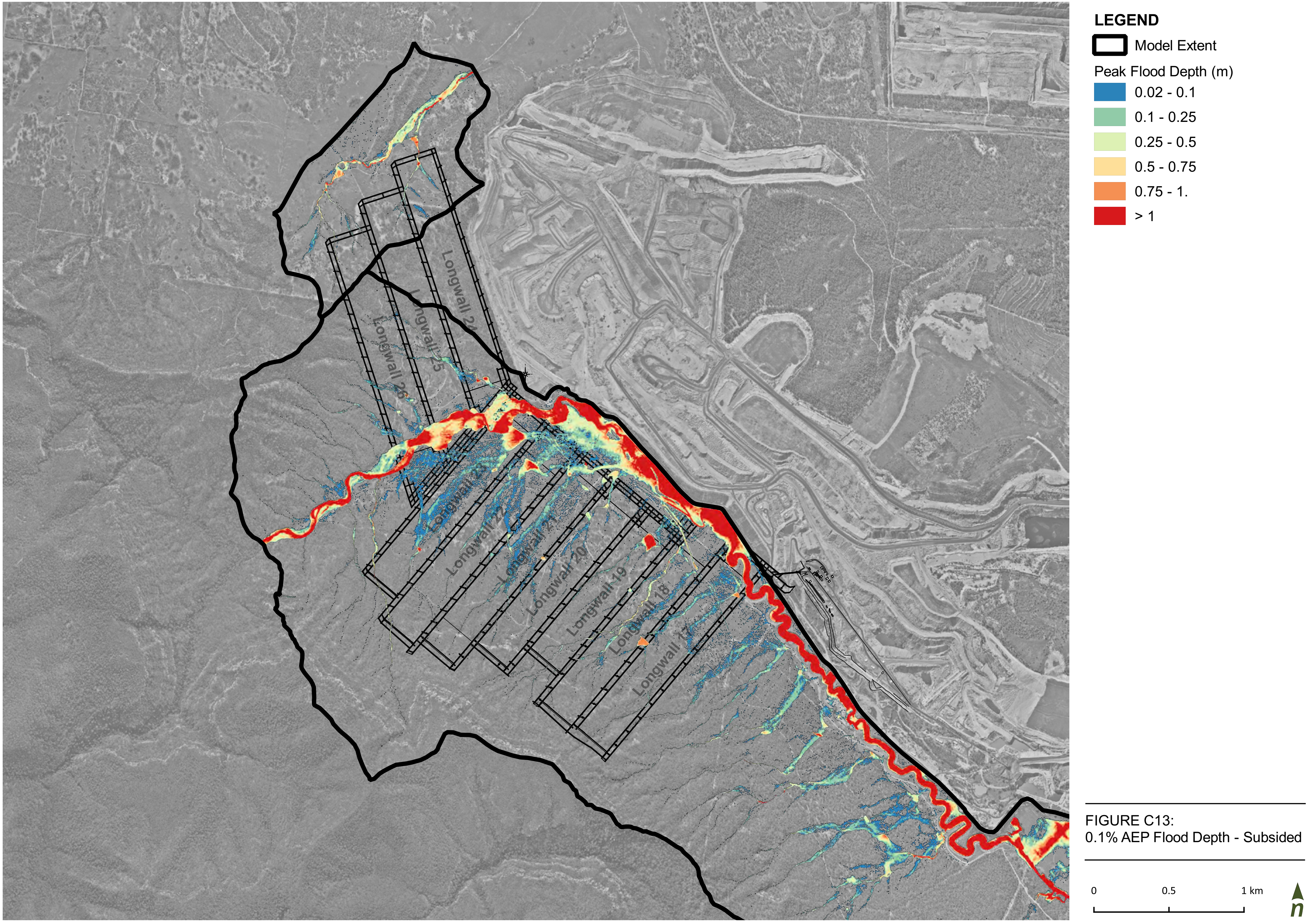
