Lake Vermont Meadowbrook EIS Project

Geomorphological Assessment Report

Bowen Basin Coal Pty Ltd

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Executive Summary

Bowen Basin Coal Pty Ltd propose to develop the Lake Vermont Meadowbrook Project - a new double-seam underground longwall coal mine, along with a small-scale open-cut pit targeting coal resources to the north and adjacent to the existing Lake Vermont Mine.

The proposed longwall panels underly and will cause subsidence in Boomerang Creek, One Mile Creek and their floodplains, as well as part of the Phillips Creek floodplain to the south. Queensland Government mapping has defined Boomerang Creek and One Mile Creek (as well as Phillips Creek) as watercourses under the *Water Act 2000*.

Subsidence would occur gradually as the Project progressively develops over the planned life of the underground mine, being 23 years or indicatively through to 2048.

The channel and floodplain of Boomerang Creek would see a maximum subsidence depth of up to 4.0 m. Maximum subsidence depths in the floodplain between One Mile Creek and Boomerang Creek would be over 4.5 m in localised areas. Maximum subsidence depths on the One Mile Creek channel and southern floodplain would be up to 3.0 m. The channel of Phillips Creek would not be directly affected by subsidence. Maximum subsidence depths on the Phillips Creek northern floodplain would be up to 3.0 m, however, the locations of the Phillips Creek floodplain troughs are such that they would not significantly increase avulsion risk of the Phillips Creek channel.

Gordon Geotechniques (GG, 2022) predicted the maximum depth of continuous subsurface subsidence cracking above the workings would not extend to the ground surface at Boomerang, One Mile and Phillips Creeks.

Surface subsidence cracks will develop in the longwall mining areas particularly at the panel edges where tensile stress is greatest. Gordon Geotechniques concluded the widest of these would extend no more than 10 to 15 m below ground level, with the majority less than 1 m deep. Maximum surface crack widths up to 200 mm could be expected in shallower areas, decreasing to less than 50 mm at greater depths. Cracks of this size and depth would not result in the loss of water from the alluvium associated with the watercourses overlying the underground workings.

Hydraulic models were developed to assist with the characterisation of the waterway channels and to assess the potential flood and geomorphic impacts of the Project. Models were developed for pre-mining conditions, which assume all approved works on the Lake Vermont lease have been implemented, and post mining conditions, which assume that all longwall panels within the Project area have been subsided and that works associated with the open cut pit (temporary levees around the mining area and mine infrastructure area, haul road/access road and earthworks to mitigate some of the Project impacts) are in place.

Boomerang Creek

In the proposed subsidence area, Boomerang Creek meanders across a broad floodplain. The channel is typically 1.5 m to 2.5 m deep with a sandy bed.

The channel capacity is relatively low, with floodwater flowing over the southern bank at several locations for the 50% annual exceedance probability (AEP) flood via two shallow southeasterly flow paths to One Mile Creek. Floodwater ponds in existing gilgai, meander cutoffs and remnant channels in the very flat floodplain between the two waterways.

Due to the relatively flat natural ground slopes and the depth of the proposed subsidence, the extent and depth of undrained depressions in the floodplain will significantly increase. These depressions will partially fill with local rainfall and runoff and slowly evaporate or seep into the local soils. The duration of ponding in the depressions would depend on the depth and duration of rainfall, but based on water balance modelling, they will be unlikely to fill completely, and will be expected to store more than 1 m of water for less than 10% of the time. However, based on modelling of the 50% AEP flood, the depressions would be expected to fill with Boomerang Creek floodwater at least every few years. The ponded water would then persist until it evaporated or seeped into the underlying soil. Depending on the volume of inflow, the ponds could then be expected to persist for several months post- filling.

Within the subsidence zone, peak flood levels would be reduced by up to approximately 3.5 m and 3.0 m in the 50% AEP and 2% AEP floods respectively. The extent of inundation would be increased slightly by backwater flowing up the subsidence troughs. During small flood events, additional flood storage would significantly reduce the peak flow rate and peak flood levels in downstream reaches of Boomerang Creek. In floods larger than the 2% AEP event, the impact of subsidence on downstream flows would be minimal.

Flow velocities would be significantly reduced across much of the floodplain as water is stored in the subsided areas. The slower velocities would promote the deposition of sediment in these areas and the surrounding floodplain. This would result in gradual accretion within the floodplain depressions.

In small floods, the proposed subsidence would result in an increase in the amount of Boomerang Creek floodwater flowing towards One Mile Creek. Velocity increases of 0.25 m/s to 0.5 m/s are predicted over a broad area where Boomerang Creek floodwater approaches One Mile Creek. However, the increased velocities remain low and would be insufficient to erode the floodplain except in localised areas as it drains into subsidence troughs.

The proposed subsidence over the nine panels (in each seam) crossing Boomerang Creek would result in a series of four main troughs in the channel bed due to the interaction of the differential settlement across the longwall panels and the intervening unmined pillars in the two overlying coal seams. These areas would see decreases in channel velocity, bed shear and stream power, causing reductions in sediment transport capacity in each trough, and promoting further aggradation of the bed (relative to the top of bank level) in these areas.

There would be increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone. The deep bed sediments in these reaches are expected to erode relatively quickly as the channel morphology changes to reflect the higher bed grade. This may also lead to marginal increases in bank erosion as the channel capacity increases.

Channel velocity, bed shear and stream power would also increase as flow enters the second and fourth subsidence troughs. The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion may potentially occur to the extent that this elevated section of stream bed will be eroded down to the upstream and downstream bed levels (which will rise as the bed aggradation occurs).

During initial flows, local incision and bank erosion can be expected over the pillars between subsidence troughs. However, given the abundant sediment supplies in Boomerang Creek, the sand bedload will infill the troughs such that the bed grade should revert to approaching the pre-mining grade over time. The expected aggradation relative to the bank levels could accelerate the potential abandonment of the existing Boomerang Creek channel. It should be emphasised that given the number of remnant channels and abundant sediment supplies in the catchment, a new Boomerang Creek channel could form in the absence of the proposed subsidence.

It should also be noted that Alluvium (2019) found that the proposed infilling of subsidence at the proposed Saraji East underground mine through Hughes and Boomerang Creek would potentially cause downstream bedload starvation for a period and this could impact the timing of infilling of the bed at the Meadowbrook Project. This would depend on the timing of flows and mining in both projects. Based on estimated average sediment supply rates to the catchment, in the absence of significant depletion of sediment in the reach of Boomerang Creek between the two projects, it is expected to take 15 to 45 years for the Meadowbrook subsidence depressions to refill with sediment post-mining. Complete replenishment of residual sediment loss attributable to the Saraji East project could take a similar time, however large floods occurring after the completion of mining could significantly reduce these timeframes.

Modelling of flow conditions at intermediate stages indicate the avulsion risk would be greatest around Year 17.

One Mile Creek

One Mile Creek is a Boomerang Creek tributary. In the downstream parts of the proposed subsidence area, One Mile Creek and Boomerang Creek share the same floodplain. However, their geomorphic characteristics are quite different, with the bed material of One Mile Creek being significantly finer, and its channel being smaller and narrower. A large proportion of the upstream catchment of One Mile Creek has been substantially impacted by ongoing mining activities and is now disconnected from the downstream reaches, affecting the flow hydrology and sediment dynamics in the Project area. Parts of the One Mile Creek channel appear to be sediment-limited – with the roots of much of the riparian vegetation being exposed following recent flow events. One Mile Creek is typically 0.75 m to 1.5 m deep, with a top width of approximately 15 m.

The proposed subsidence would result in a series of eight main troughs in the channel bed due to the differential settlement across the longwall panels and the intervening unmined pillars in the one overlying coal seam, which are aligned approximately perpendicular to the channel.

All troughs associated with the One Mile Creek floodplain would be directly connected to the main channel – and during flood flows, water would flow laterally out of the channel into the subsided areas. The north-flowing reaches of the One Mile Creek floodplain would also experience minor impact from the construction of the temporary levee proposed around the northern end of the open cut pit mining area. At the completion of open cut mining, the levee would be decommissioned, and the One Mile Creek floodplain would be restored to pre-mining levels through partial backfilling of the mined pit.

Within the subsidence zone, peak flood levels are expected to be reduced by up to 1.3 m in the 50% AEP flood; and up to 1.5 m in the 2% AEP flood. In floods larger than the 2% AEP event, the impact of subsidence on downstream flows would be minimal.

Parts of the channel within subsidence troughs would see decreases in channel velocity, as well as decreases in bed shear and stream power, causing reductions in sediment transport capacity in each trough, and promoting further aggradation of the bed (relative to the top of bank level) in these areas.

There would be increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone. Velocities in this area would remain low but given the relatively fine sediment in this area and the apparent limitation in sediment supply, these reaches are expected to erode as the channel morphology changes, to reflect the higher bed grade. This may also lead to increases in bank erosion as the channel capacity increases.

Channel velocity, bed shear and stream power also increase as flow enters the second to fifth subsidence troughs. The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion would occur through this elevated section of stream bed.

If there was sufficient sediment supply, the post subsidence channel velocity, bed shear and stream power would revert towards pre-mining conditions. However, as it appears sediment supply is limited by upstream activities, the ponds formed by the subsidence may persist for a comparatively long time.

To promote the movement of water and sediment through this reach, Bowen Basin Coal is committed to decommissioning the existing farm dam on One Mile Creek prior to the commencement of mining.

Where practical, minor drainage channels are proposed to drain the subsidence panels, however as this is not possible in all areas, ponding of runoff captured in the floodplain between Boomerang and One Mile Creeks would effectively reduce the local catchment draining to One Mile Creek by approximately 9 km^2 (6.9%).

During open cut operations, water which would normally flow to One Mile Creek would be intercepted by the proposed mine water management system within the levees protecting the mine pit and sediment dams. During the period of peak open cut mining disturbance, the temporary maximum additional reduction in catchment area to One Mile Creek would be approximately 3 km^2 (i.e. a total of 12 km^2) At the completion of mining and rehabilitation of the final landform, this would reduce to approximately 1.5 km^2 (i.e. a total catchment loss of 10.5 km^2 - 8%).

This catchment loss would impact the downstream 4 km to 6 km reach of One Mile Creek in minor runoff events, (which has been impacted by historical mining activities in the upper catchment) but would not significantly further alter the flow regime. The impacts of the catchment loss would be minimal downstream of the confluence, where it would make up 1.8% of the 489 km^2 total catchment.

Water balance modelling of the overland flow into the One Mile Creek depressions shows their median stored volume would total only 20 ML, but they could intercept approximately 283 ML/a of catchment runoff on average (median 96 ML/a).

Phillips Creek floodplain

The main channel of Phillips Creek will not be impacted by the proposed subsidence. However, four underground panels crossing the northern Phillips Creek floodplain would impact flooding and drainage. The proposed temporary levee around the south-eastern end of the open cut mining area would also impact flood flows until it was decommissioned.

A minor drainage channel would be constructed around the toe of the levee to ensure the floodplain is free draining. Drainage channels would be cut through the pillars separating the subsidence troughs to allow free drainage of catchment runoff through the subsidence zone. The drainage channels would be designed to manage the risk of erosion that would result from the localised concentration of flow. Small embankments are also proposed across the subsidence panels to restrict the flow of water from Phillips Creek to One Mile Creek. The remaining small depression would intercept a portion of the overland flow from the local catchment of 1,436 ha (about 2.8% of the total Phillips Creek catchment). The average annual volume captured by the pond is estimated to be 167 ML/a (about 0.8% of the average annual flow in Phillips Creek at the project).

There would be a 0.3 km^2 temporary loss of Phillips Creek catchment to the mine water management system during open cut operations and a loss of 0.03 km^2 after rehabilitation of the final landform. These losses would have negligible impacts on downstream flows.

Ongoing monitoring and mitigation measures

A subsidence monitoring plan will be developed to assess the changes in bed levels and the impact of increased localised sedimentation. Bank protection measures will be considered if monitoring indicates that the increase in erosion is having a demonstrable impact on the channel form.

Overland flow from local catchments captured in subsidence depressions may be pumped downstream if required to manage impacts on downstream flow paths.

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1 Introduction

1.1 BACKGROUND

The 'Lake Vermont Meadowbrook Project' (the Project) is a proposed extension of the existing Lake Vermont Mine, proposed by Bowen Basin Coal Pty Ltd (BBC). The Project is located approximately 25 kilometres northeast of Dysart and approximately 160 kilometres southwest of Mackay, within central Queensland (Figure 1.1).

WRM Water & Environment Pty Ltd (WRM) was commissioned by Bowen Basin Coal to undertake a surface water assessment for the Project. The surface water assessment will form part of an Environmental Impact Statement (EIS) for the Project under the *Environment Protection Act 1994 (QLD)*.

This report details the assessment of the potential impacts of the Project on the geomorphology of streams crossing the Project area.

1.2 PROJECT DESCRIPTION

The Project is proposed to include the development of a double-seam underground longwall coal mine, along with a small-scale open-cut pit targeting coal resources adjacent to the north of the existing Lake Vermont Mine.

To support the operation of the proposed underground development, a new 'satellite' mine infrastructure area (MIA) will be constructed. A new infrastructure corridor will also be constructed, linking the new MIA to the existing infrastructure located at Lake Vermont Mine. This infrastructure corridor will enable the delivery of power and water, provide personnel and materials access, as well as facilitate the clearance of run-of-mine (ROM) coal to the existing Coal Handling and Preparation Plant (CHPP). A conceptual project layout is provided through Figure 1.2.

The Project is expected to produce approximately nine million tonnes per annum (Mtpa) of metallurgical product coal (for the export and domestic market) over an operational mine life of approximately 30 years. The output from the Project will supplement the scheduled decline in production from the existing open-cut operations, so that the total output from the Lake Vermont complex will be maintained within the existing Environmental Authority (EA) limit of 12 Mtpa of ROM coal.

The proposed mine development will therefore be comprised of:

- a double seam underground longwall coal mine (supported by some bord and pillar mining development);
- a small 'satellite' open-cut pit;
- a mine clean water dam as well as a dewatering dam (with locations and sizing to be determined as part of detailed technical studies);
- a new MIA;
- a surface ROM stockpile located within the new MIA;
- a truck haulage road to deliver ROM coal from the new MIA to the existing CHPP;
- an infrastructure corridor for the delivery of power and water as well as an access roadway for the movement of personnel and materials; and
- a network of gas drainage bores and associated surface infrastructure, including access tracks, across the underground mine footprint.

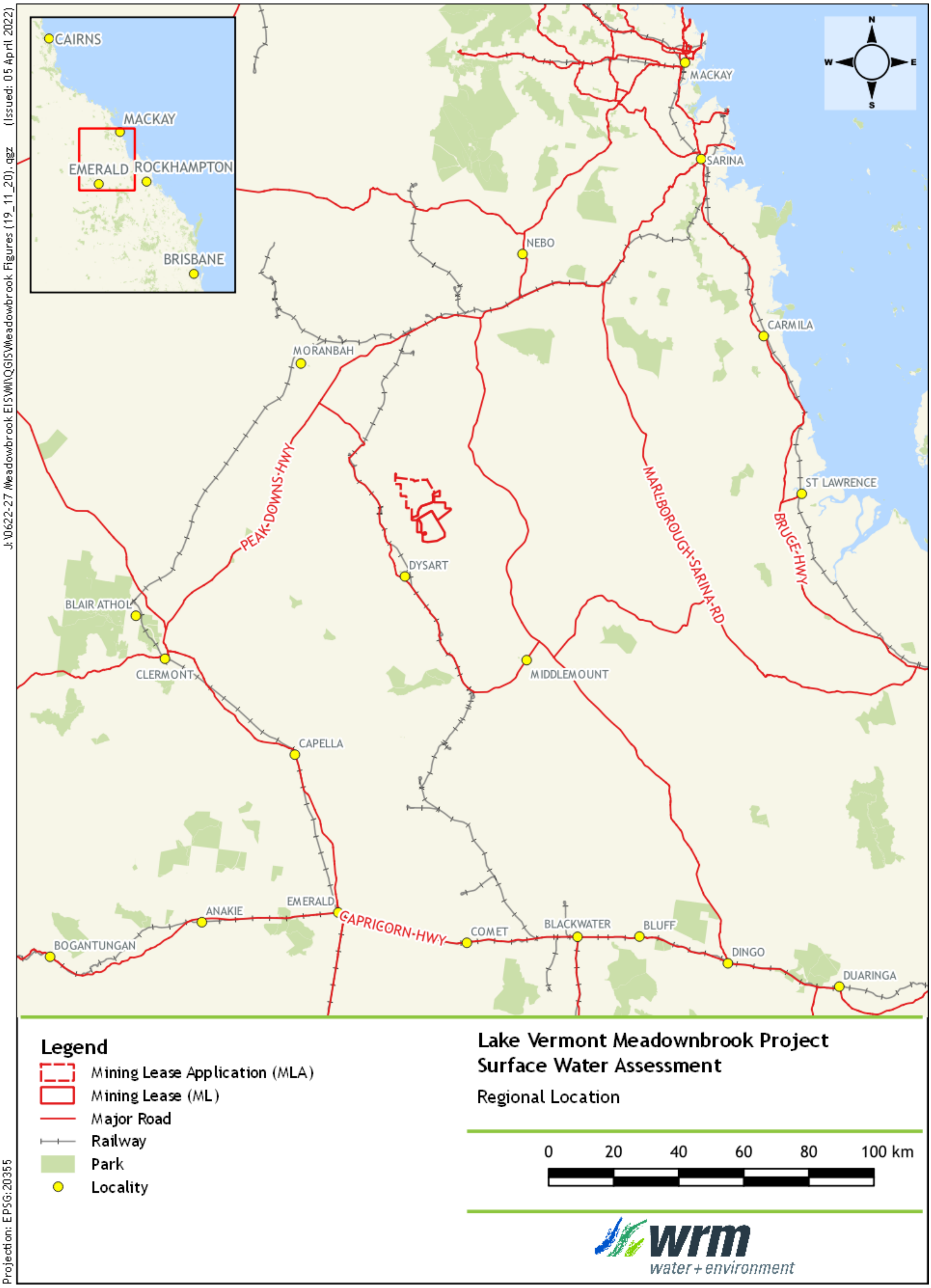

Figure 1.1 – Regional location

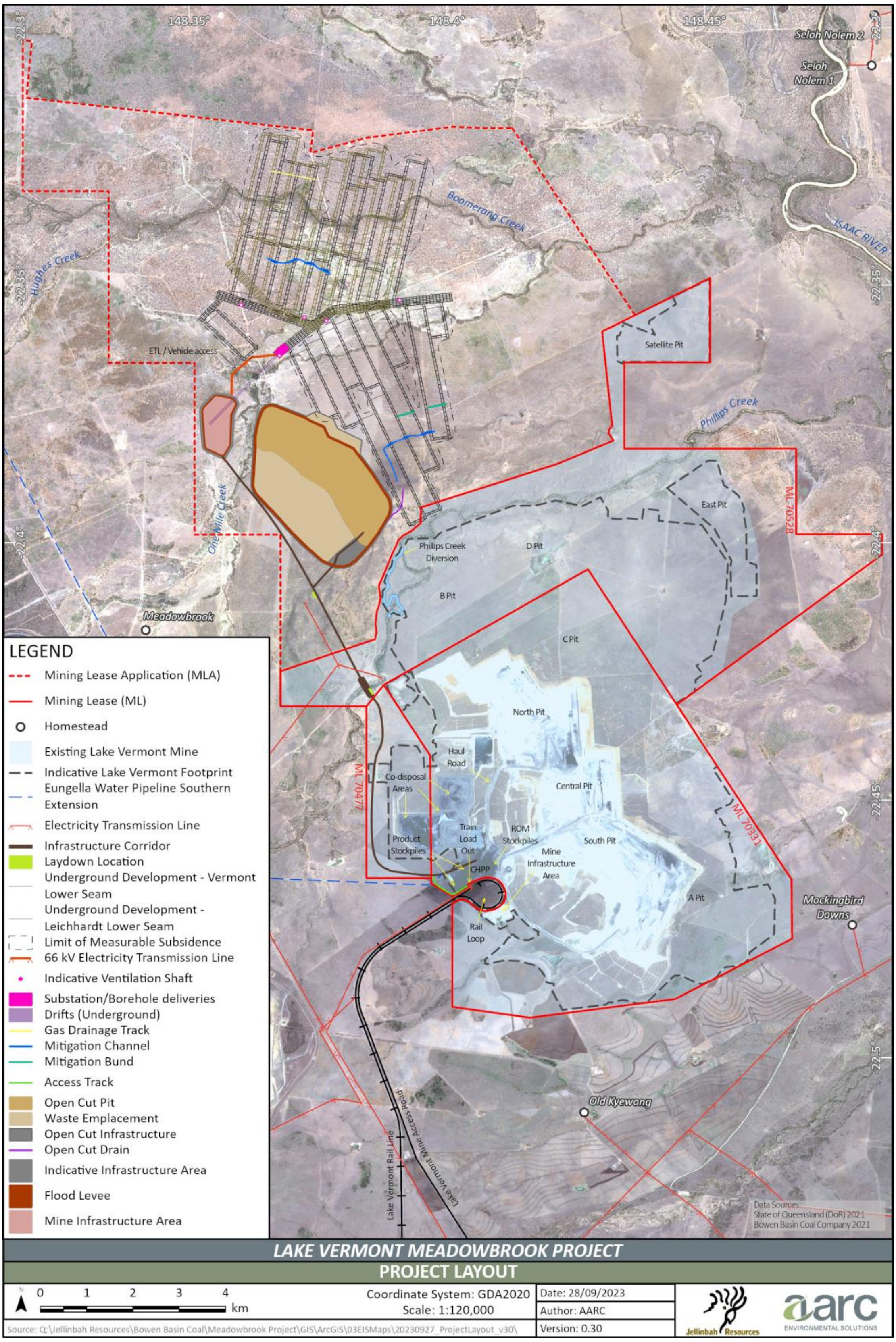

Figure 1.2 – Project layout

1.3 TERMS OF REFERENCE

This assessment forms part of an EIS which has been prepared in accordance with Queensland's Environmental Protection Act 1979 (EP Act). This assessment has been prepared to satisfy the requirements of the Project Terms of Reference (TOR) issued in April 2020 (Queensland Government, 2020).

1.4 METHOD OF ASSESSMENT

This report describes the various waterways that will be impacted by Project activities and particularly mine subsidence associated with longwall mining and identifies the locations at which preventative works may be required to mitigate potential impacts.

The existing geomorphic condition of waterways that will be affected by mining have been described following a site inspection and hydraulic modelling. The site inspection identified the current condition of the streams including bank vegetation, bed form (sediment characteristics) and identified existing locations and types of bed or bank erosion.

A two-dimensional hydraulic model was developed for the flood and geomorphic assessment of the waterways crossing the Project area. The two-dimensional model results were converted to section-average results to assist with the hydraulic characterisation of the waterway channels. Models have been developed for pre-project ("approved") conditions, which assumes all approved mining activities within the existing Lake Vermont Mine have been completed, and proposed post mining conditions, which assumes that both the approved and proposed Project mining (underground and open-cut operations) have been developed. Modelling was also undertaken for intermediate stages (Year 12 and Year 17 of the project development) to identify periods of temporarily increased avulsion risk.

Stream velocity, bed shear stress and stream power have been used as indicators of potential stream impacts, where changes between pre- and post-mining conditions would suggest some change in the stream characteristics may occur. The modelling assumed that both the stream channel and overbank areas would be subsided as per the mine subsidence predictions and that no infilling or erosion of the channel bed or banks has occurred. In practice, the transport of sediment and aggradation of the bed would reduce the magnitude of the impact on stream characteristics over time compared to the modelling results presented in this report.

1.5 REPORT STRUCTURE

This report is structured as follows:

- Section 2 describes the existing catchment characteristics, including the surface topography, geology, soils, groundwater surface water hydrology and geomorphic characteristics;
- Section 3 describes the how the proposed mining activities could directly and indirectly impact the geomorphological characteristics of the waterways crossing the Project area, including potential mitigation measures; and
- Section 4 presents of summary of findings for the assessment.

2 Geomorphic setting

2.1 GEOLOGY

2.1.1 Solid geology

The Meadowbrook Project Groundwater Impact Assessment (JBT, 2022) includes the following precis of the regional geological structure, which was based on work by Minserve (2017):

- The Project lies on the western limb of the Bowen Basin, a north-south trending retro-arc basin that extends more than 250 km north to south and up to 200 km west to east.
- The Project is located at the eastern end of the Collinsville Shelf, which is characterised by a thin accumulation of sediments, gentle easterly dips and minor structural deformation.
- The eastern boundary of the Collinsville Shelf occurs at the Isaac Fault, a major thrust fault which has throws of 150 to 400 m in the Project area.
- The intensely folded and faulted sediments of the Fort Cooper Coal Measures and Rangal Coal Measures occur to the east of the Isaac Fault within the 2 to 3 km wide Isaac Block.
- The Isaac Block is flanked to the east by another major thrust fault, with sediments to the east occurring in a block known informally as the Central block.
- A third large thrust fault, with a throw of approximately 300 m, marks the eastern edge of the Central block. To the east of the third thrust fault occur subcropping sediments of the Rangal Coal Measures and overlying Rewan Group, within a fourth structural block known as the Eastern block.

The above relationships can be observed in the solid geology map in Figure 2.1. The map was prepared by removing the Cainozoic (Quaternary and Tertiary) cover sediments.

Figure 2.1 also shows the locations of geological sections (two west-east sections oriented across strike and one north-south section that has been oriented through the central area of the proposed underground mining). The west-east sections are shown in Figure 2.2 and the north-south section is shown in Figure 2.3 . The main geological units are discussed briefly below:

- **Triassic Rewan Group** – The Sagittarius Sandstone, the basal formation of the Rewan Group, occurs beneath Cainozoic sediments over much of the Project area. The unit is up to 300 m thick and comprises greyish-green sandstone, siltstone and mudstone.
- **Rangal Coal Measures** – The Late Permian Rangal Coal Measures are coal-bearing sediments that contain the target coal seams for the Meadowbrook Project (Leichhardt Lower and Vermont Lower seams).
- **Fort Cooper Coal Measures** – The Late Permian Fort Cooper Coal Measures underlie the Rangal Coal Measures. The unit subcrops beneath Tertiary sediments within the Project area due to either the dip of the strata (western area of the Project) or due to faulting (e.g. east of the Isaac Fault). The uppermost coal seam in the Fort Cooper Coal Measures in the Project area is the Girrah Seam, which subcrops to the west of the Rangal Coal Measures subcrop line.

The coal resources of the Project occur within a slightly asymmetric, north-northwest trending, north plunging synclinal structure where the coal measures crop out at the west due to the dip of the strata, but which are truncated to the east by the Isaac River. Within the Project area the dip of the coal seams is relatively steep (5° to 10° in the east near the subcrop line), but the dip flattens out to the west as shown in the west-east geological sections.

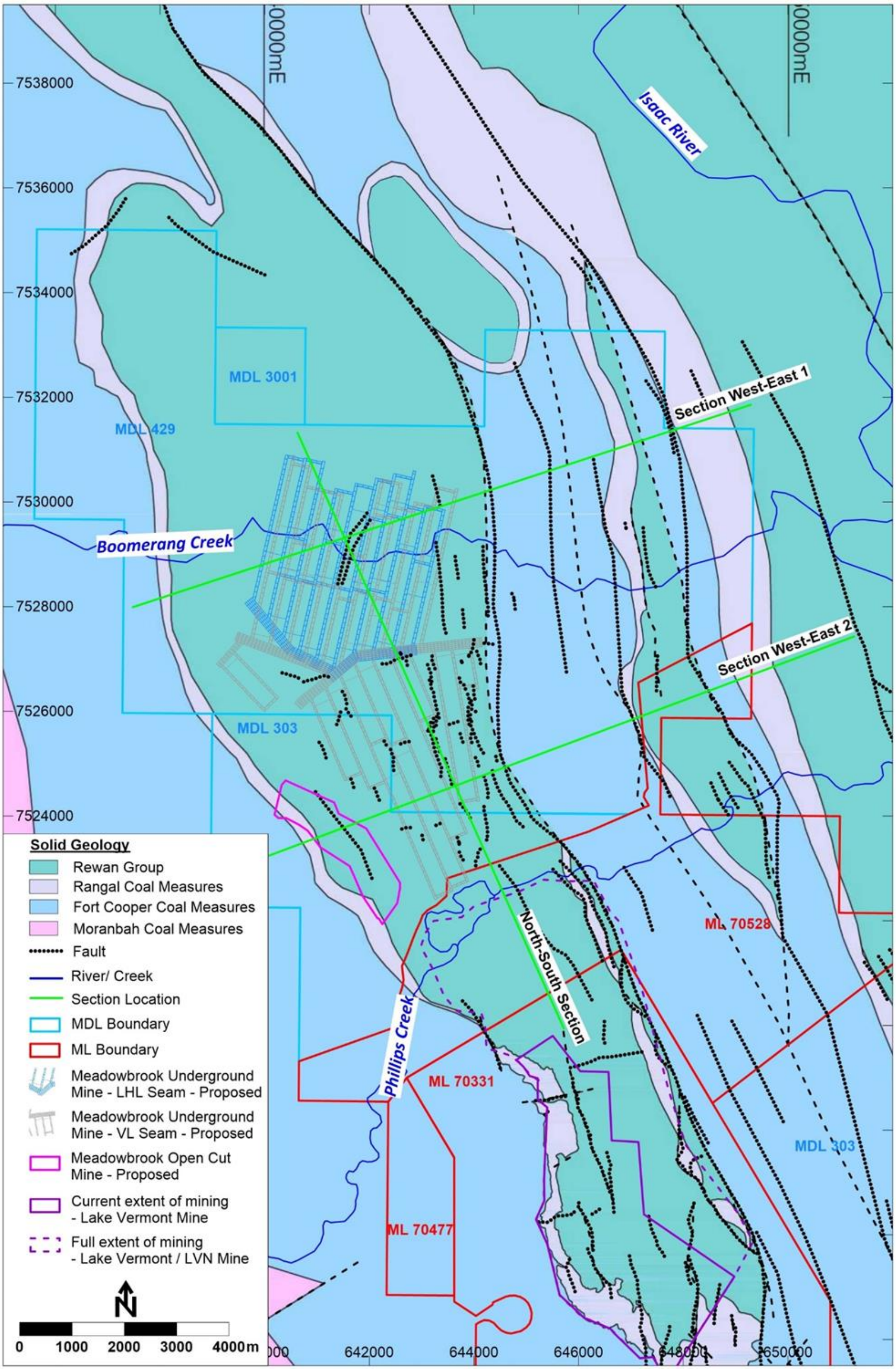

Figure 2.1 – Solid geology

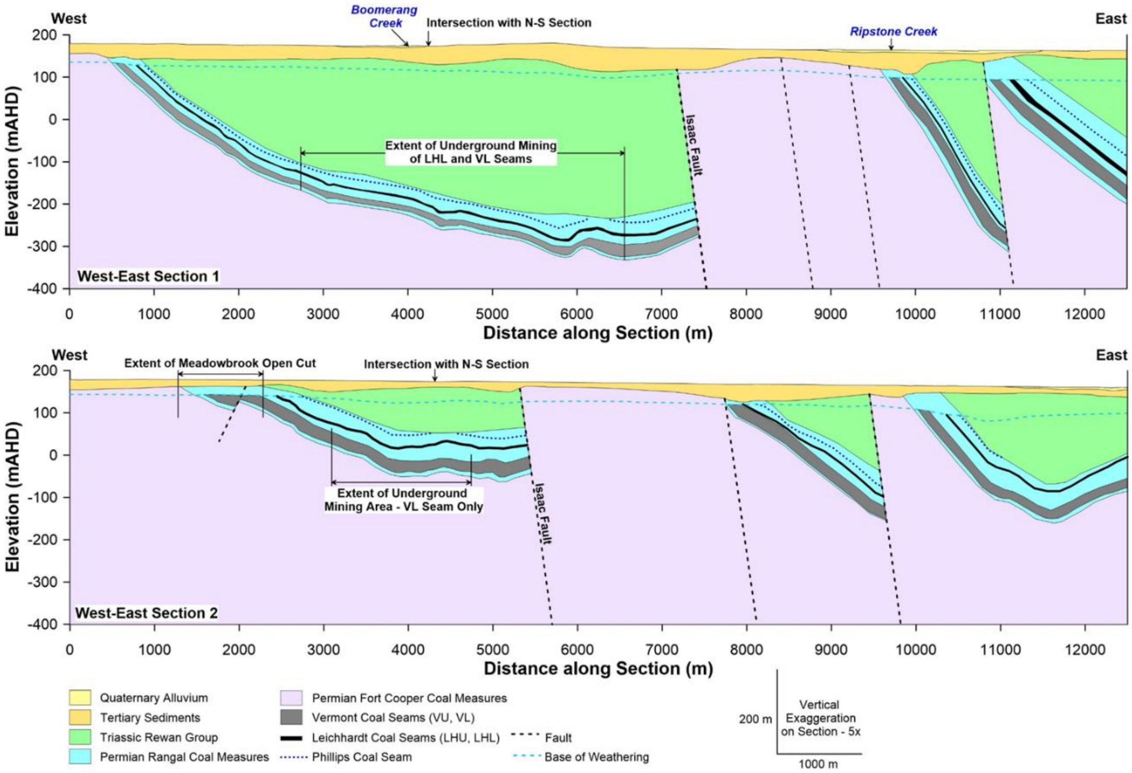

Figure 2.2 – West-East geological sections

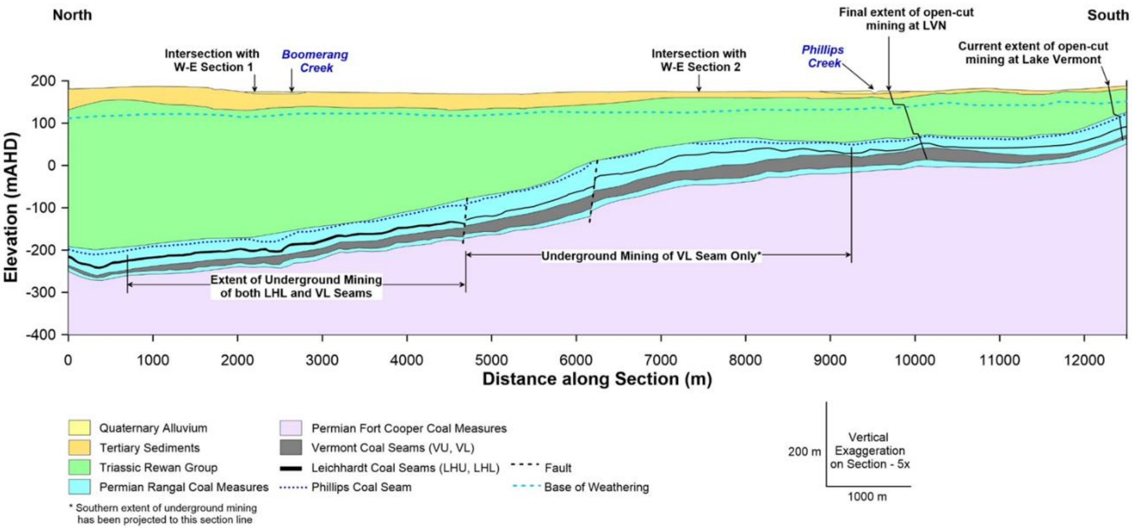

Figure 2.3 – North-South geological section

The Vermont/ Lower Vermont seam, the principal commercial seam mined in the Project area, occurs at a depth of 100 m in the southwest of the mining area where the seams subcrop (i.e. the area of the proposed Meadowbrook open cut (but deepens significantly to the northeast of the underground area where the depth to the base of the seam occurs at a depth of 500 m.

2.1.2 Surface geology

The Permian and Triassic sediments are overlain by unconsolidated to poorly consolidated Tertiary and Quaternary (Cainozoic) sediments. They comprise alluvial sands, clayey sands and clays, with a basal layer in some locations of sand and gravel (Minserve 2017).

The surface geology of the Project area is shown in Figure 2.4, which is based on 1:100,000 scale digital geological mapping of the region. However, as the Grosvenor Downs geological sheet does not delineate Boomerang Creek alluvium, the data has been supplemented based on interpretation of remote imagery, along with geological and groundwater drilling data (JBT, 2022).

JBT also estimated the thickness of Cainozoic sediments in the Project area. Due to their sandy nature (with no silty/clayey base to the recent alluvial deposits), it was not possible to reliably delineate between recent (Quaternary) alluvium and older (Tertiary) alluvium from prior channels/floodplain deposits. Based on interpretation of available data, JBT concluded that:

- The Tertiary sediments are sandier within the Project area and in the vicinity of Boomerang Creek than the area to the south (the area within ML70528 and adjacent to Phillips Creek).
- The thickness and extent of Quaternary alluvium that is associated with Phillips Creek tends to be greater than the interpreted thickness and extent of Quaternary alluvium that is associated with Boomerang Creek.
- The thickness of the Boomerang Creek alluvium may be up to 14 m, but at some locations the sand can be up to 26 m thick from the surface, and it is not possible to determine the interface between Quaternary and Tertiary sand.

2.1.3 Hydrogeology

JBT (2022) concluded:

- the regional water table is generally developed in the Tertiary sediments below the base of alluvium;
- the Quaternary alluvium in Boomerang Creek is likely to be only seasonally saturated, with downward seepage to underlying units resulting in dry alluvium for most of the year.

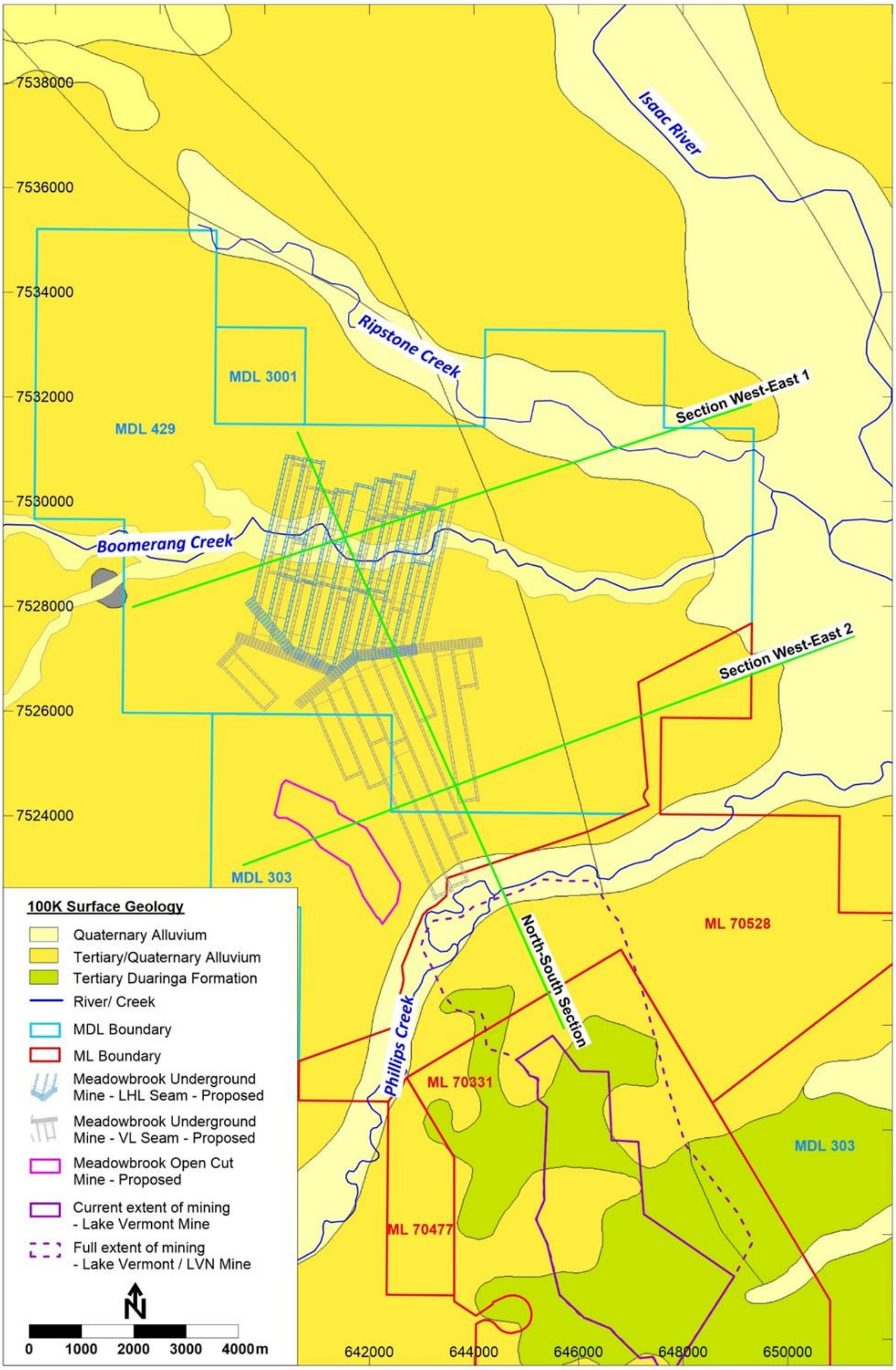

Figure 2.4 – Surface geology (JBT, 2022)

2.2 REGIONAL CATCHMENT CHARACTERISTICS

The Project is located within the Isaac-Connors sub-catchment of the greater Fitzroy Basin. The Isaac River is the main watercourse in the vicinity of the Project area and flows in a south-easterly direction to the east of the Project.

The Isaac River catchment commences at the Denham Range located about 97 km to the north of the Project. The Isaac River flows in a south-westerly direction through the Carborough and Kerlong Ranges before turning in a south-easterly direction near the Goonyella Riverside Mine. The Isaac River converges with the Connors River and then the Mackenzie River 150 km downstream of the Project.

Ultimately, the Mackenzie River joins the Fitzroy River, which flows initially north and then east towards the east coast of Queensland and discharges into the Coral Sea southeast of Rockhampton, near Port Alma.

Figure 2.5 shows the location of the Project and Isaac River catchment upstream of the Connors River confluence. Figure 2.6 shows the drainage characteristics of the Upper Isaac River to the Phillips Creek confluence, which drains through the Project area.

The greater Isaac-Connors sub-catchment area is approximately 22,364 square kilometres (km^2) (to the Mackenzie River confluence), out of a total Fitzroy River catchment of 142,665 km^2. That is, it represents around 15% of the overall Fitzroy River catchment.

The catchment area of the Isaac River to the Project is around 4,100 km^2. This represents around 2.9% of the overall Fitzroy River catchment and 18.3% of the Isaac-Connors sub-catchment.

The maximum Project disturbance footprint is approximately 70 km^2 and represents 0.05% and 0.3% of the overall Fitzroy River and Isaac-Connors catchment areas, respectively.

The Isaac River is a seasonally flowing watercourse, typically with surface flows in the wetter months from November to April, reducing to little or no flow from about May to October. All waterways and drainage lines in the vicinity of the Project area are ephemeral and experience flow only after sustained or intense rainfall in the catchment. Stream flows are highly variable, with channels drying out during winter to early spring when rainfall and runoff is historically low, although some pools hold water for extended periods. Therefore, physical attributes, water quality, and the composition of aquatic flora and fauna communities are highly variable over time.

The Isaac River catchment upstream of the Project comprises mainly scattered to medium dense bushland, grazing land and the township of Moranbah. There are several existing coal mines in the Isaac River catchment, including Burton, North Goonyella, Goonyella Riverside, Broadmeadow, Broadlea North, Isaac Plains, Moranbah North, Millennium, Daunia, Poitrel, Grosvenor, Peak Downs, Saraji, Norwich Park and Lake Vermont. In addition, Pembroke Resources' Olive Downs Project is an approved (but not constructed) mine to the north (see Figure 2.7).

