The Latrobe River system: Regional hydrologic impact assessment of EnergyAustralia Yallourn mine closure scenarios

September 2025

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

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **EnergyAustralia Yallourn** under the contract titled 'Surface water modelling assessment'.

Authors: Stuart Cleven, Elle Guthrie, Tom Stewart, Suresh Hettiarachchi, Bill Moulden
Review: Stuart Cleven
Approved: Ross Hardie

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Contents

Figures

Tables

1 Introduction

EnergyAustralia Yallourn is developing mine closure arrangements for the Yallourn mine site that considers a range of issues including geotechnical and hydro geotechnical stability of long term mine batters and the Morwell River Diversion (MRD). Alluvium Consulting Australia (Alluvium) has been engaged to assess the regional hydrologic implications associated with the preferred rehabilitation arrangements. The assessment has included the:

- Development of geomorphology and ecology context statement
- Event based hydrology and hydraulics modelling for Latrobe River system for existing and design conditions, and
- Regional water balance modelling for both a base case and proposed mine closure arrangements including environmental flow compliance assessment.

This report comprises a summation of this work including a preliminary assessment of the impacts of the preferred closure arrangements on the Latrobe River system, considering the assessment of flood hydrology and hydraulics, the water balance modelling and environmental flow compliance assessments and the regional hydrologic, geomorphology and ecology context statements.

1.1 Background

The Yallourn Mine is located in the Latrobe Valley, approximately 130 km southeast of Melbourne (refer to Figure 1) and the broader system in (Figure 2). The existing open cut pits lie either side of the Morwell River including a diverted reach of the Morwell River (the MRD – Yallourn). The mine is located immediately upstream of its presently diverted confluence with the Latrobe River. The Morwell River's upstream drainage basin spans 612 km², while the Latrobe River's catchment extends to a size of up to 1940 km². Approximately 3.5 km upstream from their confluence lies Lake Narracan on the Latrobe River.