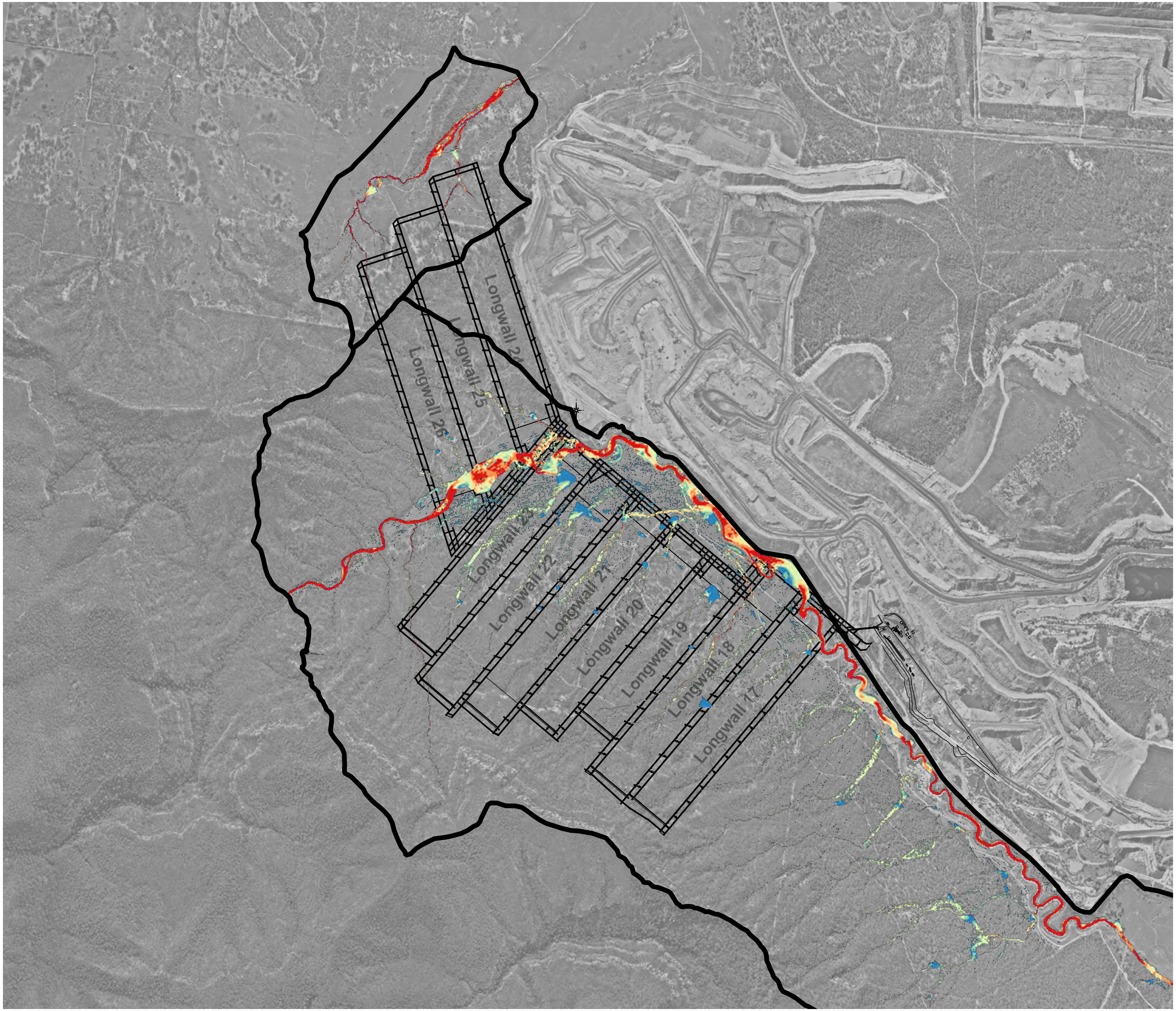