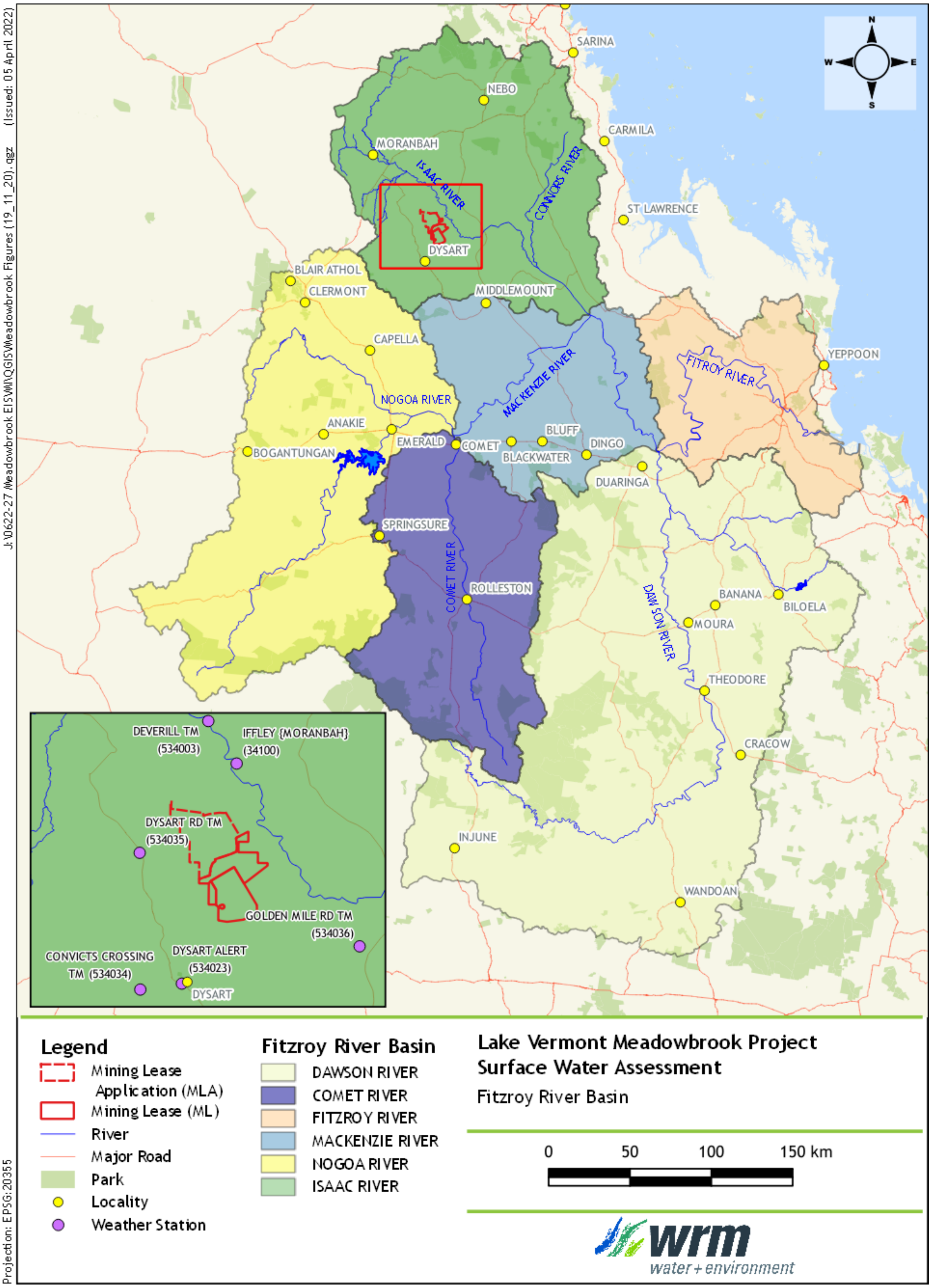

Figure 2.5 – Fitzroy River Basin

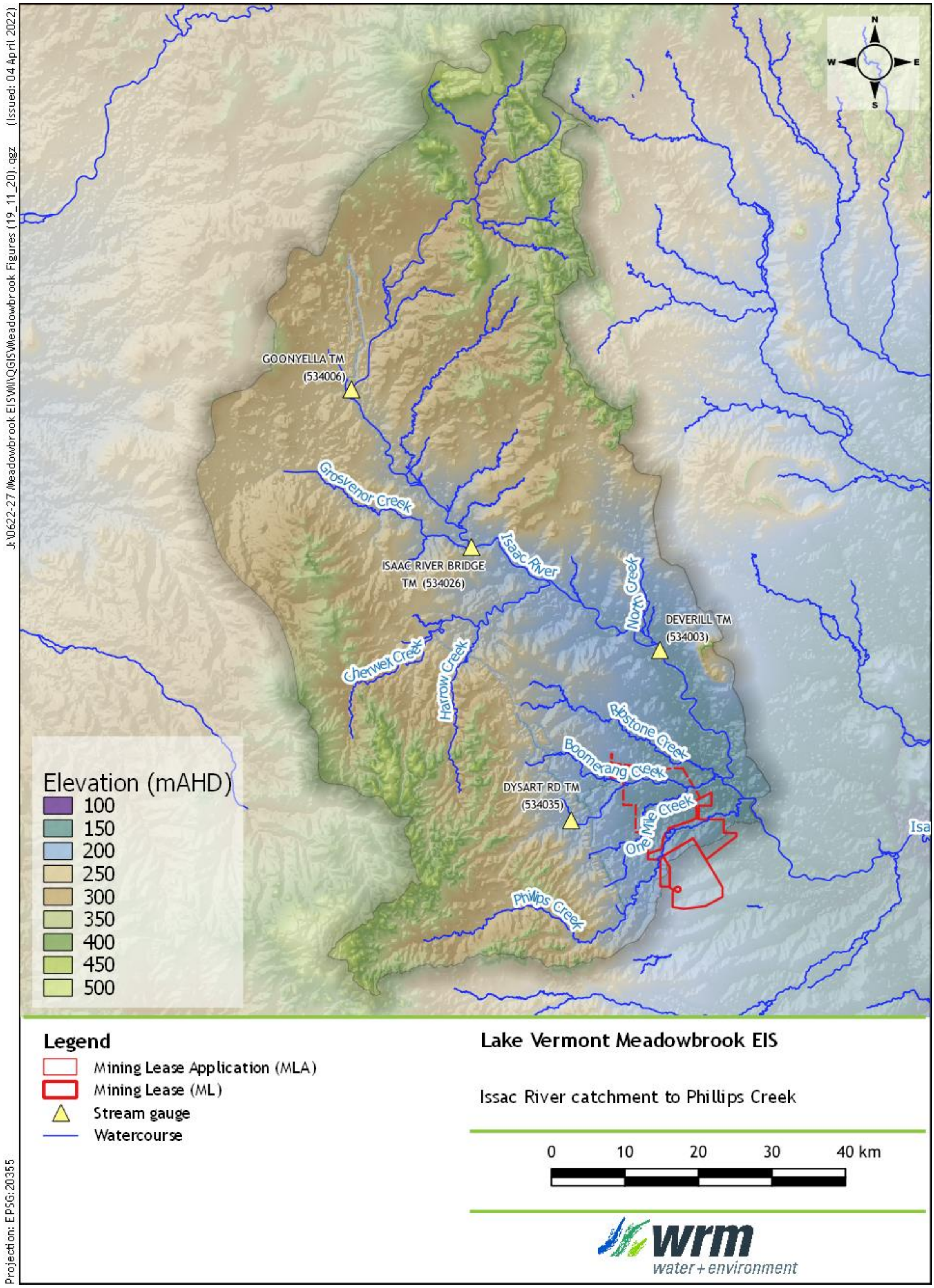

Figure 2.6 – Upper Isaac River catchment

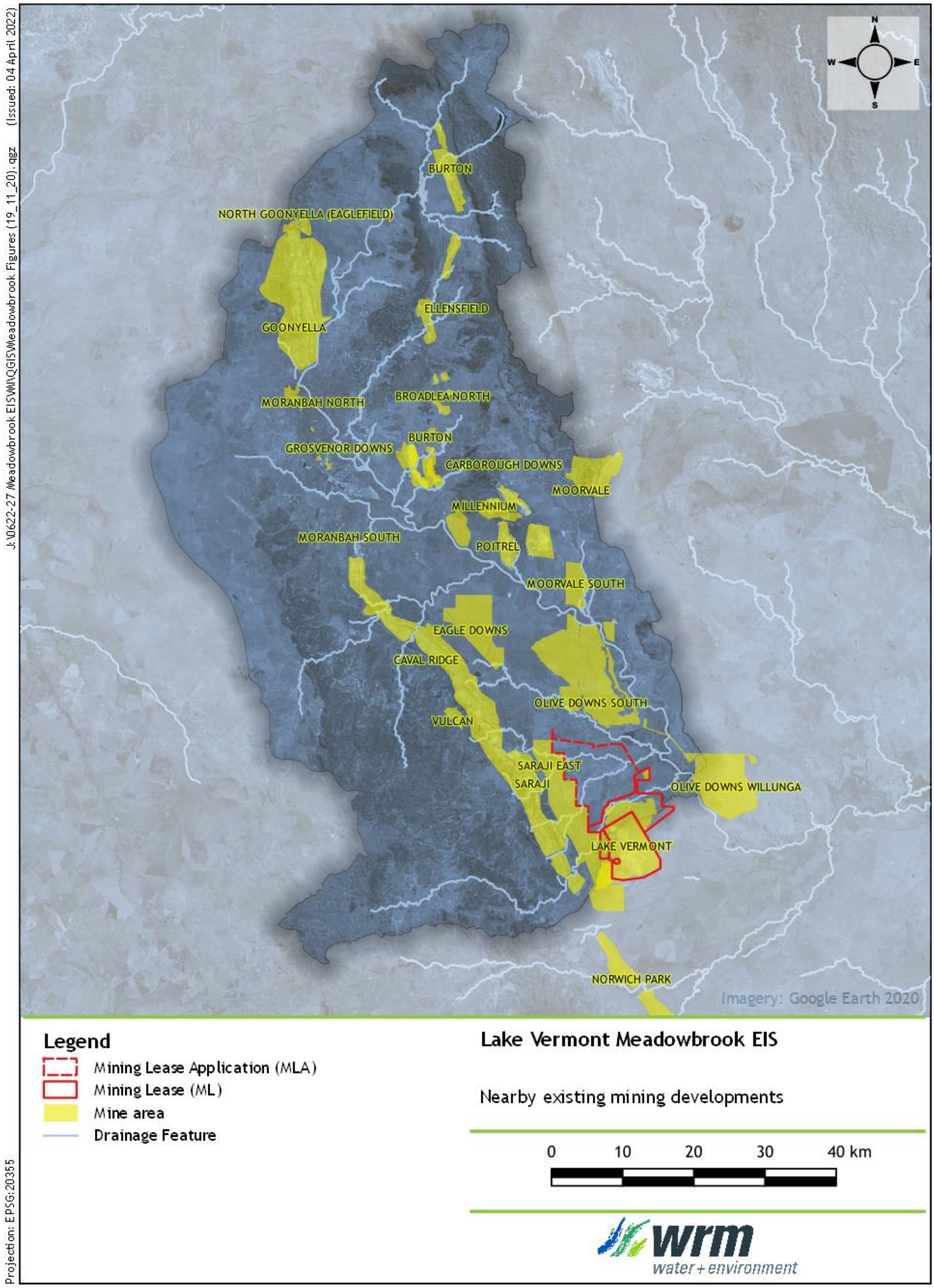

Figure 2.7 – Nearby existing mining developments

2.3 LOCAL CATCHMENT CHARACTERISTICS

2.3.1 Overview

The Project area drains to the Isaac River via tributaries of Phillips Creek (to the south) and Boomerang Creek (to the north) shown on Figure 2.8/Figure 2.9. The waterways passing through the Project area originate in the Harrow Range, where they are confined in narrow valleys by hillslopes and bedrock. Downstream of the range, they pass through Saraji mine, where they are diverted via narrow corridors between open cut pits. A description of the various waterways in the vicinity of the project is as follows:

- **Ripstone Creek** commences about 20 km to the northwest of the Project area and traverses in a southeasterly direction across the northern parts of the Project area before draining to Boomerang Creek approximately 0.5 km to the east of the Project area. Ripstone Creek has a catchment area of approximately 303 km^2 to the confluence with Boomerang Creek, of which 12% is within the Project area. The lower reaches of Ripstone Creek are relatively flat (0.12% slope) and the main channel of the creek is meandering with a sinuosity index of 1.5 (measured as the ratio of main channel length to valley length). A value of greater than 1.5 is meandering (Garcia, 2015). Ripstone Creek will not be impacted by the Project.
- **Boomerang Creek** catchment begins about 21 km to the west of the Project area and discharges into the Isaac River approximately 4 km east of the Project area. The Boomerang Creek catchment to its confluence with Isaac River is approximately 796 km^2 and comprises the sub-catchments of Ripstone Creek, Plumtree Creek, East Creek, Hughes Creek, Barrett Creek, East Creek, One Mile Creek and Spring Creek. The Project area covers an area of approximately 95.5 km^2, or 12% of the Boomerang Creek catchment. The lower reach of Boomerang Creek through the Project area is relatively flat (0.15% slope) and the main channel of the creek is of low sinuosity (sinuosity index of 1.2).
- **Hughes Creek** commences about 25 km west of the Project area and drains in an easterly direction to its confluence with Boomerang Creek near the upstream boundary of the Project area. Hughes Creek has a catchment area of 175 km^2, of which 0.2% is within the Project area. Barrett Creek drains into Hughes Creek upstream of Saraji Mine.
- **One Mile Creek** commences about 15 km southwest of the Project area and drains in a northeasterly direction through the Project area to Boomerang Creek. The channel and catchment of One Mile Creek have been significantly modified within the Saraji Mine. Spring Creek drains to One Mile Creek approximately 0.6 km upstream of the Project area. One Mile Creek has a catchment area (including Spring Creek) of approximately 132 km^2, of which 27% is within the Project area. One Mile Creek through the Project area is relatively flat (0.1% slope) and the main channel is meandering (sinuosity index of 1.6).
- **Phillips Creek** runs west to east into the Isaac River, south of the Project area. It has a catchment area of approximately 514 km^2 to its confluence with the Isaac River. The Project area covers an area of approximately 24.5 km^2, or 4.8% of the Phillips Creek catchment, and both these streams would be crossed by the proposed haul road.

The proposed underground mining operations underly Boomerang Creek and One Mile Creek and the floodplain of Phillips Creek. The proposed open cut operations are located between Phillips Creek and One Mile Creek. Phillips Creek and Hughes Creek/Boomerang Creek and One Mile Creek have been determined as watercourses under the *Water Act 2000* (QLD).

Land uses within these catchments include cattle grazing and open cut mining. Mining activities upstream at Peak Downs and Saraji mine have altered flow paths, with major diversions of Ripstone Creek, Boomerang Creek, East Creek, Hughes Creek, One Mile Creek, Spring Creek and Phillips Creek. Lake Vermont Resources has approval for a proposed diversion of Phillips Creek adjacent to the Project area and Pembroke Resources has approval for a diversion of Ripstone Creek, both of which have not yet been constructed.

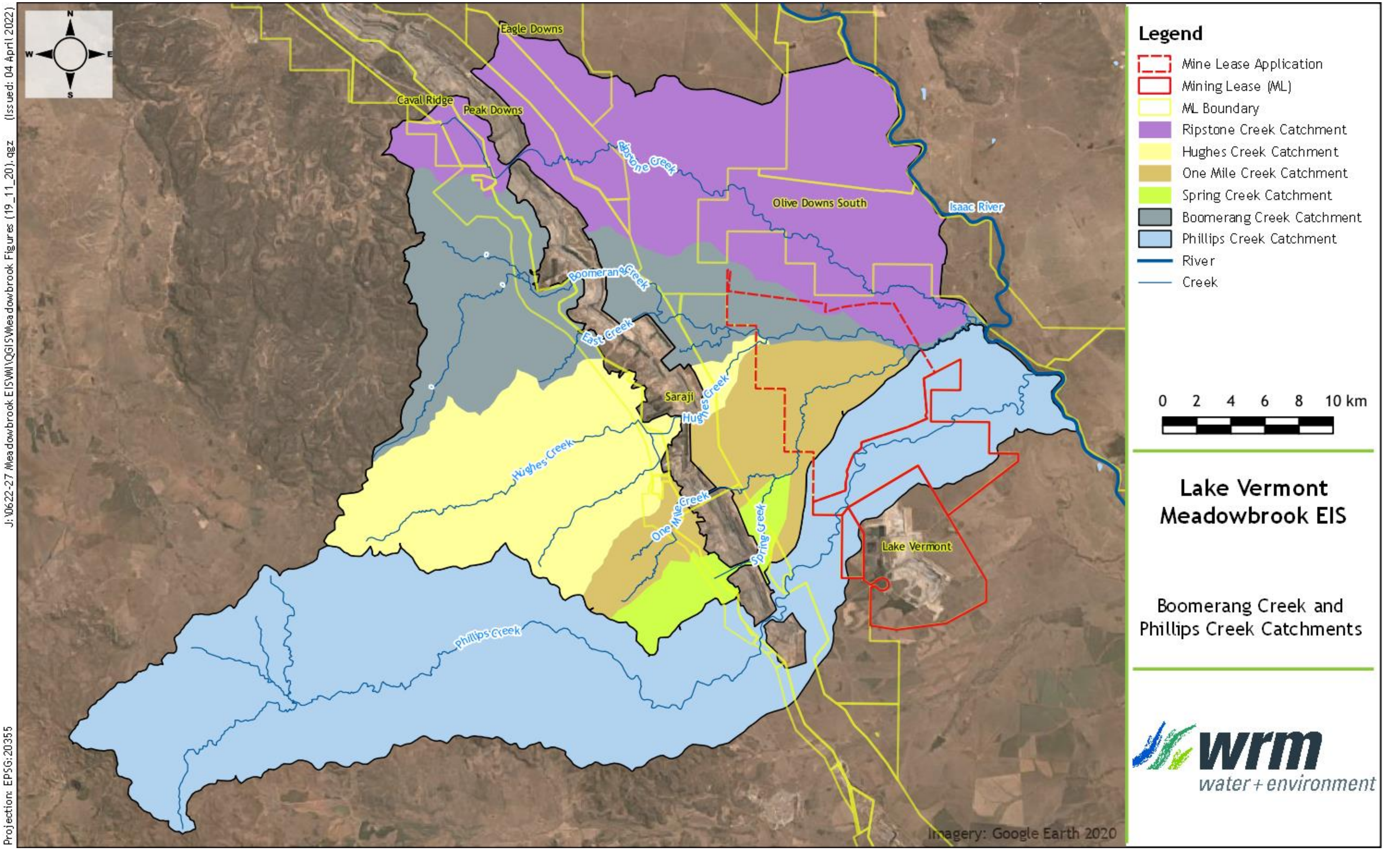

Figure 2.8 – Catchments draining through the Project area

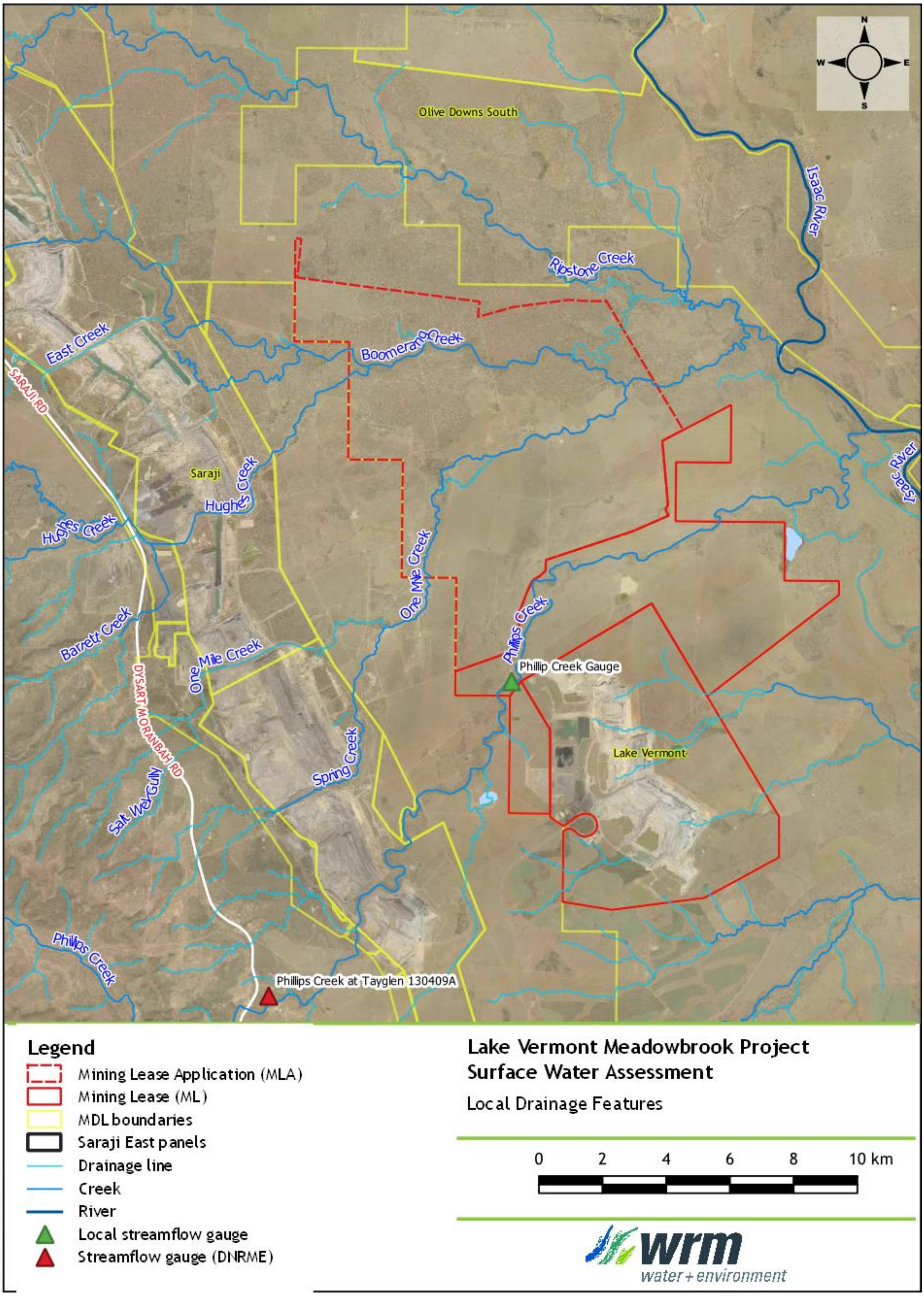

Figure 2.9 – Local drainage features

2.3.2 Landform characteristics

As shown in Figure 2.10, the ground surface levels within the Project area range from approximately 200 mAHD at the north-western boundary to approximately 150 mAHD near the eastern boundary. Over most of the Project area, land slopes are very flat, typically less than 2° (refer Figure 2.11).

Figure 2.12 shows the Multiresolution index of valley bottom flatness (MRVBF) across the Project area. MRVBF uses slope and elevation percentile to assist in the objective separation of floodplains from their surrounding hillslopes. Values of MRVBF greater than 5 correlate well with the extent of flooding in large floods across the Project area.

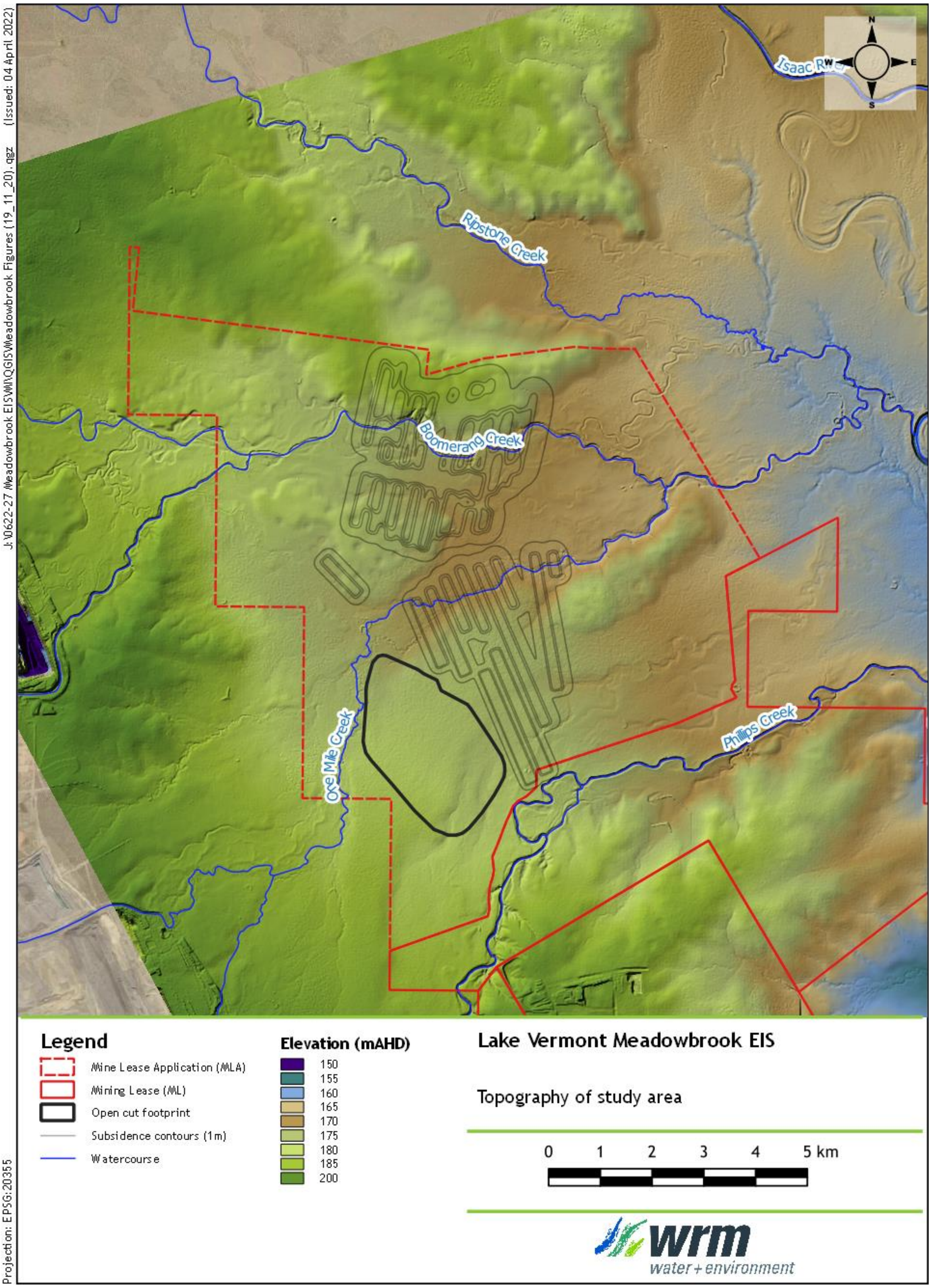

Figure 2.10 – Ground elevations at the Project area

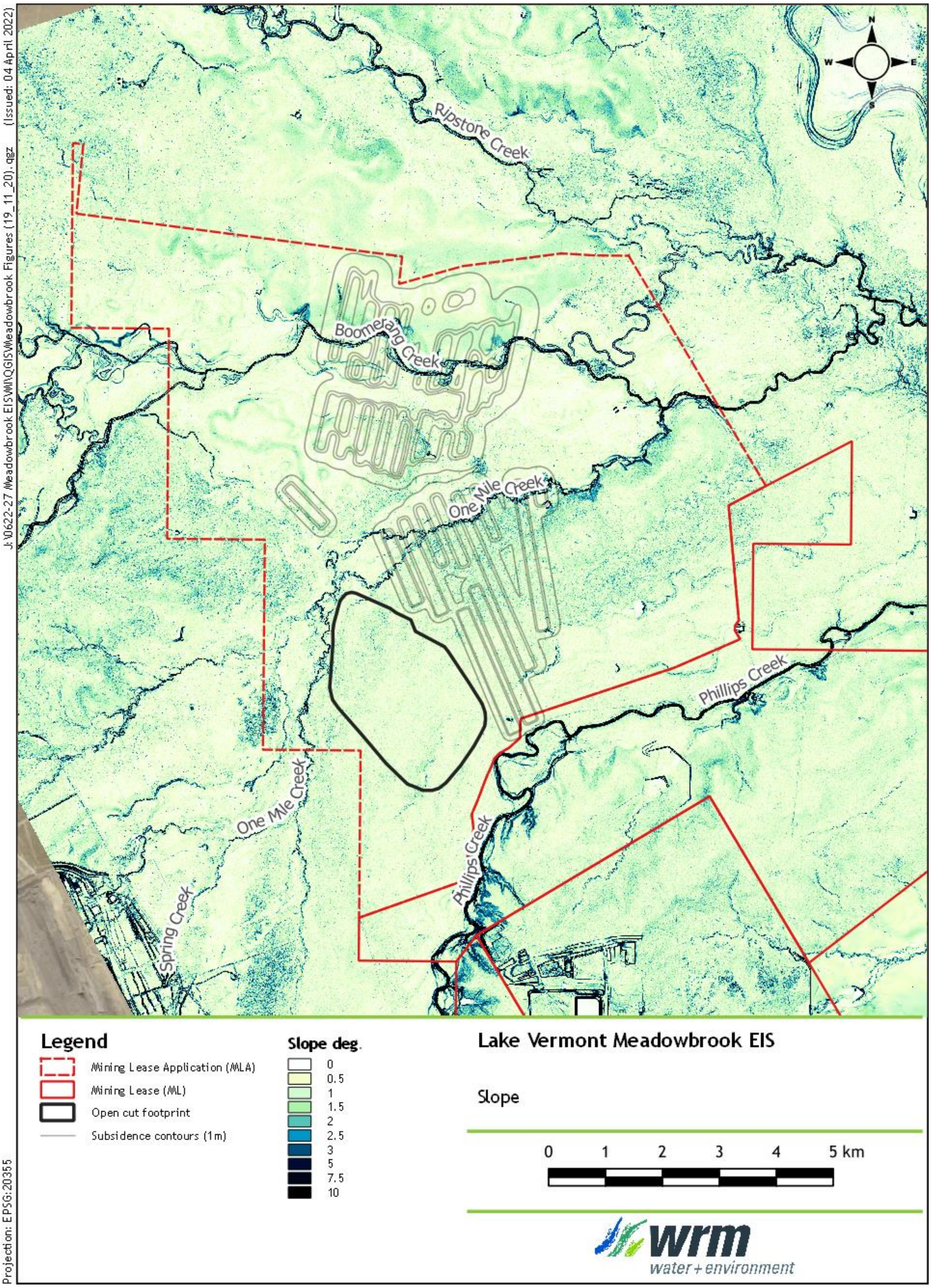

Figure 2.11 – Ground slope across the Project area

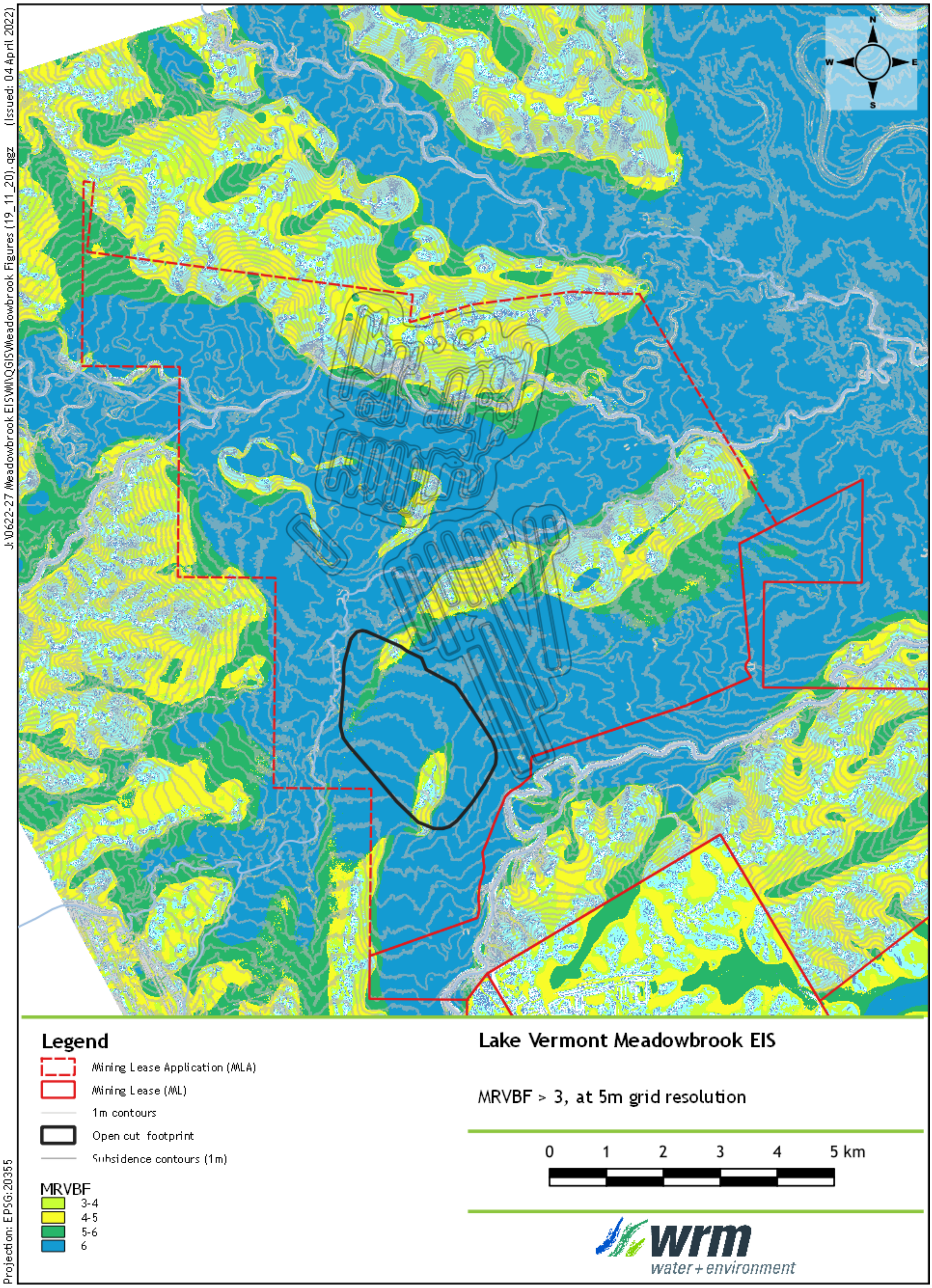

Figure 2.12 – Multiresolution index of valley bottom flatness

Across the Project area, the Boomerang Creek channel is partially confined by hillslopes to the north. It meanders across a broad floodplain draining in an easterly direction towards One Mile Creek. Sediment loads are high, aggrading the channel bed and obliquely accreting the channel banks. Meander cut-offs have formed billabongs adjacent to Boomerang Creek (Alluvium, 2019).

The long-term deposition of sediment over the channel banks during flooding has resulted in the formation of natural levees along the southern bank of Boomerang Creek such that it is perched above the adjacent floodplain. As a result, runoff from out-of-bank areas immediately to the south of the channel drain independently of the Boomerang Creek channel and drain to One Mile Creek. Over time (and without any disturbance from mining activities), there is a chance that a new Boomerang Creek channel will form along this flow path and the existing Boomerang Creek channel will become abandoned.

Abandoned Boomerang Creek channels are evident across the floodplain (See Figure 2.13). There is a more recent abandoned channel which drains to Ripstone Creek and another older channel that follows the current floodplain overflow path to One Mile Creek. A much older channel links the existing Hughes Creek upstream of the Project area to One Mile Creek. The number of abandoned channels indicate that this evolution of the channel across the floodplain will continue.

In the proposed subsidence area, the channel of Boomerang Creek is typically 1.5 m to 2.5 m deep, with a 30 m top width.

One Mile Creek has a much smaller catchment, and the channel is therefore shallower, typically 0.75 m to 1.5 m deep, and narrower – around 15 m wide. One Mile Creek drains along the southern boundary of the Boomerang Creek floodplain likely formed from the toe slope of the valley fill. The lower reaches of the creek are larger and likely formed the main Boomerang Creek channel that has since been abandoned. The upper reaches, unaffected by Boomerang Creek flows have similar characteristics to Boomerang Creek with several abandoned flood channels evident across the floodplain within the Project area.

The floodplain across the Project area contains an elevated landform between the Boomerang and One Mile Creek channels. The elevated landform contains several gilgai features. Gilgai are repeated mounds and depressions formed on shrink-swell and cracking clay soils (or vertosols). Water can accumulate seasonally in the depressions to form gilgai wetlands[1]. The abandoned Hughes Creek channel drains around the western side of the elevated landform.

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[1] https://wetlandinfo.des.qld.gov.au/resources/static/pdf/resources/tools/conceptual-model-case-studies/cs-gilgai-12-04-13.pdf

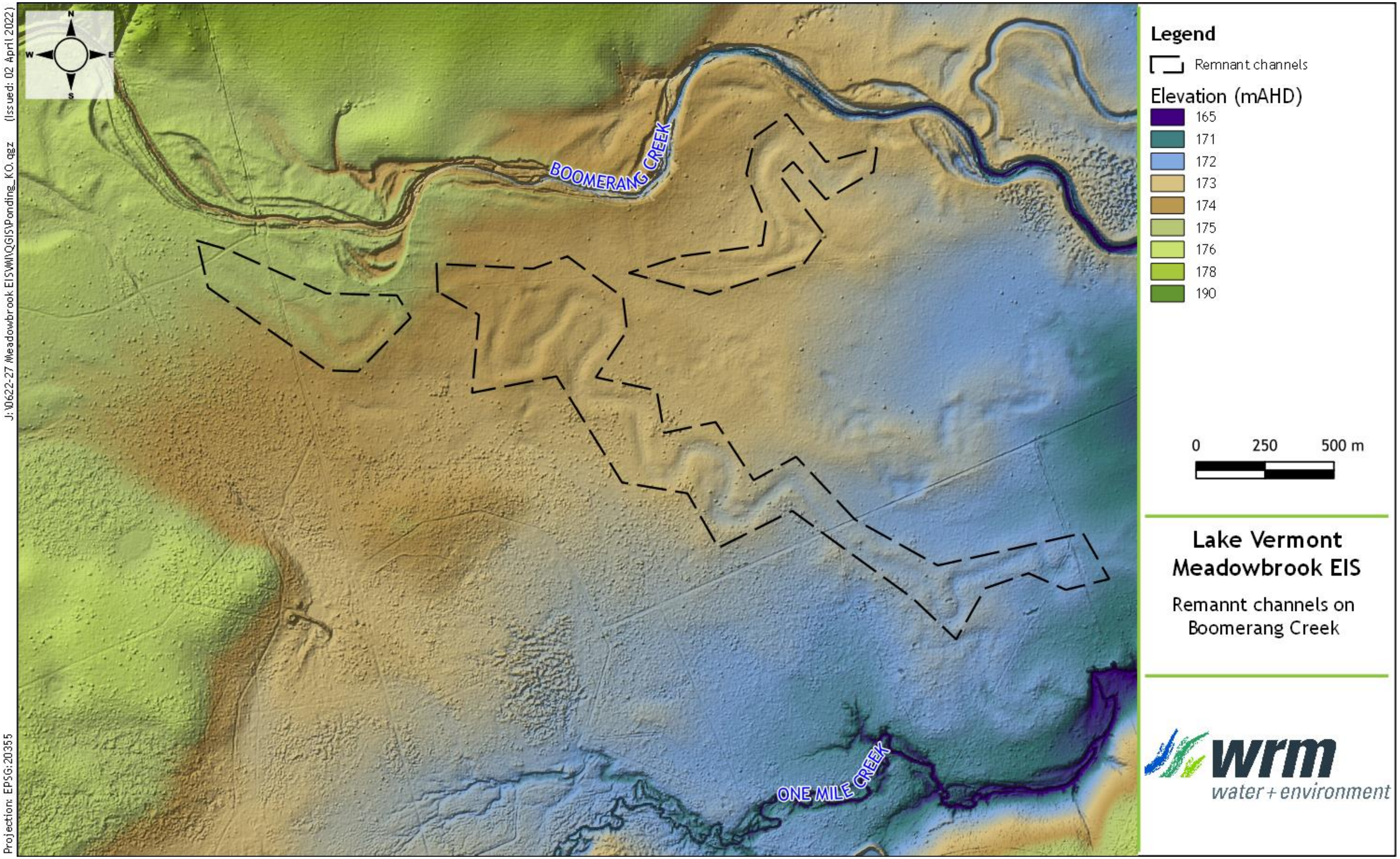

Figure 2.13 – Remnant Boomerang Creek channels

2.3.3 Soil types and erodibility

Mapping of soils across the Project area according to the Australian soil atlas classification are shown in Figure 2.14. The mapping shows significant differences between the soils adjacent to each of the three major waterways crossing the disturbance areas associated with the Project:

- Boomerang Creek and its floodplain are overlain by sodosols (yellow duplex).
- The soils in One Mile Creek's upper reaches and southern floodplain are vertosols (cracking clays).
- The soils close to the channel of Phillips Creek are chromosols.

Figure 2.15 overlays a dataset of erodible soils prepared by the Department of Environment and Science across the Fitzroy River catchment to improve understanding of sediment source locations for reducing sediment loads under the Reef Water Quality Program. The maps shows that the surface soils of the Project area are moderately stable, with erodible non-cohesive soils and dispersive soils occurring in a band along the northern side of Boomerang Creek.

2.3.4 Bed sediment

There is little historical data concerning the condition of the streams prior to the land cover and drainage being modified for agricultural and mining use. The extensive sandy Cainozoic sediments along the stream channels suggest sand-bed waterways would occur naturally in this region (Fluvial Systems, 2018). However, it is clear the streams would carry higher sediment loads than pre-European conditions due to elevated upstream catchment erosion rates from agricultural and mining activities.

Sediment samples were collected from the bed of each of the channels crossing the Project area in March 2020 and September 2021 during field work for the aquatic ecology assessment (AARC, 2022). Particle size distributions obtained from these samples are presented in Figure 2.16 (their locations are shown in Figure 2.17).

The results show that samples collected from Hughes Creek, Boomerang Creek and the Isaac River have very uniform particle size distributions – with most particles being fine to medium grained sand. More than 95% of particles are greater than 0.075 mm, and 80% are smaller than 1 mm.

Samples taken from One Mile Creek vary significantly. One sample collected from One Mile Creek (just upstream of the Boomerang Creek confluence) shares a similar distribution with the Boomerang Creek samples, but the other samples generally comprise much finer material (fine sands, silts and clay), with between 20% and 75% of particles being less than 0.075 mm. More than 80% of particles measured in One Mile Creek were smaller than 0.5 mm.

These characteristics affect the potential transportation of bed material, and the potential for waterholes to store water for prolonged periods post-flow.

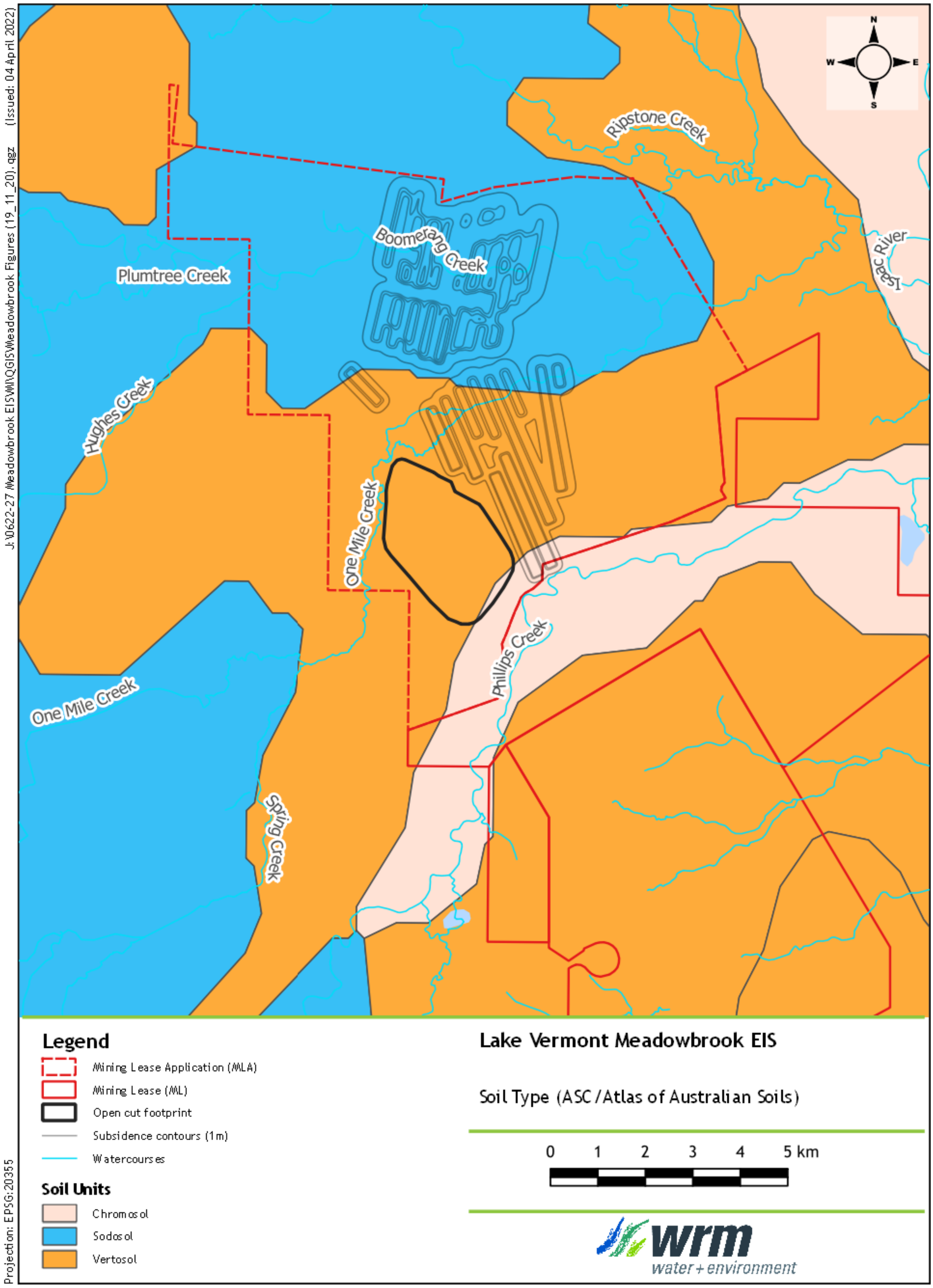

Figure 2.14 – Soil types

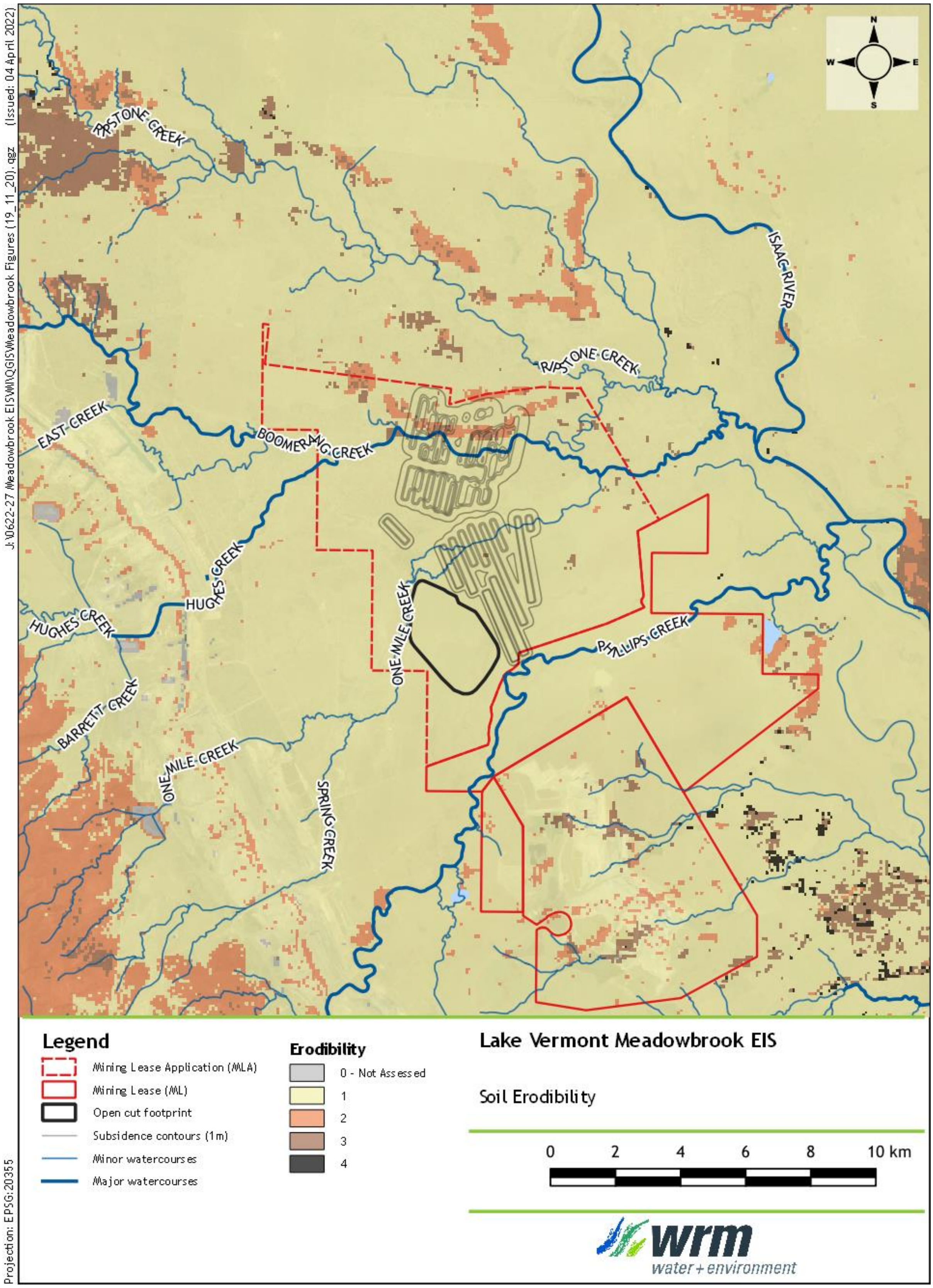

Figure 2.15 – Soil erodibility

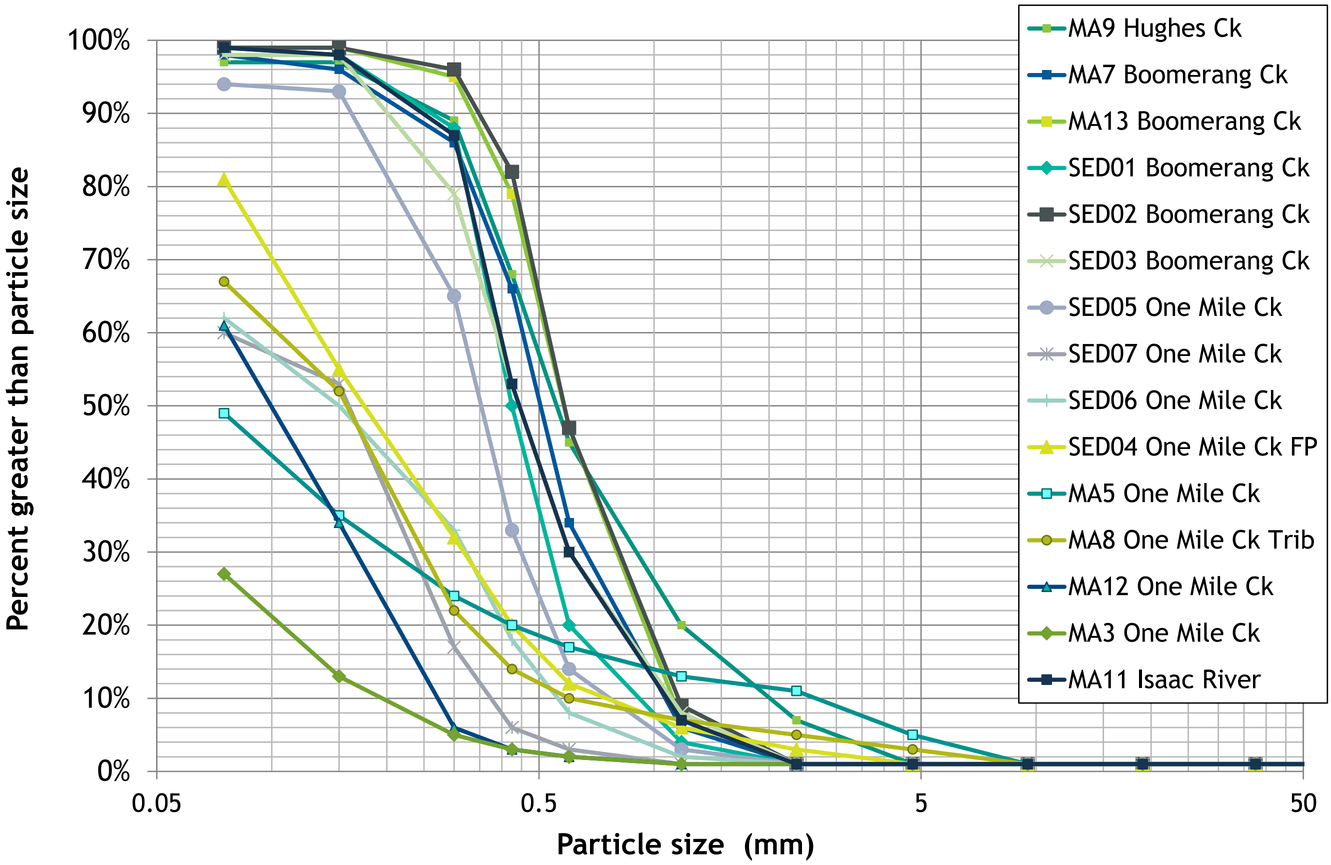

Figure 2.16 – Particle-size distributions of bed sediment

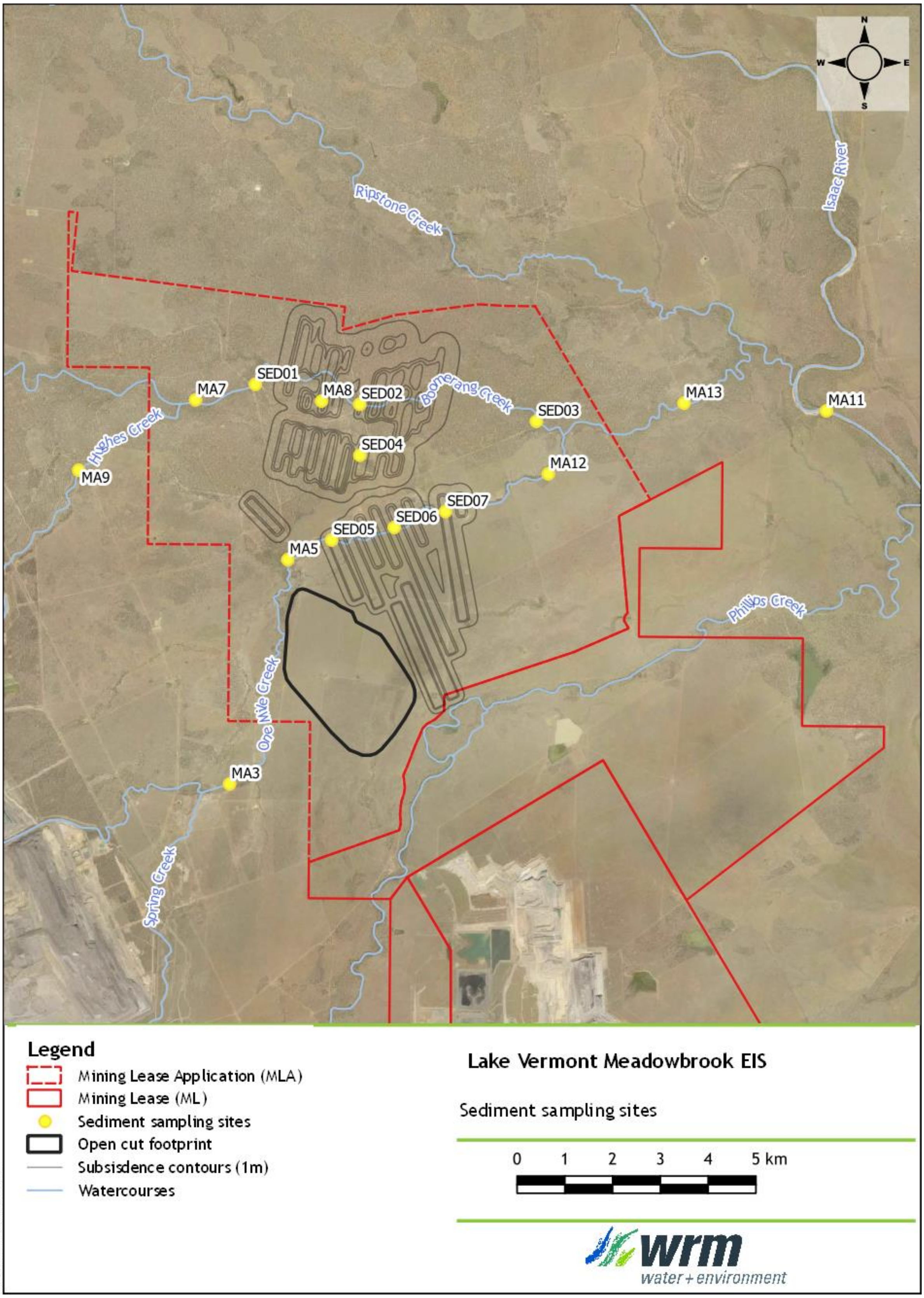

Figure 2.17 – Locations of sediment sampling sites

2.3.5 Field inspection

A detailed inspection of the waterways and floodplains crossed by the Project was undertaken on 21 July 2021. The purpose of the inspection was to confirm and document channel dimensions, condition, bed material and vegetation. Photographs taken throughout the Project area (including subsequent site visits) are provided in Annexure A. The selection of photographs in the following pages show the condition of the channel at the following key locations within the subsidence zone:

- One Mile Creek – Figure 2.18 to Figure 2.20;
- Boomerang Creek – Figure 2.21 to Figure 2.24;
- Phillips Creek floodplain – Figure 2.25 and Figure 2.26.