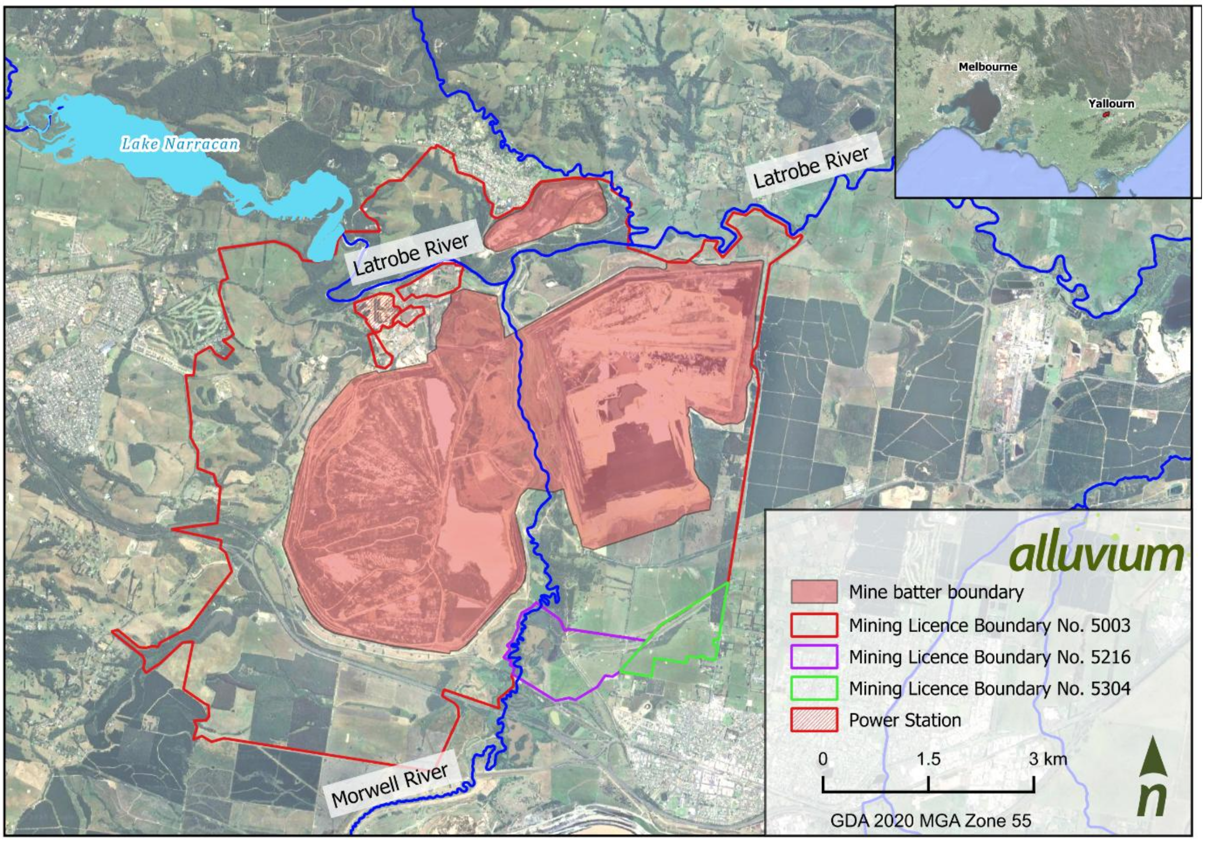

Figure 1. *The subject site*

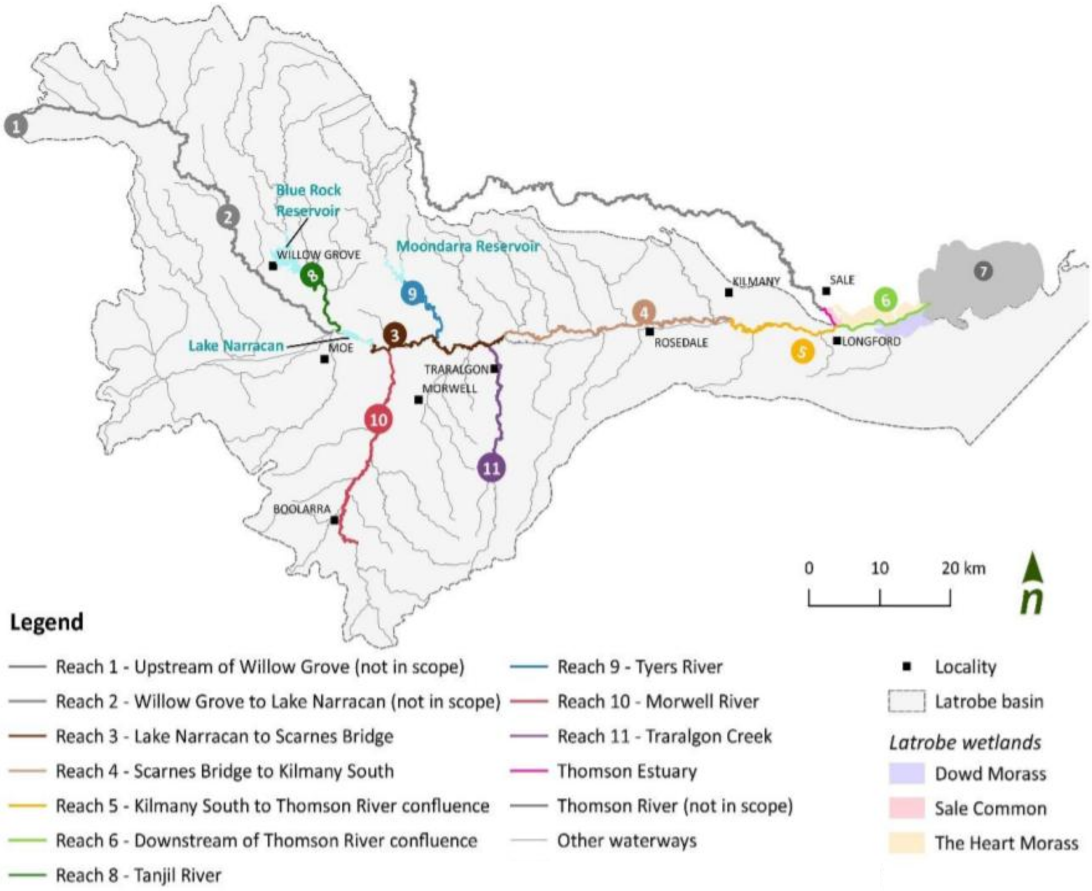

Figure 2. *Reaches of the Latrobe River System and important tributaries (source: Alluvium, 2020)*

The Latrobe River (Durt-Yowan) system, including its wetlands, floodplains and estuary, supports a wide range of social, environmental, economic and cultural values and assets. Environmental values include native fish populations, vegetation communities, and the internationally significant wetlands of the Gippsland Lakes that are listed under the Ramsar convention (including some of the lower Latrobe wetlands and all of Lake Wellington). The river system also supports a diversity of recreational (e.g., boating and angling), cultural and amenity values. Taken together, these values, and the opportunities they present, are becoming increasingly important to the Latrobe valley and its communities.