FIGURE C13:
0.1% AEP Flood Depth - Subsided



LEGEND

Model Extent

Peak Flood Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C14:
0.5EY Flood Velocity - Subsided

0 0.5 1 km

n

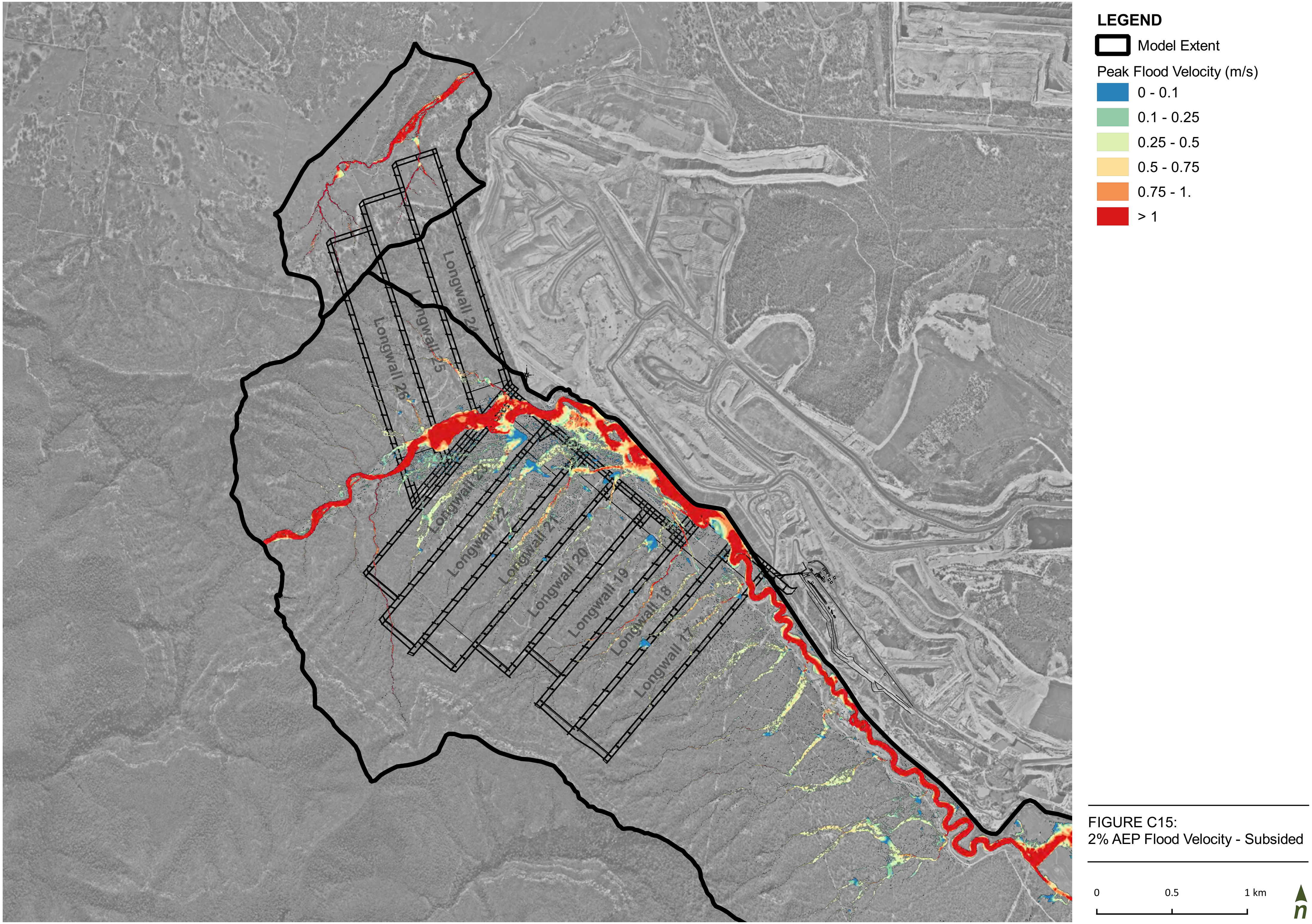
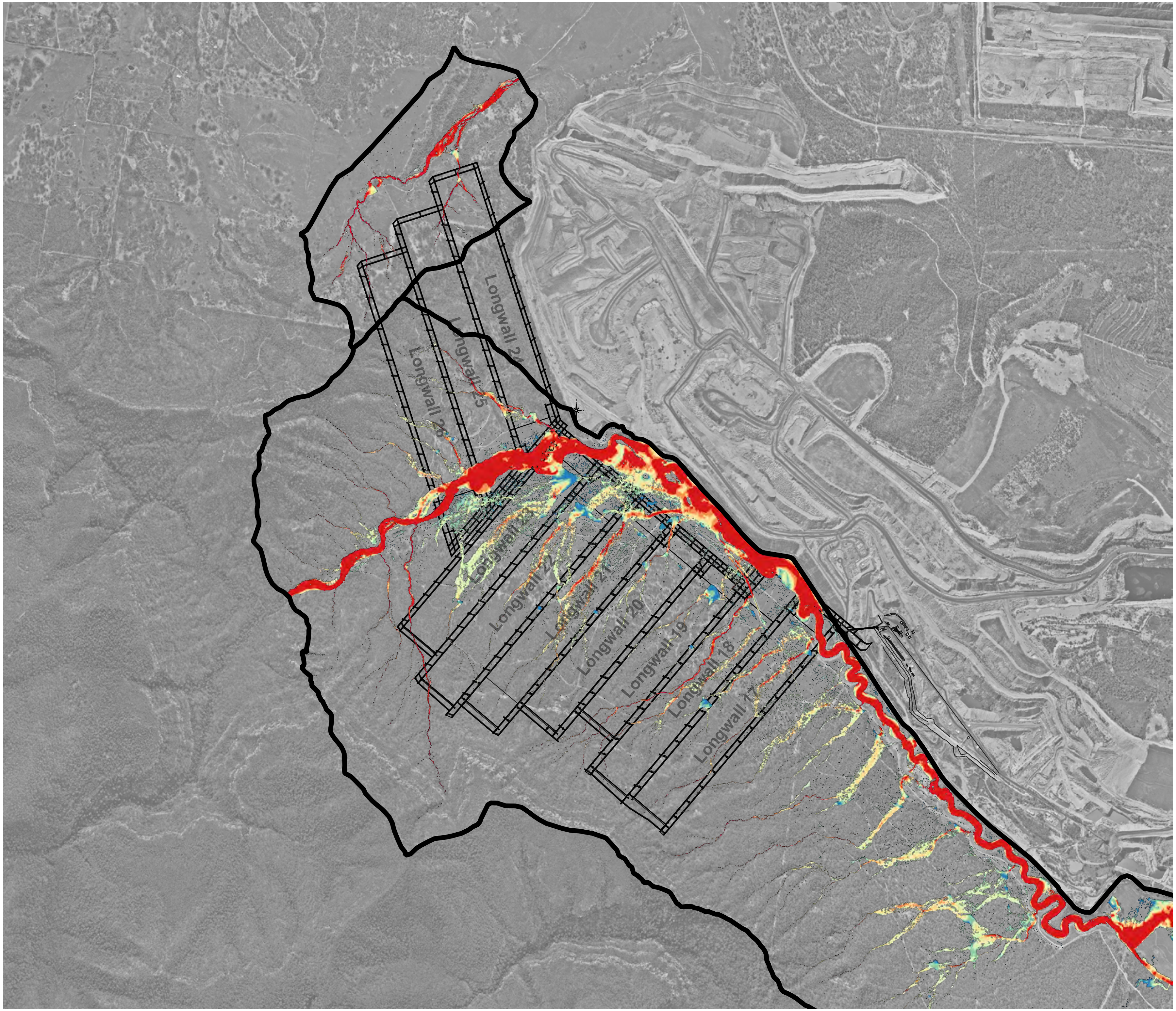