Approximately 70 mm of rain fell in the area over the 3-day period to 4 July 2021 (17 days prior to the site main inspection). Ponded water was still evident in pools on the clayey soils of the Phillips Creek floodplain and the channel of One Mile Creek. No ponds were evident in the deep sandy bed of Boomerang Creek.

The One Mile Creek bank vegetation comprised mostly small trees and shrubs, whereas Boomerang Creek is lined with large paperbarks and casuarina, and lomandra and other grasses on the banks. The northern Phillips Creek floodplain and much of the One Mile Creek floodplain has been extensively cleared for grazing, with large areas of pasture and low shrubby regrowth.

While localised thick deposits of sand were encountered at various locations, compared to the deep uniform drape of sand in the channel of Boomerang Creek, the bed material of One Mile Creek is comparatively fine, comprising fine sands, silts and clay (consistent with the particle size distributions of the bed sediment samples). Along much of One Mile Creek, the roots of the woody bank vegetation were exposed, and the channel was devoid of in-channel vegetation. Farm dams constructed on the channel of One Mile Creek upstream of the Project area were full and were likely impacting the movement of water and sediment through the Project area.

Figure 2.18 – Photograph of One Mile Creek channel (Chainage 11,080 – site O11)

Figure 2.19 – Photograph of One Mile Creek channel (Chainage 12,500 – site O14)

Figure 2.20 – Photograph of One Mile Creek channel (Chainage 14,075 – site O16)

Figure 2.21 – Photograph of Boomerang Creek channel (Chainage 9,900 – site B2)

Figure 2.22 – Photograph of Boomerang Creek channel (Chainage 11,300 – site B4)

Figure 2.23 – Photograph of Boomerang Creek channel (Chainage 12,200 – site B6)

Figure 2.24 – Photograph of Boomerang Creek channel (Chainage 13,250 – site B8)

Figure 2.25 – Photograph of Phillips Creek northern floodplain channel – site PT2

Figure 2.26 – Photograph of Phillips Creek northern floodplain channel – site PT2

2.4 HYDROLOGY

2.4.1 Flow regime

The Queensland Department of Regional Development, Manufacturing and Water operates a nearby surface water monitoring site on the Isaac River at Deverill (GS 130410). Water monitoring data is also available from Phillips Creek at the Tayglen gauge (GS 130409) however this gauge is no longer operational. Figure 2.27 shows that over the period of record at Tayglen (1968 to 1988), flows occurred in Phillips Creek about 25% of the time.

Limited surface water monitoring data is also available from Lake Vermont Resources monitoring stations on Phillips Creek. The locations of these monitoring stations are shown in Figure 2.9.

The Tayglen gauge was located at the upstream extent of the Phillips Creek quaternary alluvium. While very low flows would be observed at that location, they would seep into the deep sandy bed of the downstream reaches of Phillips Creek and not reappear as surface flow. This is consistent with field observations during water sampling, and post-flood water level measurements at Lake Vermont, that indicate Phillips Creek typically ceases to flow within 24 hours of the cessation of rainfall.

The natural flow regime in One Mile Creek and Boomerang Creek would be similar to the characteristics of Phillips Creek. Flow monitoring data is not available for the reaches of these streams crossing the project area. Flows in One Mile Creek are significantly affected by upstream mining activities.

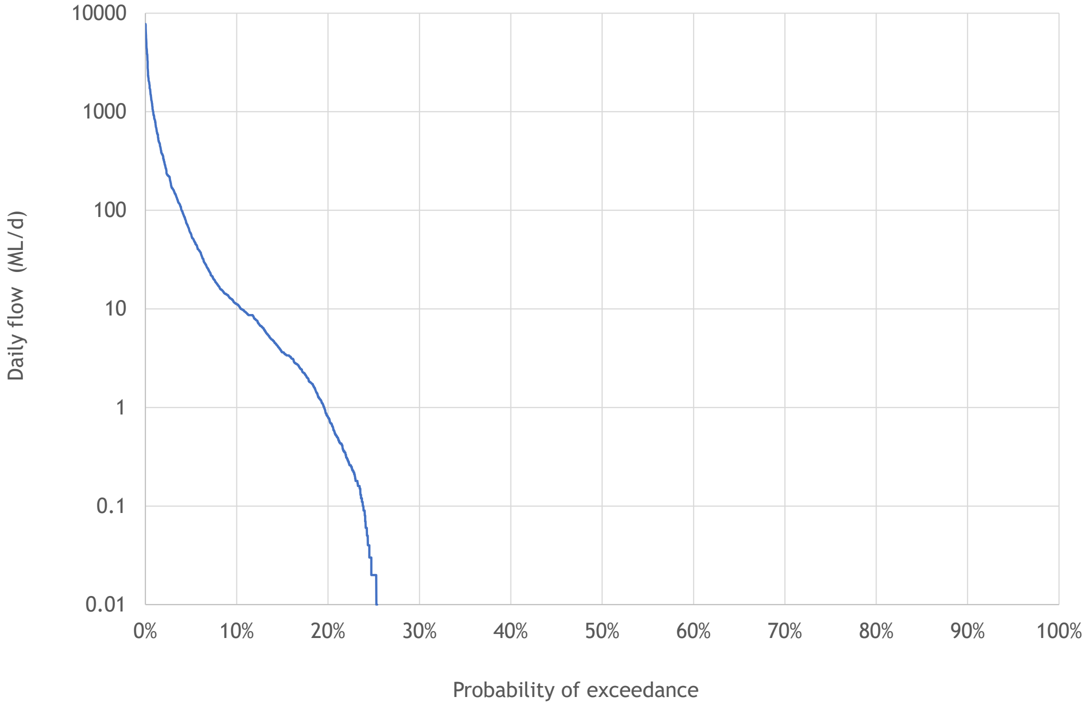

Figure 2.27 – Frequency of daily flows recorded at Phillips Creek at Tayglen

2.4.2 Flood hydrology

The development, validation and calibration of the hydrological and hydraulic models are described in detail in the Lake Vermont Meadowbrook Project Flood Modelling Assessment report (WRM, 2022).

In summary, separate XP-RAFTS runoff-routing models of the Isaac River and local creek catchments were used to estimate the 50%, 10%, 2%, 1%, and 0.1% annual exceedance probability (AEP) peak design discharges as well as the probable maximum flood (PMF) for a range of durations up to 48 hours. Rainfall data (rainfall depths, areal reduction factors and temporal patterns) were applied in accordance with ensemble event procedures in Australian Rainfall & Runoff (AR&R) (Ball et al., 2019).

Design peak flows from the regional Isaac River model were reconciled against a flood frequency analysis (FFA) of the peak annual flow series at the Deverill gauge. The local flood model was calibrated to flows recorded at the Lake Vermont Mine Phillips Creek streamflow gauge, for the Cyclone Debbie flood event (March 2017). Design peak flows in Phillips Creek were reconciled against the flood frequency analysis of the peak annual flow series of historical flow data recorded at the Tayglen gauge. All local creek design flows were validated by comparing against the design discharges from the Regional Flood Frequency Estimation Model (RFFE). The adopted design flows to the outlet of each of the main waterways crossing the Project area shown in Table 2.1.

Table 2.1 – Design flow rates at the outlet of the main waterways in the vicinity of the Project area

Design event	Adopted peak flow rate (m^3/s)			
	Boomerang Creek	One Mile Creek	Ripstone Creek	Phillips Creek
50% AEP	108	32	67	104
10% AEP	469	152	305	469
2% AEP	892	296	587	900
1% AEP	1,097	370	734	1,130

2.5 EXISTING FLOODING CHARACTERISTICS

2.5.1 Overview

The TUFLOW hydrodynamic model (BMT, 2018) was used to simulate the flow behaviour (flood extents, depths and velocities) of the Isaac River, Ripstone Creek, Boomerang Creek, Hughes Creek, One Mile Creek and Phillips Creek in the vicinity of the Project.

TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow (BMT, 2018). The TUFLOW model was run using the Heavily Parallelised Compute (HPC) GPU solver which uses adaptive time stepping. The grid size was varied throughout the model using a quadtree mesh. Complex areas within the Project area were modelled using a fine mesh, while floodplain areas of less importance to the impact assessment were modelled using a coarse mesh. Sub-grid sampling (SGS) was enabled so that each 2d cell face was represented by multiple elevation values. The number and spacing of SGS sampling points varies with cell size.

For this investigation, all flood modelling has focussed on storm event durations causing the largest flood peaks in the waterways crossing the Project area. While Isaac River flooding can have a minor impact on flood levels in the eastern part of the Project area, the Isaac River does not impact on the mine subsidence areas impacted by the Project. Therefore, the local catchment flooding is of most importance when considering the geomorphic response of these waterways.

The existing conditions modelling assumes that the Phillips Creek diversion has been constructed in accordance with the approved functional design (WRM, 2022) but no infrastructure is located across the Boomerang Creek or One Mile catchments. The hydraulic model parameters have been used to define the hydraulic characteristics of relevance to the floodplain morphology:

- Stream velocity has been used as an indicator of stream impacts, where increases in velocities would suggest some change in the stream characteristics may occur. Note there is not a direct relationship between velocity and the force exerted on soil particles at the boundary and thus stream power and shear stress are used as more reliable indicators of erosion potential.
- Shear stress provides a measure of the tractive force acting on sediment particles at the boundary of the stream and is used to determine the threshold of motion for bed material. It provides an indication of the potential for erosion of cohesive sediments or movement of non-cohesive sediments at the channel boundary.
- Stream power is a function of discharge, hydraulic gradient and flow width. It represents the energy that is available to do work in and on the channel. High stream powers are indicative of elevated erosion potential.

The modelling included:

- An assessment of the 50% AEP design flood to represent the behaviour of the creek channels at bank full flow conditions. The bank full flow is the maximum flow that the channel can carry before it overflows onto the adjacent floodplain. In geomorphologic studies, the bank full flow is often considered to be the stream forming flow, because it often exerts the greatest influence on channel geometry.
- An assessment of the 2% AEP design flood to represent the behaviour of the creeks and associated floodplains during large floods. It can be used to identify whether the changed out of bank flood behaviour could inadvertently cause an avulsion of the channel.

2.5.2 Flood extent, depths and velocities

Figure 2.28 and Figure 2.29 show the 50% AEP flood depths and flood velocities across the Project area. The modelling results show:

- The upper reach of Boomerang Creek has a low channel capacity. Floodwater from this frequent event would flow over the southern bank of Boomerang Creek (and Hughes Creek) at several locations near the western lease boundary and flow in a southeasterly direction via two main shallow floodplain flow paths to One Mile Creek.
- Boomerang Creek downstream of the overflow path to the One Mile Creek confluence drains independently of the floodplain flows with the remaining 50% AEP flows contained in bank.
- One Mile Creek also has low channel capacity with the 50% AEP flows draining along several channels and as shallow overbank flows.
- One Mile Creek receives Hughes Creek overflows and then Boomerang Creek overflows to effectively become the primary flow path during flood flows.
- Boomerang Creek downstream of the One Mile Creek confluence is also perched with a significant proportion of the One Mile Creek flood flows bypassing the main channel and flowing independently along the southern floodplain eventually draining to Phillips Creek.
- Flows would be contained in-bank in Phillips Creek, with local catchment runoff contributing all flow in its northern floodplain.
- Flows are confined within Ripstone Creek upstream of the Project but then lose definition with a low carrying capacity downstream of the Project area.
- Apart from some localised areas where overbank flows are concentrated, floodplain flow velocities are relatively low (less than 0.5 m/s).

Figure 2.30 and Figure 2.31 show the 2% AEP flood depths and flood velocities across the Project area. The modelling results show:

- With the exception specific locations along remnant channels, floodplain flow velocities are relatively low (less than 1.0 m/s).
- The southeast-flowing overflow paths from Boomerang Creek to One Mile Creek are significantly wider and deeper, but the perched Boomerang Creek channel downstream of the overflow paths continues to drain independently of the floodplain
- Along the southern margin of the larger eastern flood overflow path, depths exceed 2 m and velocities exceed 2 m/s.
- Flooding along One Mile Creek becomes wider. Downstream of the flow path from Boomerang Creek, flow depths increase beyond 4 m, but with the exception of relatively short sections of the main channel, velocities are less than 1 m/s.
- Flows escape the channel of Phillips Creek just upstream of the Project area, and flow north along a drainage path on the left Phillips Creek floodplain before turning east. The

Phillips Creek channel is perched, with a wide levee of naturally deposited material separating the independently flowing channel from its floodplain.

- Very shallow minor overflow paths begin to establish in parts of the Project between Phillips Creek and One Mile Creek in this event.
- In their lower reaches, the Ripstone Creek, Boomerang Creek, One Mile Creek and Phillips Creek floodplains combine and merge with the Isaac River floodplain.

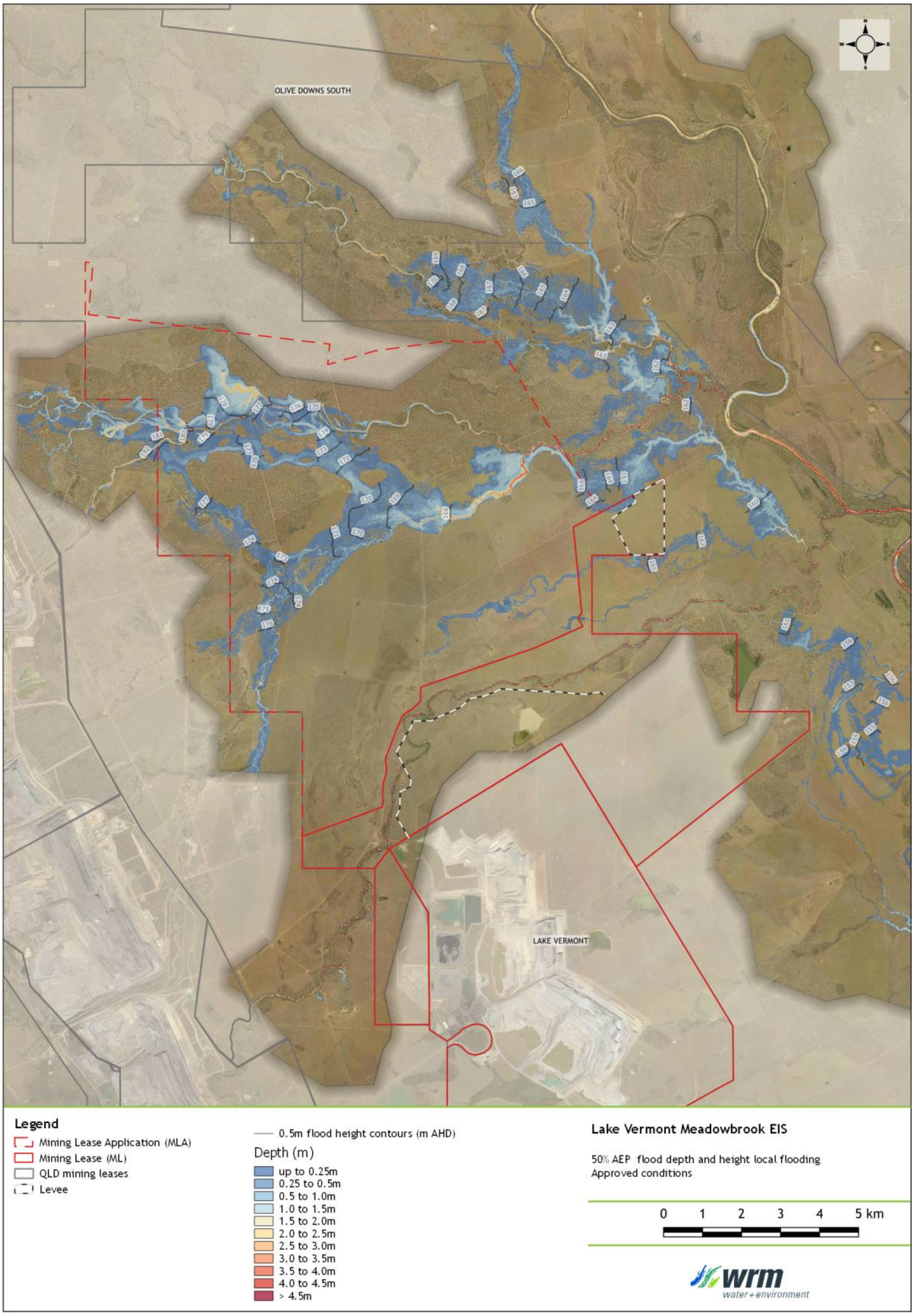

Figure 2.28 – Modelled flood depth and levels – 50% AEP pre-mining (“approved”) conditions

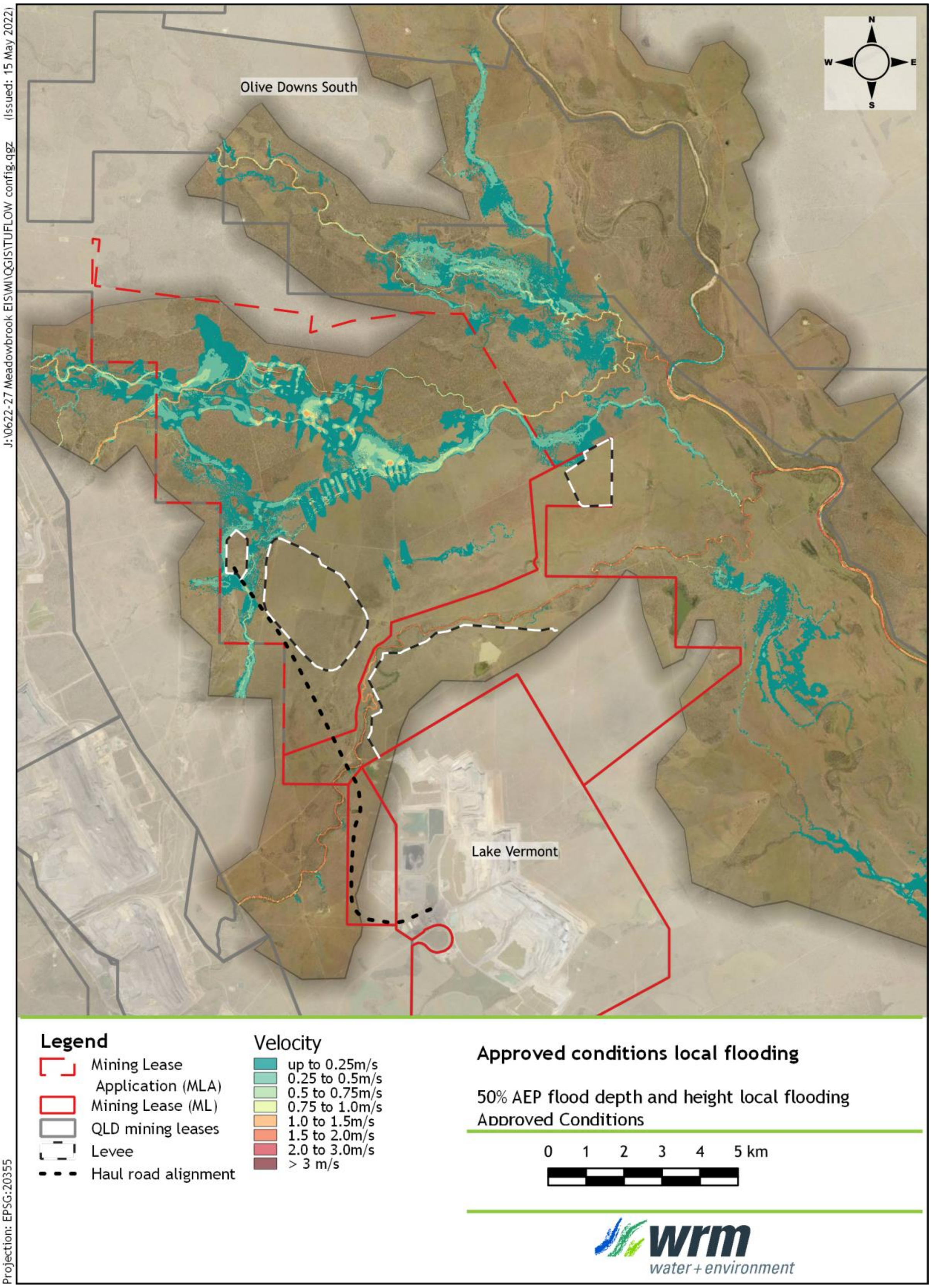

Figure 2.29 – Modelled flood velocity – 50% AEP pre-mining (“approved”) conditions

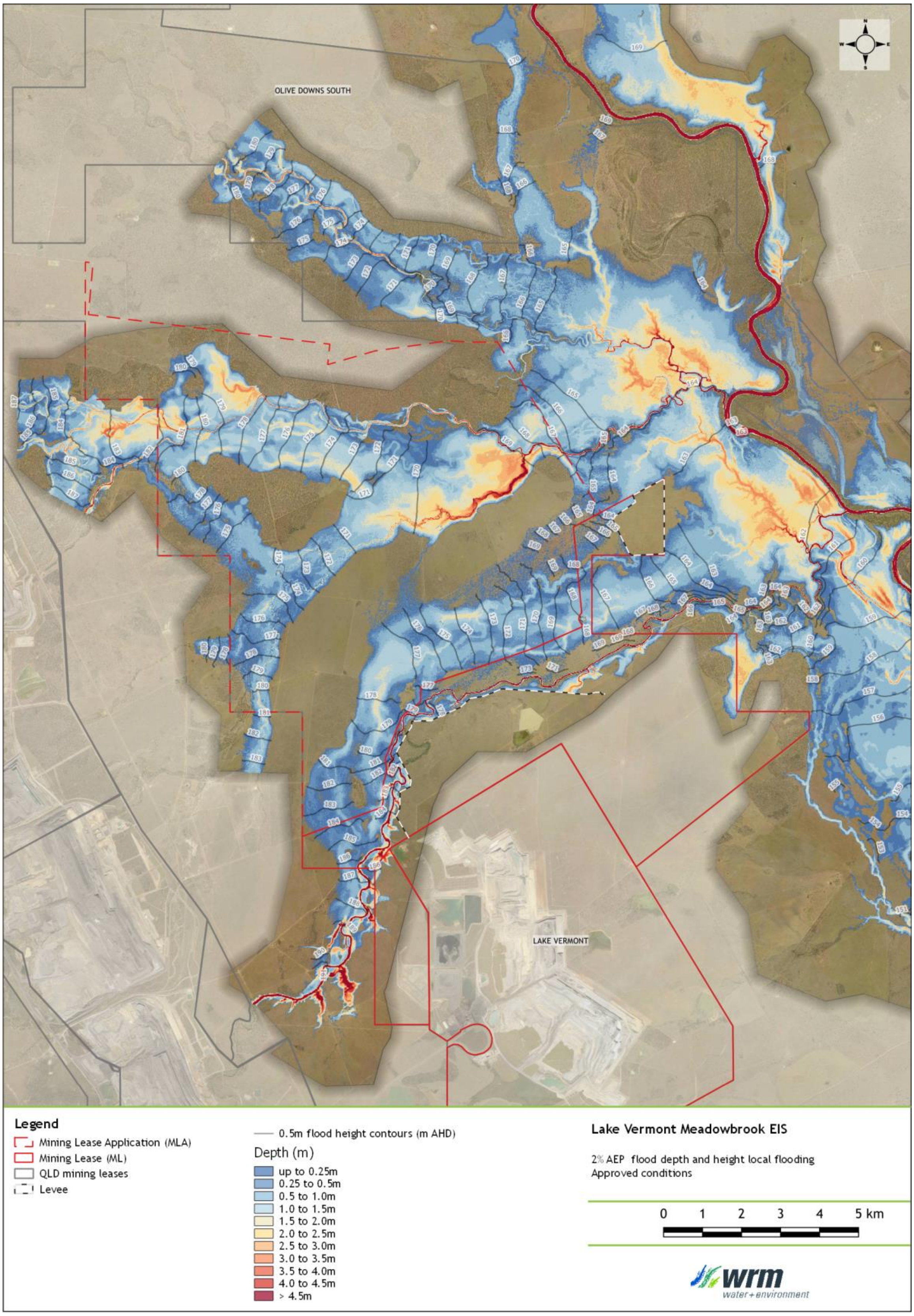

Figure 2.30 – Modelled flood depth and levels – 2% AEP pre-mining ("approved") conditions

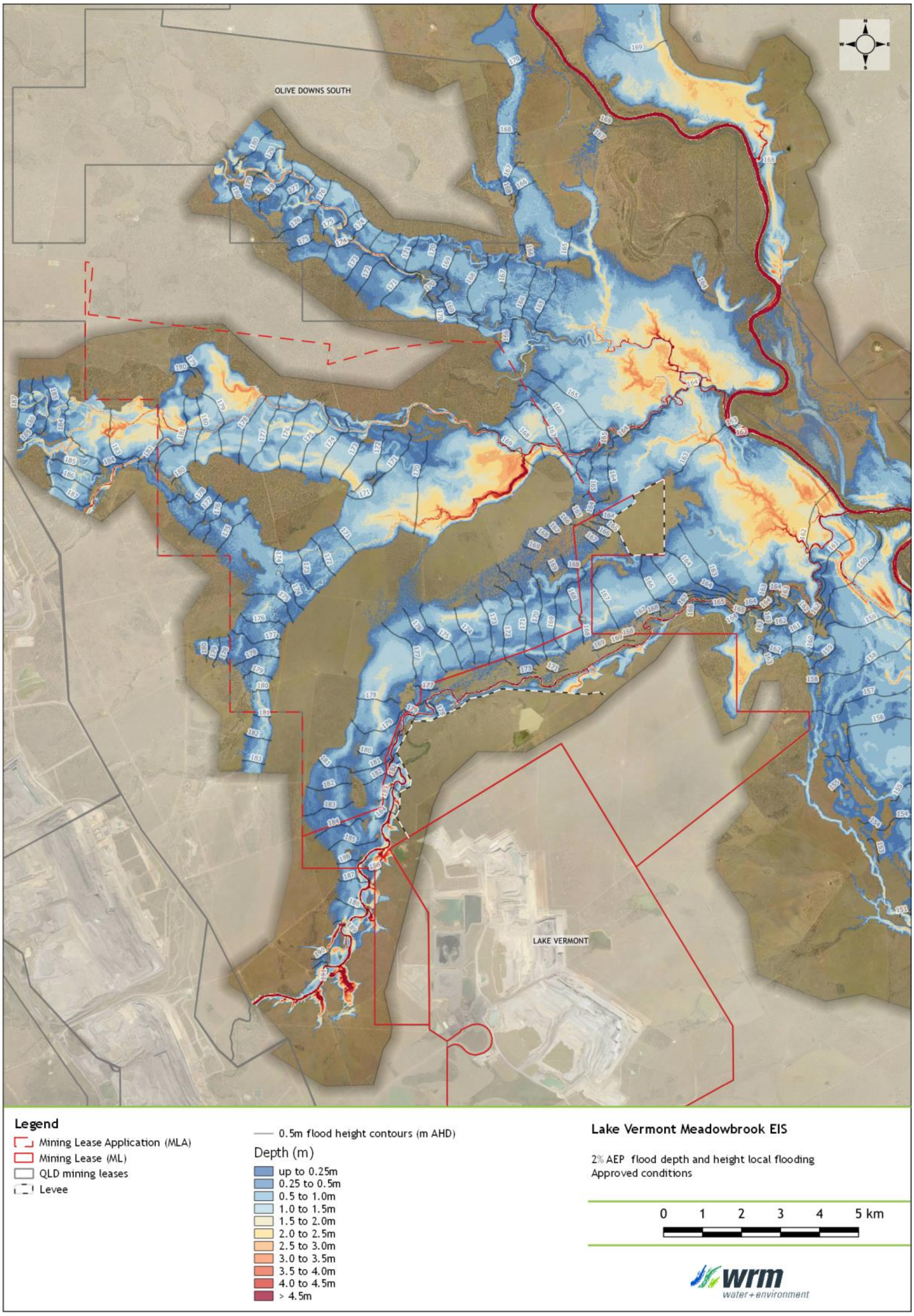

Figure 2.31 – Modelled flood velocity – 2% AEP pre-mining (“approved”) conditions

2.5.3 Channel hydraulic characteristics

Table 2.2 and Table 2.3 show the range of peak velocity, bed shear stress and stream power along the Boomerang Creek and One Mile Creek channels along the reach proposed to be impacted by the Project for the 50% AEP and 2% AEP events respectively. The values were determined from 1-dimensional section-averaged cross sections created every 50 m along the channels. Results every 1 m along the section were sampled from the two-dimensional model result grids. An assessment of these model results against post mining conditions is provided in Section 3.4.

Table 2.2 – Range of 50% AEP peak velocity, bed shear stress and stream power in Boomerang Creek and One Mile Creek

Parameter	Boomerang Creek			One Mile Creek		
	10th %ile	median	90th %ile	10th %ile	median	90th %ile
Peak velocity (m/s)	0.81	0.95	1.16	0.30	0.46	0.63
Bed shear stress (Pa)	19.4	28.4	39.1	3.3	8.7	13.6
Stream Power (N/ms)	16.6	26.4	40.5	0.8	3.8	7.4
Hydraulic Depth (m)	1.84	2.26	2.71	0.78	1.26	1.90

Table 2.3 – Range of 2% AEP peak velocity, bed shear stress and stream power in Boomerang Creek and One Mile Creek

Parameter	Boomerang Creek			One Mile Creek		
	10th %ile	median	90th %ile	10th %ile	median	90th %ile
Peak velocity (m/s)	0.89	1.06	1.32	0.41	0.57	0.75
Bed shear stress (Pa)	20.1	32.3	60.9	2.5	10.1	21.4
Stream Power (N/ms)	16.8	30.3	61.6	0.4	4.3	12.4
Hydraulic Depth (m)	2.21	2.78	3.85	1.39	1.87	3.33

2.5.4 Sediment transport

There are several methods to determine the flow conditions under which the stream bed material will become mobilised. The simplest of which is the Hjulstrom Curve (see Figure 2.32 and Figure 2.33). Hjulstrom (1935) developed a diagram showing the relationship in a channel between particle size and the mean velocity required for entrainment. It shows that an entrained particle can be transported in suspension at a lower velocity than that required to lift the particle initially. When the stream velocity slows to a critical speed, the particle is deposited. Based on the hydraulic parameters in Table 2.2, almost all the bed sediments would erode during a 50% AEP flood event. These sediments would be entrained on the rising limb of the flood and deposit on the falling limb of the flood.

This is supported by the observations during the site visit, which found extensive sediment deposits along Boomerang Creek. Based on aerial photographs of the upstream reaches of Boomerang Creek, and its tributary Hughes Creek, sediment supply is not limited and exceeds or at least matches the sediment transport rates.

In One Mile Creek, it appears the capacity of the channel to transport sediment exceeds the sediment supply in the potentially impacted reaches – as tree roots are exposed and vegetation is sparse. However, the tree roots and cohesive nature of the bed material prevent excessive bed erosion.

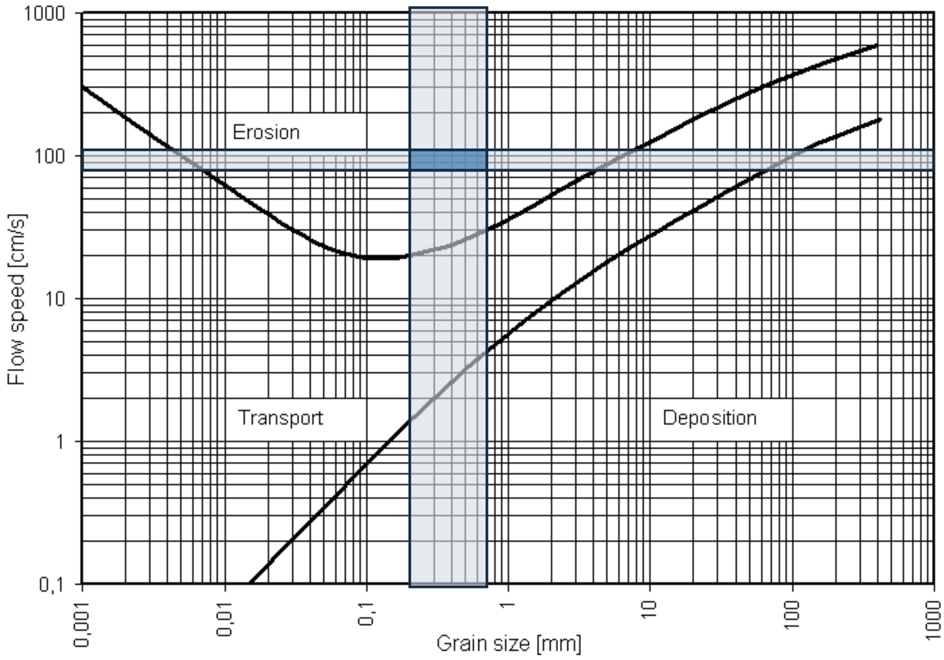

Figure 2.32 – Hjulstrom curve – Boomerang Creek

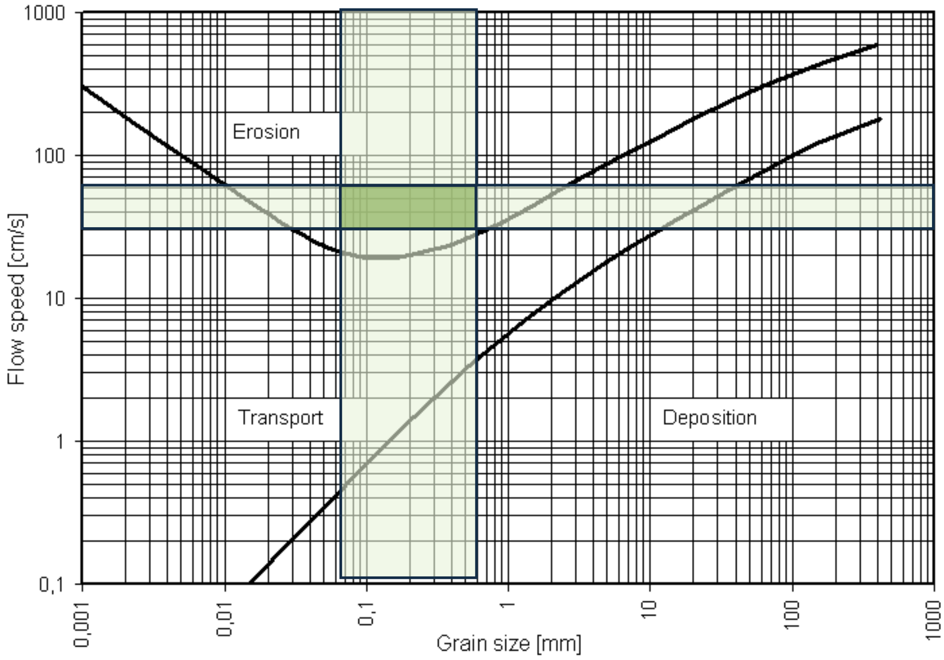

Figure 2.33 – Hjulstrom curve – One Mile Creek

3 Predicted direct subsidence impacts

3.1 MINE SCHEDULE AND SEQUENCE

Coal reserves in the underground mining area will be mined over approximately 23 years. The primary underground target seam is the Vermont Lower Seam, which extends across the whole underground mining footprint. The overlying Leichardt Lower Seam, which is a secondary underground target seam is only present across the northern half of the underground footprint.

The provisional mine schedule and sequence is based on maintaining a total Lake Vermont Mine Complex product coal output of approximately 9 Mtpa. The timing may however vary to consider factors such as localised geological features, market conditions or mining economics.

Underground mining will commence in the Vermont Lower Seam in Project Year 1 (indicatively 2026). Approximately 22 months of initial in-seam development with continuous miners is planned before the longwall commences operation. It is planned to extract the southern longwall panels in the Vermont Lower seam first, progressing from west to east. Upon completing extraction of the southern Vermont Lower seam panels, the longwall will commence mining the northern Leichardt Lower seam panels. Once the northern Leichardt Lower seam panels have been extracted, mining will commence in the Vermont Lower Seam. Coal reserves in the open cut pit will be mined for approximately 11 years starting in Project Year 20 (indicatively 2045).

3.2 DEPTH AND EXTENT OF SUBSIDENCE

Longwall mining typically results in subsidence which leads to progressive development of shallow, trough-like depressions on the surface above each extracted longwall panel. These trough-like depressions have gentle grades and develop relative to the natural surface.
The depressions on the surface develop as the roof strata above the coal seam progressively collapse to fill the void created by the extraction of coal in the area behind the longwall. As the roof collapses into the mined area (referred to as the 'goaf'), the fracturing and settlement of rocks progresses upwards through the overlying strata and results in sagging and bending of the near surface layers.

The predicted depth and extent of mine induced subsidence was estimated by Gordon Geotechniques (GG, 2022) and is shown in Figure 3.1. The maximum depth of predicted subsidence varies with location around the proposed operation, depending on whether two seams are being mined in an area. The map in Figure 3.1 shows:

- The channel of Phillips Creek would not be directly affected by subsidence. Maximum subsidence depths on the Phillips Creek northern floodplain would be up to 2.5 m to 3.0 m.
- Maximum subsidence depths on the One Mile Creek channel and southern floodplain would be up to 2.5 m to 3.0 m.
- Maximum subsidence depths in the floodplain between One Mile Creek and Boomerang would be over 4.5 m in localised areas.
- The channel and floodplain of Boomerang Creek would see maximum subsidence depths of up to 4.0 m.

Subsidence would occur gradually over time, as the longwall progresses. The total surface area predicted to be affected by subsidence within the Project area is approximately 2,195 ha. The post-mining surface topography was developed by subtracting subsidence contour profiles for the Project from the base topographic surface.

Changes to the local topography induced by subsidence are illustrated in the ground elevation contour maps in Figure 3.2 to Figure 3.7.