Planning is underway for a transition away from coal-based power production in the Latrobe Valley. This transition includes the planned closure and rehabilitation of the Yallourn open cut mine site. The proposed rehabilitation of the Yallourn mine includes establishment of a pit lake and requires decisions on issues that impact on the both the site and the broader Latrobe River system. Management decisions impacting on the wider Latrobe River system include those addressed by this report namely:

1. The management of the Morwell River Diversion through the site, and
2. The use of water resources to fill the mine void and maintain the pit lake

These decisions have the potential to impact and benefit the water and waterway related values of the Latrobe River system and communities that rely on these values.

1.2 Assessment method

Closure planning for the site requires an assessment of mine closure options for various elements of the site reconfiguration, for which various modelling and desktop assessments has been undertaken. An overview of the assessment process and various reports and how they have fed into the development of the regional hydrologic assessment of mine closure scenarios is shown in Figure 1. The work by Alluvium has provided input to and relied on outputs from pit lake water balance modelling undertaken by RGS.

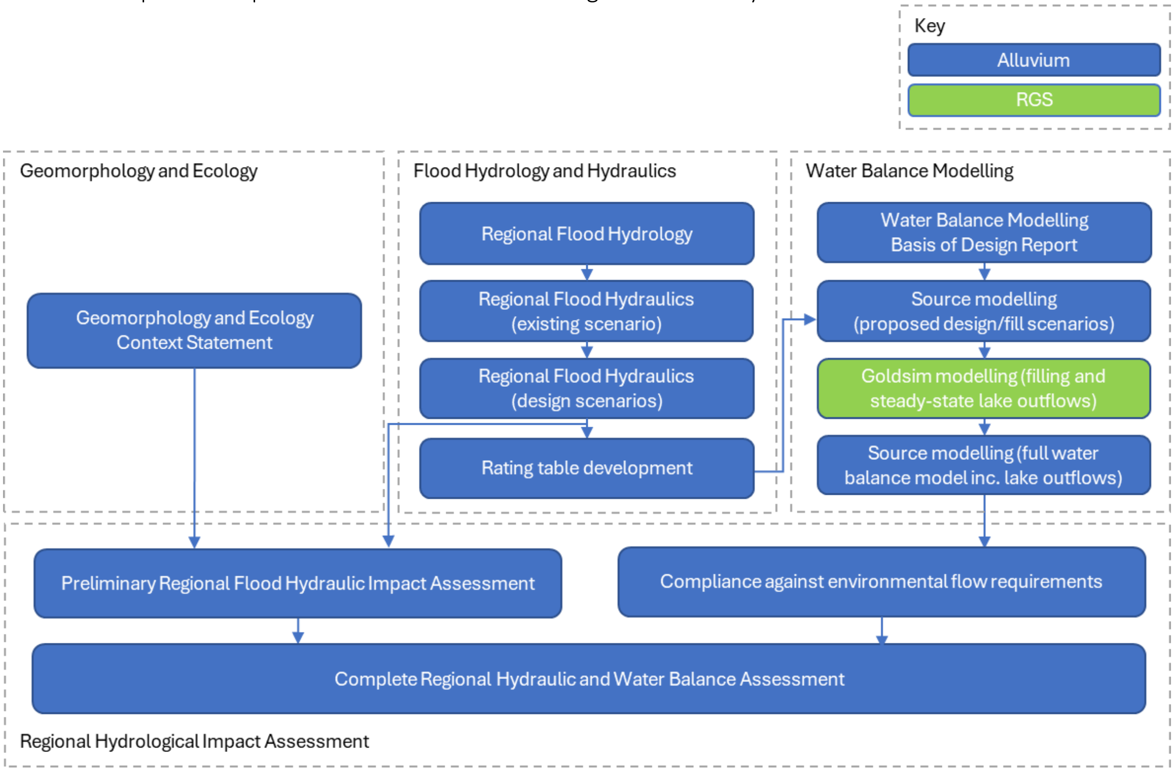

Figure 3. *Overview of assessment method and reporting*

The following table provides a high-level summary of the key modelling and design assessments that has been completed under this scope of works. Each of these modelling assessments are described in detail in the respective modelling and analysis reports attached to this document.