FIGURE C15:
2% AEP Flood Velocity - Subsided



LEGEND

Model Extent

Peak Flood Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.
- > 1

FIGURE C16:
1% AEP Flood Velocity - Subsided

0 0.5 1 km

n

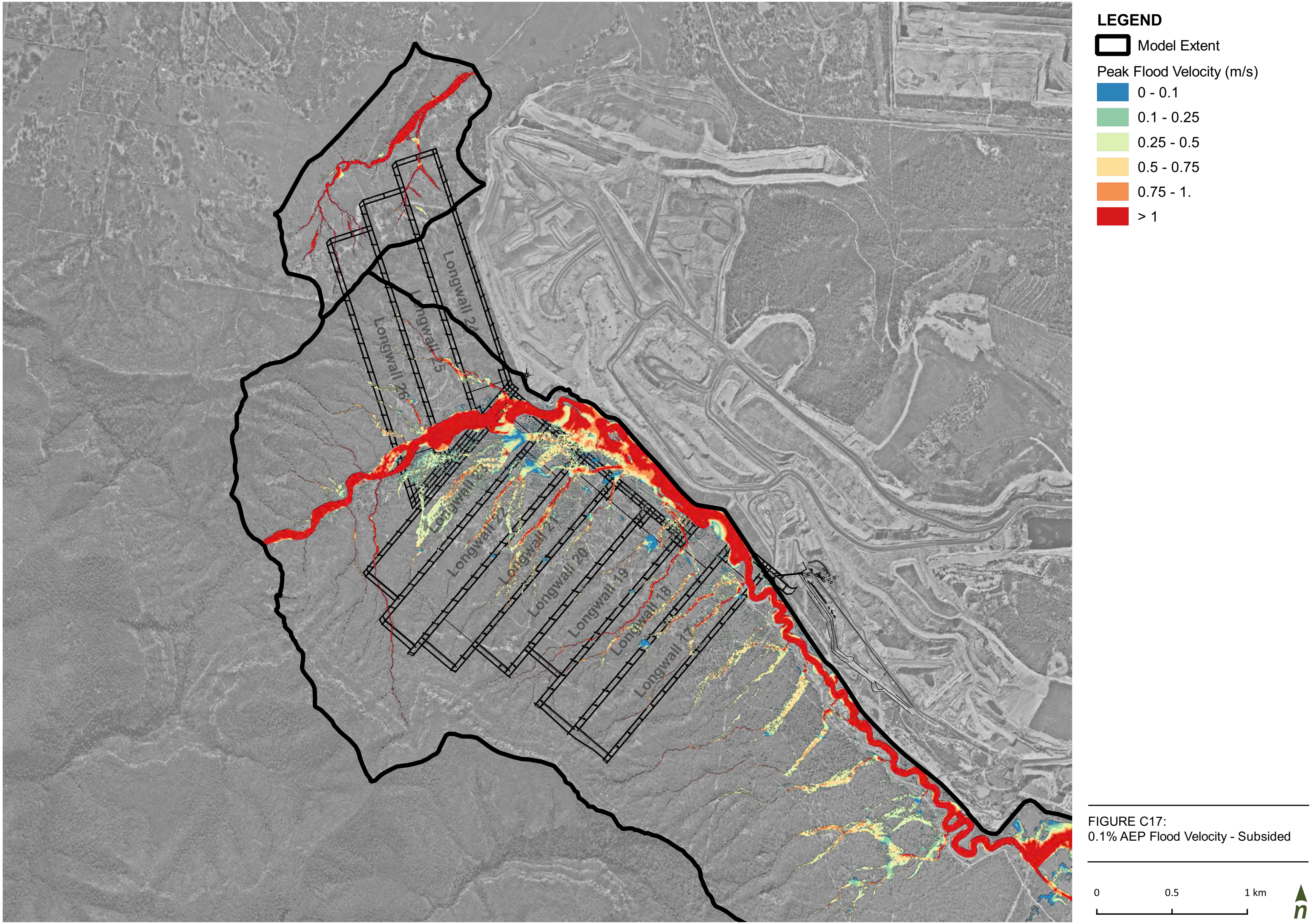


FIGURE C17:
0.1% AEP Flood Velocity - Subsided