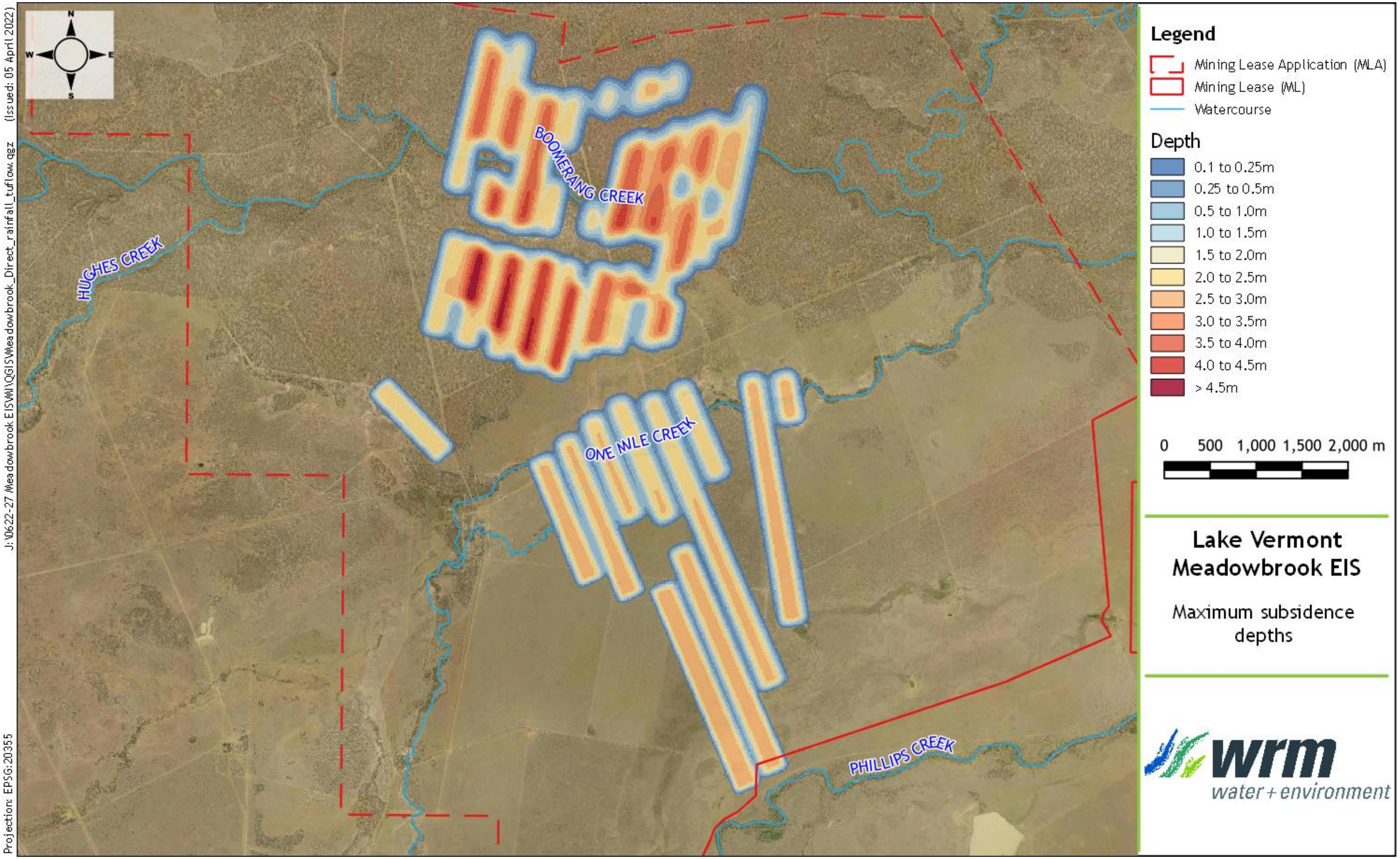

Figure 3.1 – Maximum depth and extent of predicted mining-induced subsidence

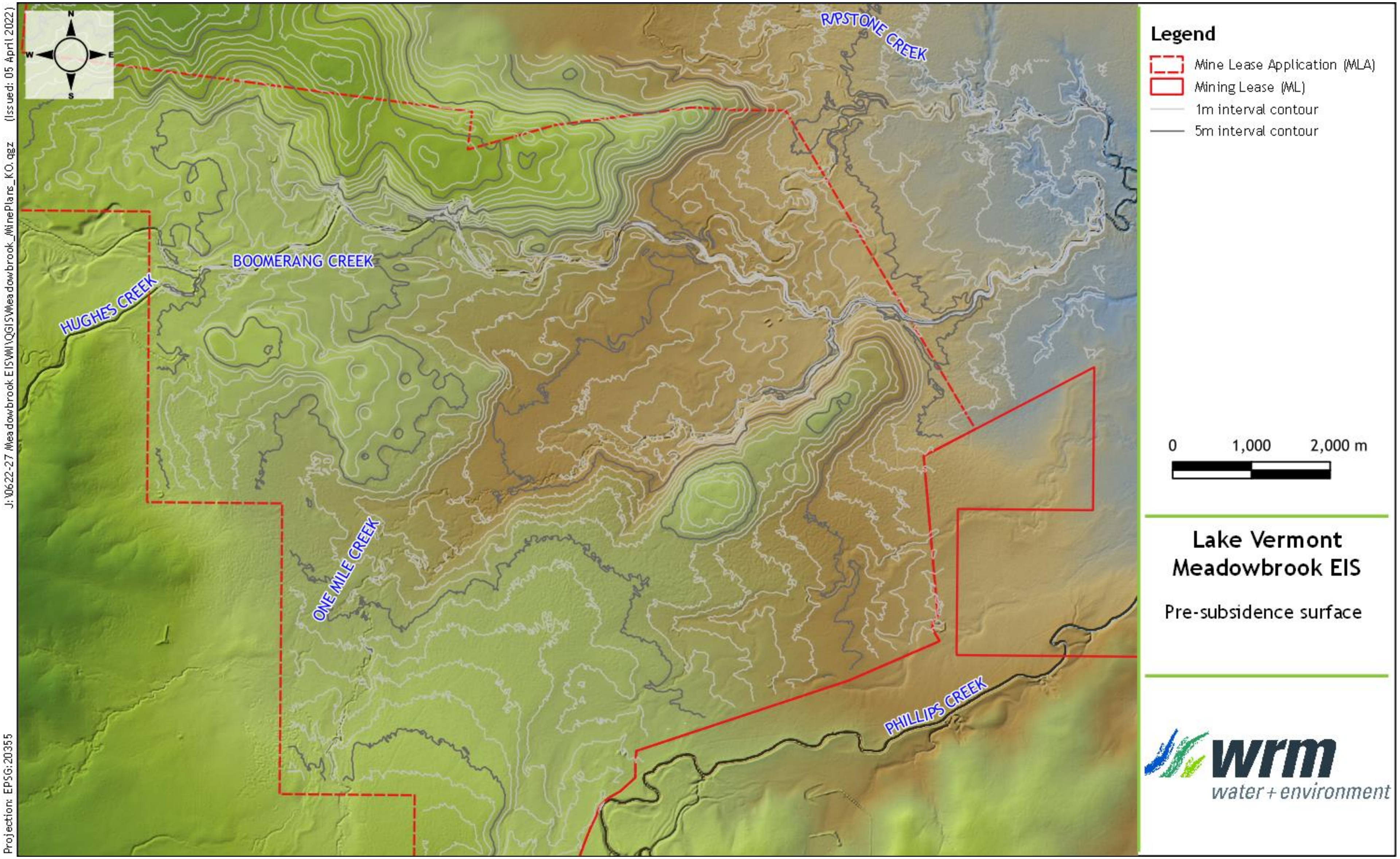

Figure 3.2 – Pre-subsidence topography

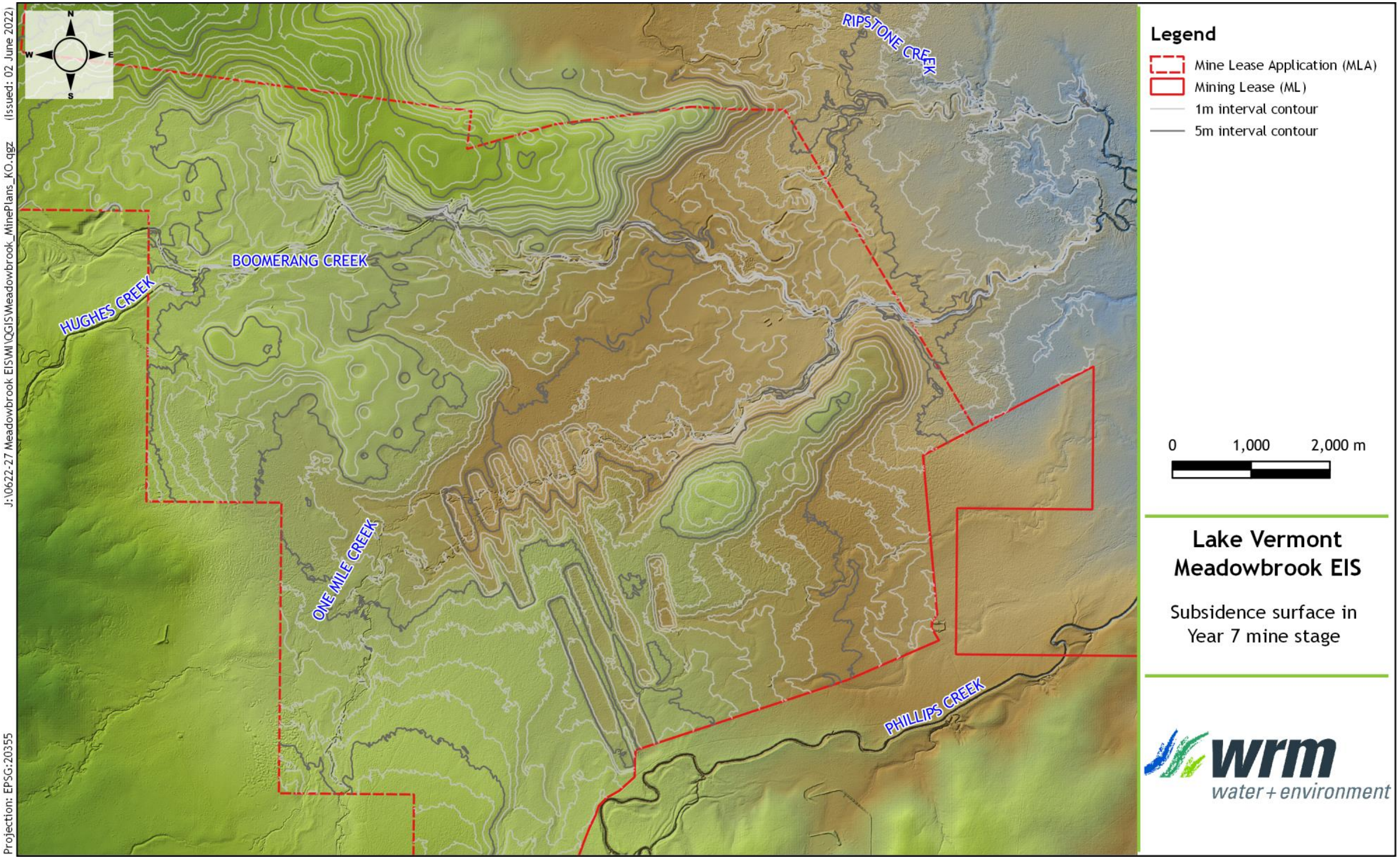

Figure 3.3 - Subsided ground surface - Year 7

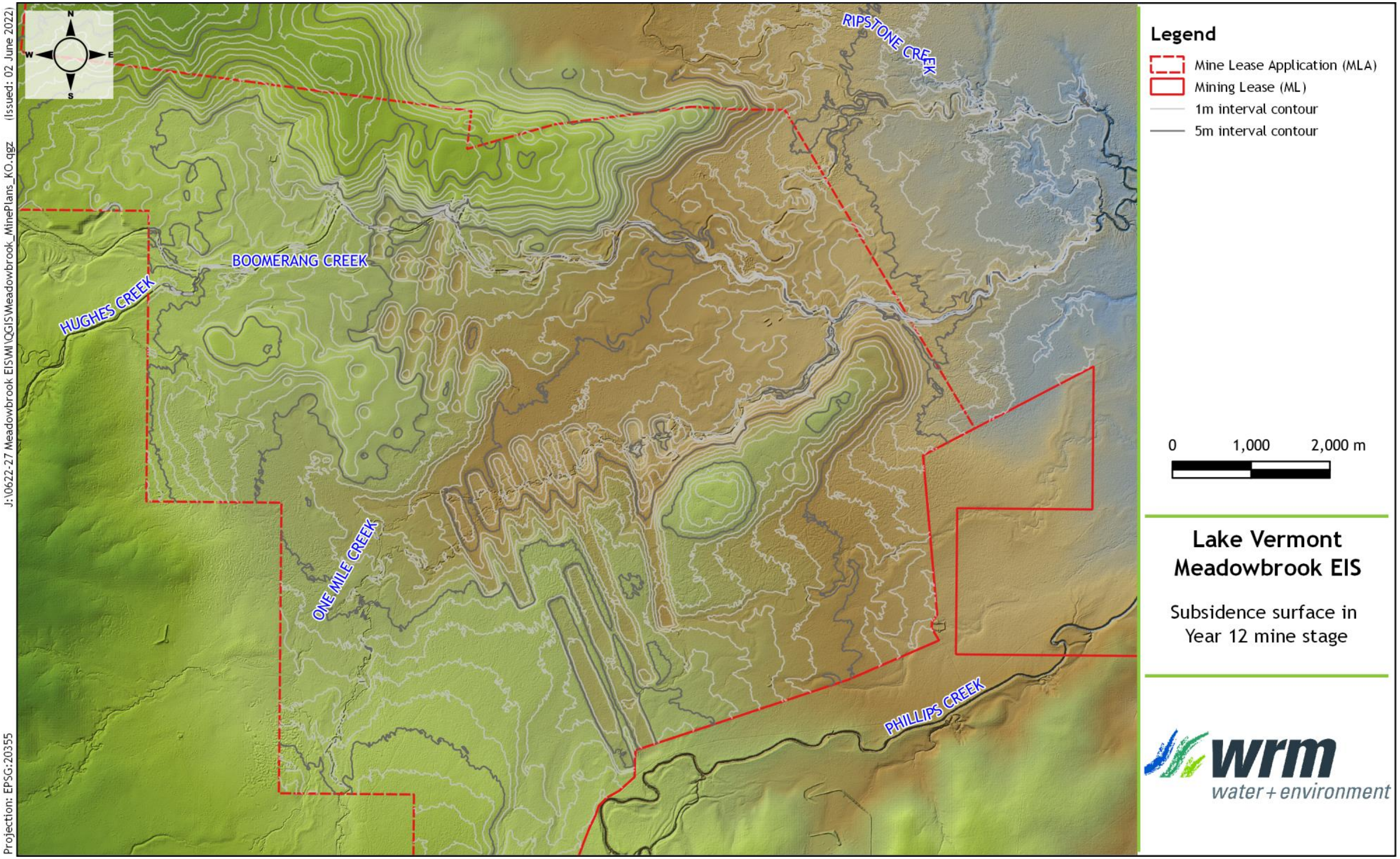

Figure 3.4 – Subsided ground surface – Year 12

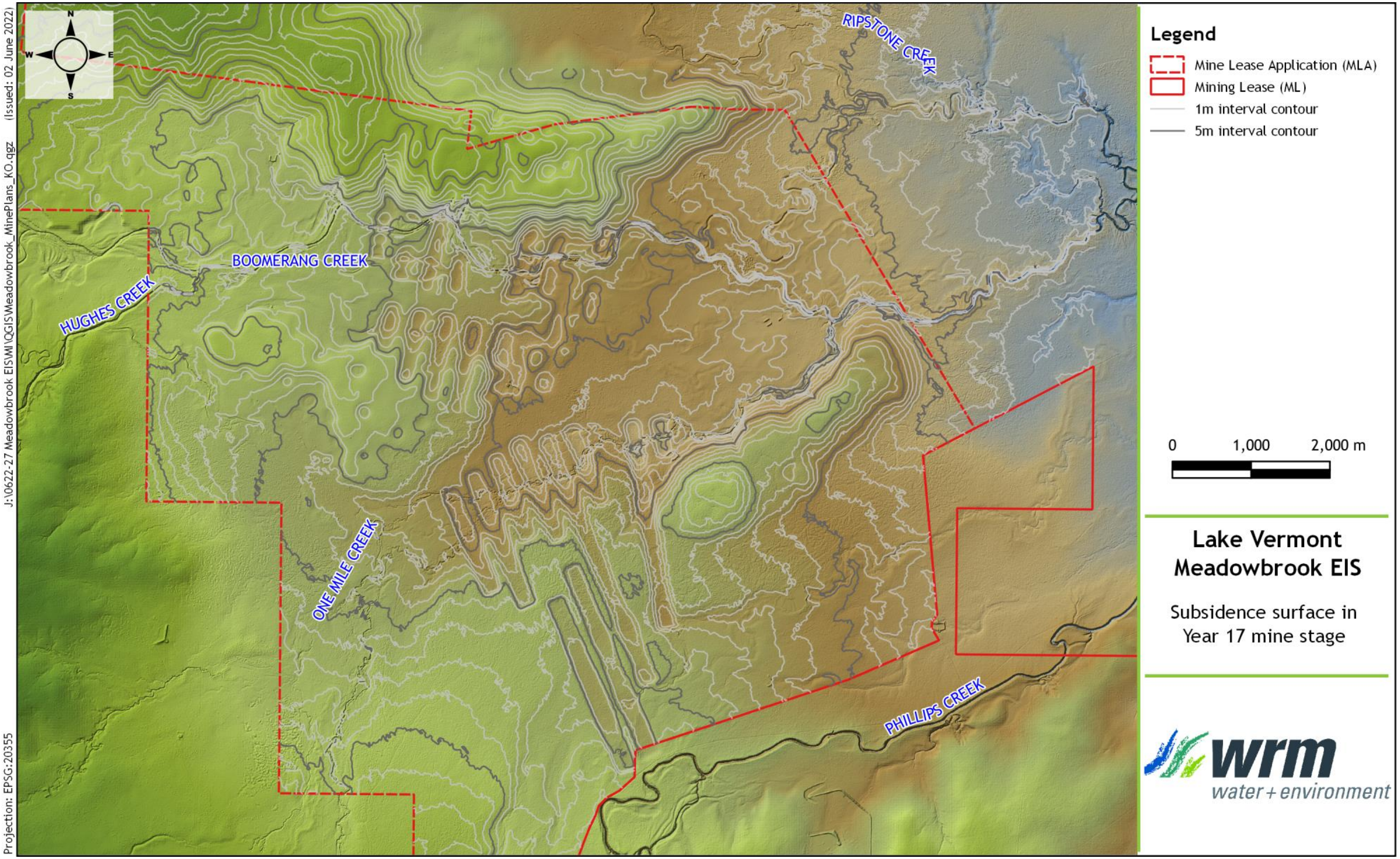

Figure 3.5 – Subsided ground surface – Year 17

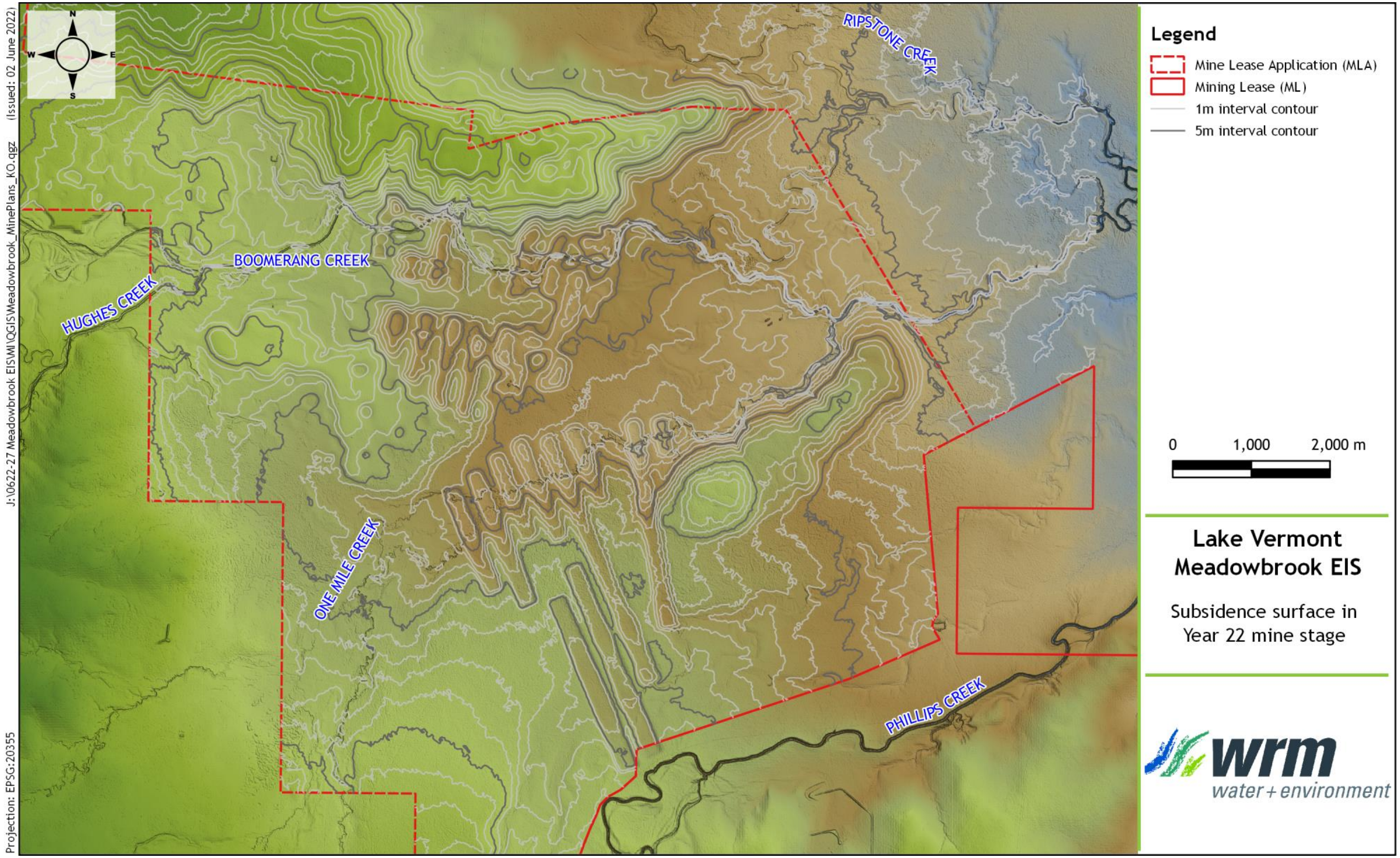

Figure 3.6 – Subsided ground surface – Year 22

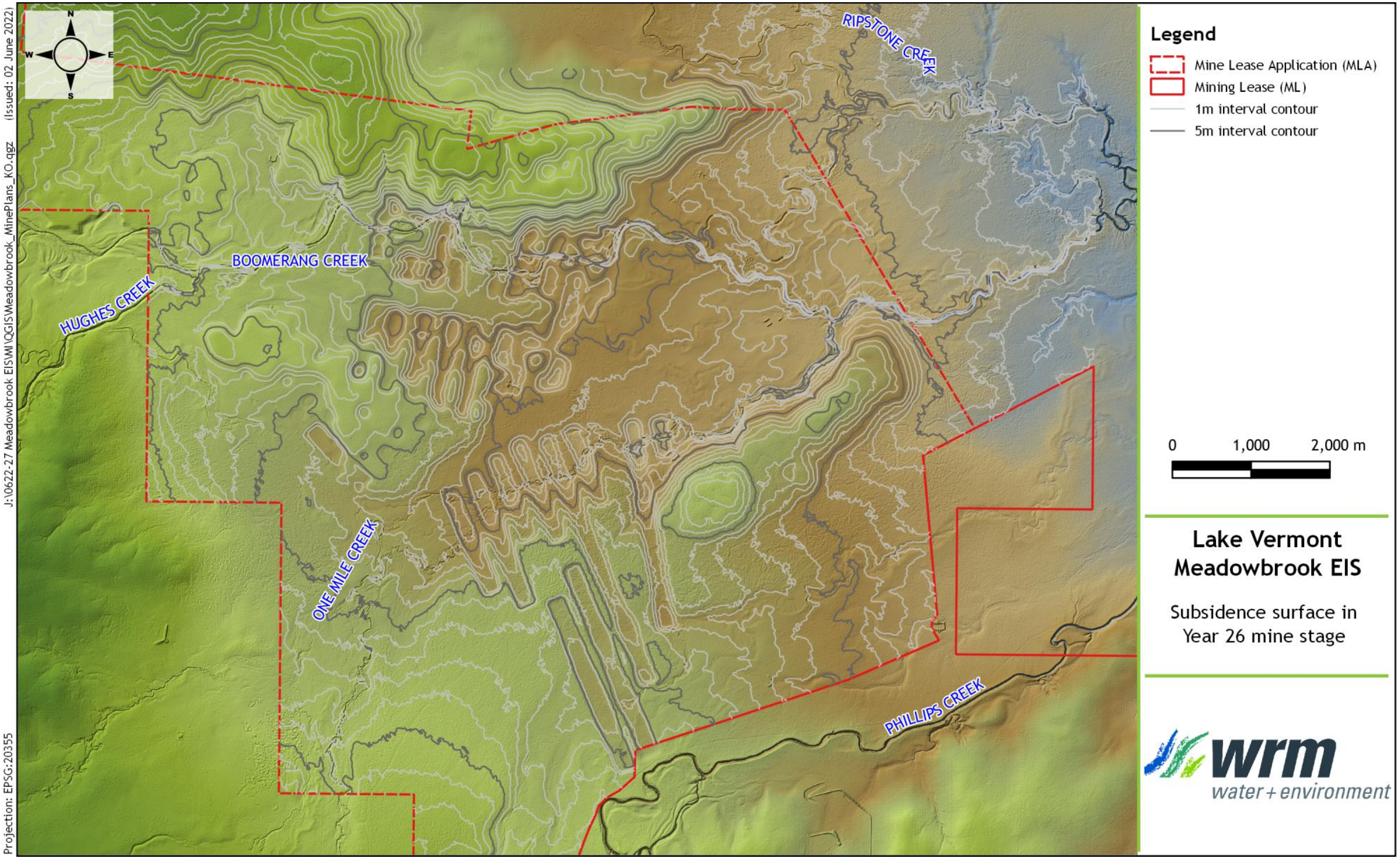

Figure 3.7 – Subsided ground surface – Year 26

3.3 IMPACTS OF SUBSIDENCE ON FLOODPLAIN DRAINAGE

3.3.1 Residual ponding

Changes to local topography resulting from the predicted subsidence would increase the number and extent of areas which are not free draining.

Figure 3.8 shows the potential extent of ponded water under existing conditions. Larger areas of pondage on the Phillips Creek floodplain are associated with embankments constructed across minor drainage paths for stock watering. However, small gilgai depressions are evident on the Phillips Creek floodplain and larger ephemeral gilgai wetlands are visible between One Mile Creek and Boomerang Creek. Billabongs created by meander cutoffs are also visible along One Mile Creek and Boomerang Creek.

Figure 3.9 shows the potential extent of ponded water for Year 26 (ultimate) subsidence predictions. These extents were derived from an interrogation of the subsided ground surface shown in Figure 3.7 to determine the overflow level of each subsided area. Note that this represents the worst-case scenario assuming the areas are full of water, which will rarely be the case.

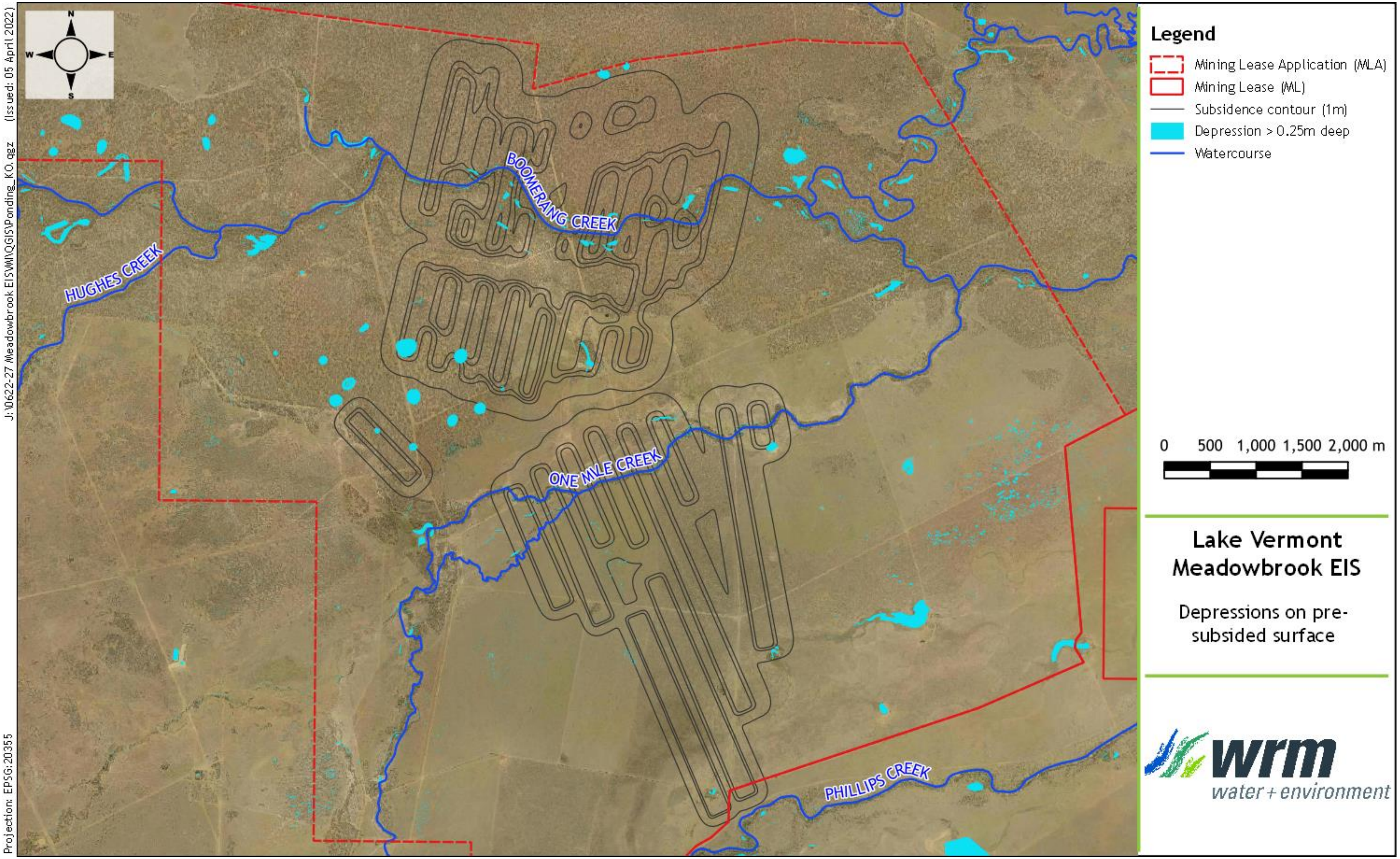

Figure 3.8 – Pre-subsidence ponding

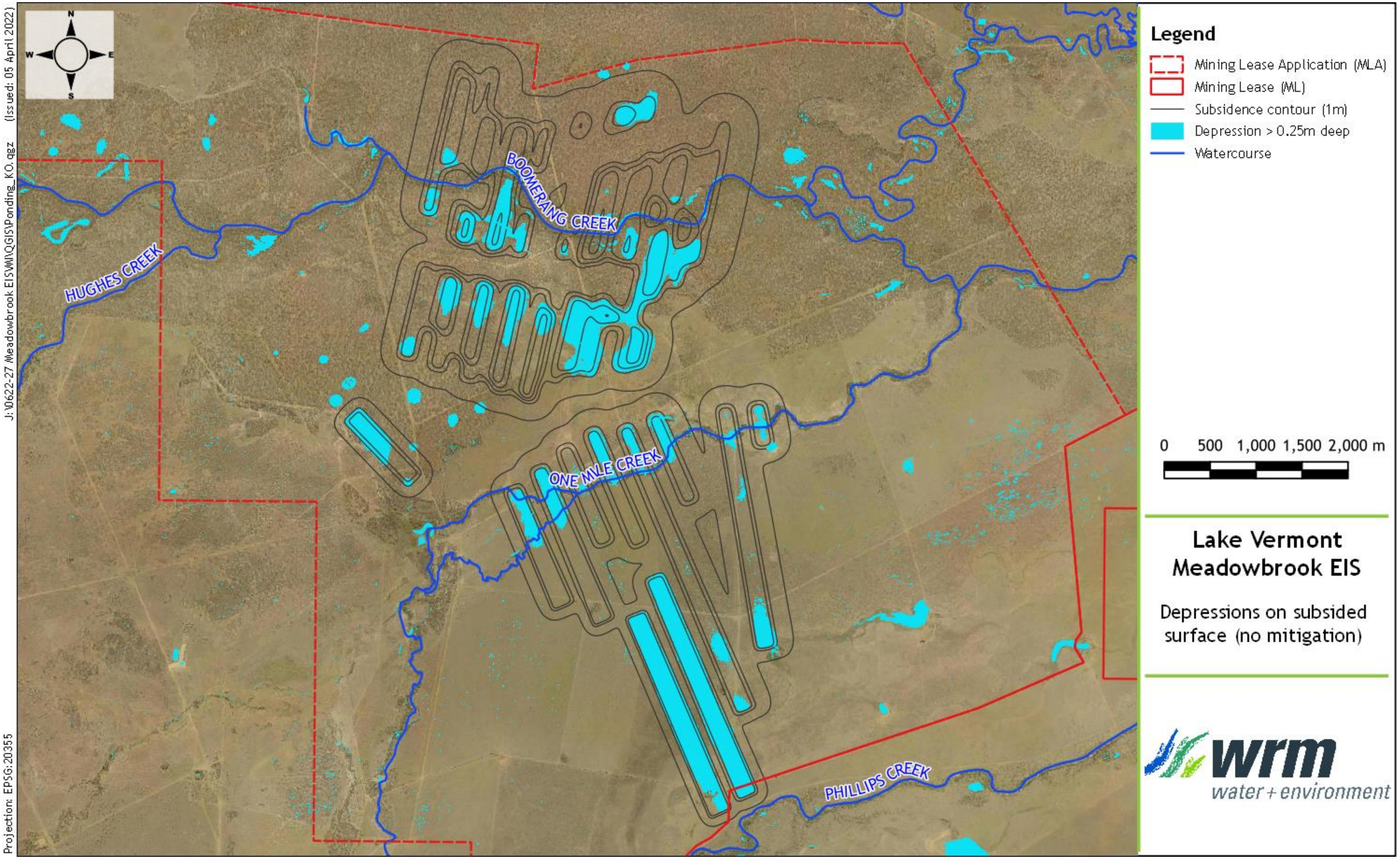

Figure 3.9 – Post-subsidence ponding (unmitigated)

3.3.2 Mitigation of increased residual ponding

Where practical, mitigation earthworks would be constructed to reduce the extent of ponding and to reinstate the free drainage of the floodplain, to maintain flow into the existing downstream landform. The two main areas of proposed works are:

1. On the northern Phillips Creek floodplain (refer Figure 3.10): A minor drainage channel is proposed to drain the four subsided panels downstream to the existing minor drainage path. The proposed earthworks would extend for approximately 2.5 km from the deepest point of the westernmost panel. The channel would be up to 2.8 m deep at the peak of each pillar and would have a base with of approximately 5 m - consistent with the existing floodplain channel in the area. In later stages of design, alternative alignments of the downstream reaches would be considered with a view to minimising the grade along the proposed flow path.

   Small embankments are also proposed across the panels in the Phillips Creek floodplain to maintain flows in the minor drainage paths during flood conditions - and to reduce the potential for Phillips Creek floodwater to be diverted to One Mile Creek in minor floods.

2. On the northern Phillips Creek floodplain (refer Figure 3.10): A temporary minor drainage channel is proposed to direct runoff from the local catchment around the proposed open cut mining area. A flood levee would be constructed around the full extent of the open cut mining activities, prior to commencement, to exclude floodwater in the 0.1% AEP design flood. Without this channel, the flood levee would prevent the free flow of water down the existing drainage path.
3. On the floodplain between One Mile Creek and Boomerang Creek (refer Figure 3.11). A minor drainage channel is proposed to drain four subsided panels. The proposed earthworks would extend for approximately 1.4 km from the deepest point of the westernmost panel. The channel would be up to 3 m deep at the peak of each pillar, and would have a base with of approximately 5 m.

Figure 3.12, show the potential maximum extent of ponded areas after implementation of these mitigation works.

More detailed maps showing the maximum depth of ponding are provided in Figure 3.13 to Figure 3.18. It should be noted that the extent of inundation is the maximum depth before overflow from the pond would occur. In practice, catchment runoff may not be sufficient to fill these ponds to the maximum level.

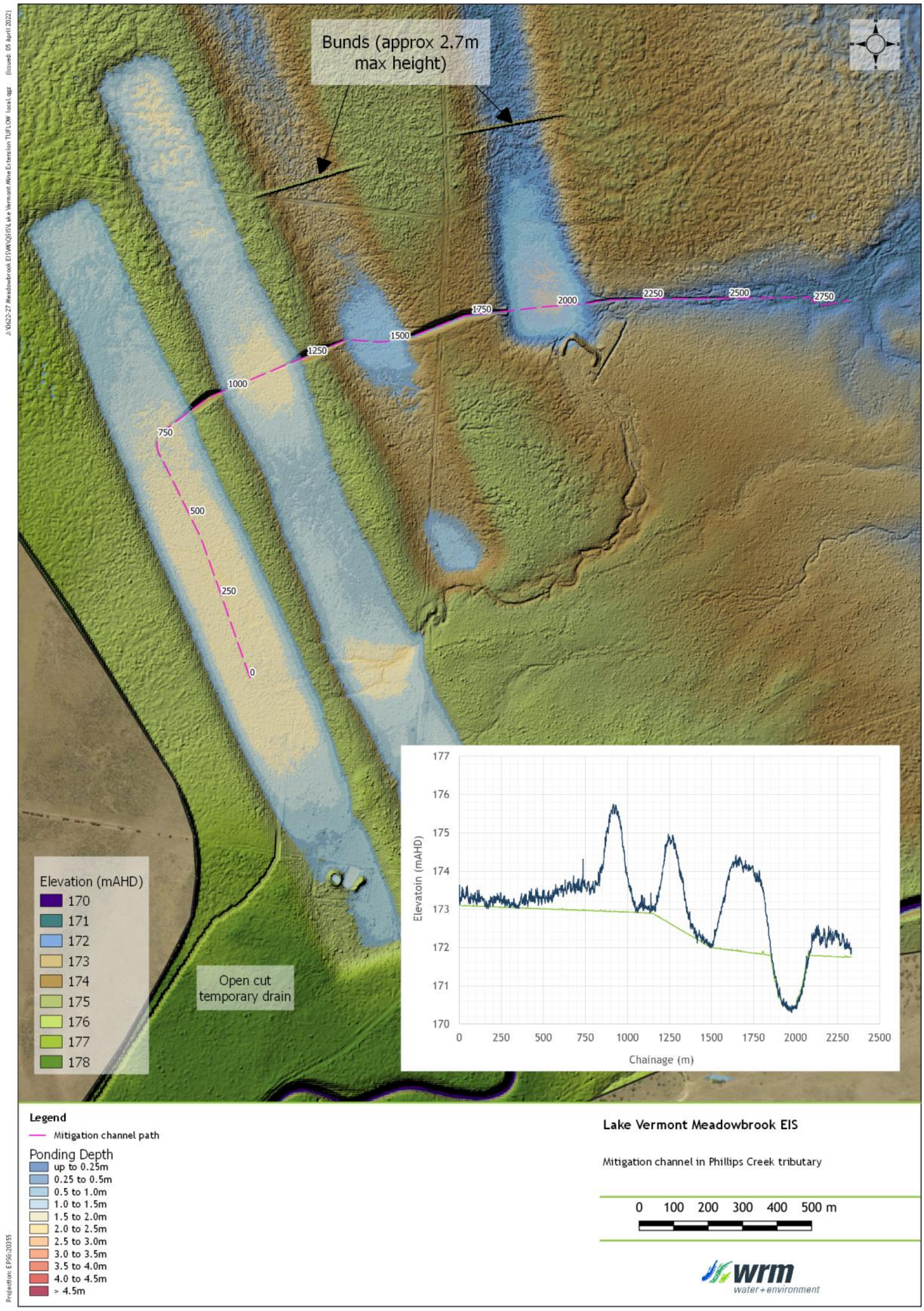

Figure 3.10 – Proposed ponding mitigation works – Phillips Creek floodplain

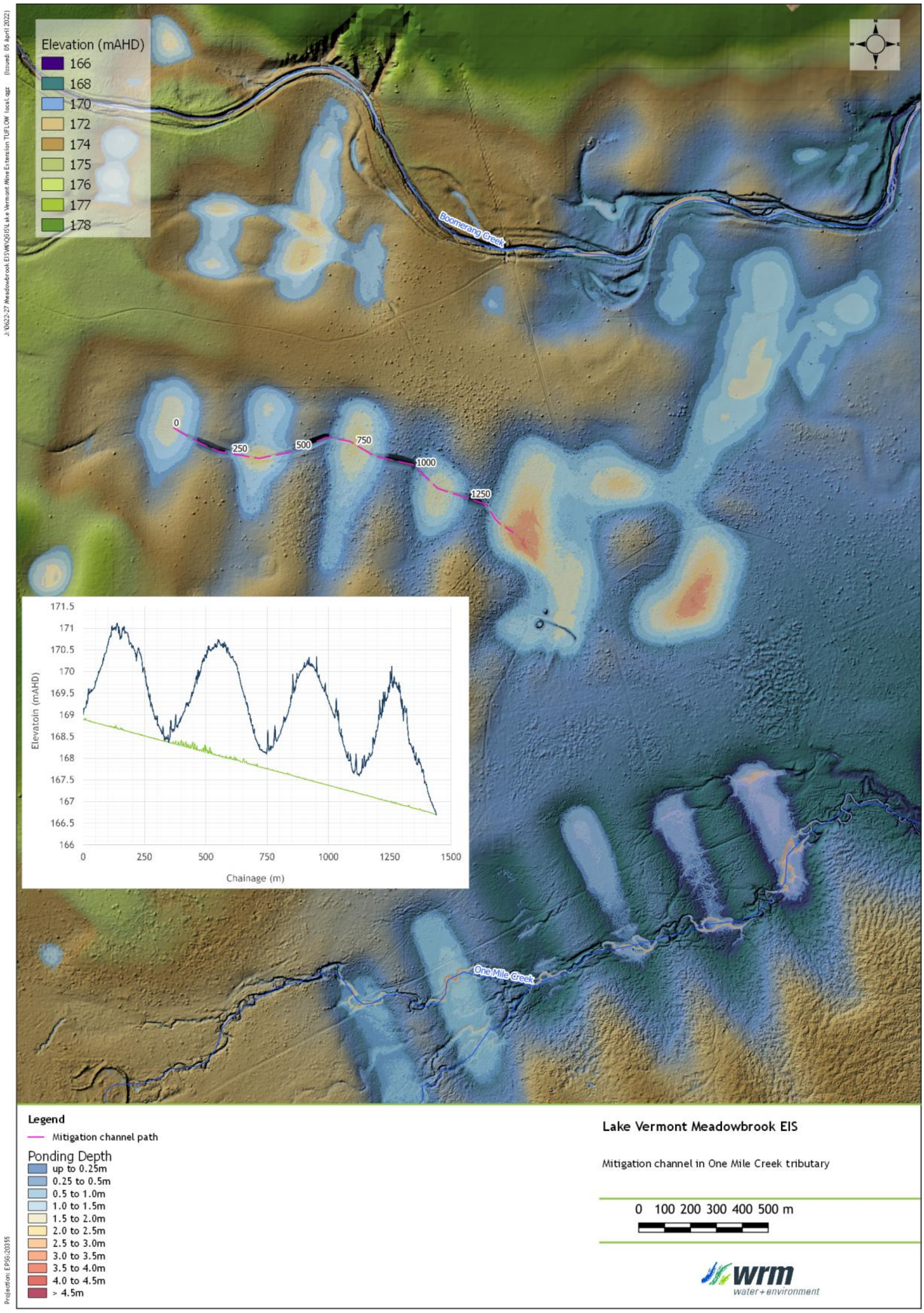

Figure 3.11 – Proposed ponding mitigation works – One Mile Creek floodplain

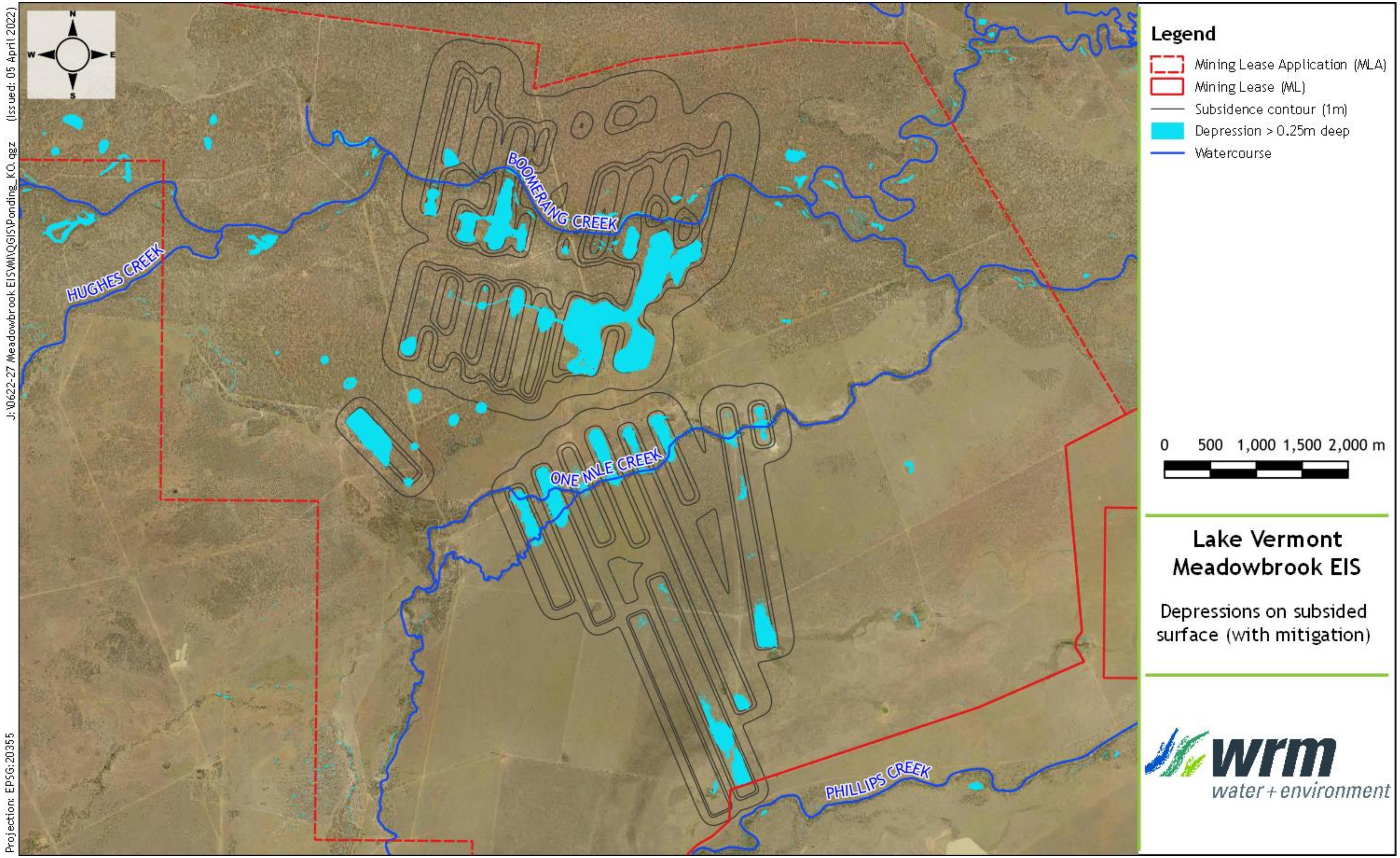

Figure 3.12 – Post-subsidence ponding (mitigated)

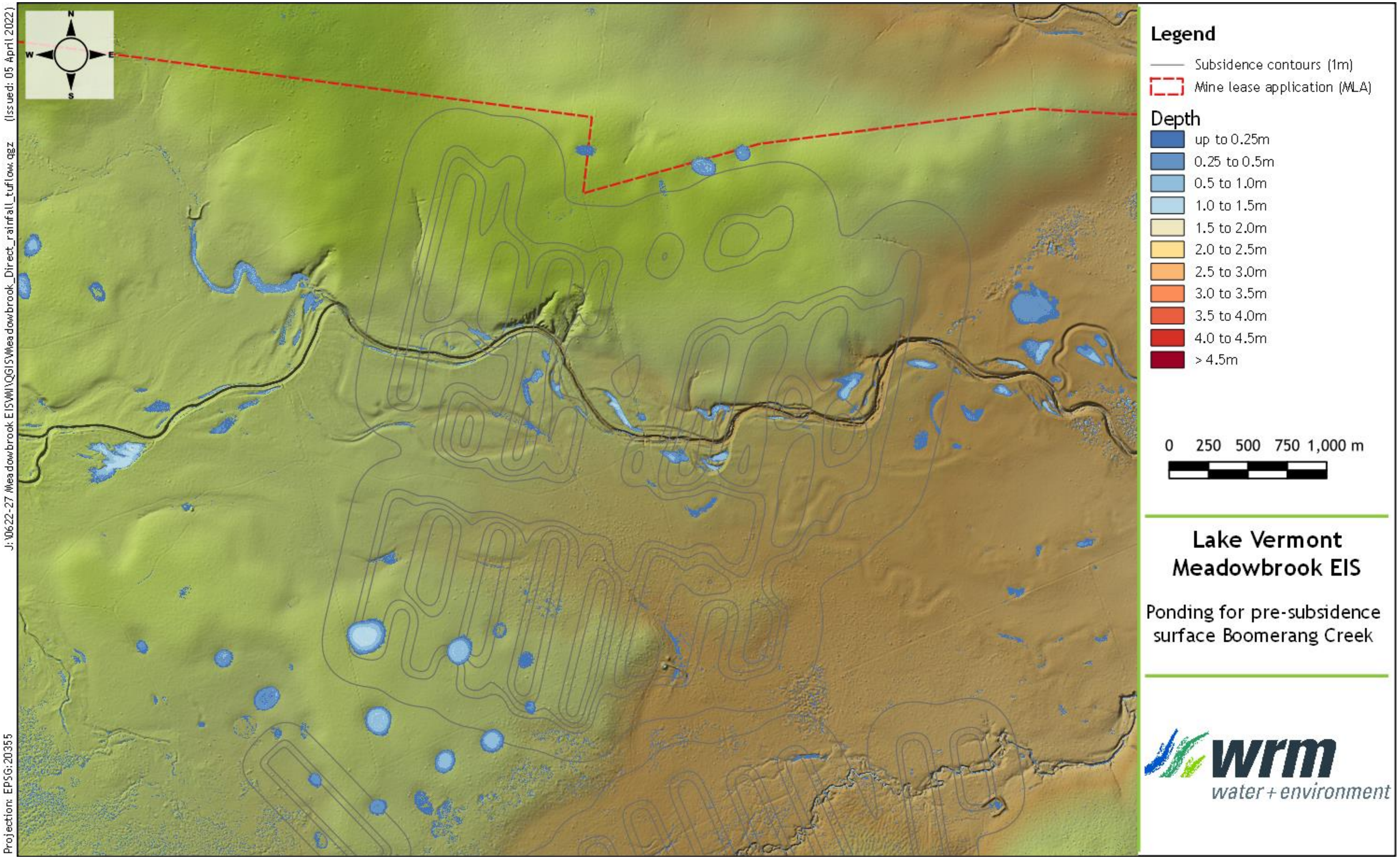

Figure 3.13 – Pre-subsidence ponding (Boomerang Creek)

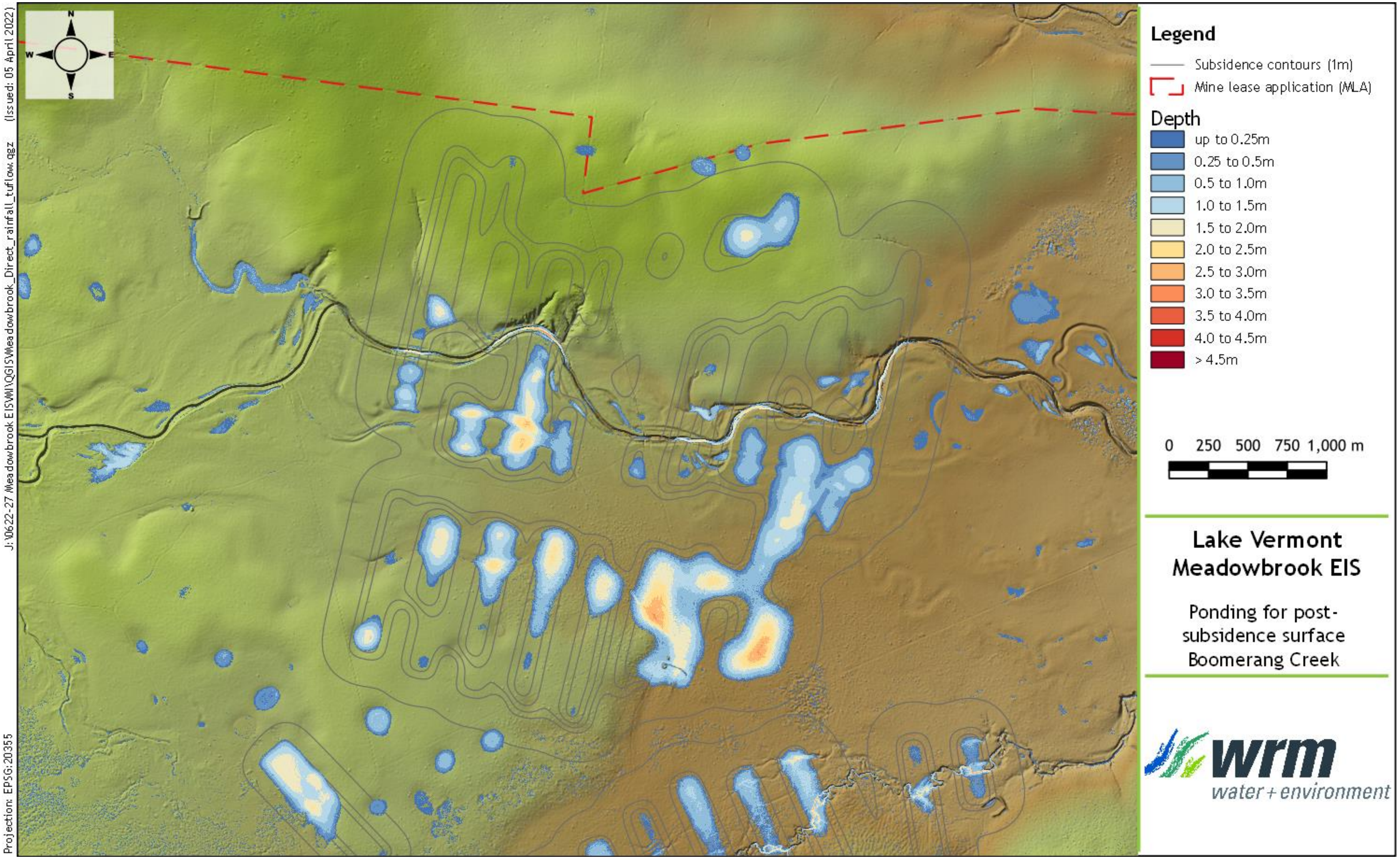

Figure 3.14 – Post-subsidence ponding (Boomerang Creek)

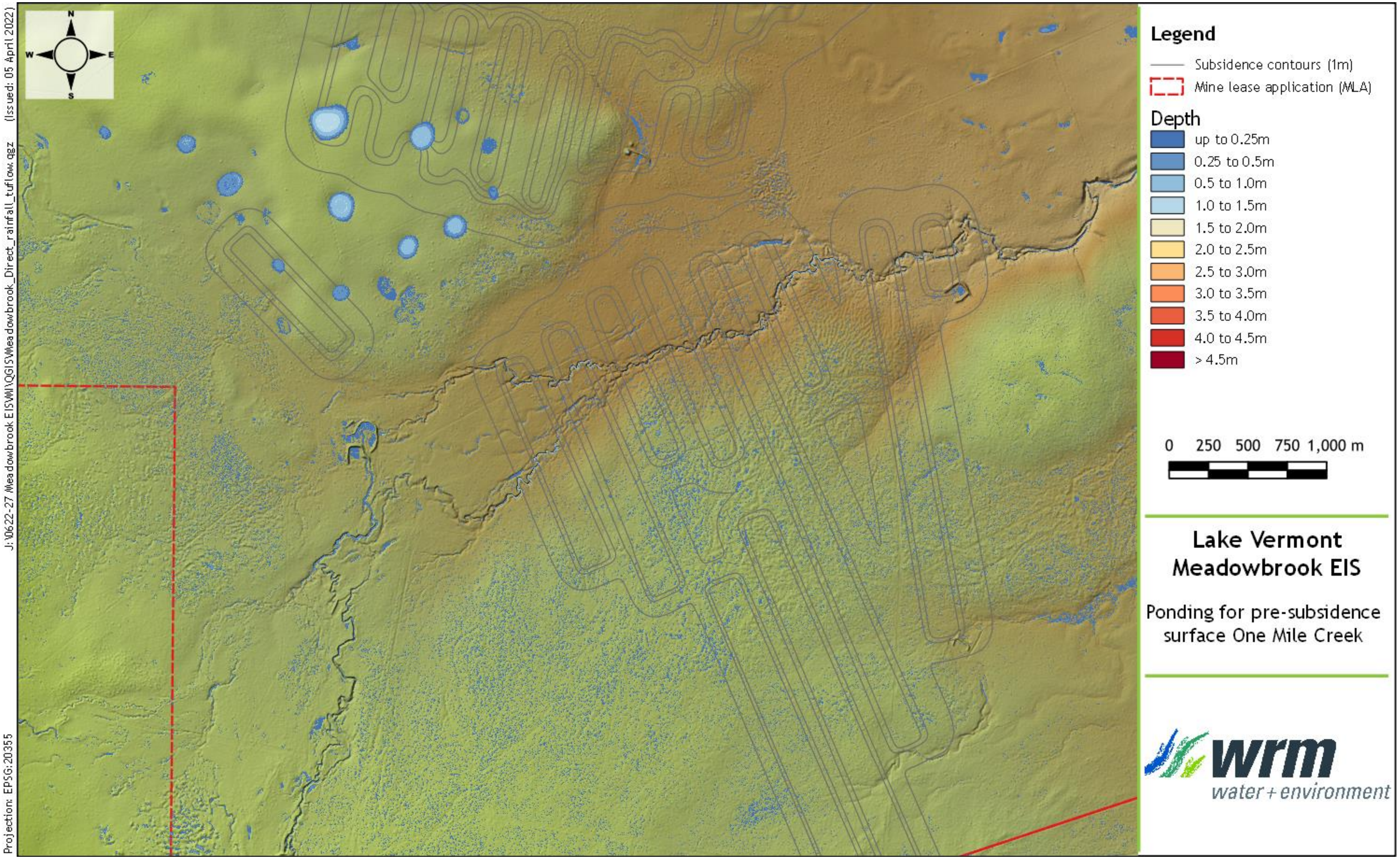

Figure 3.15 – Pre-subsidence ponding (One Mile Creek)

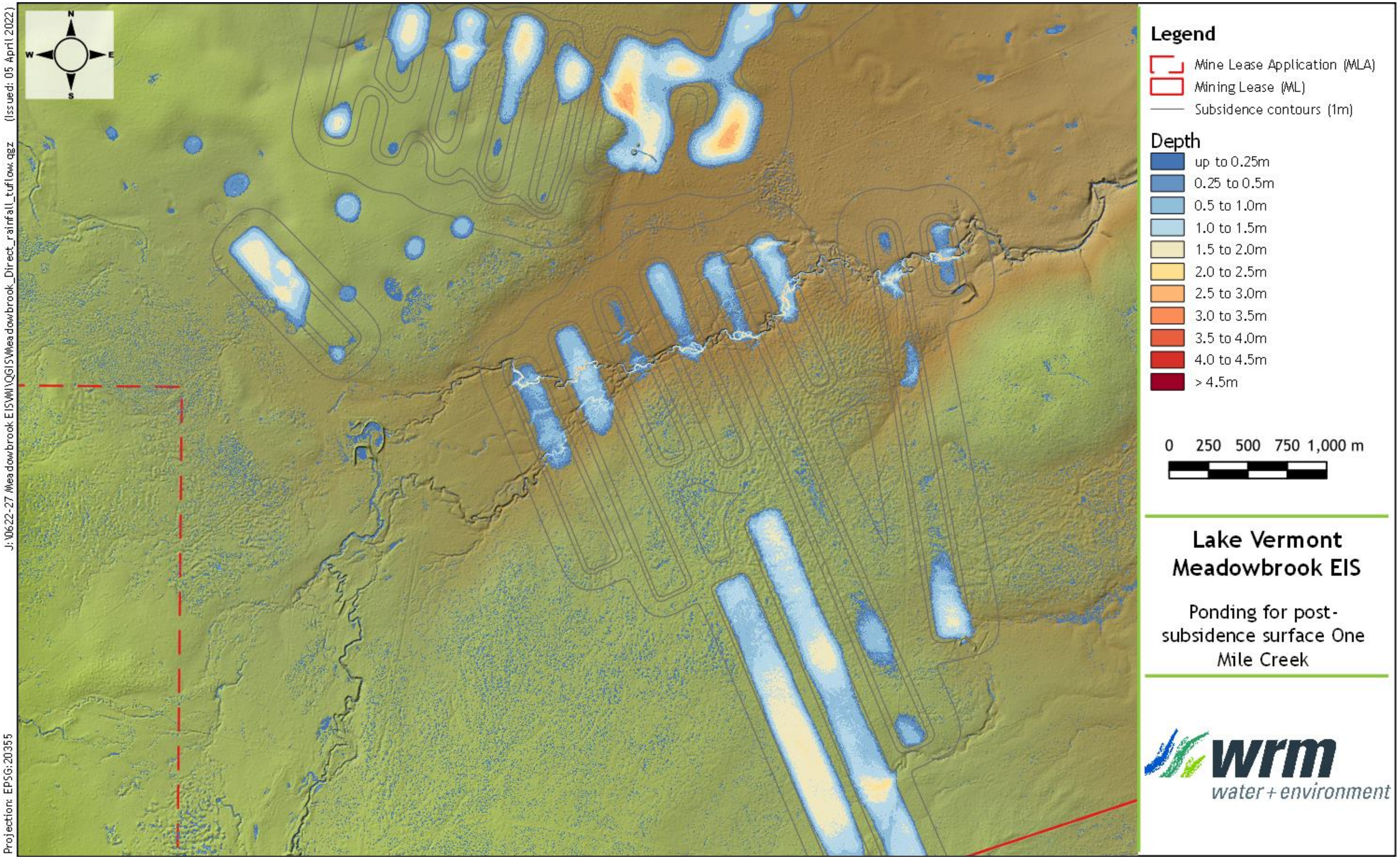

Figure 3.16 – Post-subsidence ponding (One Mile Creek)

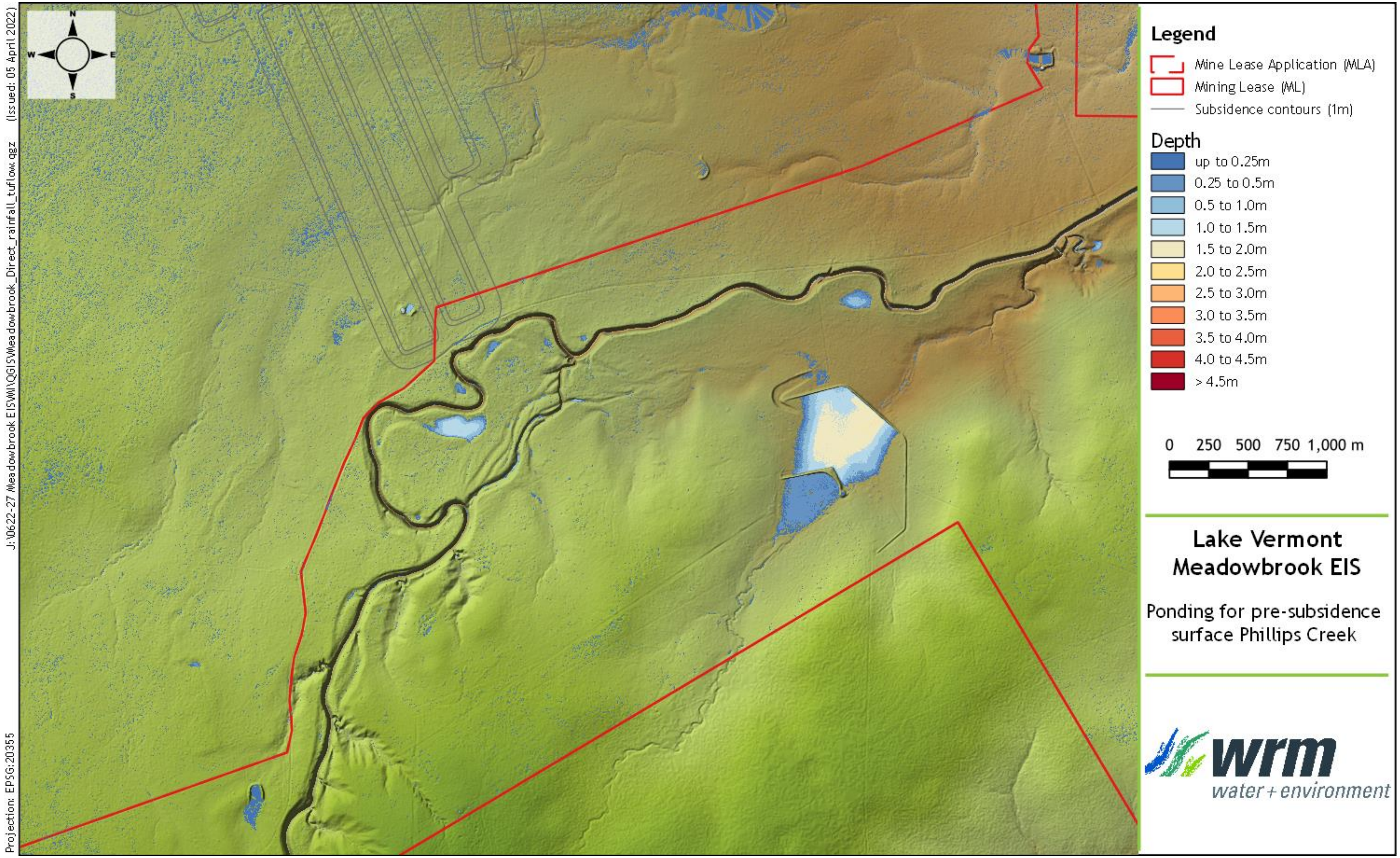

Figure 3.17 – Pre-subsidence ponding (Phillips Creek northern floodplain)

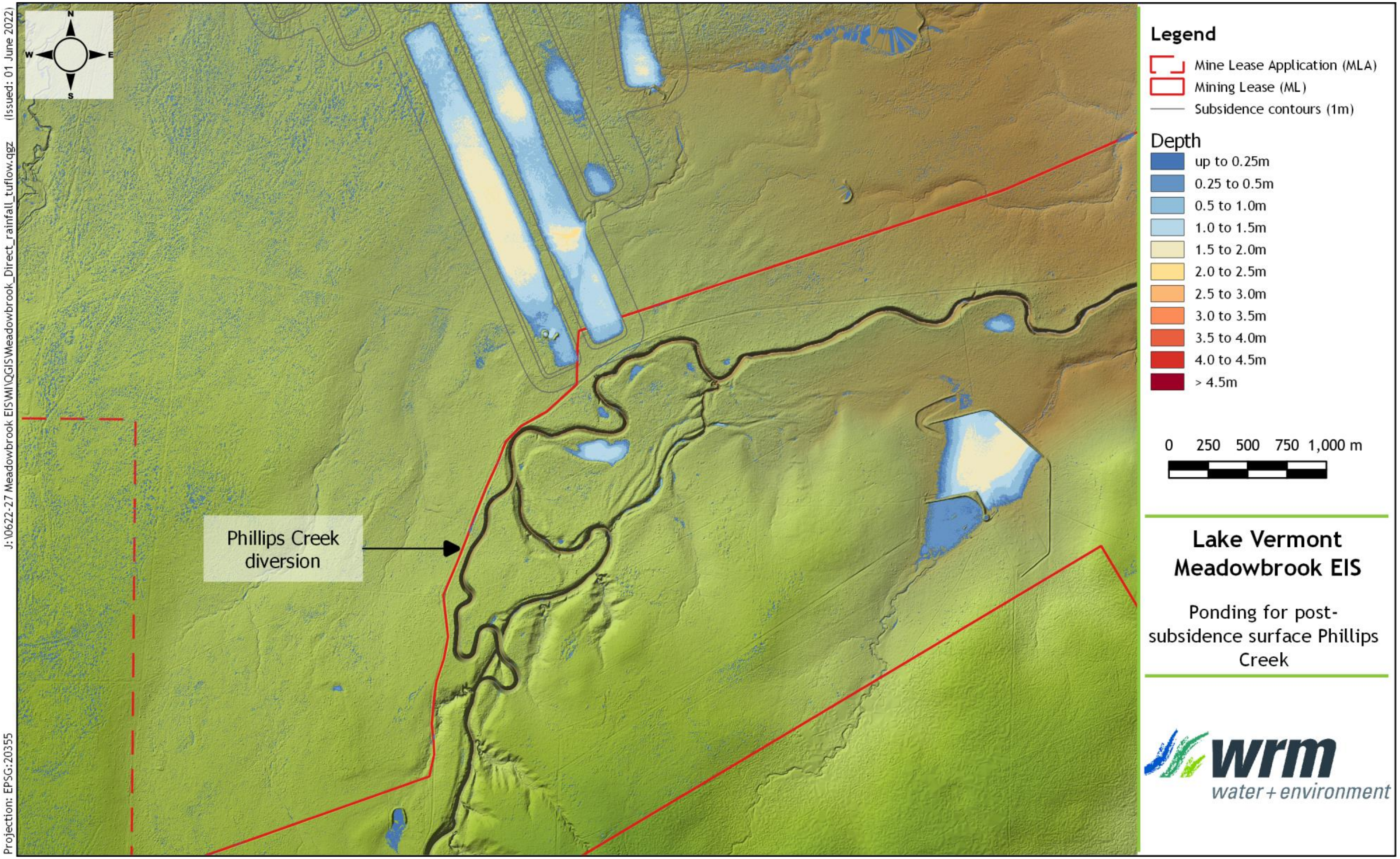

Figure 3.18 – Post-subsidence ponding (Phillips Creek northern floodplain)

3.3.3 Frequency and duration of residual ponding

Figure 3.24 shows how the One Mile Creek catchment would change post-subsidence (after construction of the mitigation works). The proposed mitigation works will reduce the extent of areas of residual ponding by draining the ponded water away as soon as downstream water levels allow.

However, in the northeastern part of the One Mile Creek and Boomerang Creek floodplain, due to their relative elevations, it is impractical to drain the subsided areas to the creek channel - and residual ponded areas would form after rainfall and or flooding. In local rainfall events, this runoff would be unlikely to overflow into One Mile Creek or Boomerang Creek (though the post-subsidence overflow path to Boomerang Creek is slightly lower than the overflow path to One Mile Creek).

The depth and frequency of residual ponding would depend on the location of the pond in relation to the flood extents, and the size of the local catchment area. Based on mapping of the 50% AEP design flood, all residual ponds created by the subsidence would be inundated by flooding at least every few years on average.

Flood water or runoff would remain in the ponds until it evaporated or seeped into the alluvium. An assessment of the potential frequency and duration of ponding in subsided areas is given in Section 4.

3.3.4 Loss of catchment runoff

3.3.4.1 Residual post-subsidence depressions

Where practical, minor drainage channels are proposed to drain the subsidence panels, however as this is not possible in all areas, ponding of runoff captured in the floodplain between Boomerang and One Mile Creeks would effectively reduce the local catchment draining to One Mile Creek by approximately 9 km^2 (6.9%). This catchment loss would impact the downstream 4 km reach of One Mile Creek in minor runoff events (which has been impacted by historical mining activities in the upper catchment) but would not significantly further alter the flow regime. The impact of the catchment loss would be minimal downstream of the confluence, where it would make up 1.8% of the 489 km^2 total catchment.

This is an overestimate, because following prolonged rainfall, the volume of local overland flow would be sufficient to fill and overflow the depressions. The volume of overland flow captured in the main floodplain depressions was estimated using a daily timestep surface water balance model.

Each depression was modelled as a surface storage receiving inflows from direct rainfall and catchment runoff (simulated using the Australian Water Balance Model (AWBM) with runoff parameters derived from calibration to the Phillips Creek at Tayglen streamflow record). Figure 3.19 shows the local overland flow catchments draining to each surface depression.

Evaporation outflows were estimated from daily Morton's Lake evaporation over the surface area calculated from a storage curve derived from the post-mining subsided surface with mitigation drainage in place. When water levels were calculated to exceed the overflow level of a depression, the excess volume was assumed to overflow in that day. The captured volume was calculated as the difference between inflows and overflows on each day.

In this analysis, the potential periodic filling of these depressions by floodwater overflowing from the main channels of Boomerang, One Mile and Phillips Creeks was excluded from the analysis. As a result, the analysis likely overestimates the volume of overland flow water captured (as the ponds would sometimes be partially full of floodwater on the arrival of overland flow).

Table 3.1 summarises the estimated volumes and depths of water stored in the main post-mining subsidence depressions. As rainfall is highly variable, the captured volume also varies considerably. The median stored volumes are small (totalling 21 ML across all four main depressions, with depths typically less than 0.65 m) but can be more substantial following wet periods (with 90th percentile volumes ranging from 43 ML to 190 ML across the depressions, and depths exceeding 1 m). Frequency curves of modelled stored water depth and volume are provided in Figure 3.20 and Figure 3.21 respectively.

Table 3.1 – Estimated volume and depth of overland flow stored in the main floodplain depressions

Catchment	Pond	Total capacity	Median stored volume	90th percentile stored volume	Median water depth (above lowest point)	90th percentile water depth (above lowest point)
		ML	ML	ML	m	m
One Mile Ck	**O1**	279	1.5	45.3	0.15	1.23
One Mile Ck	**O2**	1,084	12.0	188.3	0.65	1.85
One Mile Ck	**O3**	199	6.4	69.7	0.58	1.02
Total						
Phillips Ck	**P1**	165	0.8	43.2	0.13	0.91

The annual rainfall/runoff volume captured was calculated at each timestep as the difference between inflow and outflow at each depression.

The results of the analysis presented in Table 3.2, show that the subsidence depressions in the One Mile Creek floodplain capture approximately 72% of the average annual runoff from their local catchments. In the Phillips Creek floodplain, where the mitigated depressions have relatively small storage compared to the size of the catchment draining to them, only 29% of runoff is captured, but the total volumes captured are of similar magnitude, due to the relatively large size of the Phillips Creek floodplain catchment. Overall, the depressions capture 46% of the local runoff draining to them.

Table 3.2 – Estimated annual volume of overland flow captured by main floodplain depressions

Catchment	Pond	Catchment area	Total capacity in floodplain depressions	Average annual local runoff to depressions	Median annual volume captured	Average annual volume captured	Proportion of average annual runoff captured
		ha	ML	ML	ML	ML	
One Mile Ck	**O1**	166	279	67	16	48	72%
One Mile Ck	**O2**	655	1,084	264	65	190	72%
One Mile Ck	**O3**	161	199	65	15	45	70%
Total One Mile Ck		**1,562**	**981**	**395**	**96**	**283**	**72%**
Phillips Ck	**P1**	1,436	165	577	128	167	29%
	Total	**2,417**	**1,727**	**972**	**224**	**450**	**46%**

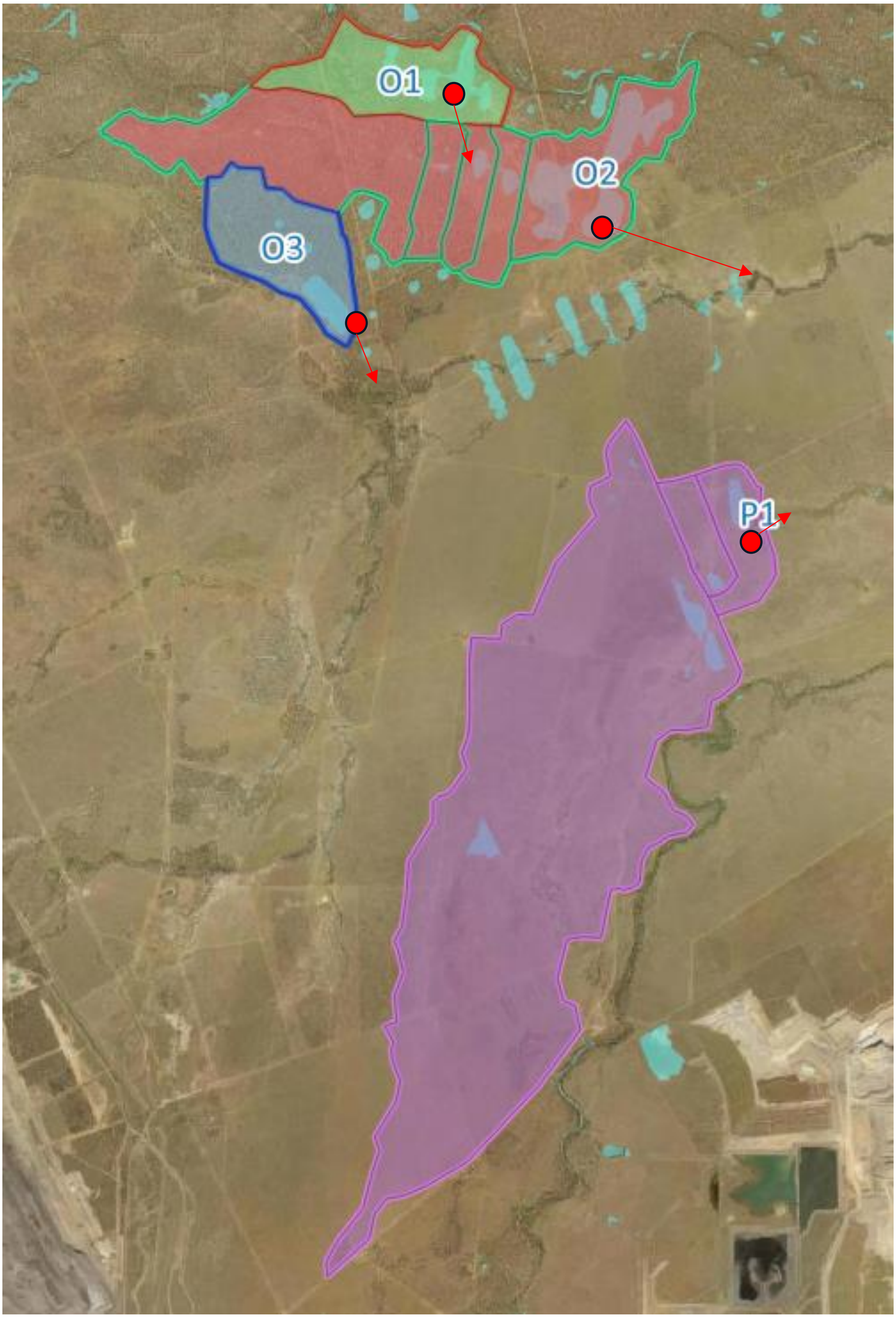

Figure 3.19 – Local overland flow catchments to the main subsidence depressions

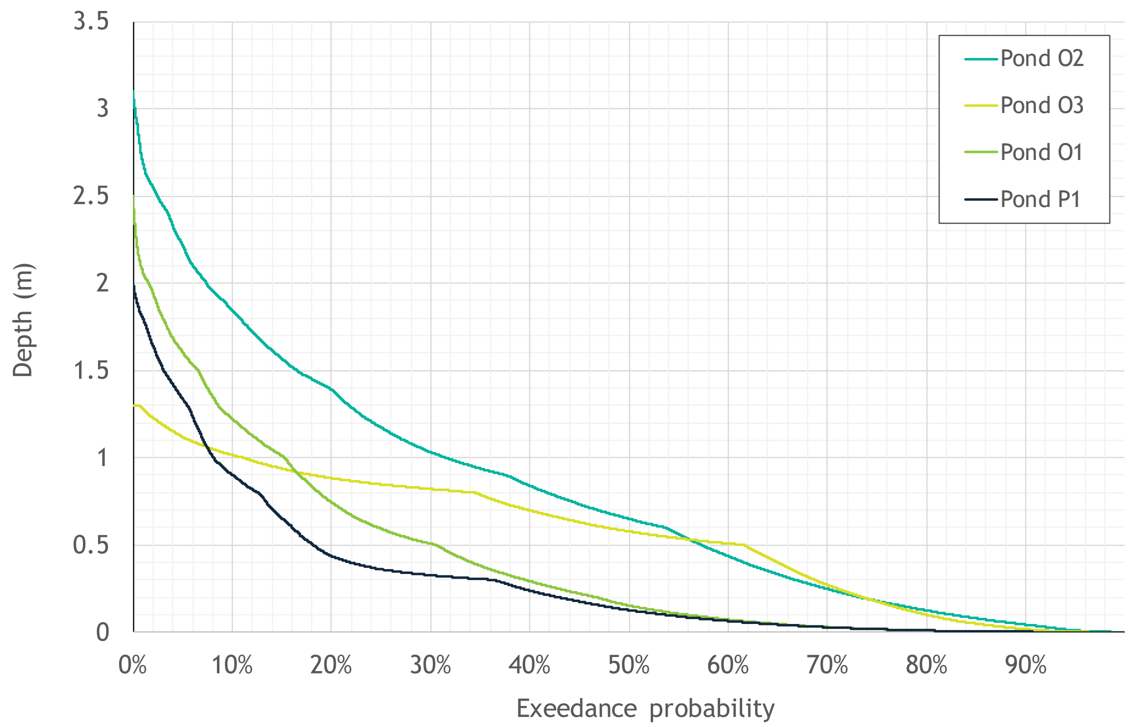

Figure 3.20 – Modelled water depths in the main post-mining subsidence depressions

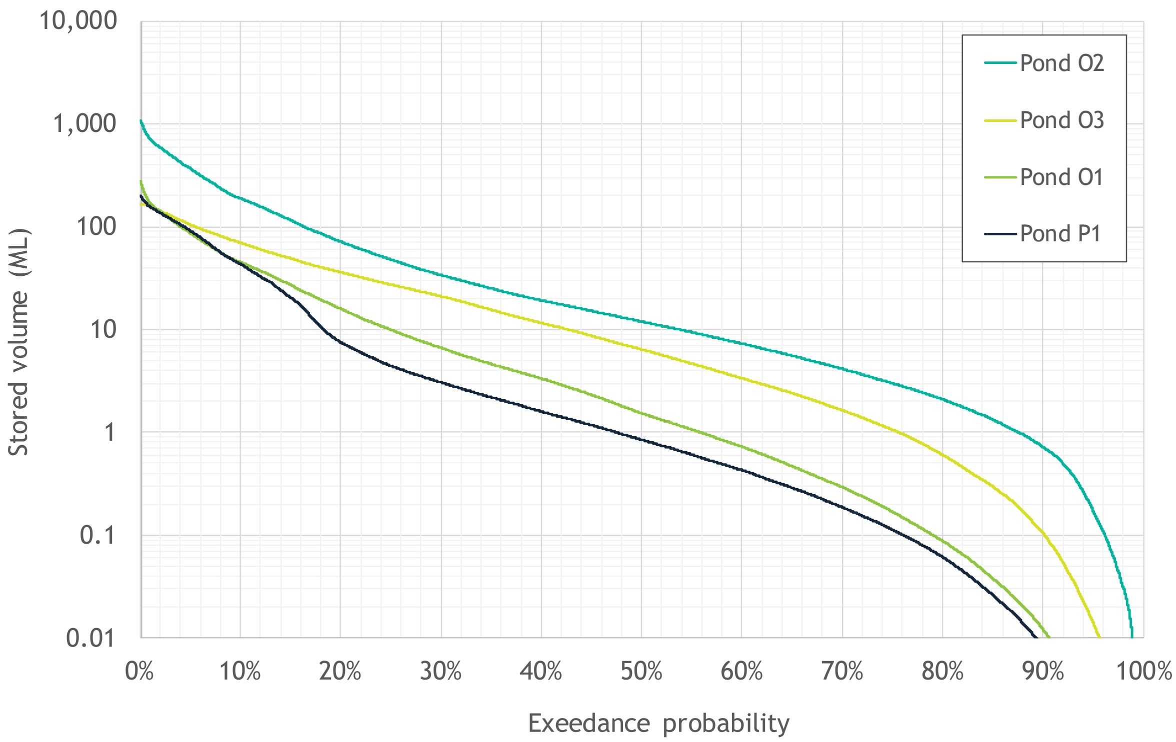

Figure 3.21 – Modelled water volumes in the main post-mining subsidence depressions

Lake Vermont Resources proposes to use mobile pumping equipment to further reduce the total volume of overland flow captured by pumping from the ponds into the downstream flow paths when accumulated volumes become significant. The pumps would be located at the deepest sections of each subsidence depression and deliver water to the pre-mining overland flow path (as indicated in Figure 3.19). The effectiveness of pumping out each of each the depressions at a nominal rate of 50 L/s (4.3 ML/d) when water the depth exceeds 0.5 m above the lowest point, was tested using the water balance model. The results summarised in Table 3.3 below show that pumping reduces the volume captured in the depressions to 11% of the total runoff draining to the depressions.

Table 3.3 – Estimated annual volume of overland flow captured by main floodplain depressions

Catchment	Pond	Catchment area	Total capacity in floodplain depressions	Average annual local runoff to depressions	Median annual volume captured	Average annual volume captured	Proportion of average annual runoff captured
		ha	ML	ML	ML	ML	
One Mile Ck	**O1**	166	279	67	9	12	19%
One Mile Ck	**O2**	655	1,084	264	18	49	19%
One Mile Ck	**O3**	161	199	65	13	16	25%
Total One Mile Ck		**981**	**1,562**	**395**	**40**	**78**	**25%**
Phillips Ck	**P1**	1,436	1,436	577	12	31	5%
	Total	**2,417**	**1,727**	**972**	**52**	**109**	**11%**

3.3.4.2 Potential loss in the open cut mining area

During open cut operations, water which would normally flow to One Mile Creek and Phillips Creek would be intercepted by the proposed mine water management system within the levees protecting the mine pit and sediment dams. The construction of the sediment dams would be staged, and in large rainfall events they could overflow. However, during the period of peak open cut mining disturbance, the temporary maximum additional reduction in catchment area draining to the downstream 6 km reach of One Mile Creek would be approximately 3 km^2. At the completion of mining and rehabilitation of the final landform, this would reduce to approximately 1.5 km^2 (i.e. a total catchment loss of 10.5 km^2 – 8%).

At Phillips Creek, there would be a corresponding 0.3 km^2 temporary loss of catchment during operations and a loss of 0.03 km^2 after rehabilitation of the final landform. These losses are insignificant in terms of impacts to the flow regime of Phillips Creek and its floodplain.

The areas of potential surface runoff catchment loss are indicated in Figure 3.22 and Figure 3.23 for the maximum disturbance and final landform scenarios respectively.

3.3.4.3 Potential loss to underground workings

Based on field measurements and observations at similar operations Gordon Geotechniques (GG, 2022) predicted the maximum depth of continuous subsurface subsidence cracking above the workings would be:

- up to 120 m in the single seam extraction areas;
- up to 180 m in areas where both the Leichhardt Lower and Vermont Lower Seam are to be extracted.

Table 3.4 compares the depth of cover above the watercourses crossing the mine area. Based on this information, Gordon Geotechniques concluded subsurface subsidence cracking would not extend to the ground surface, including Boomerang, One Mile and Phillips creeks.

Table 3.4 – Estimated depth of predicted depth of continuous cracking and depth of cover

Stream	Depth of cover m	Depth of continuous subsurface cracking m
One Mile Creek	240-320	< 180
Boomerang Creek	320-470	< 180
Phillips Creek	>150	< 120

3.3.4.4 Potential loss to surface cracking

Surface subsidence cracks will develop in the proposed longwall mining areas. The areas with the highest potential for cracking are those located at the panel edges where the maximum tensile strain occurs. Gordon Geotechniques concluded the widest of these cracks would extend to no more than 10 to 15 m below ground level, with the majority less than 1 m deep. Maximum surface crack widths up to 200 mm could be expected in the shallower parts of the area, decreasing to less than 50 mm at greater depths. Some reworking and widening of existing cracks are predicted where both seams are extracted. Cracks of this depth would not result in the loss of water from the alluvium associated with the watercourses overlying the underground workings

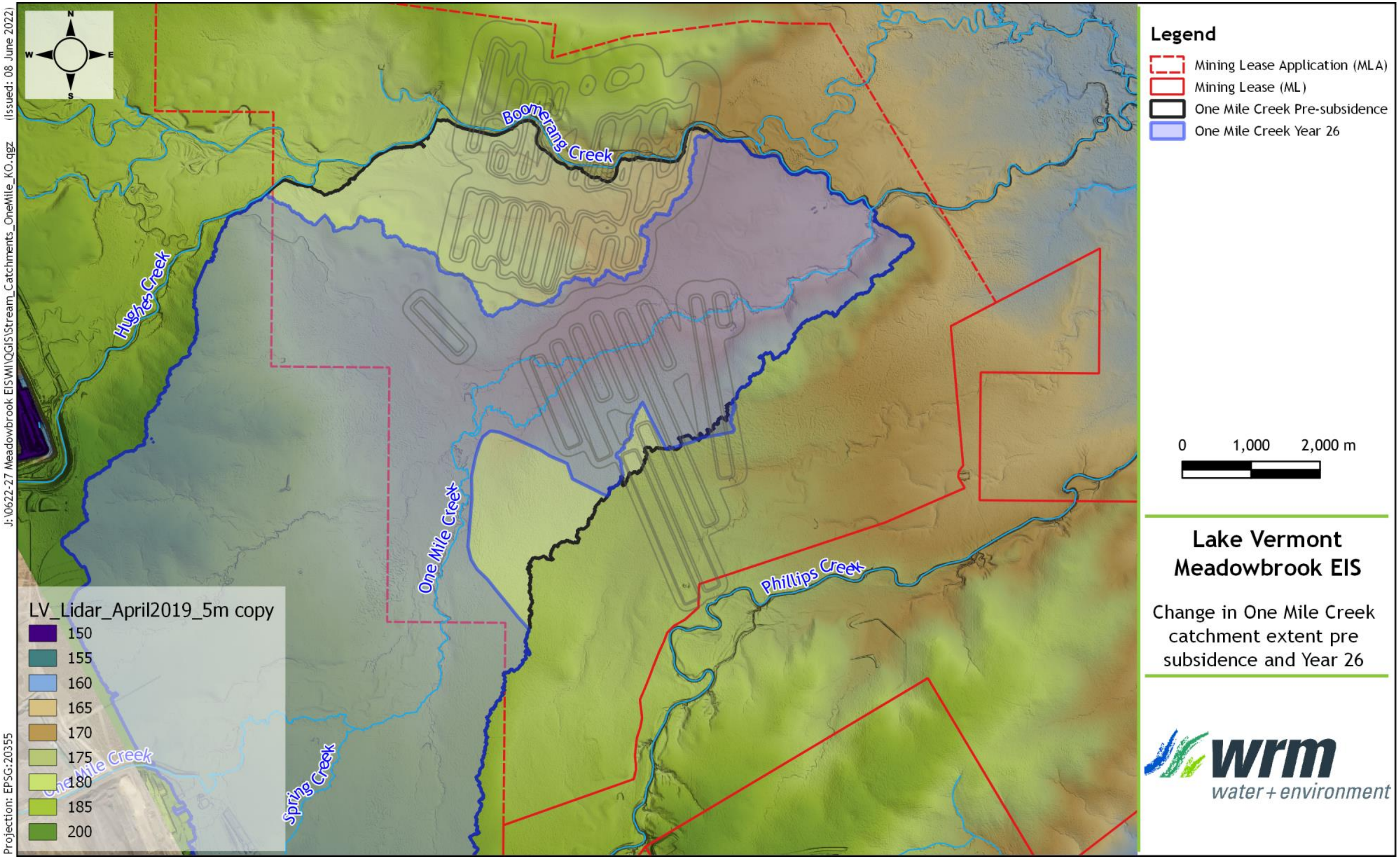

Figure 3.22 – Changes in flow paths – with mitigation works – One Mile Creek - maximum open cut disturbance

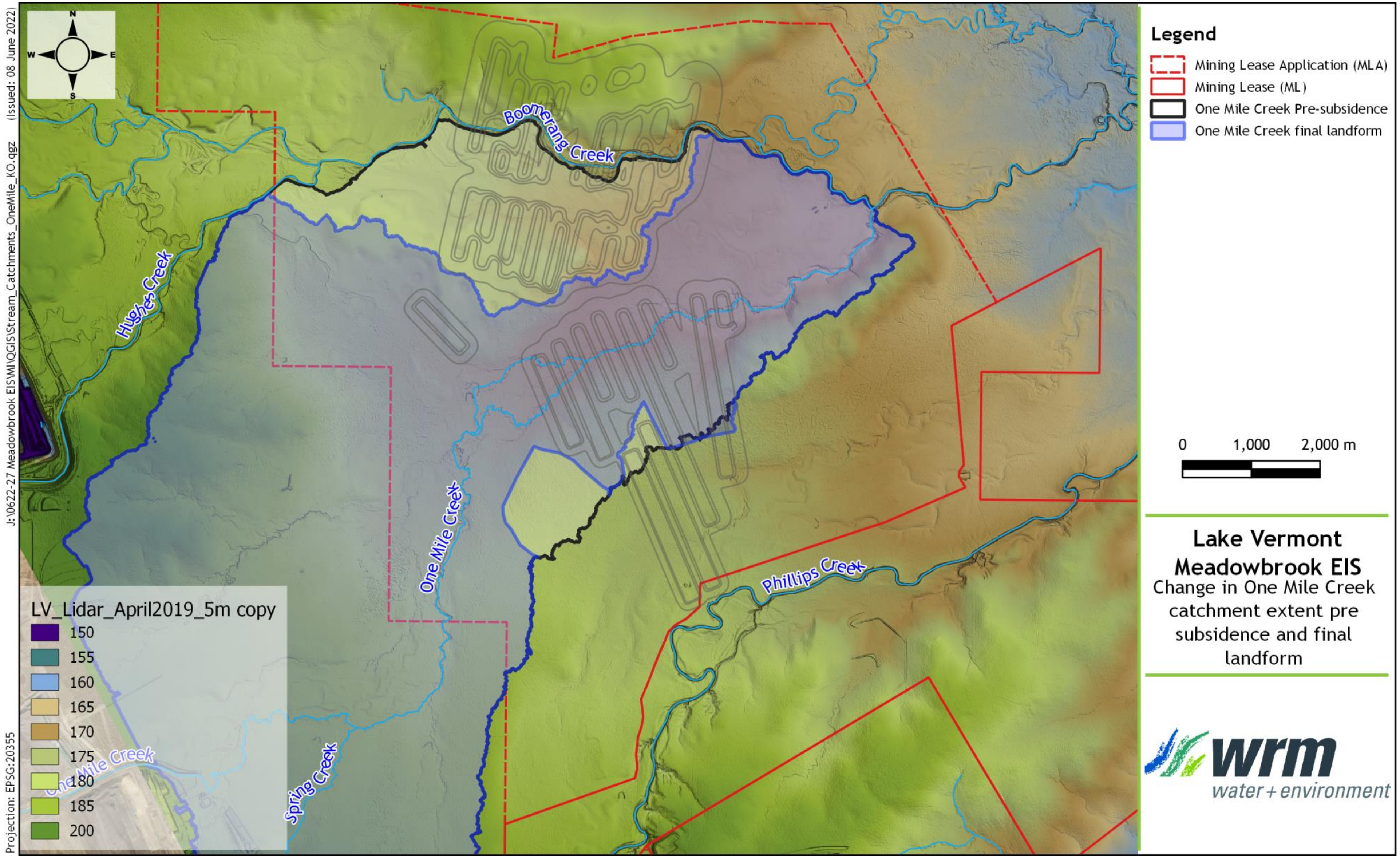

Figure 3.23 – Changes in flow paths – with mitigation works – One Mile Creek – final landform

3.3.5 Direct impacts on vertical alignment of waterway channels

The changes to the local topography resulting from the predicted subsidence would locally reduce the bed elevations of the channels and adjacent banks in Boomerang Creek and One Mile Creek over distances of 5 km and 6 km respectively.

In Boomerang Creek the subsidence (over the nine panels proposed for each seam) would form four broad troughs due to the combined effect of mining both underlying coal seams, and range in maximum depth from 2 m to 4 m. The change in longitudinal profile of the Boomerang Creek channel is shown in Figure 3.24 (based on the section line in Figure 3.25). Typical cross-sections along Boomerang Creek are shown in Figure 3.26 to Figure 3.31

In One Mile Creek eight troughs would be formed with maximum depths of 2.5 m to 3 m. The change in longitudinal profile of the One Mile Creek channel is shown in Figure 3.32 (based on the section line in Figure 3.33). Typical cross-sections along Boomerang Creek are shown in Figure 3.34 to Figure 3.39.

Two main troughs of approximately 2.5 m maximum depth would cross the main Phillips Creek floodplain flow-path, as shown in the longitudinal profile in Figure 3.40 (refer Figure 3.41 for section line location).

An assessment of these impacts is given in Section 4.

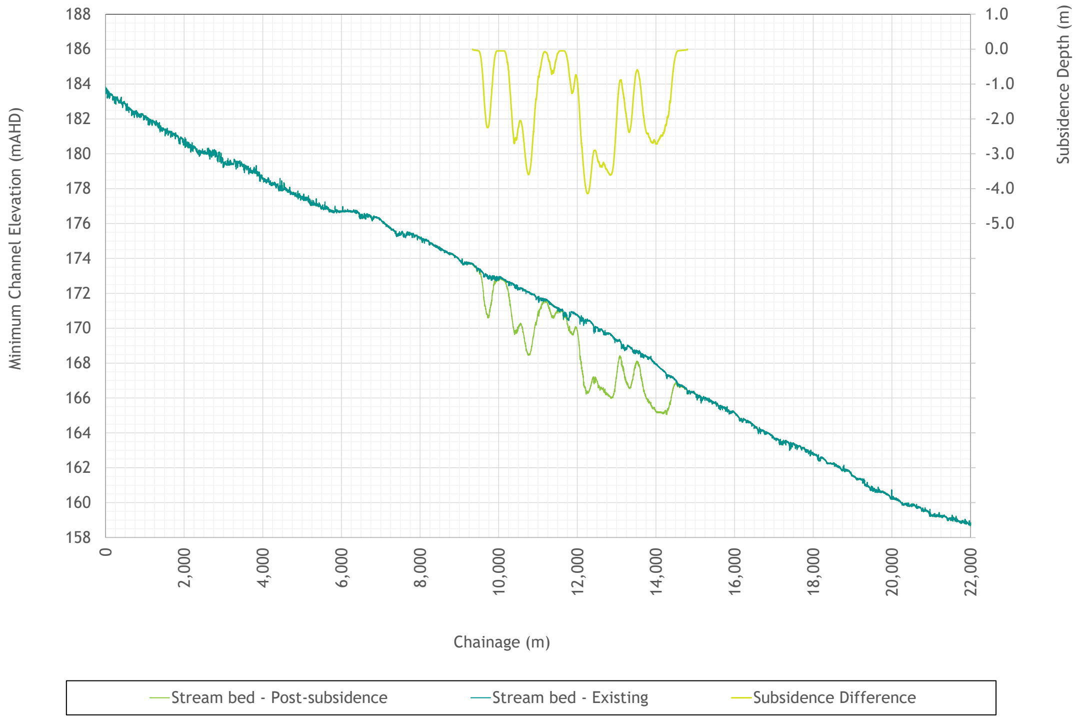

Figure 3.24 – Longitudinal profile Boomerang Creek main channel

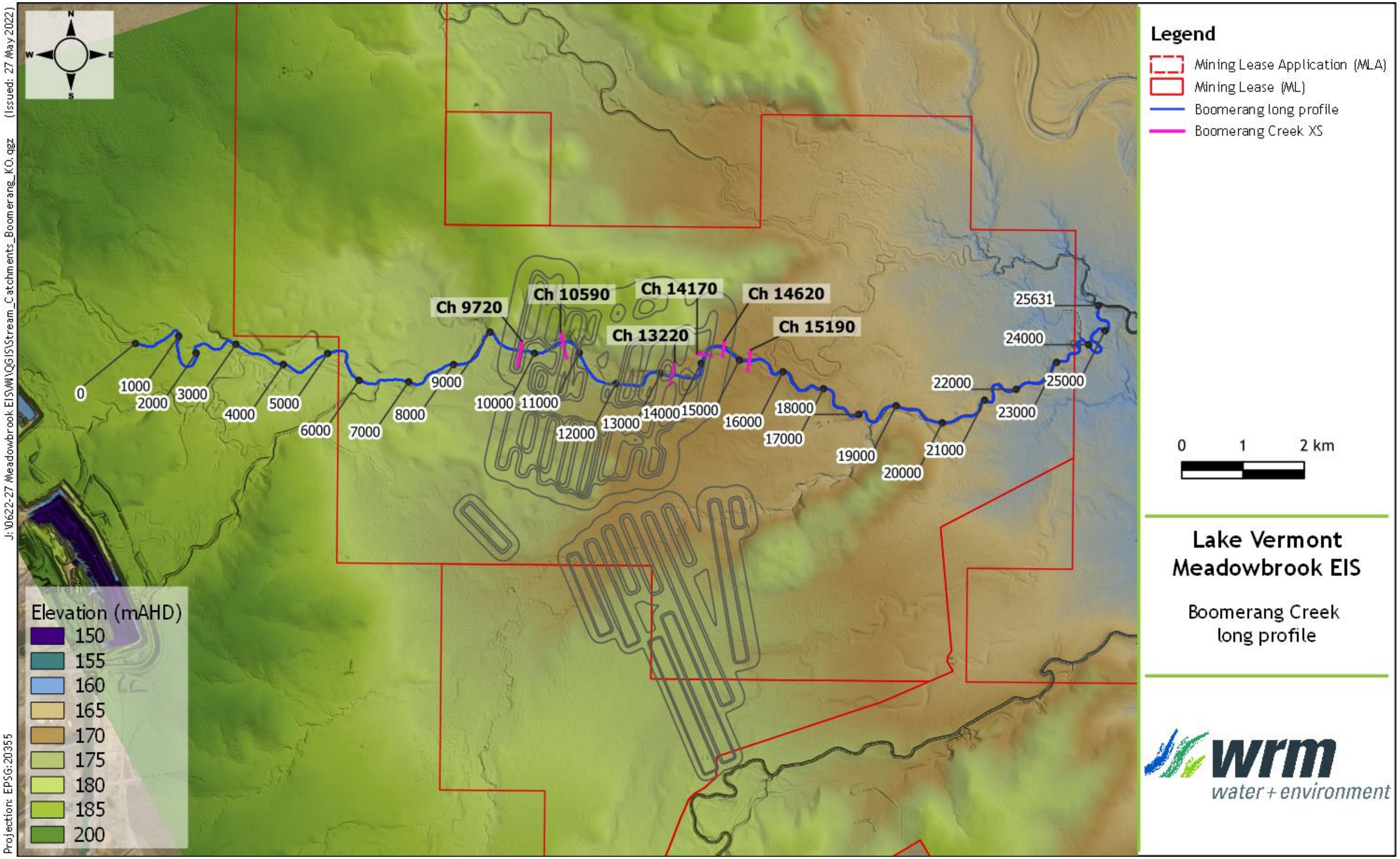

Figure 3.25 – Longitudinal profile chainages and cross-section locations – Boomerang Creek main channel

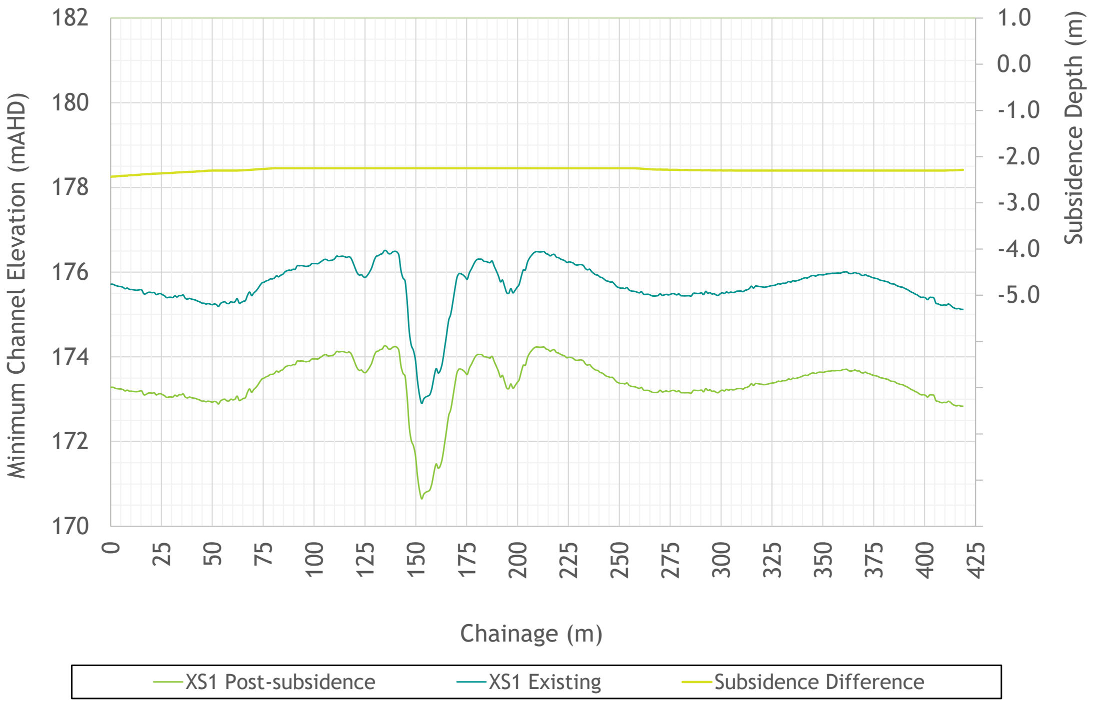

Figure 3.26 – Cross-section – Boomerang Creek main channel Ch 9,720

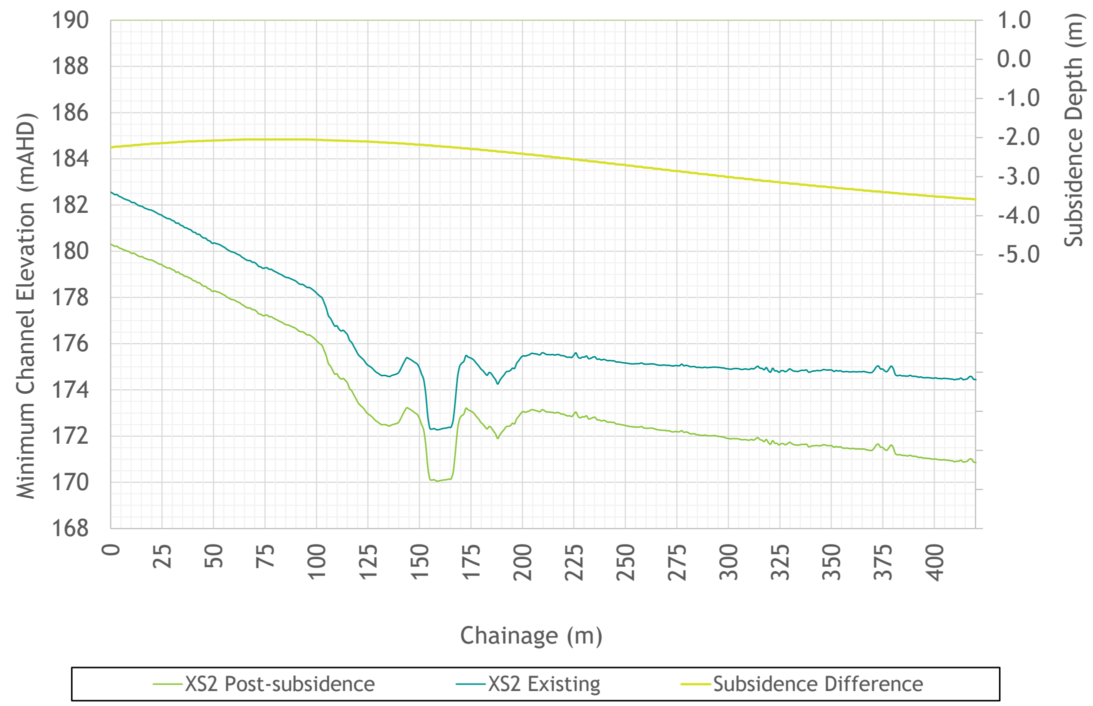

Figure 3.27 – Cross-section – Boomerang Creek main channel Ch 10,590

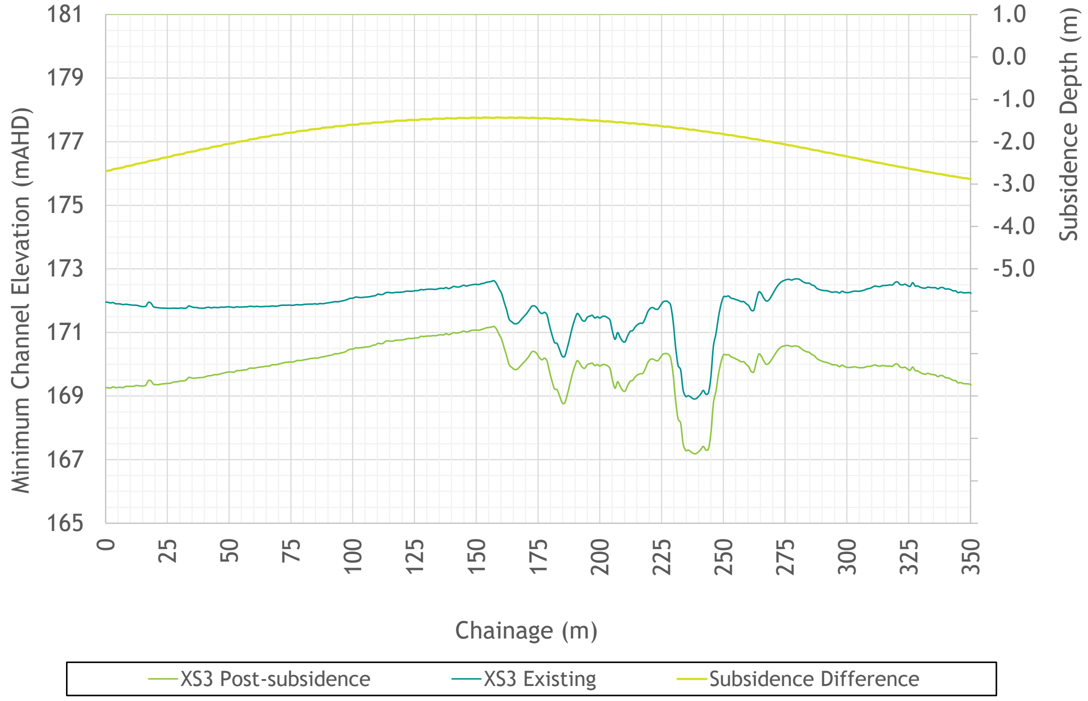

Figure 3.28 – Cross-section – Boomerang Creek main channel Ch 13,220

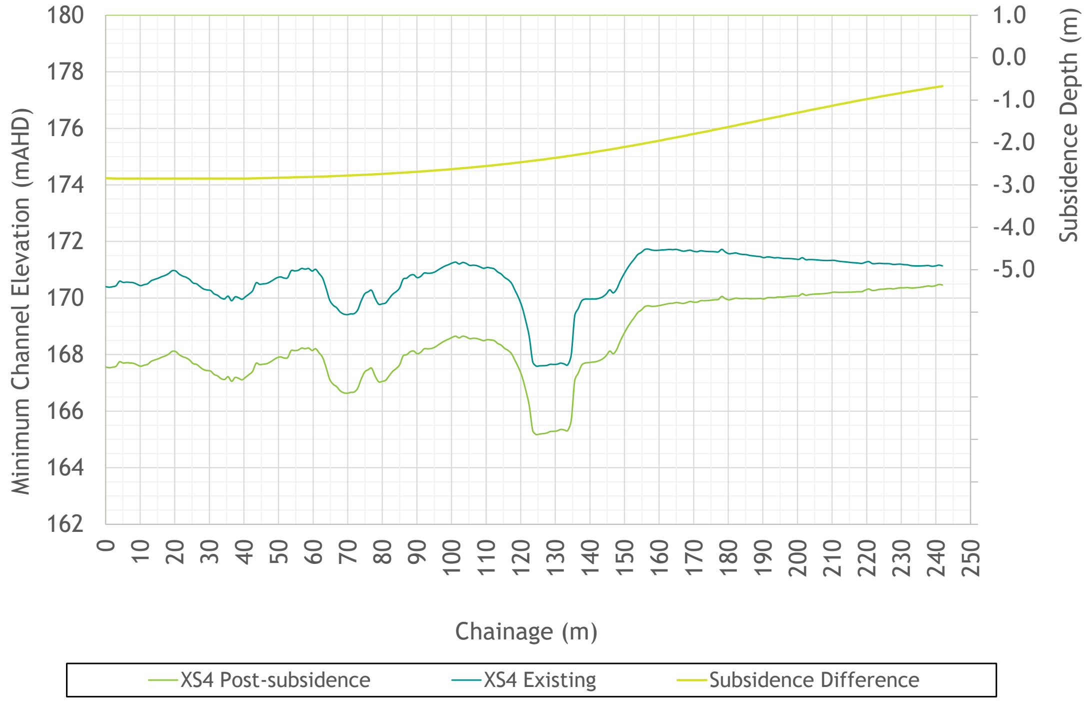

Figure 3.29 – Cross-section – Boomerang Creek main channel Ch 14,170

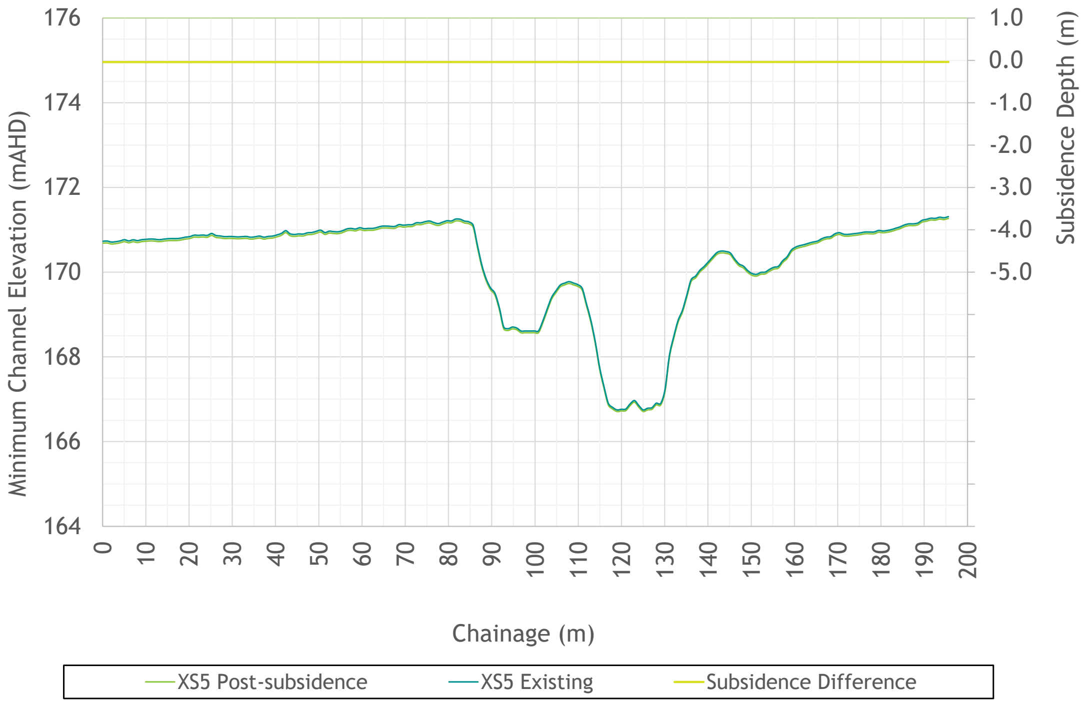

Figure 3.30 - Cross-section - Boomerang Creek main channel Ch 14,620

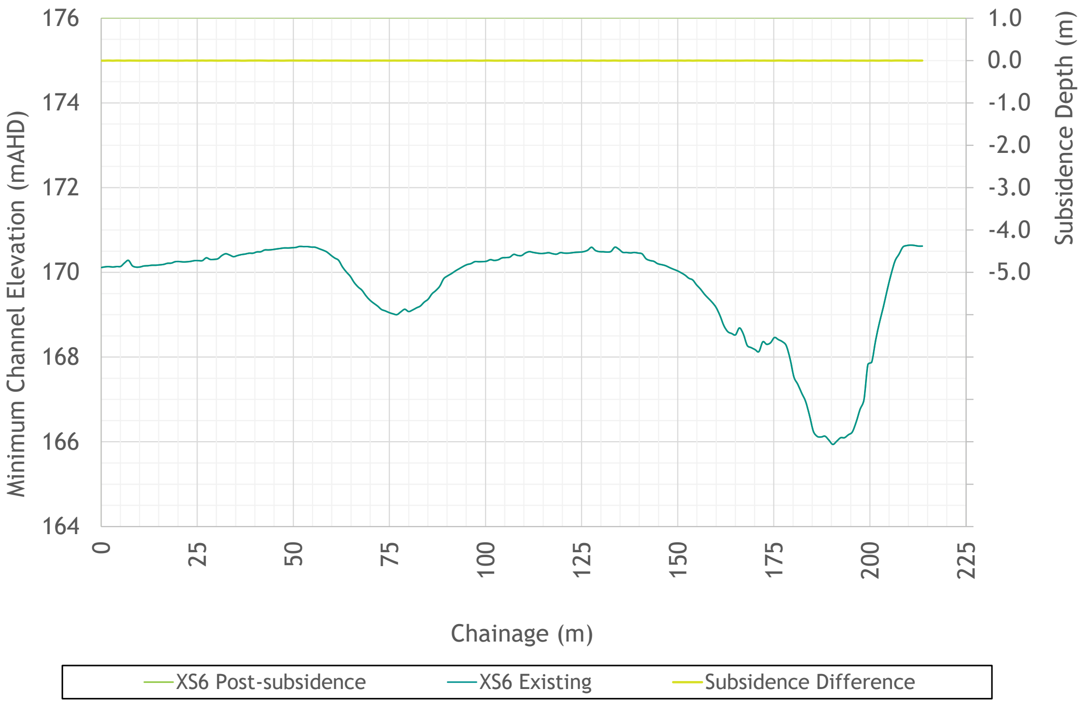

Figure 3.31 - Cross-section - Boomerang Creek main channel Ch 15,190

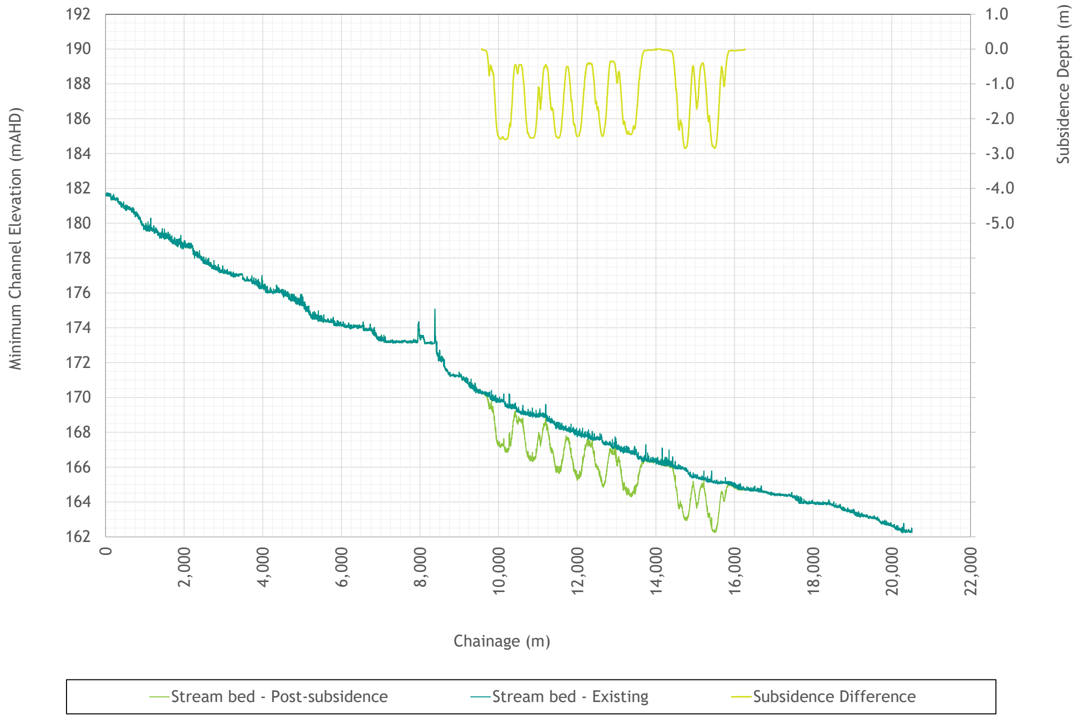

Figure 3.32 – Longitudinal profile – One Mile Creek main channel

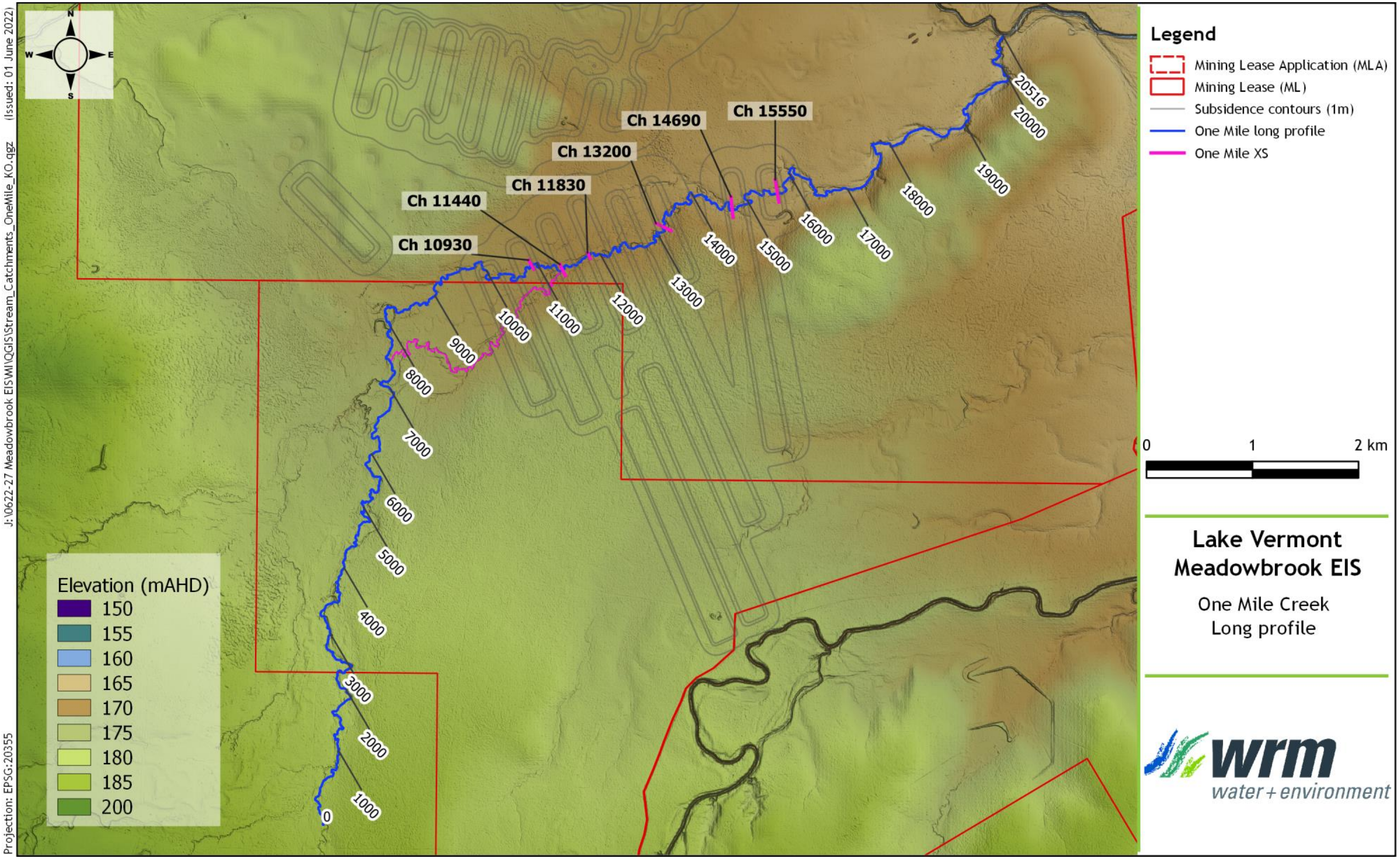

Figure 3.33 – Longitudinal profile chainages – One Mile Creek main channel

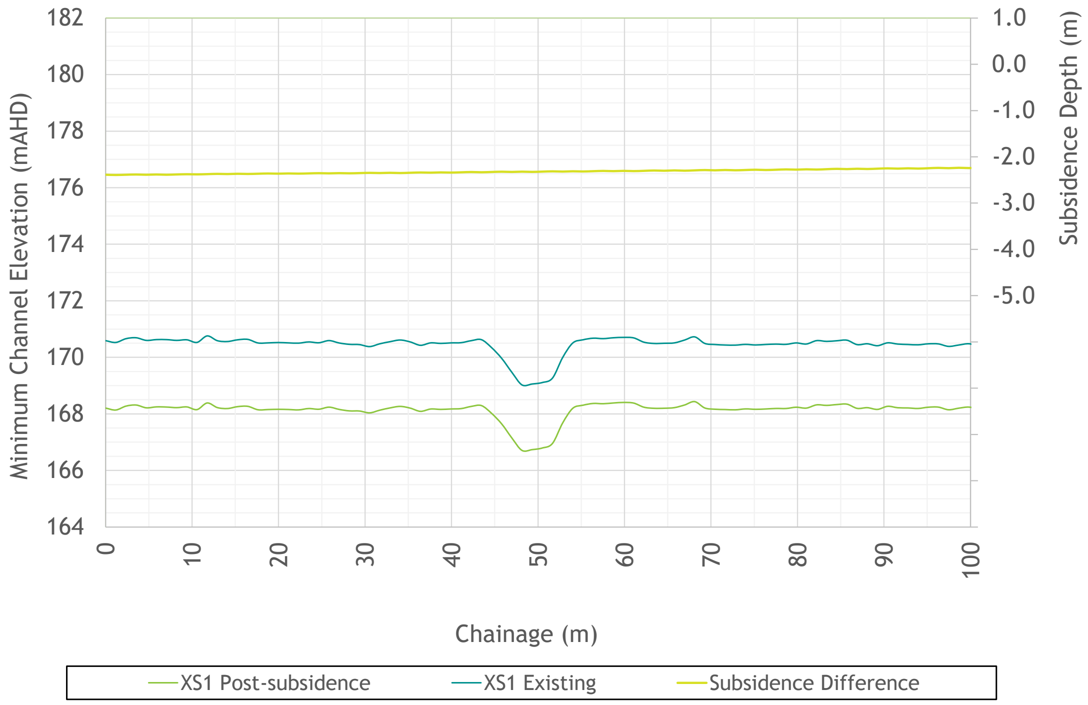

Figure 3.34 – Cross-sections – One Mile Creek main channel Ch 10,930

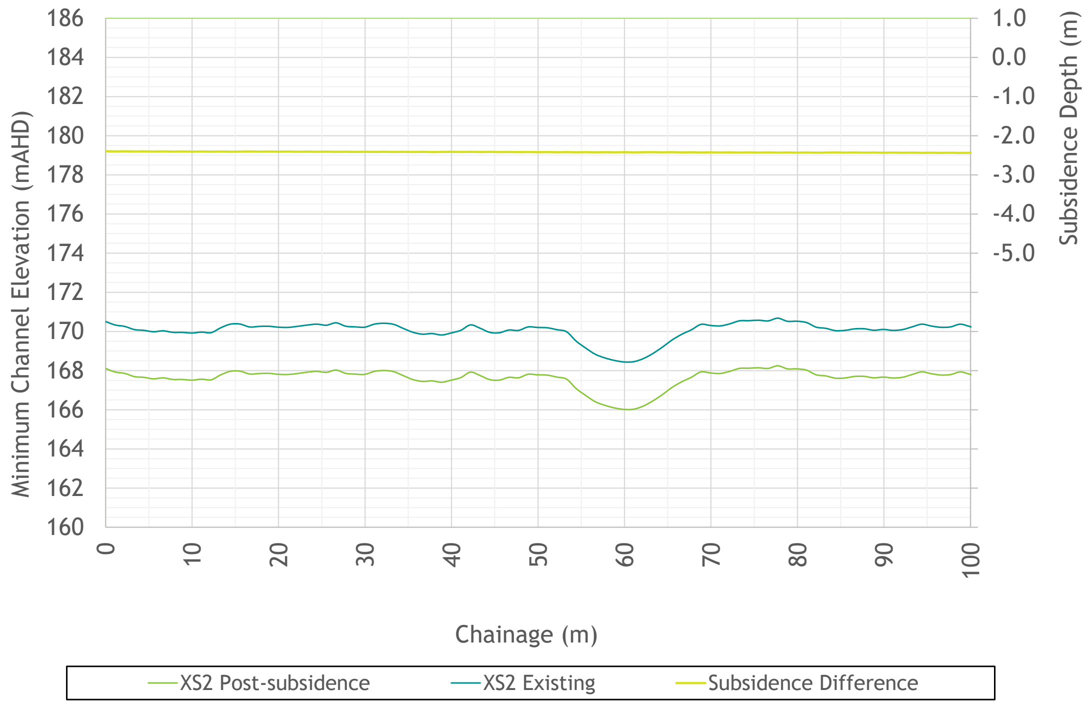

Figure 3.35 – Cross-sections – One Mile Creek main channel Ch 11,440

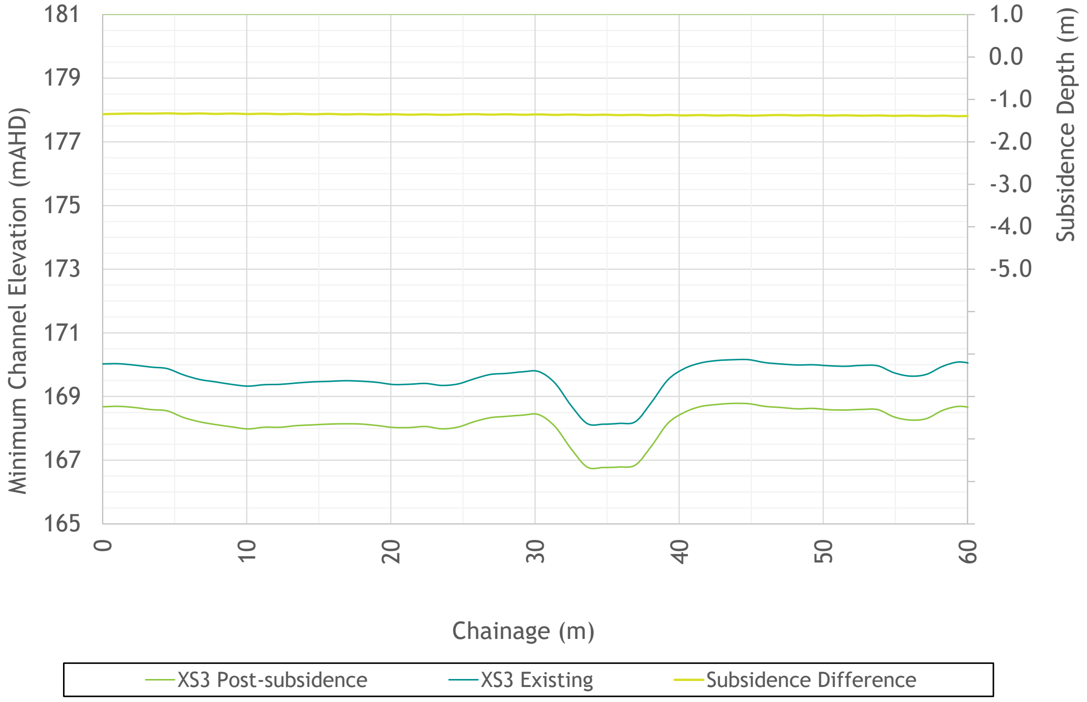

Figure 3.36 – Cross-sections – One Mile Creek main channel Ch 11,830

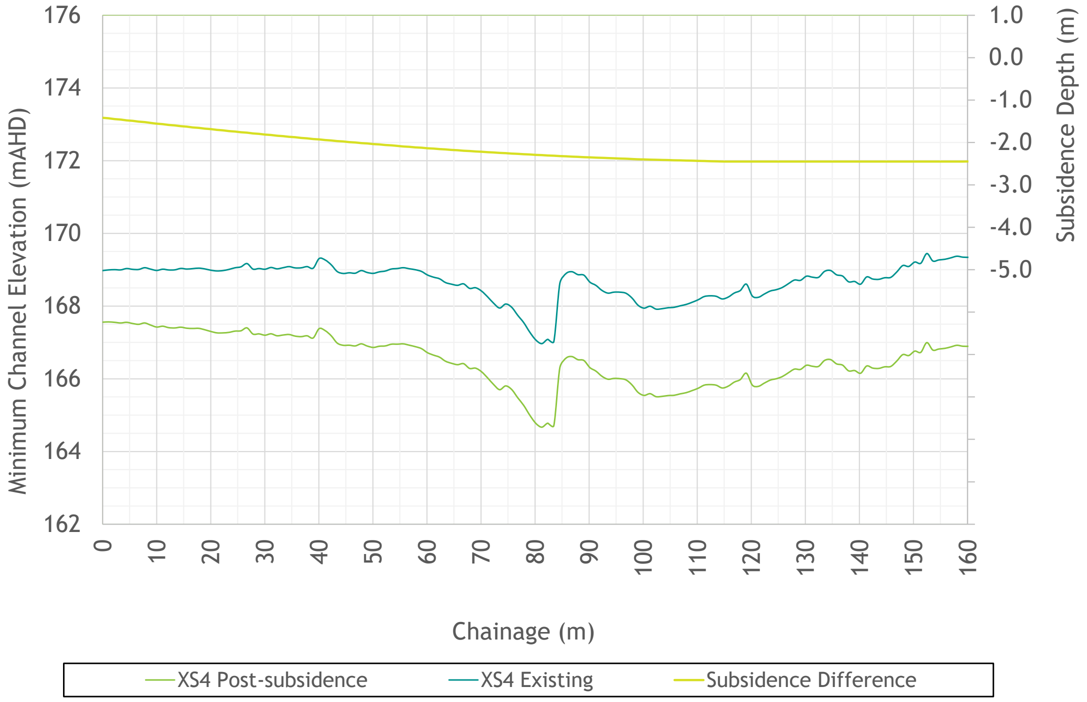

Figure 3.37 – Cross-sections – One Mile Creek main channel Ch 13,200

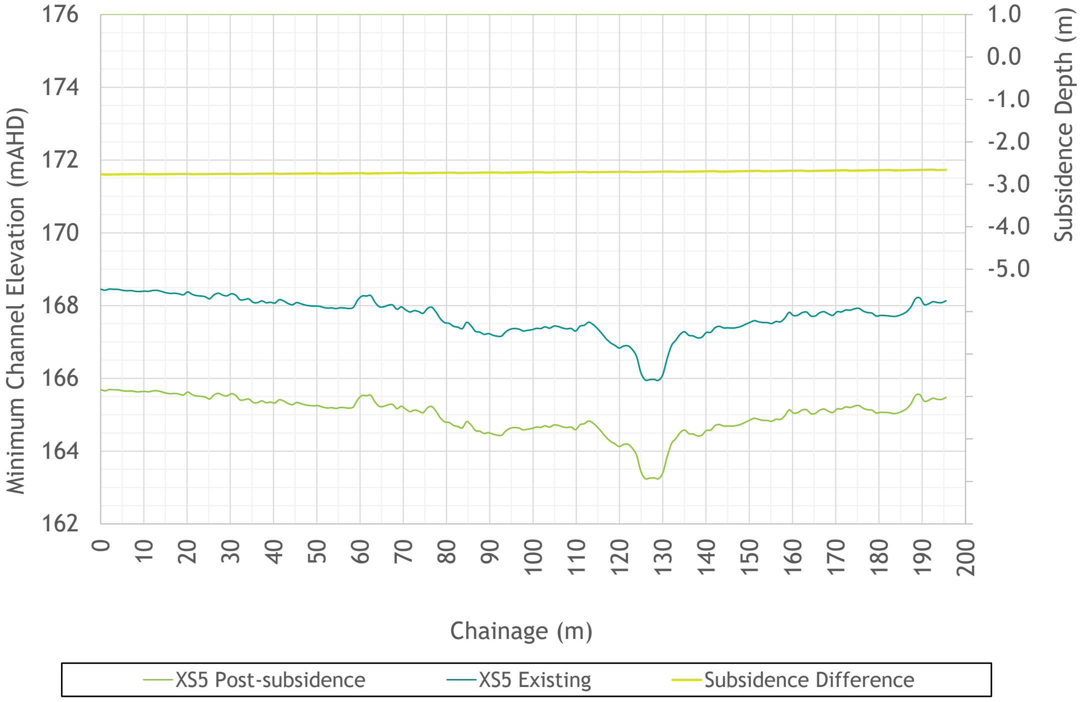

Figure 3.38 – Cross-sections – One Mile Creek main channel Ch 14,690

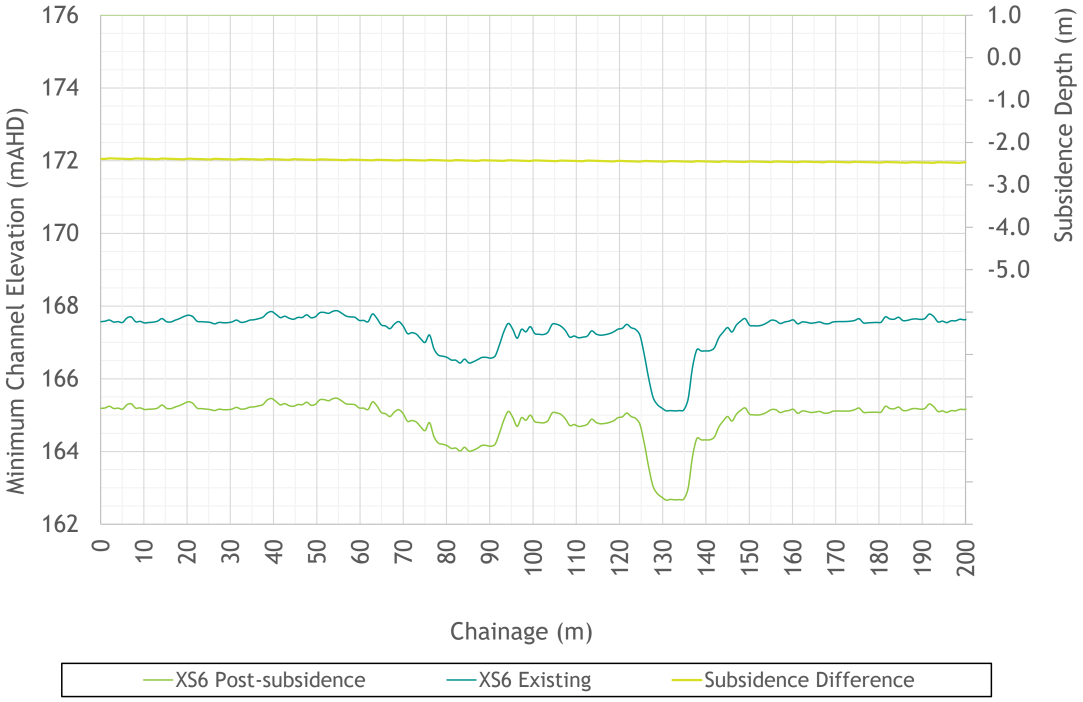

Figure 3.39 – Cross-sections – One Mile Creek main channel Ch 14,690

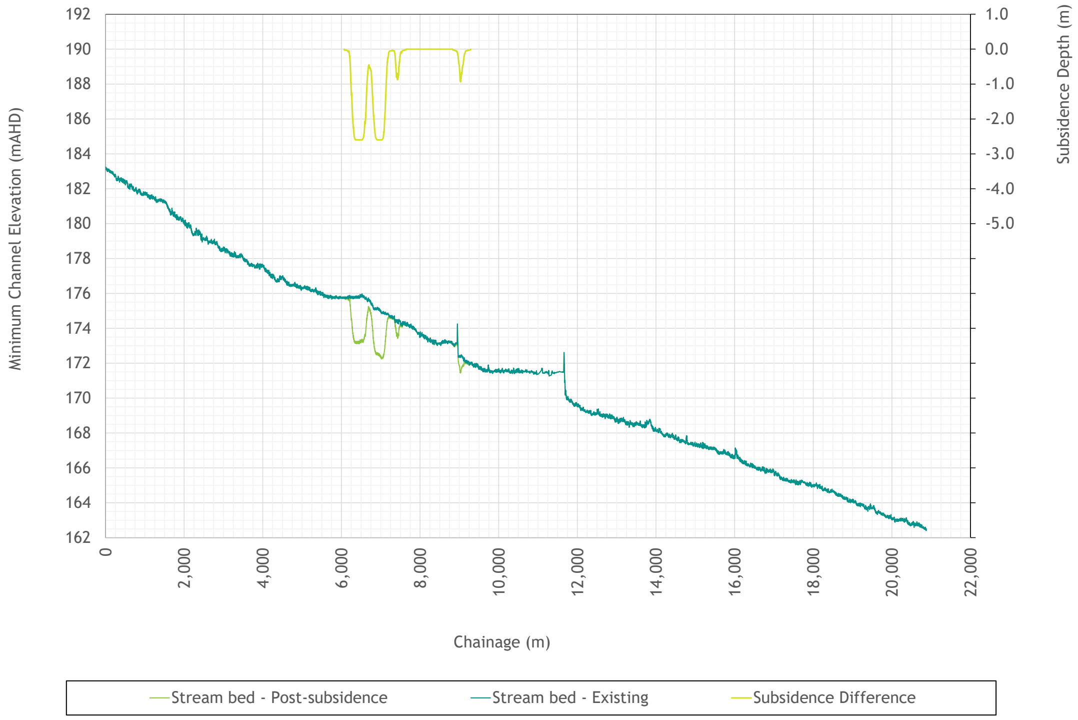

Figure 3.40 – Phillips Creek floodplain

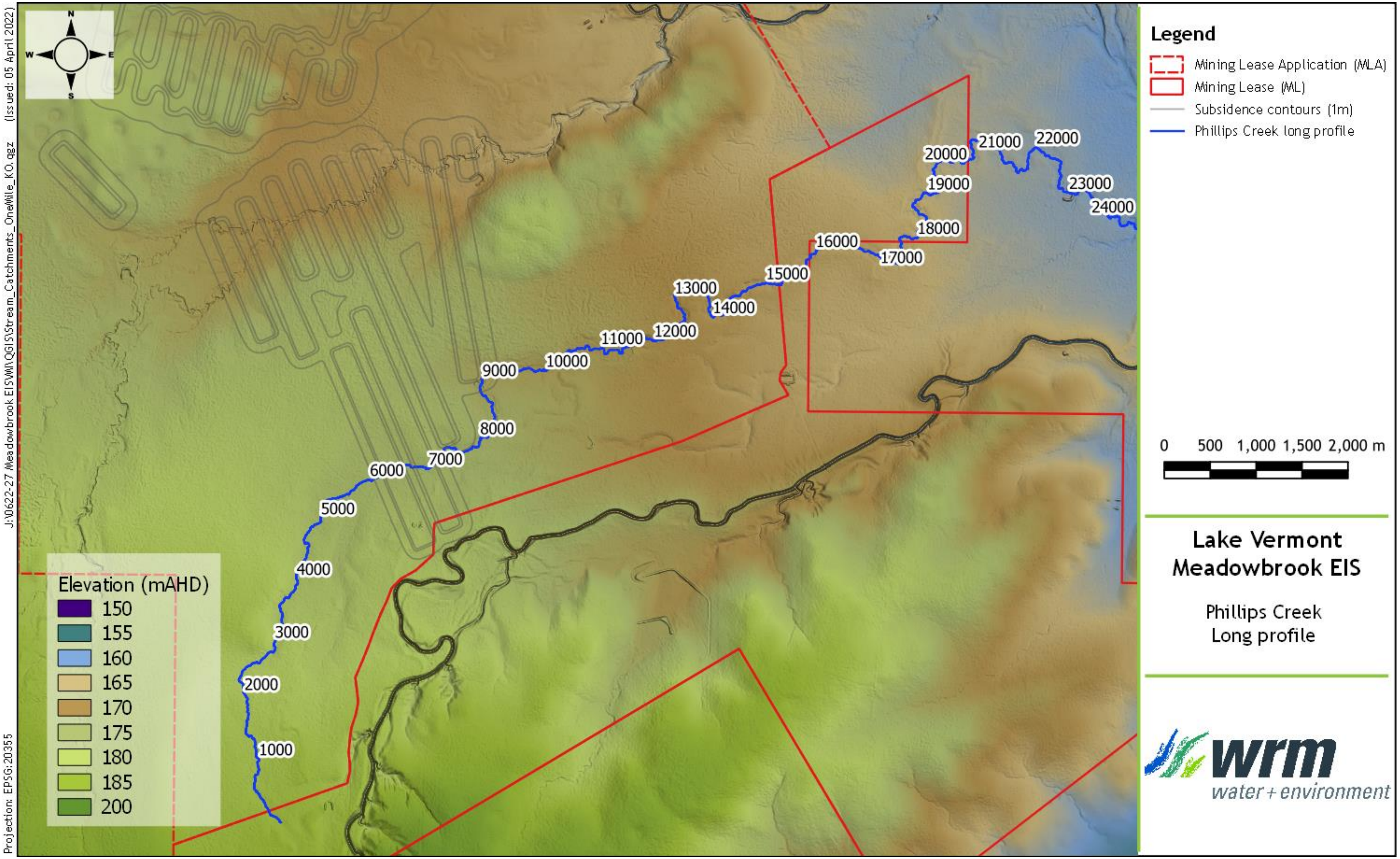

Figure 3.41 – Longitudinal profile chainages – Phillips Creek northern floodplain

4 Assessment of impacts

4.1 GENERAL

To assess the potential impacts of the Project on the hydraulic and geomorphic behaviour of the waterways and floodplains crossing the Project, the 2D hydraulic models developed of the Project area for existing (approved conditions) as described in Section 2.5 were modified to represent a Year 26 (ultimate) scenario under post-subsidence conditions. The results of the analysis are described in the following sections.

4.2 IMPACT ON FLOOD LEVELS AND EXTENTS

Figure 4.1 and Figure 4.2 show the predicted 50% and 2% AEP flood depths and extent for the proposed Year 26 ultimate development conditions. Figure 4.3 and Figure 4.4 show the flood impacts, determined by subtracting the post mining (Year 26) flood levels from existing (approved) conditions flood levels. The results show that peak flood levels would reduce throughout the subsidence zone, as expected. However, at the margins of the subsided area, where floodwater encroaches along the subsided panels, the extent of flooding would increase.

There would be a reduction in overbank flood extent downstream of the mining areas for the 50% AEP due to the additional flood storage. The impact on the 2% AEP extent downstream is not significant.

The subsidence panels will redistribute floodplain flow and would result in minor localised increases in flood level (up to 0.25 m) just upstream of the One Mile Creek/Boomerang Creek confluence. Temporary local increases in flood level would also occur during operations upstream of the MIA and haul road, and at the southern end of the open cut pit levee.

These flood level and extent changes are residual impacts of the Project that do not impact on infrastructure outside of the MLA. Overall, the changes are not significant.

Figure 4.5 shows the depth and extent of flooding in the 0.1% AEP flood after reinstatement of the floodplain between One Mile Creek and Phillips Creek and partial backfilling of the open cut pit. The final landform would be shaped to exclude floodwater from the residual depression in the final landform.

4.3 IMPACT ON DOWNSTREAM CHANNEL FLOWS

Figure 4.6 and Figure 4.7 show the modelled flood hydrographs downstream of the Boomerang Creek/One Mile Creek confluence for the 50% and 2% AEP events (the assessment assumes all waterways are empty at the start of the design flood). The results show that the increased flood storage introduced by the subsidence would attenuate the flood hydrograph for the 50% AEP event, reducing and delaying the flood peak compared to existing conditions. This reduction in flow would reduce the 50% AEP flood depths in the Boomerang Creek by about 0.3 m to 0.5 m. In larger floods, the effect of storage on flood flows and downstream flood levels is minimal.

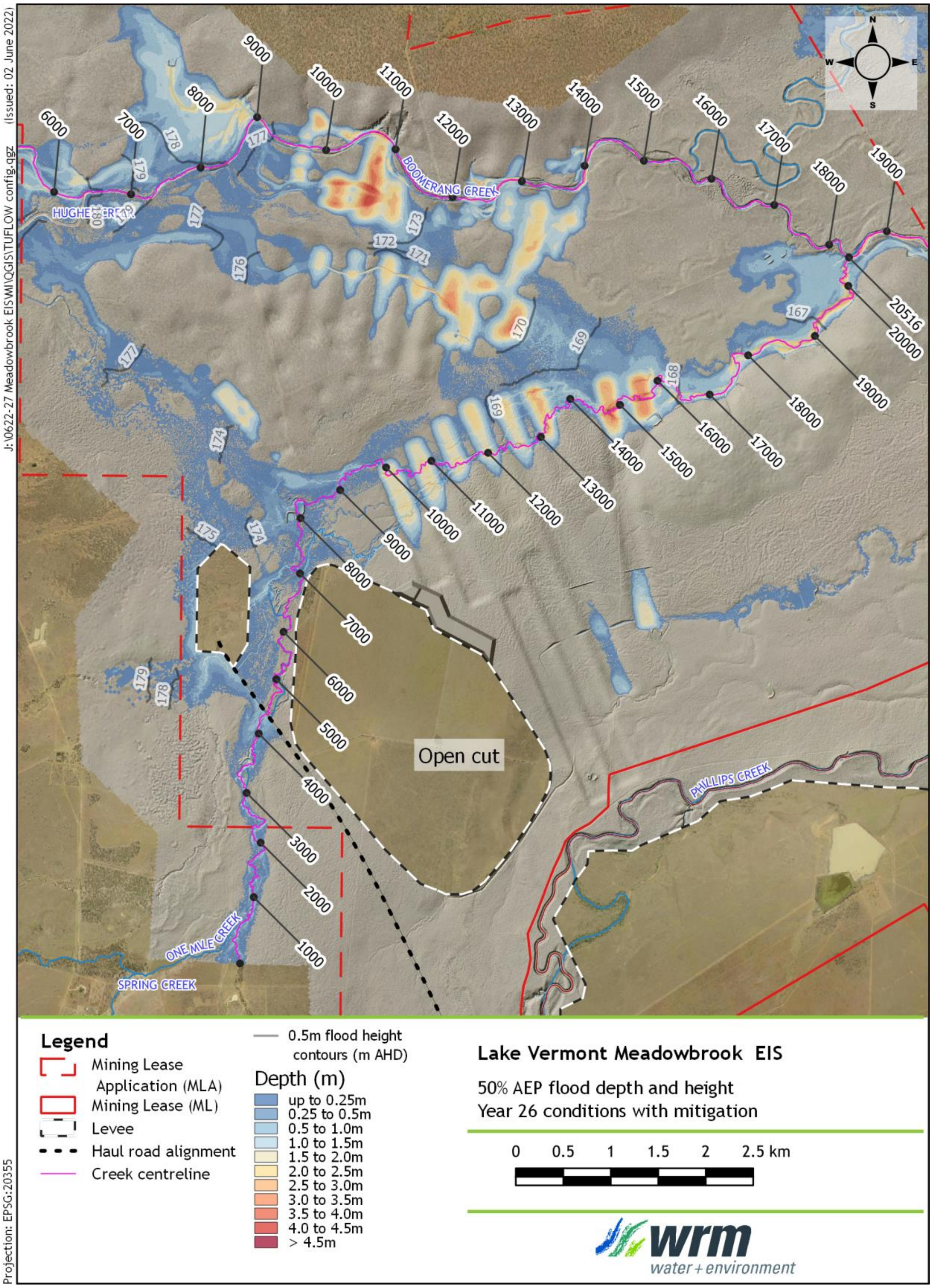

Figure 4.1 – Modelled flood depth and extent – 50% AEP

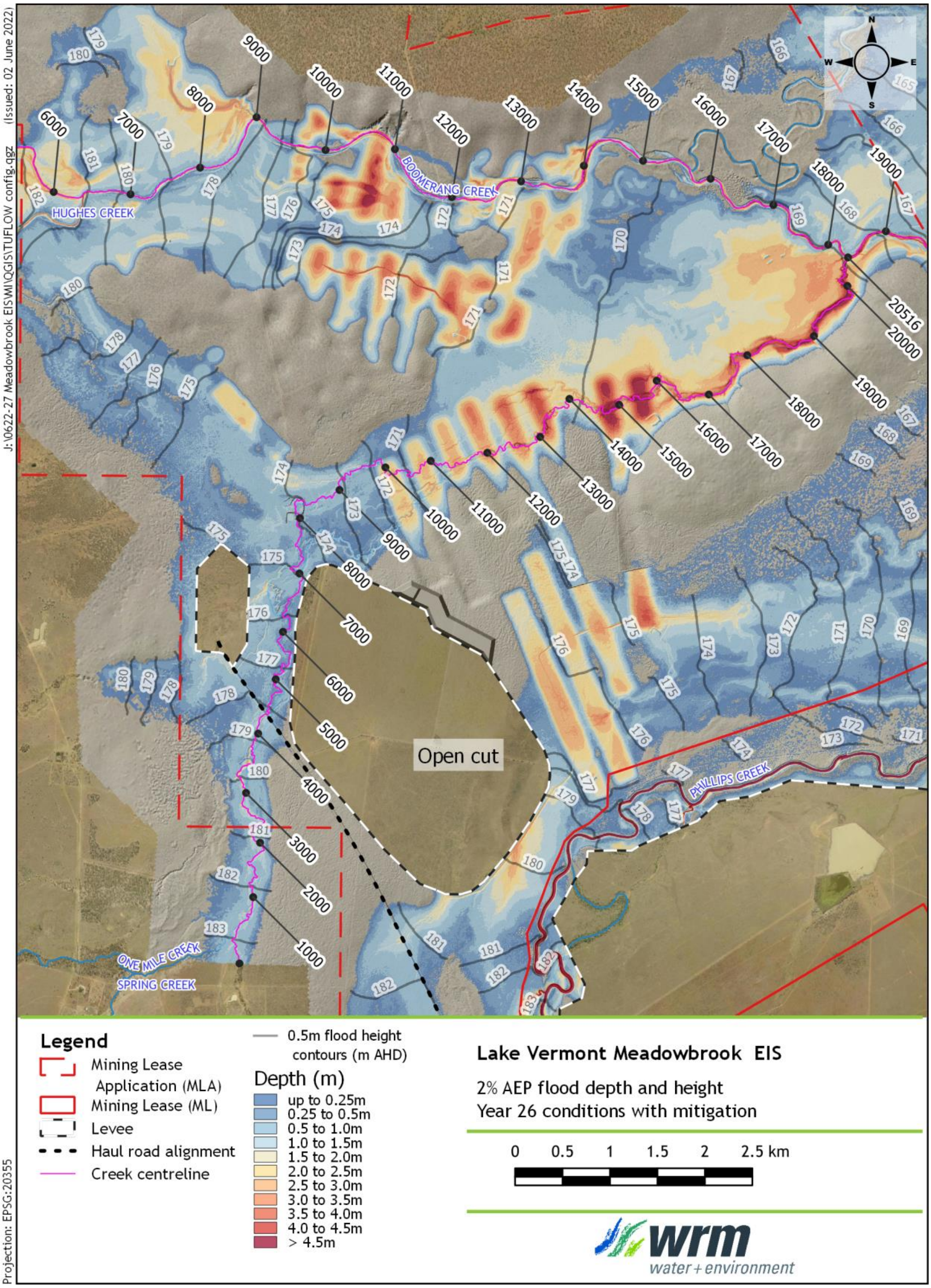

Figure 4.2 – Modelled flood depth and extent – 2% AEP

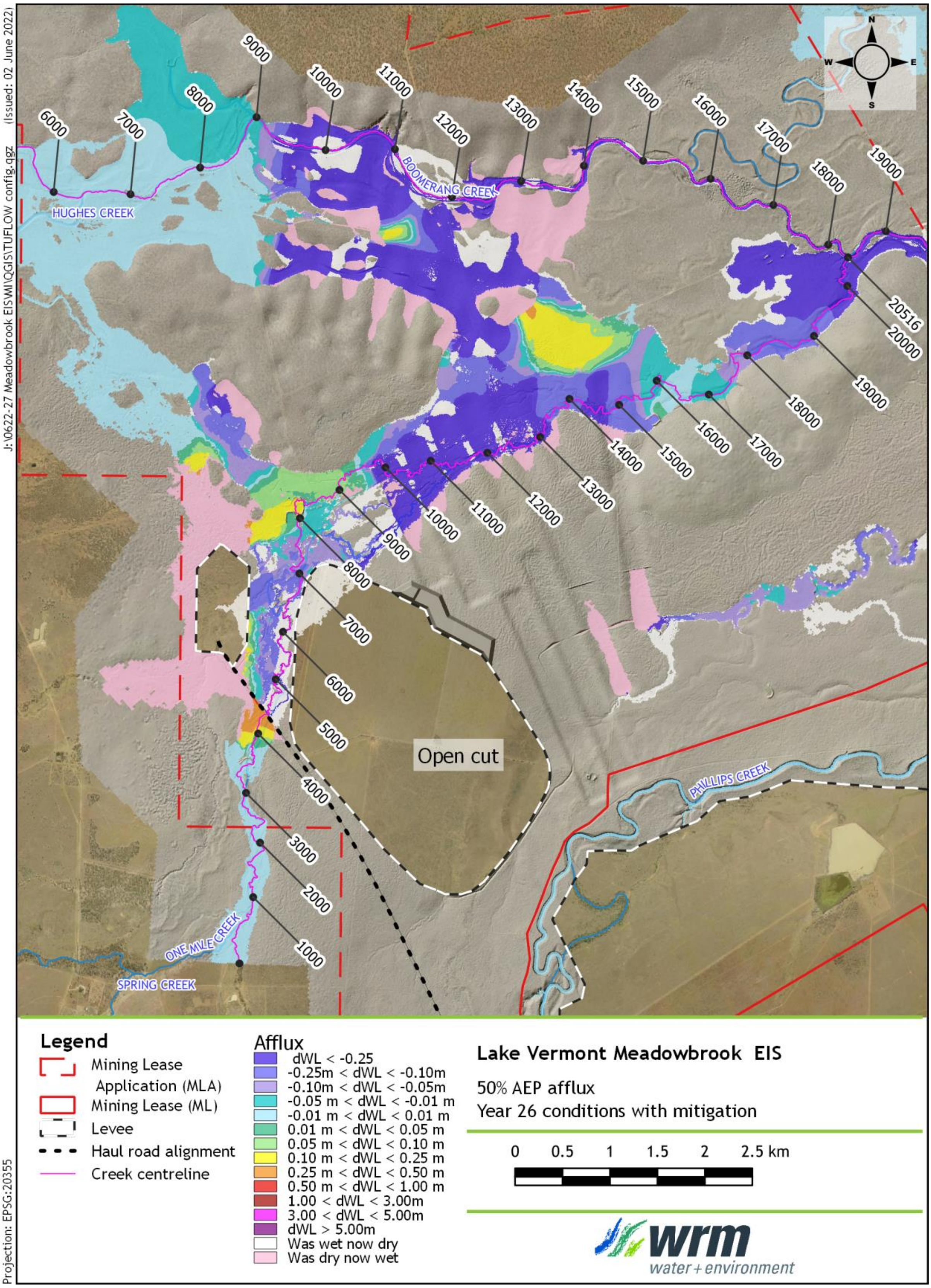

Figure 4.3 – Modelled change in flood level – 50% AEP

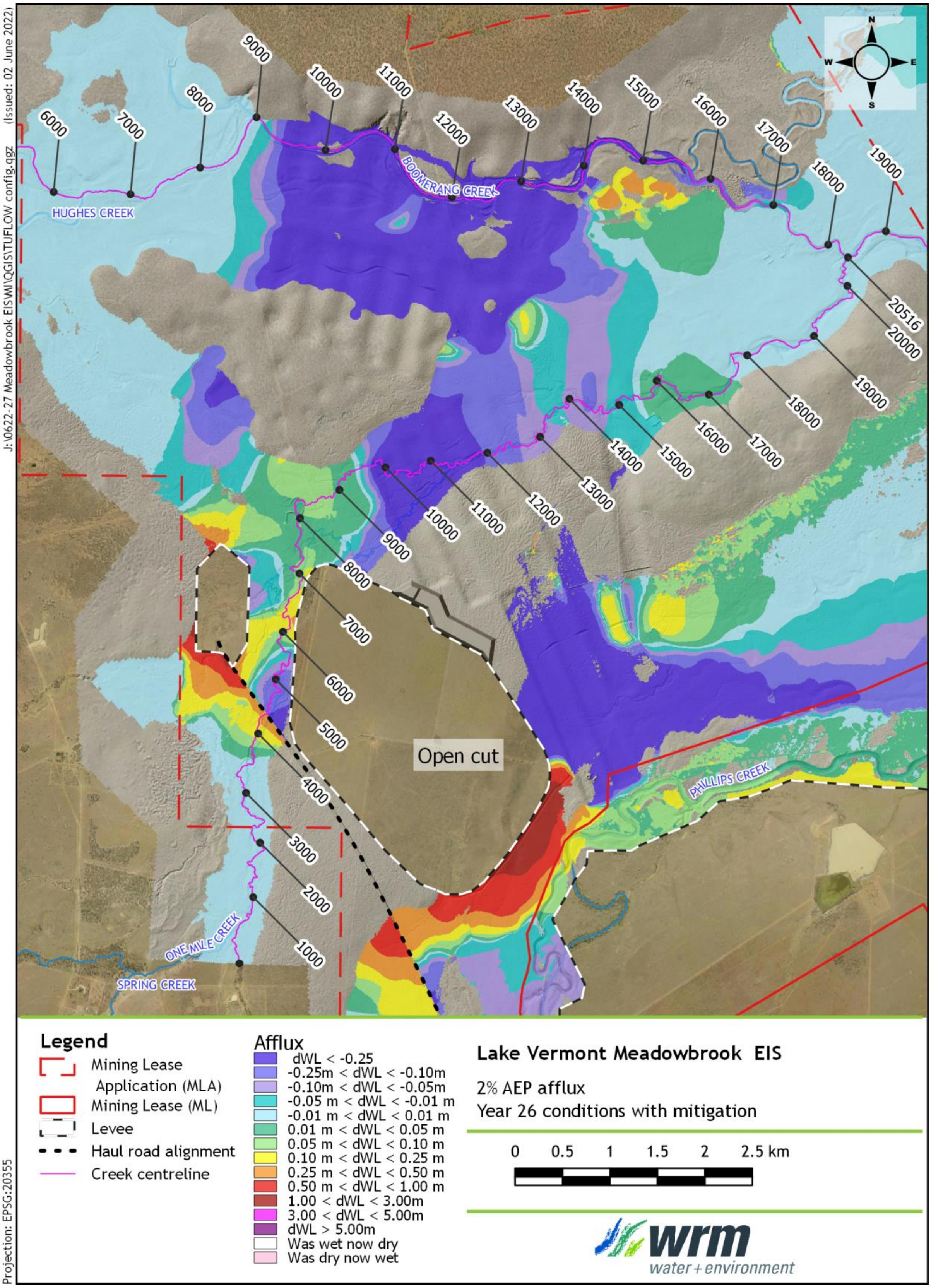

Figure 4.4 – Modelled change in flood level – 2% AEP

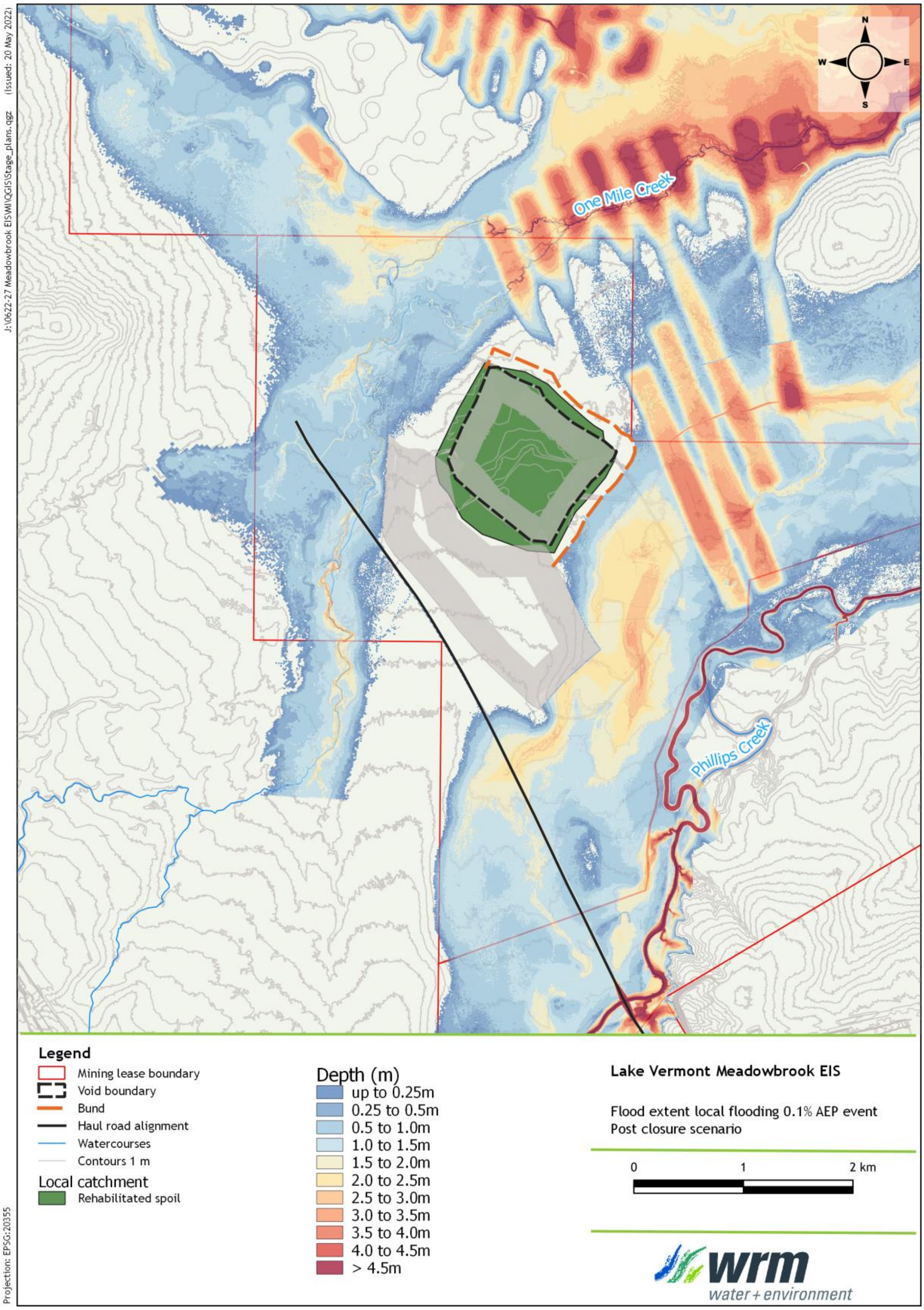

Figure 4.5 – Modelled post closure flood depth and extent – 0.1% AEP

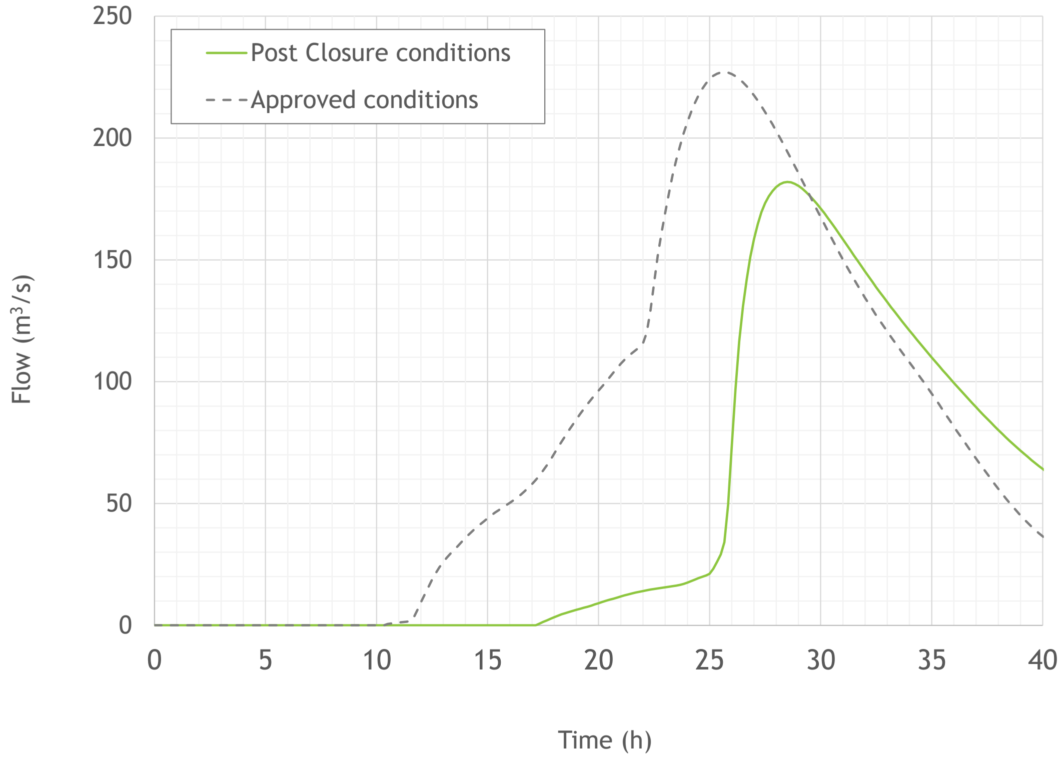

Figure 4.6 - Change in downstream flood hydrograph - Boomerang/One Mile Creek - 50% AEP

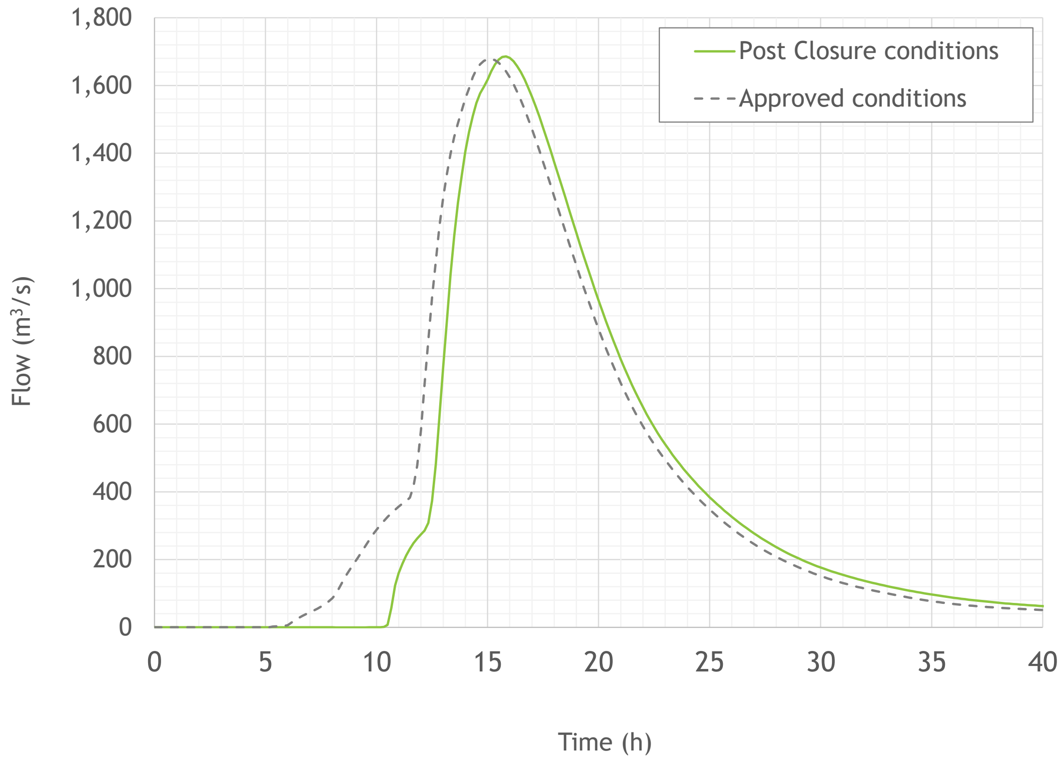

Figure 4.7 - Change in downstream flood hydrograph - Boomerang/One Mile Creek - 2% AEP

4.4 IMPACT ON FLOODPLAIN MORPHOLOGY

Gully erosion is likely to occur where minor flow enters the subsidence troughs. Some minor flow paths would be realigned along the subsidence troughs.

Figure 4.8 and Figure 4.9 show the predicted 50% and 2% AEP flood velocities for proposed Year 26 ultimate development conditions. Figure 4.10 and Figure 4.11 show the flood impacts, determined by subtracting the post mining (Year 26) flood velocities from existing (approved) conditions flood levels.

Flow velocities will be significantly reduced across much of the floodplain as water is stored in the subsided areas. The slower velocities would promote the deposition of sediment in these areas and the surrounding floodplain. In the long-term, this would result in the gradual accretion of the floodplain depressions.

The velocity impact maps in Figure 4.8 and Figure 4.9 show locations of increased velocities occur mostly in areas where overbank floodwater drains into subsidence troughs. In the 50% AEP event, increases of more than 0.5 m/s cover small areas of floodplain, and may initially cause localised erosion. Increases of 0.25 m/s to 0.5 m/s are predicted over a broad area where additional floodplain flows (originating mostly from between Ch 12,000 to Ch 13,000 on Boomerang Creek) enter One Mile Creek between Ch 14,000 to Ch 16,000. However, the increased velocities would generally remain below 0.75 m/s. Similarly, in the 2% AEP flood, velocities in this area would largely remain below 1 m/s and would be unlikely to significantly alter floodplain morphology.

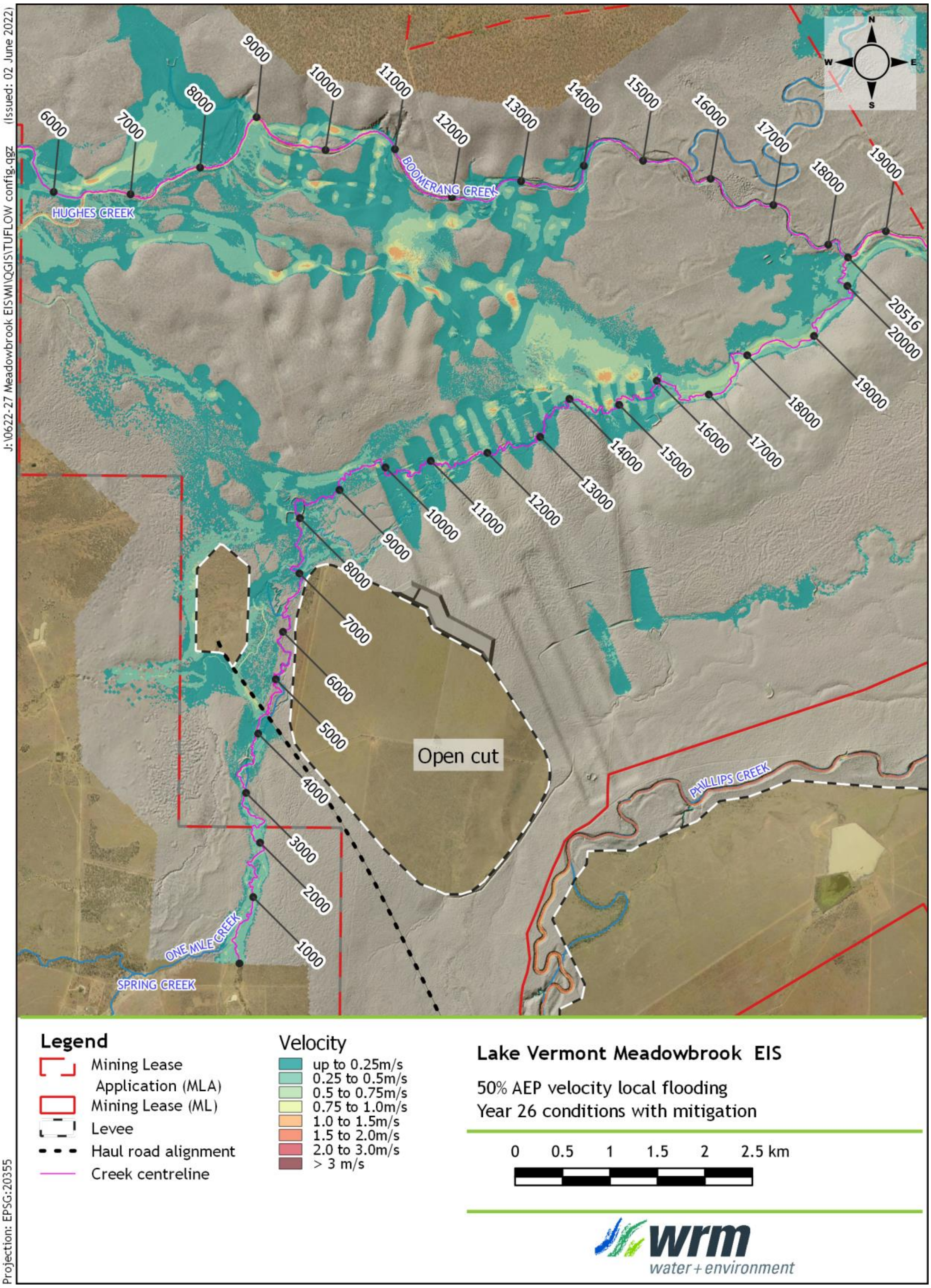

Figure 4.8 – Modelled flood velocity – 50% AEP

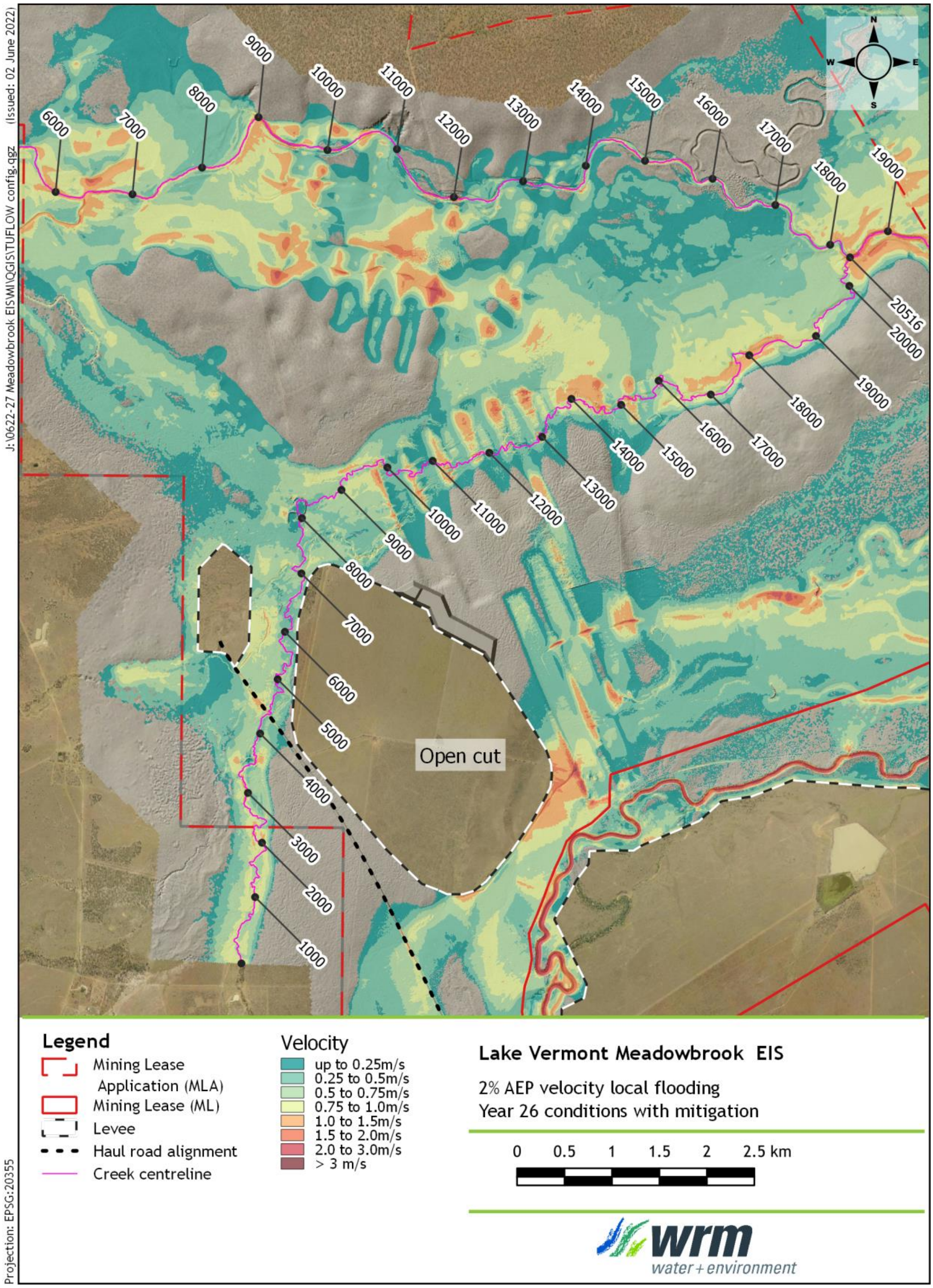

Figure 4.9 – Modelled flood velocity – 2% AEP

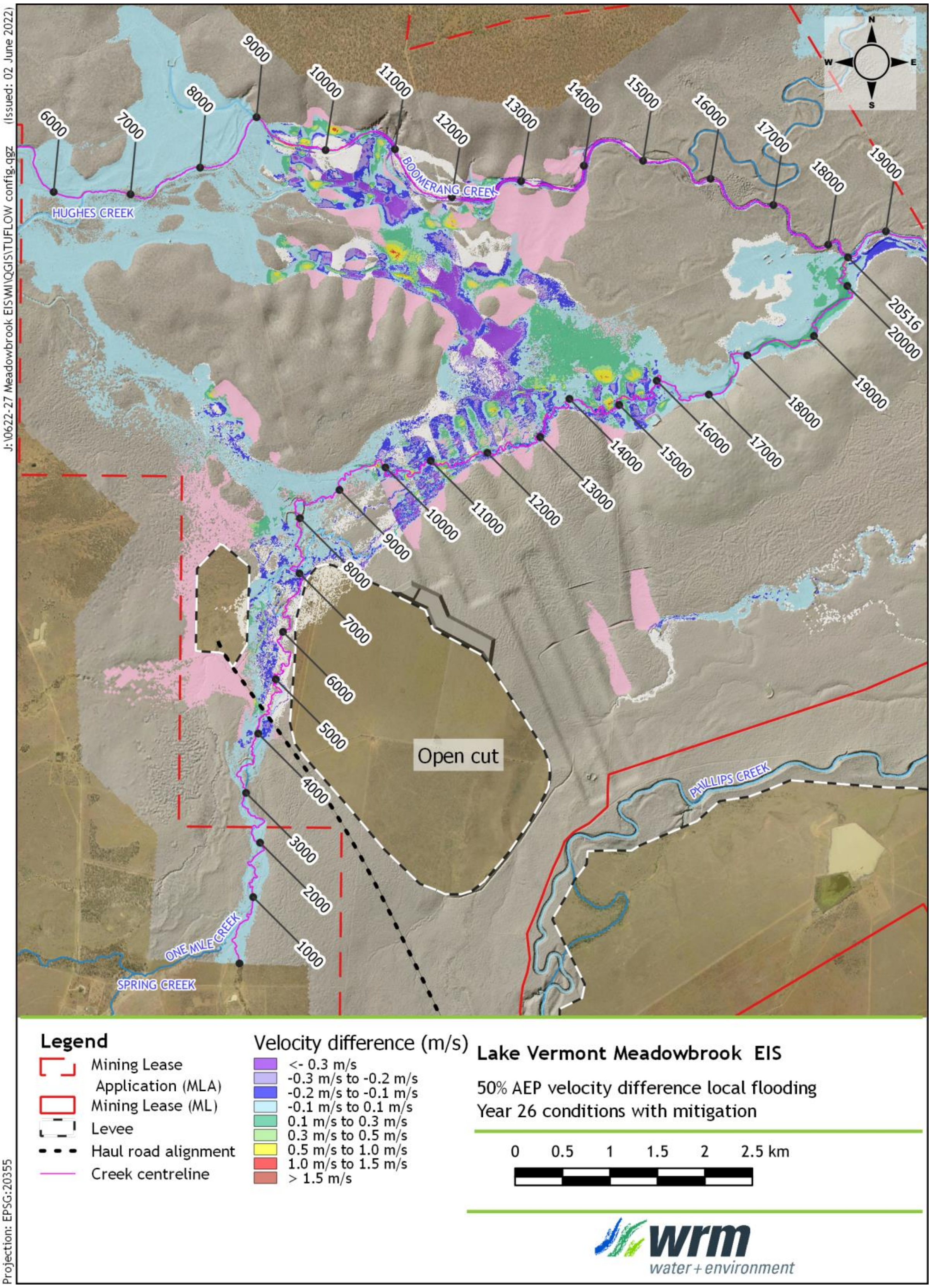

Figure 4.10 – Modelled change in flood velocity – 50% AEP

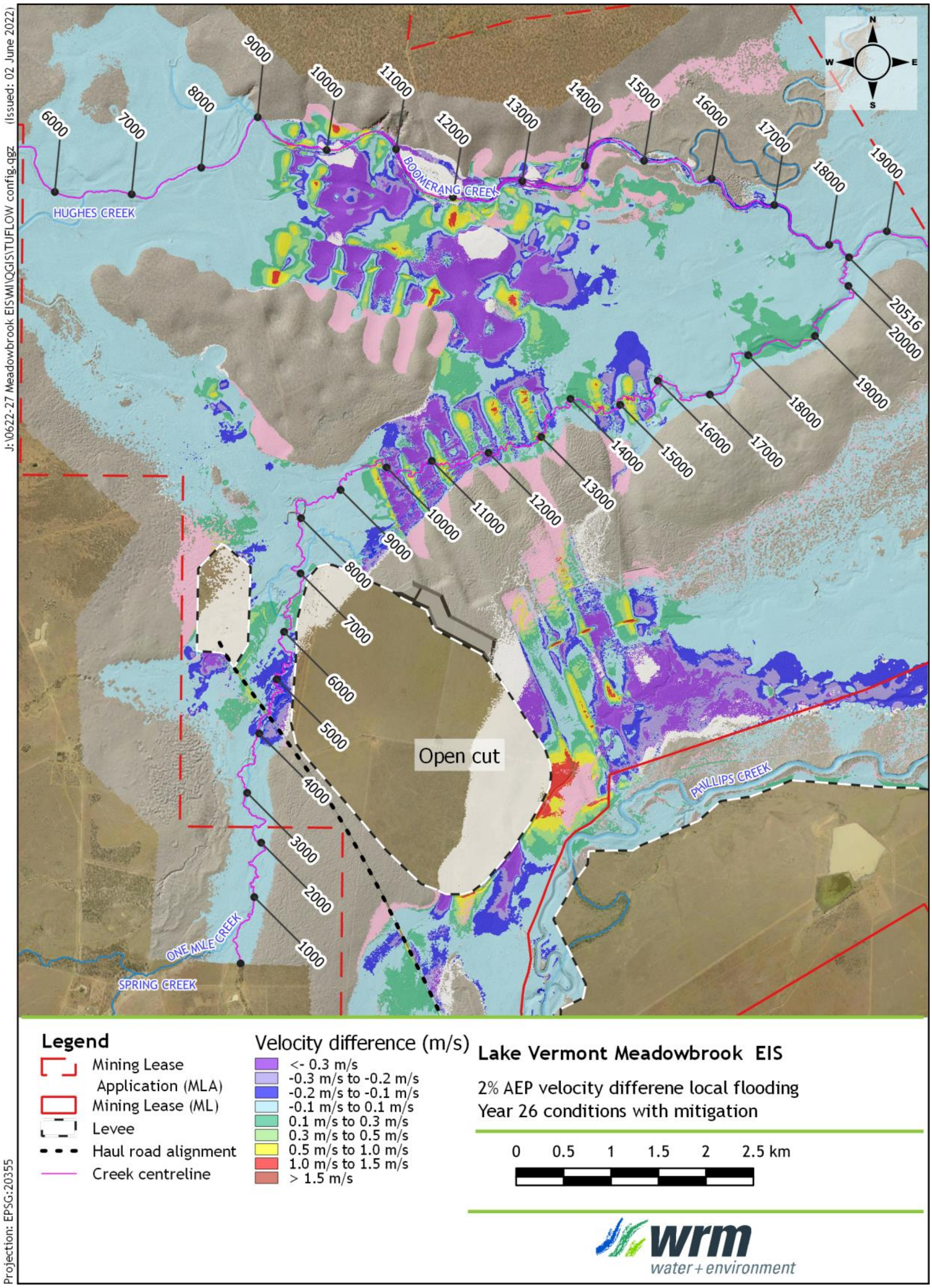

Figure 4.11 – Modelled change in flood velocity – 2% AEP

4.5 IMPACT ON CHANNEL MORPHOLOGY

The post-subsidence two-dimensional flood model results were converted to 1-dimensional section-averaged characteristics using the same methodology described in section 3 for characterising the sediment transport characteristics of the existing waterway. The assessment was undertaken for Year 26 (Ultimate) conditions which includes subsidence due to mining of two seams. Some interim channel adjustment would be expected following the mining of the first seam, which has not been described in detail, however the hydraulic model was also used to investigate flow conditions in two preceding stages (Year 12 and Year 17) to determine if there would be a temporarily increased avulsion risk during the mine development.

The values of hydraulic parameters were compared against design criteria specified in the Queensland Government *Guideline: Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000*, (DNRME, 2019) in longitudinal profiles of the main channels for the 50% AEP and 2% AEP events. Although these guidelines are not site specific, they provide some guidance as to the relative channel velocities, stream power and shear stress that would be expected across the Bowen Basin.

4.5.1 Boomerang Creek

The longitudinal profiles in Figure 4.12 to Figure 4.17 show several distinct locations where significant changes in peak flood velocities, bed shear and stream power occur along the Boomerang Creek channel. It is expected that the channel morphology will be impacted at these locations. A discussion of these impacts is given below.

The figures show that subsidence results in a series of 6 main troughs in the bed due to the interaction of the differential settlement across the longwall panels and the intervening unmined pillars in the two overlying coal seams.

The subsidence troughs above each longwall panel cause decreases in channel velocity, bed shear and stream power as the channel drains out of each subsidence trough and traverses the adjoining chain pillar. This will cause a reduction in sediment transport capacity in each trough and promote further aggradation of the bed (relative to the top of bank level) in these areas.

There is an increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone at Ch 9,250. The deep bed sediments in these reaches are expected to erode relatively quickly as the channel morphology changes to reflect the higher bed grade. This may also lead to an increase in bank erosion as the channel capacity increases. A monitoring program will be implemented to assess the extent of the channel changes in this reach. Bank protection measures will be considered if monitoring indicates that the increase in erosion is having a demonstrable impact on the channel form.

Channel velocity, bed shear and stream power also increase as flow enters the second and fourth subsidence troughs (Ch 10,200, and Ch 11,700 to Ch 12,000). The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion may potentially occur to the extent that this elevated section of stream bed will be eroded down to the upstream bed level (which will rise as the bed aggradation occurs). The depth of the bed sediments in this area could not be determined during the site visit, however, the observed volumes of sediment in the overall system are significant enough to expect aggradation would occur. If this occurred, the post subsidence channel velocity, bed shear and stream power would revert towards pre-mining conditions.

The expected aggradation relative to the bank levels could accelerate the potential abandonment of the existing Boomerang Creek channel. It should be emphasised that given the number of remnant channels and abundant sediment supplies in the catchment (refer section 4.5.1.1), a new Boomerang Creek channel could form in the absence of the proposed subsidence. Notwithstanding, these areas will be monitored as part of the subsidence monitoring plan to assess the changes in bed levels and the impact of increased localised sediment. Hydraulic modelling of earlier stages of underground operations indicated that the avulsion risk would be greatest in Year 17 prior to the development of the easternmost panels.

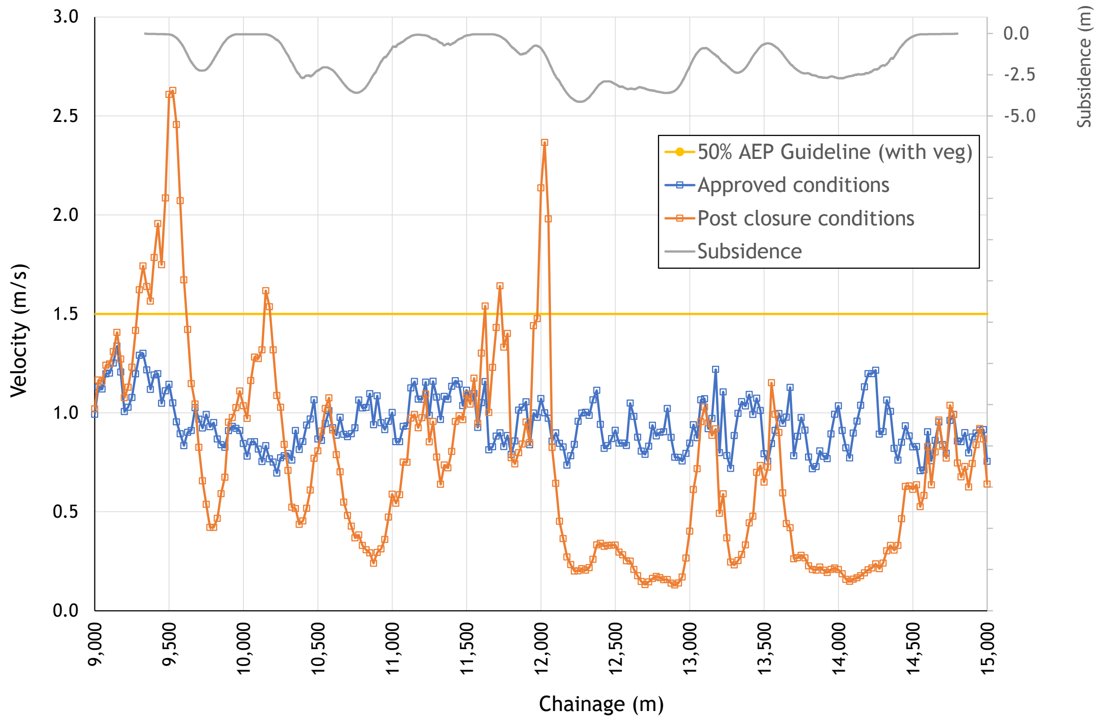

Figure 4.12 - Boomerang Creek - 50% AEP - velocity

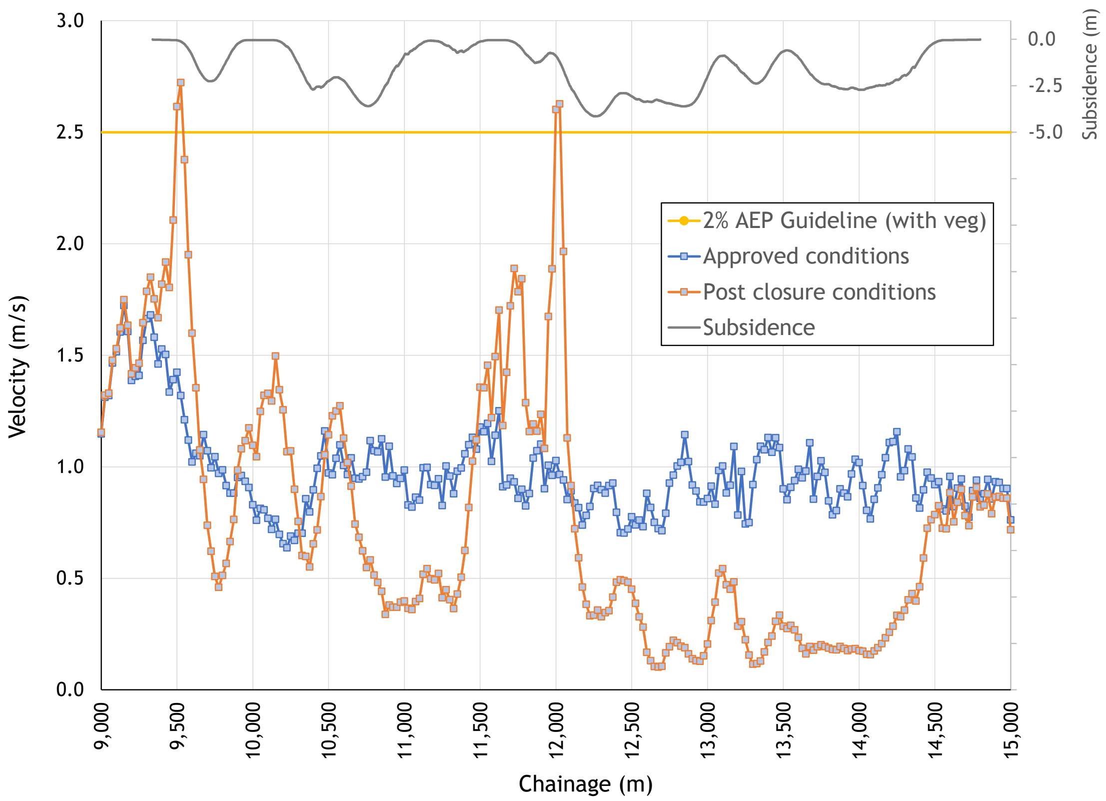

Figure 4.13 - Boomerang Creek - 2% AEP - velocity

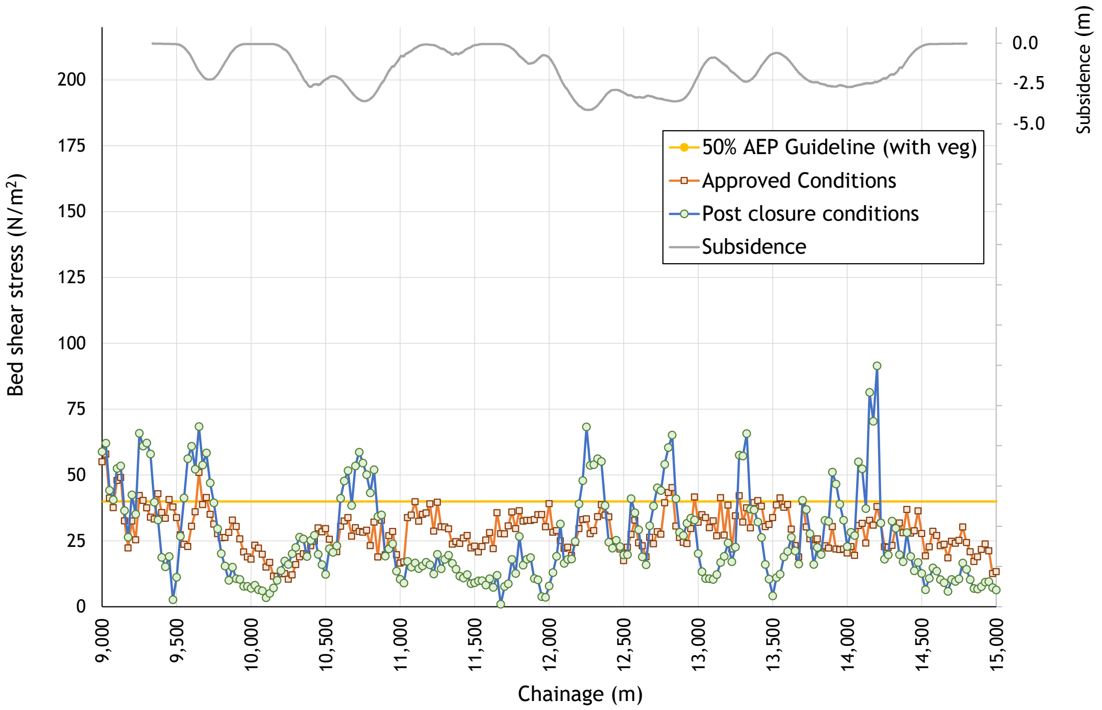

Figure 4.14 - Boomerang Creek - 50% AEP - bed shear stress

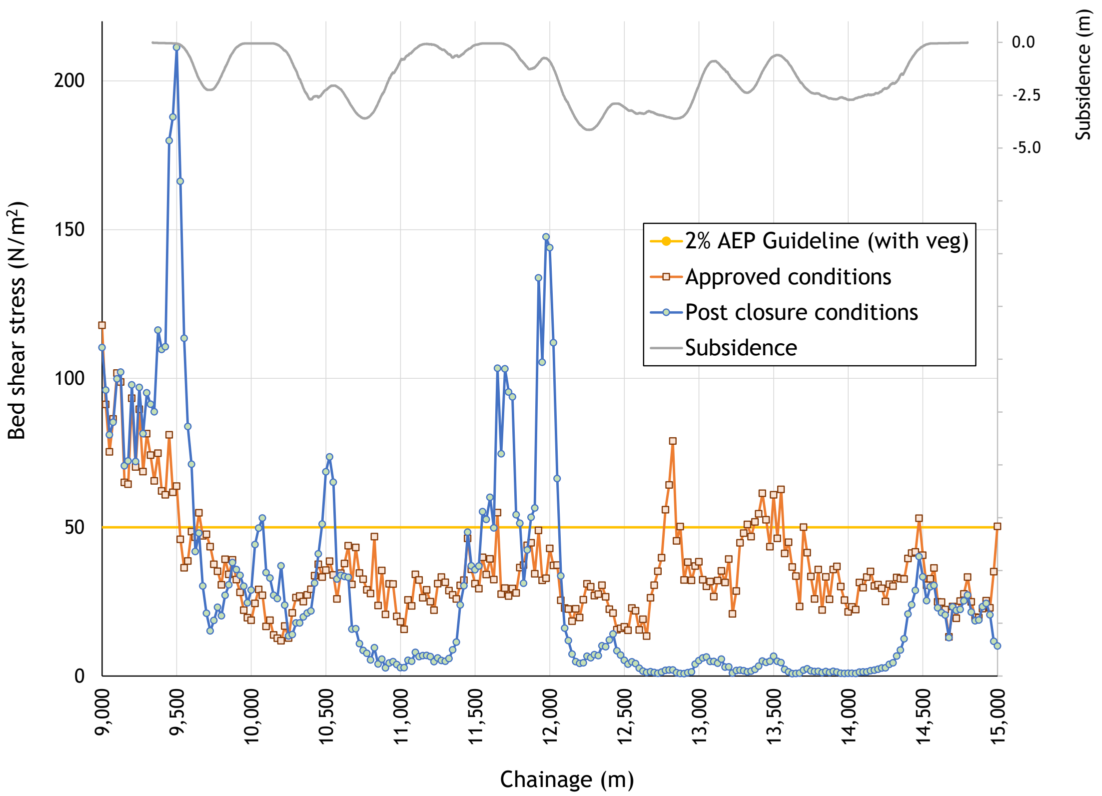

Figure 4.15 - Boomerang Creek - 2% AEP - bed shear stress

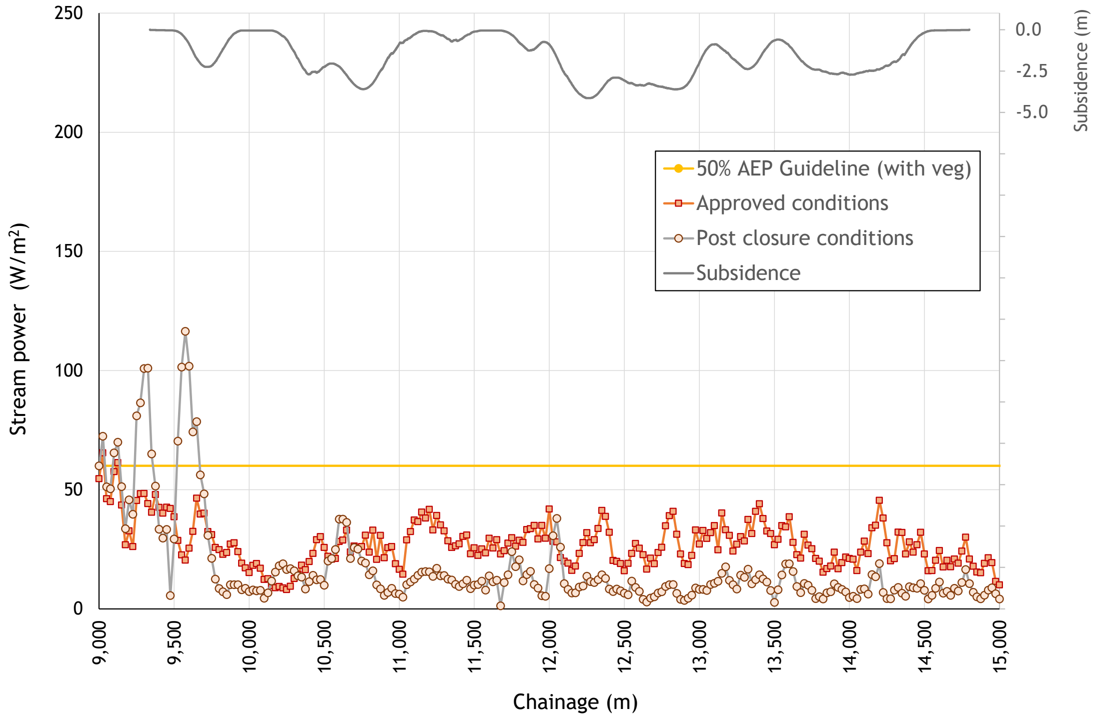

Figure 4.16 - Boomerang Creek - 50% AEP - stream power

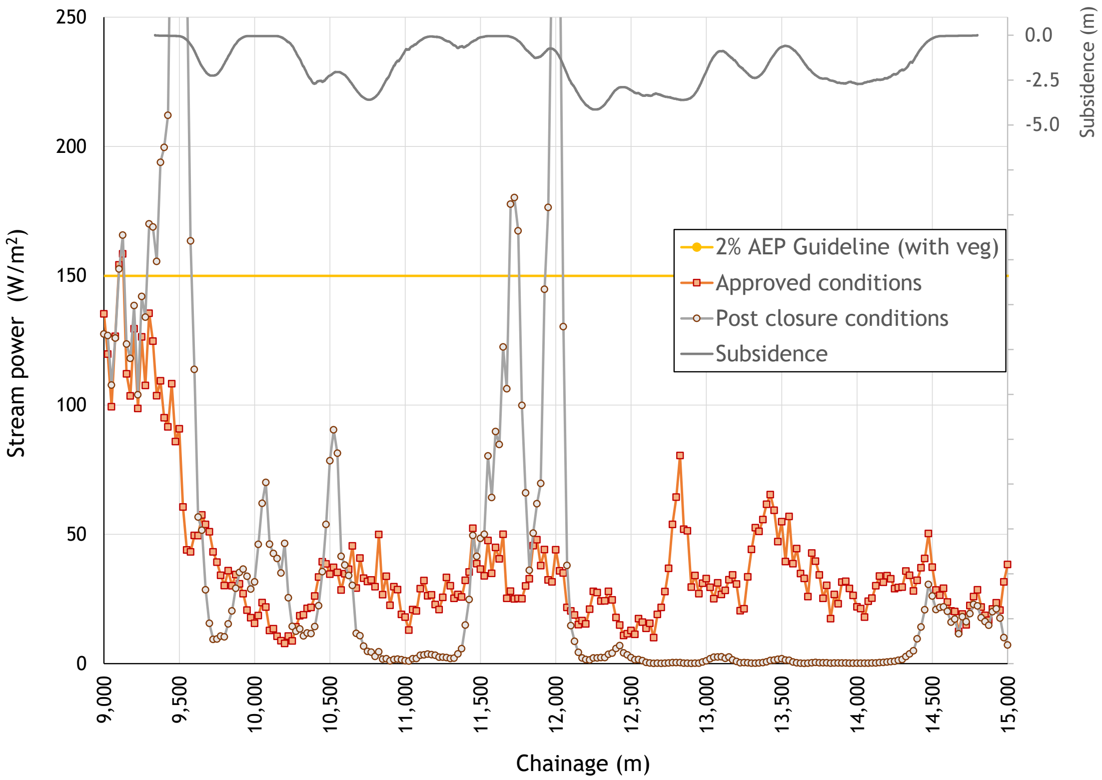

Figure 4.17 - Boomerang Creek - 2% AEP - stream power

4.5.1.1 Sediment availability

The likelihood of sedimentation of the troughs formed by the mine subsidence under the Boomerang Creek channel was assessed by comparing the scale of the subsidence voids to the sediment transport capacity, as proposed by Alluvium (2009).

The total volume of subsidence troughs to be created by the Project activities within the channel of Boomerang Creek is estimated to be approximately 130,000 m^3 (approximately 5,000 m^3/ year averaged over the 26 year life of the underground operations).

By comparison, the volume of sand currently within the channel upstream of the subsidence zone is approximately 380,000 m^3 (assuming a 3 m average depth over the 8.5 km reach of Boomerang Creek and Hughes Creek between the outlet of the Hughes Creek diversion at Saraji and the proposed underground operations.

Sand supplies in the Boomerang Creek channel will continue to be replenished from erosion in the upper catchment of Boomerang Creek. The total annual sediment supply rate suggested by SedNET modelling undertaken for the Fitzroy River Basin undertaken by the Queensland Government (Dougall, C. et. al, 2009)) is estimated to be approximately 0.3 to 0.6 t /ha/year. Assuming 50% of the annual sediment supply contributes to bedload, the bed sediment supply to the Boomerang Channel is between 4,500 t/year and 9,000 t/year (approximately 2,370 m^3/ year to 4,750 m^3/year). The rate of subsidence is therefore likely of a similar order to the annual bedload sediment supply to Boomerang Creek.

Alluvium (2019) found that (based on sediment transport modelling using the Toffaletti function), the reach of Boomerang Creek between the Saraji East project and the proposed subsidence zone has a bed sediment transport capacity of approximately 2,000 t/day (1,050 m^3/day) in a 2 year ARI flow. As a result, relatively rapid progressive infilling of the subsidence panels can be expected when high stream flows occur, and in an overall sense, the sediment supply would be more than sufficient to infill the anticipated subsidence troughs.

However, depending on the timing of upstream operations, the capture of sediment within the subsidence zone of the Saraji East underground project would limit sediment supply in the reaches of Boomerang Creek in the vicinity of the proposed underground operations. Depending on the timing of flows and mining of the upstream project, this could impact the timing of infilling of the bed at the Meadowbrook Project. In combination, the projects could have the cumulative impact of temporarily reducing the movement of sand into the reaches of Boomerang Creek between the proposed underground operations and the Ripstone creek confluence until the subsidence troughs were filled.

Assuming the quantity of sand currently upstream of the project area remains sufficient to replenish the subsidence depressions at Meadowbrook during operations, at the above average sediment supply rates) the net sediment loss over the project life would be between 7,000 m^3 and 70,000 m^3. It is therefore expected to take around 25 years for the subsidence depressions to refill post-mining. Complete replenishment of residual sediment losses attributable to the Saraji East project could take a similar additional time, however large floods could significantly reduce these timeframes (and prolonged drought could increase them).

4.5.2 One Mile Creek

The longitudinal profiles in Figure 4.18 to Figure 4.23 show several distinct locations where significant changes in peak flood velocities, bed shear and stream power occur along the One Mile Creek channel. It is expected that the channel morphology will be impacted at these locations. A discussion of these impacts is given below.

The figures show that subsidence results in a series of 8 main troughs in the bed due to the interaction of the differential settlement across the longwall panels and the intervening unmined pillars in the two overlying coal seams.

The subsidence troughs above each longwall panel significantly decrease in-channel velocity, bed shear and stream power as the channel drains out of each subsidence trough and traverses the adjoining chain pillar. This will cause a major reduction in sediment transport capacity in each trough and promote aggradation of the bed in these areas.

There is an increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone at Ch 9,750. Velocities in this area would remain less than guidelines values but given the relatively fine sediment in this area and the apparent limitation is sediment supply, these reaches are expected to erode as the channel morphology changes to reflect the higher bed grade. This may also lead to increases in bank erosion as the channel capacity increases. A monitoring program will be implemented to assess the extent of the channel changes in this reach. Bank protection measures will be considered if monitoring indicates that the increase in erosion is having a demonstrable impact on the channel form.

Channel velocity, bed shear and stream power also increase as flow enters the second to fifth subsidence troughs (Ch 10,600, and Ch 11,200 to Ch 11,750 and Ch 12,250). The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion would occur through this elevated section of stream bed.

If there was sufficient sediment supply, the post subsidence channel velocity, bed shear and stream power would revert towards pre-mining conditions. However, as it appears sediment supply is limited, this may take a long time, and the ponds formed by the sediment may persist for a comparatively long time. The area will be monitored as part of the subsidence monitoring plan to assess the changes in bed levels and the impact of increased localised sedimentation. To promote the movement of water and sediment through this reach, Bowen Basin Coal will consider decommissioning the existing farm dam on One Mile Creek prior to the commencement of mining.

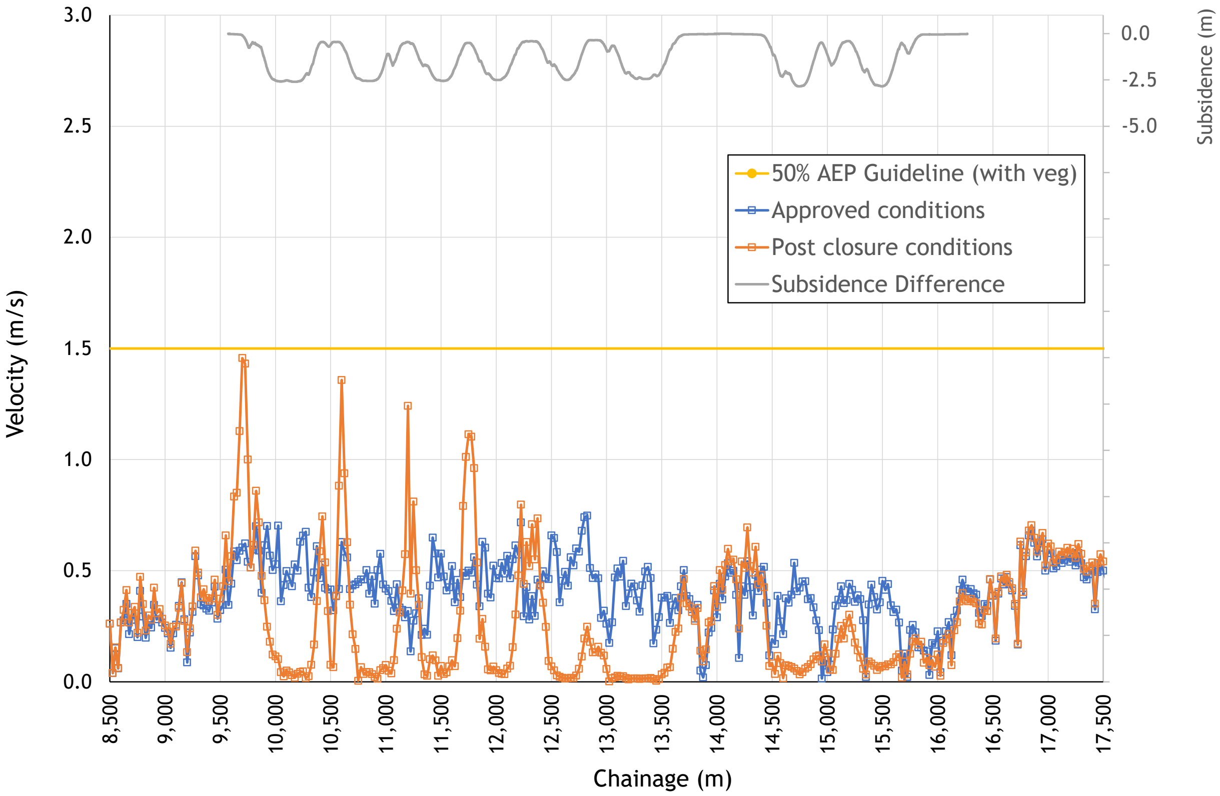

Figure 4.18 – One Mile Creek – 50% AEP velocity

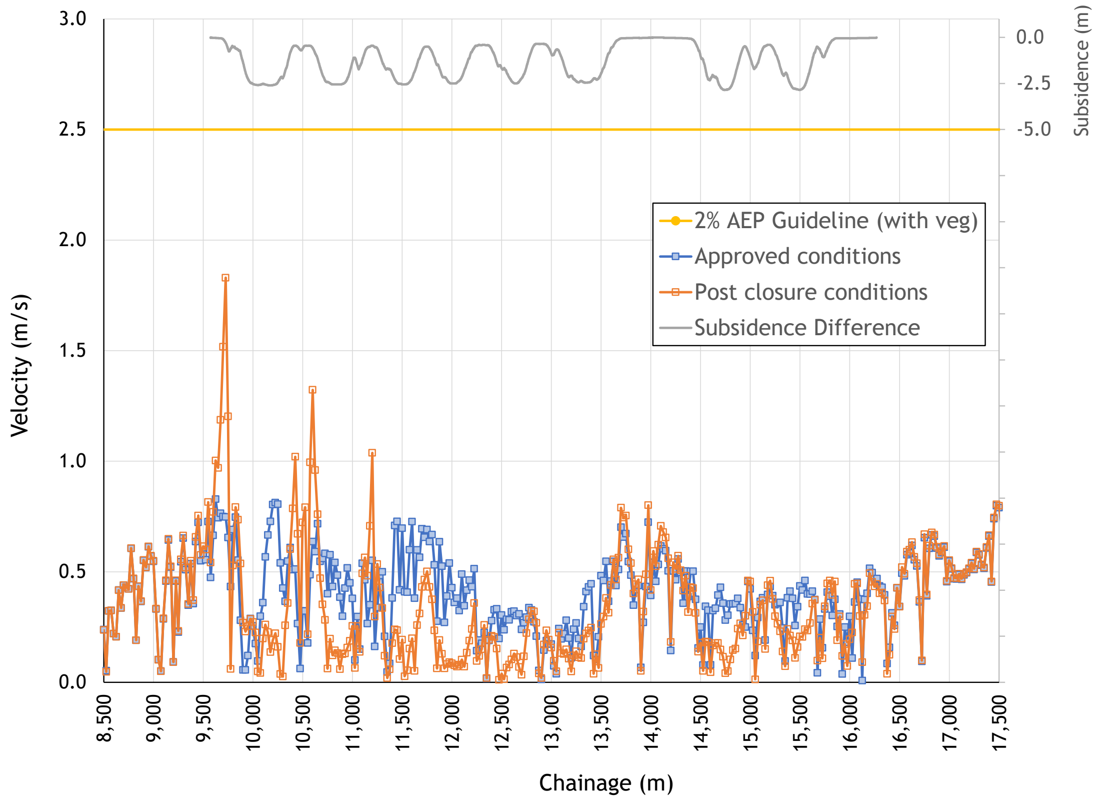

Figure 4.19 - One Mile Creek - 2% AEP velocity

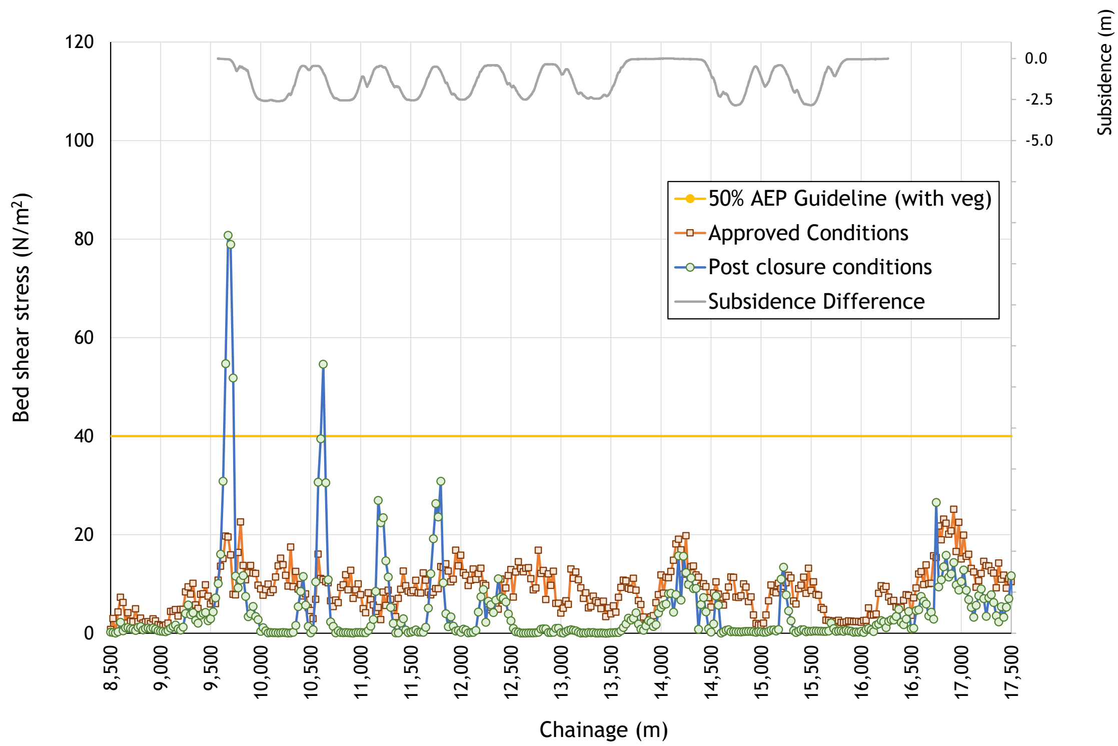

Figure 4.20 - One Mile Creek - 50% AEP - bed shear stress

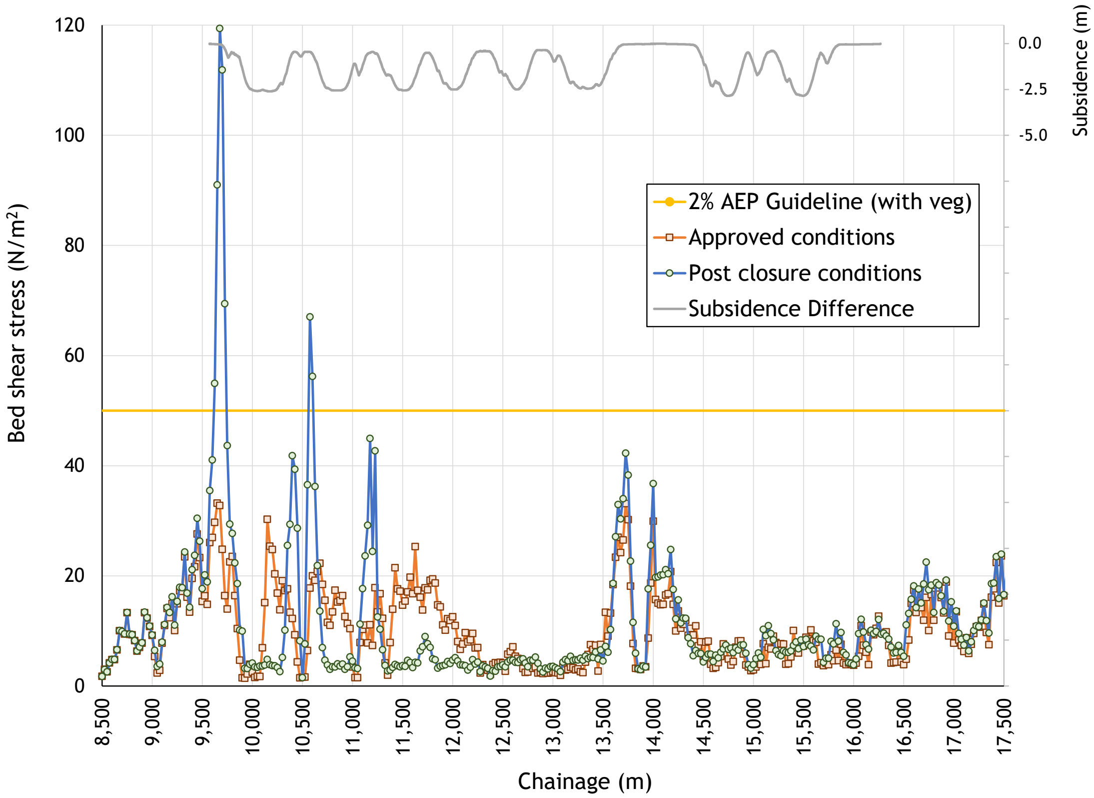

Figure 4.21 - One Mile Creek - 2% AEP - bed shear stress

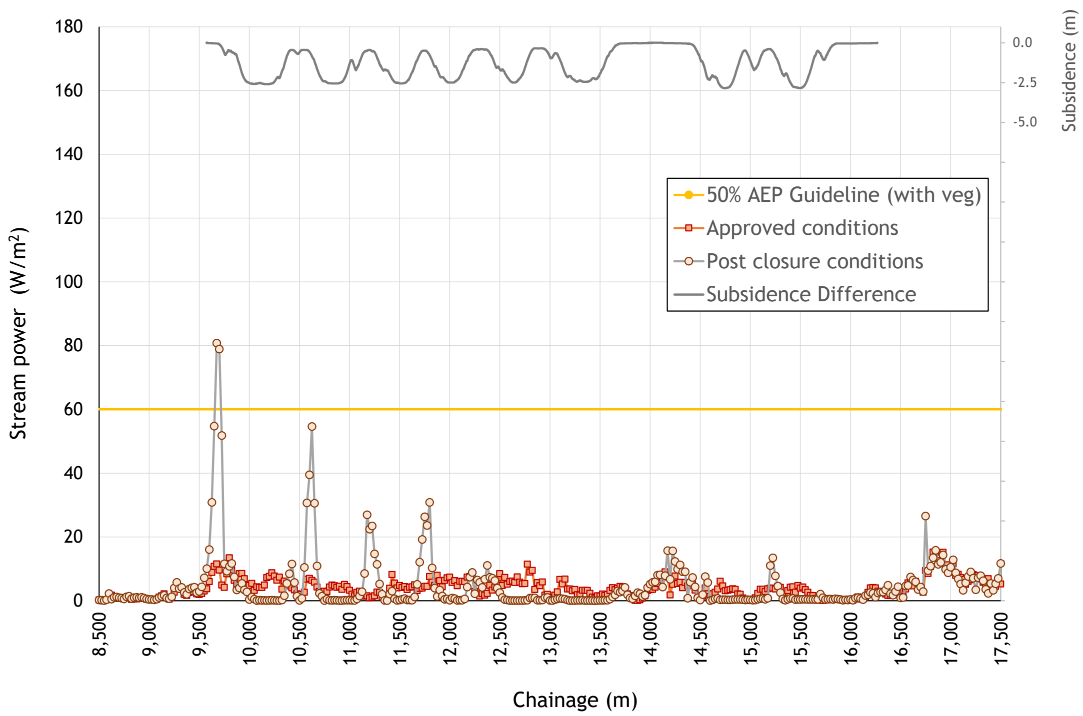

Figure 4.22 - One Mile Creek - 50% AEP - stream power

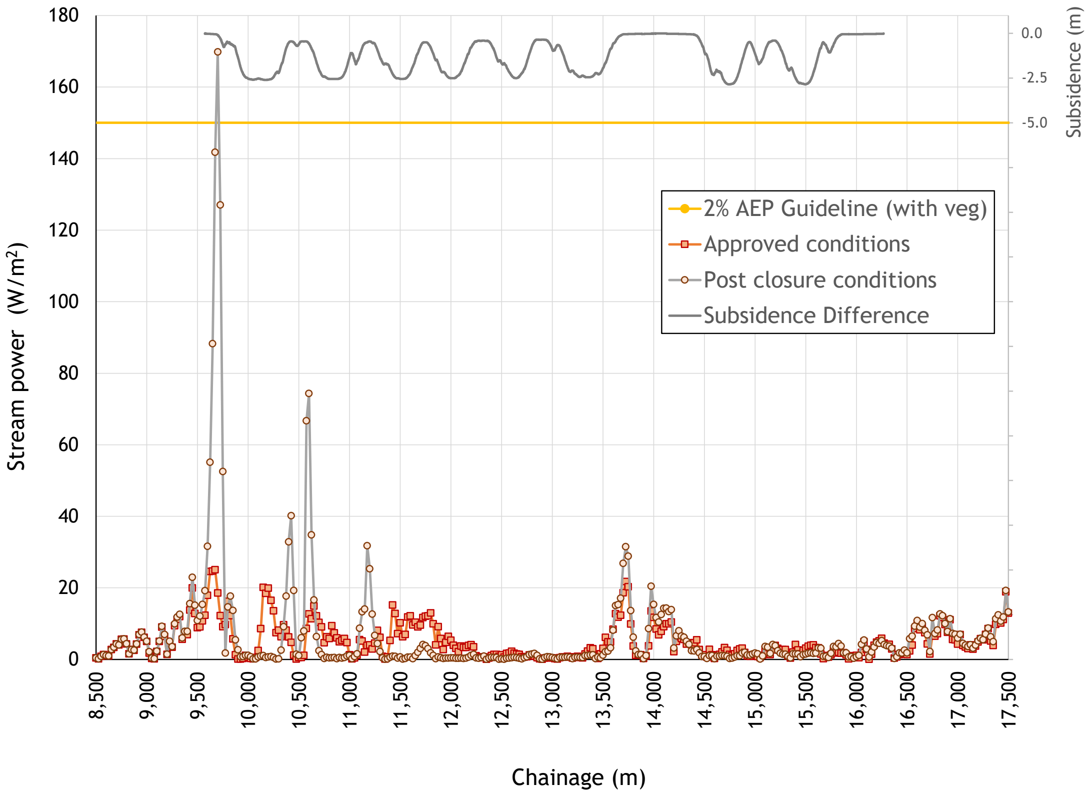

Figure 4.23 - One Mile Creek - 2% AEP - stream power

5 Summary of findings

5.1 OVERVIEW

Bowen Basin Coal Pty Ltd propose to develop the Lake Vermont Meadowbrook Project - a new double-seam underground longwall coal mine, along with a small-scale open-cut pit targeting coal resources adjacent to the north of the existing Lake Vermont Mine.

The proposed longwall panels underly and will cause subsidence in Boomerang Creek, One Mile Creek and their floodplains, was well as part of the Phillips Creek floodplain to the south. Queensland Government mapping has defined Boomerang Creek and One Mile Creek as a watercourse under the Water Act 2000.

Subsidence would occur gradually as the Project progressively develops over the planned life of the underground mine of 22 years to 2048. The total surface area predicted to be affected by subsidence within the Project area is approximately 2,195 ha.

The channel and floodplain of Boomerang Creek would see a maximum subsidence depth of up to 4.0 m. Maximum subsidence depths in the floodplain between One Mile Creek and Boomerang would be over 4.5 m in localised areas. Maximum subsidence depths on the One Mile Creek channel and southern floodplain would be up to 3.0 m. Maximum subsidence depths on the Phillips Creek northern floodplain would be up to 3.0 m. The channel of Phillips Creek would not be directly affected by subsidence.

Gordon Geotechniques (GG, 2022) predicted the maximum depth of continuous subsurface subsidence cracking above the workings would not extend to the ground surface at Boomerang, One Mile and Phillips Creeks.

Surface subsidence cracks will develop in the longwall mining areas particularly in areas of maximum tensile at the panel edges. Gordon Geotechniques concluded the widest of these cracks would extend no more than 10 to 15 m below ground level, with the majority less than 1 m deep. Maximum surface crack widths up to 200 mm could be expected in shallower areas, decreasing to less than 50 mm at greater depths. Cracks of this size and depth would not result in the loss of water from the alluvium associated with the watercourses overlying the underground workings.

Hydraulic models were developed to assist with the characterisation of the waterway channels and to assess the potential flood and geomorphic impacts of the Project. Models were developed for pre-mining conditions, which assume all approved works on the Lake Vermont lease have been implemented, and post mining conditions, which assume that the additional longwall panels within the Project area have also been subsided and that works associated with the open cut pit (temporary levees around the mining area and mine infrastructure area, haul road/access road and earthworks to mitigate some of the Project impacts) are in place.

5.2 BOOMERANG CREEK

In the proposed subsidence area, Boomerang Creek meanders across a broad floodplain. The channel is typically 1.5 m to 2.5 m deep with a sandy bed.

The channel capacity is relatively low, with floodwater flowing over the southern bank at several locations for the 50% AEP flood via two shallow southeasterly flow paths to One Mile Creek. Floodwater ponds in existing gilgai, meander cutoffs and remnant channels in the very flat floodplain between the two waterways.

Due to the relatively flat natural ground slopes and the depth of the proposed subsidence, the extent and depth of undrained depressions in the floodplain would significantly increase. These depressions would partially fill with local rainfall and runoff and slowly evaporate or seep into the local soils. The duration of ponding in these depressions would depend on the depth and duration of rainfall, but based on water balance modelling, they would be unlikely to fill completely, and would be expected to store more than 1 m of water less than 10% of the time. However, based on modelling of the 50% AEP flood, the depressions would be expected to fill with Boomerang Creek floodwater at least every few years. The ponded water would then persist until it evaporated or seeped into the underlying soil. In the absence of seepage, depending on their depth, the ponds could then be expected to persist for several months post filling.

Within the subsidence zone, peak flood levels would be reduced by up to approximately 3.5 m and 3.0 m in the 50% AEP and 2% AEP floods respectively. The extent of inundation would be increased slightly by backwater flowing up the subsidence troughs. During small flood events, additional flood storage would significantly reduce the peak flow rate, and peak flood levels in downstream reaches of Boomerang Creek by as much as 0.3 m to 0.5 m. In floods larger than the 2% AEP event, the impact of subsidence on downstream flows would be minimal.

In small floods, the proposed subsidence would result in an increase in the amount of Boomerang Creek floodwater flowing towards One Mile Creek. Velocity increases of 0.25 m/s to 0.5 m/s are predicted over a broad area where Boomerang Creek floodwater approaches One Mile Creek between Ch 14,000 to Ch 16,000. However, the increased velocities would be insufficient to erode the floodplain except in localised areas as it drains into subsidence troughs. Where vegetation coverage is poor over dispersive soils new flow paths would be likely to establish over time.

The proposed subsidence would result in a series of 4 main troughs in the channel bed due to the interaction of the differential settlement across the nine longwall panels and the intervening unmined pillars in each of the two overlying coal seams. These areas would see decreases in channel velocity, bed shear and stream power, causing reductions in sediment transport capacity in each trough, and promoting further aggradation of the bed (relative to the top of bank level) in these areas.

There would be increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone at Ch 9,250. The deep bed sediments in these reaches are expected to erode relatively quickly as the channel morphology changes to reflect the higher bed grade. This may also lead to marginal increases in bank erosion as the channel capacity increases.

Channel velocity, bed shear and stream power would also increase as flow enters the second and fourth subsidence troughs (Ch 10,200, and Ch 11,700 to Ch 12,000). The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion may potentially occur to the extent that this elevated section of stream bed will be eroded down to the upstream and downstream bed levels (which will rise as the bed aggradation occurs). The expected aggradation relative to the bank levels could accelerate the potential abandonment of the existing Boomerang Creek channel. It should be emphasised that given the number of remnant channels and abundant sediment supplies in the catchment, a new Boomerang Creek channel could form in the absence of the proposed subsidence. Hydraulic modelling of earlier stages of underground operations indicated that the avulsion risk would be greatest in Year 17 prior to the development of the easternmost panels.

During initial flows, local incision and bank erosion can be expected over the pillars between subsidence troughs. However, given the abundant sediment supplies in Boomerang Creek, the sand bedload will infill the troughs such that the bed grade should revert to approaching the pre-mining grade over time. he expected aggradation relative to the bank levels could accelerate the potential abandonment of the existing Boomerang Creek channel. It should be emphasised that given the number of remnant channels and abundant sediment supplies in the catchment, a new Boomerang Creek channel could form in the absence of the proposed subsidence.

It should be noted that Alluvium (2019) found that depending on the timing of flows and mining and the infilling of subsidence at the proposed Saraji East underground mine through Hughes and Boomerang Creek would potentially cause downstream bedload starvation for a period and this could impact the timing of infilling of the bed at the Meadowbrook Project. Assuming the quantity of sand currently upstream of the project area remains sufficient to replenish the subsidence depressions at Meadowbrook during operations it is expected to take around 25 years for the subsidence depressions to refill post-mining. Complete replenishment of residual sediment losses attributable to the Saraji East project could take a similar additional time, however large floods could significantly reduce these timeframes (and prolonged drought could increase them).

5.3 ONE MILE CREEK

One Mile Creek is a Boomerang Creek tributary. In the downstream parts of the proposed subsidence area, One Mile Creek and Boomerang Creek share the same floodplain. However, their geomorphic characteristics are quite different, with the bed material of One Mile Creek being significantly finer, and its channel being smaller and narrower. Parts of the One Mile Creek channel appear to be sediment-limited – with the roots of much of the riparian vegetation being exposed following recent flow events. One Mile Creek is typically 0.75 m to 1.5 m deep, with a top width of approximately 15 m.

The proposed subsidence would result in a series of 8 main troughs in the channel bed due to the differential settlement across the longwall panels and the intervening unmined pillars in the one overlying coal seam which are aligned approximately perpendicular to the channel.

All troughs associated with the One Mile Creek floodplain would be directly connected to the main channel – and during flood flows, water would flow laterally into the subsidence areas. The north-flowing reaches of the One Mile Creek floodplain would also experience minor impact from the construction of the temporary levee proposed around the northern end of the open cut pit mining area. At the completion of open cut mining, the levee would be decommissioned, and the One Mile Creek floodplain would be restored to pre-mining levels through the placement of in-pit overburden in the final landform.

Within the subsidence zone, peak flood levels would be reduced by up to approximately 1.3 m and 1.5 m in the 50% AEP and 2% AEP floods respectively. In floods larger than the 2% AEP event, the impact of subsidence on downstream flows would be minimal.

Parts of the channel within subsidence troughs would see decreases in channel velocity, bed shear and stream power, causing reductions in sediment transport capacity in each trough, and promoting further aggradation of the bed (relative to the top of bank level) in these areas.

There would be increased channel velocity, bed shear and stream power as the channel drains into the mine subsidence zone at Ch 9,750. Velocities in this area would remain less than guidelines values but given the relatively fine sediment in this area and the apparent limitation in sediment supply, these reaches are expected to erode as the channel morphology changes to reflect the higher bed grade. This may also lead to increases in bank erosion as the channel capacity increases.

Channel velocity, bed shear and stream power also increase as flow enters the second to fifth subsidence troughs (Ch 10,600, and Ch 11,200 to Ch 11,750 and Ch 12,250). The bed sediments on the downstream side of these localised elevated sections of the stream bed are expected to scour and headward erosion would occur through this elevated section of stream bed.

If there was sufficient sediment supply, the post subsidence channel velocity, bed shear and stream power would revert towards pre-mining conditions. However, as it appears sediment supply is limited, this may take a long time, and the ponds formed by the sediment may persist for a comparatively long time.

To promote the movement of water and sediment through this reach, Bowen Basin Coal will consider decommissioning the existing farm dam on One Mile Creek prior to the commencement of mining.

Where practical, minor drainage channels are proposed to drain the subsidence panels, however as this is not possible in all areas, ponding of runoff captured in the floodplain between Boomerang and One Mile Creeks would effectively reduce the local catchment draining to One Mile Creek by approximately 9 km^2 (6.9%).

Water balance modelling of the overland flow into the One Mile Creek depressions shows their median stored volume would total only 20 ML, but they could intercept approximately 283 ML/a of catchment runoff on average (median 96 ML/a).

During open cut operations, water which would normally flow to One Mile Creek would be intercepted by the proposed mine water management system within the levees protecting the mine pit and sediment dams. During the period of peak open cut mining disturbance, the temporary maximum additional reduction in catchment area to One Mile Creek would be approximately 3 km^2 (i.e. a total of 12 km^2). At the completion of mining and rehabilitation of the final landform, this would reduce to approximately 1.5 km^2 (i.e. a total catchment loss of 10.5 km^2 – 8%).

This catchment loss would impact the downstream 4 km to 6 km reach of One Mile Creek in minor runoff events, (which has been impacted by historical mining activities in the upper catchment) but would not significantly further alter the flow regime. The impacts of the catchment loss would be minimal downstream of the confluence, where it would make up 1.8% of the 489 km^2 total catchment.

5.4 PHILLIPS CREEK FLOODPLAIN

The main channel of Phillips Creek will not be impacted by the proposed subsidence. However, four underground panels crossing the northern Phillips Creek floodplain would impact flooding and drainage. The proposed temporary levee around the southeastern end of the open cut mining area would also impact flood flows until it was decommissioned, and pre-mining ground levels restored at the end of mining.

A minor drainage channel would be constructed around the toe of the levee to ensure the floodplain is free draining. Drainage channels would be cut through the pillars separating the subsidence troughs to allow free drainage of catchment runoff through the subsidence zone. Small embankments are also proposed across the subsidence panels to restrict the flow of water from Phillips Creek to One Mile Creek. The remaining small depression would intercept a portion of the overland flow from the local catchment of 1,436 ha (about 2.8% of the total Phillips Creek catchment). The average annual volume captured by the pond is estimated to be 167 ML/a (about 0.8% of the average annual flow in Phillips Creek at the project).

5.5 ONGOING MONITORING AND MITIGATION MEASURES

A subsidence monitoring plan will be developed to assess the changes in bed levels and the impact of increased localised sedimentation. Bank protection measures will be considered if monitoring indicates that the increase in erosion is having a demonstrable impact on the channel form.

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Annexure A. Photographs of site waterways and floodplains

Contents

List of Figures

A1 Map of field inspection sites

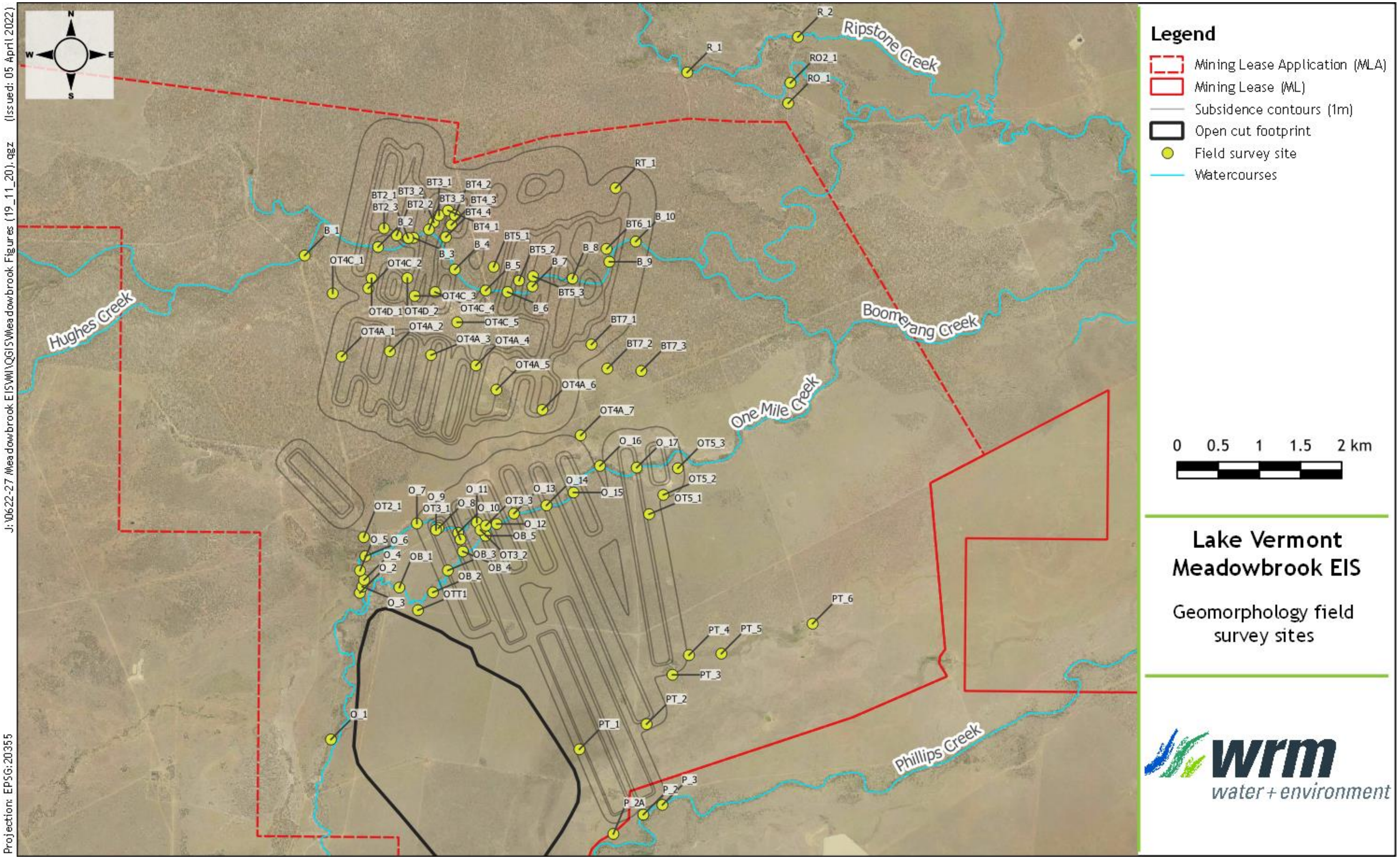

Figure A.1: Locations of field inspection sites

A2 Boomerang Creek

A3 One Mile Creek

A4 Phillips Creek