Table 1. Summary of the modelling and design reporting

Project component	Report	Assessment of impact
Geomorphology, and ecology context statement	Attachment A_ *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine (Alluvium 2024a)*	Current hydrologic and ecological condition of the Morwell and Latrobe River systems and the implications of these conditions on options for the Yallourn Mine closure planning
Regional Flood Hydrology	Attachment B_ *Yallourn Rehabilitation Assessment – Hydrological modelling (Alluvium 2024b)*	Approach and outcomes of a hydrological assessment of the Latrobe and Morwell Rivers within the context of the Yallourn Mine
Regional Hydraulic modelling	Attachment C_ *Yallourn Rehabilitation Assessment - Hydraulic Modelling and Analysis (Alluvium 2025a)*	Hydraulic modelling assessment of post mine rehabilitation for existing and design scenarios
Water Balance Modelling Basis of Design	Attachment D_ *The Latrobe River system: Water balance modelling - Basis of design(Alluvium 2024c)*	Water balance assessment design and testing of proposed mine closure plan
Environmental Flow Compliance assessment	Attachment E_*Water Balance Modelling and Environmental Flow Compliance report (Alluvium 2025b)*	Water balance assessment of post mine rehabilitation impact on environmental values in line with LVRRS

2 Geomorphic and ecological design considerations

2.1 Design principles

The potential to adversely impact and/ or benefit the water and waterway related values of the Latrobe River system has been documented in *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine* (Alluvium 2024a) (refer to Attachment A).

The following key hydrologic, geomorphic and ecological function design principles identified in that context statement (Attaqchment A) are relevant to the regional hydrologic assessment of the mine closure design:

- Hydrologic, geomorphic and ecological functioning.
    - Hydrologic regime. The arrangement should provide for both:
        - longitudinal hydrologic connectivity
        - lateral floodplain connectivity
    - Geomorphic processes. The arrangement should:
        - not be subject to accelerated high rates of erosion and deposition
        - be robust i.e. resistant to change and have the ability to adapt and repair following change without comprising the other values and outcomes
        - provide for ongoing longitudinal and lateral bed load sediment movements
    - Ecological condition and processes
        - Provides for ongoing benthic ecological processes
        - Meets instream and riparian habitat and transfer (e.g. fish passage) requirements

Additionally, a number of key design stability conditions have been identified through EnergyAustralia Yallourn led risk workshops including the potential for the catastrophic failure / collapse of the MRD associated with ongoing channel and embankment stability.

2.2 Design concept formation

Without management intervention the current MRD poses significant risk to the health and function of the Morwell and Latrobe Rivers and the key hydrologic, geomorphic and ecological function design principles above. These risks are largely associated with a potential catastrophic failure / collapse of the MRD. The implications of failure of the current MRD are discussed in detail in Attachment 1, including:

- Major channel incision that could lead to potentially catastrophic upstream impacts associated with large-scale Morwell River channel deepening and widening
- Cessation of bedload sediment supply and benthic processes, exacerbating the existing sediment starvation and accelerated rates of bank erosion the Latrobe River
- Cessation of baseflows to Latrobe River system, loss of benthic process in the Morwell River system and loss of fish passage through the Morwell River

In light of this, design concept options were explored on a preferred MRD rehabilitation arrangement. Various alternatives were considered for the MRD including:

1. Fully connected Lake and MRD i.e. a flow through pit lake whereby the MRD is decommissioned, and all flow directed through a pit lake
2. Disconnected Morwell River Diversion: Morwell River diversion retained but remain hydrologically disconnected from the pit lake
3. Partially connected Morwell River: Morwell River diversion retained for passing of the environmental flows and modified via a high flow connection to pit lake

EnergyAustralia Yallourn has indicated a preference for the partially connected arrangement (Option 3 above). A discussion on geomorphic and ecological implications of this option is provided in below.

Morwell River Diversion preferred option: Partially connected Morwell River

This option is included in the conceptual arrangement for the site (refer Figure 4) and seeks to increase the robustness of the existing MRD by not confining flood events within the MRD. This option seeks to provide a controlled spill of floodwater from the Morwell River (and or Diversion) channel to the pit lake, and the subsequent return of the flood water to the Morwell and / or Latrobe Rivers via a return flow spillway/ floodway.

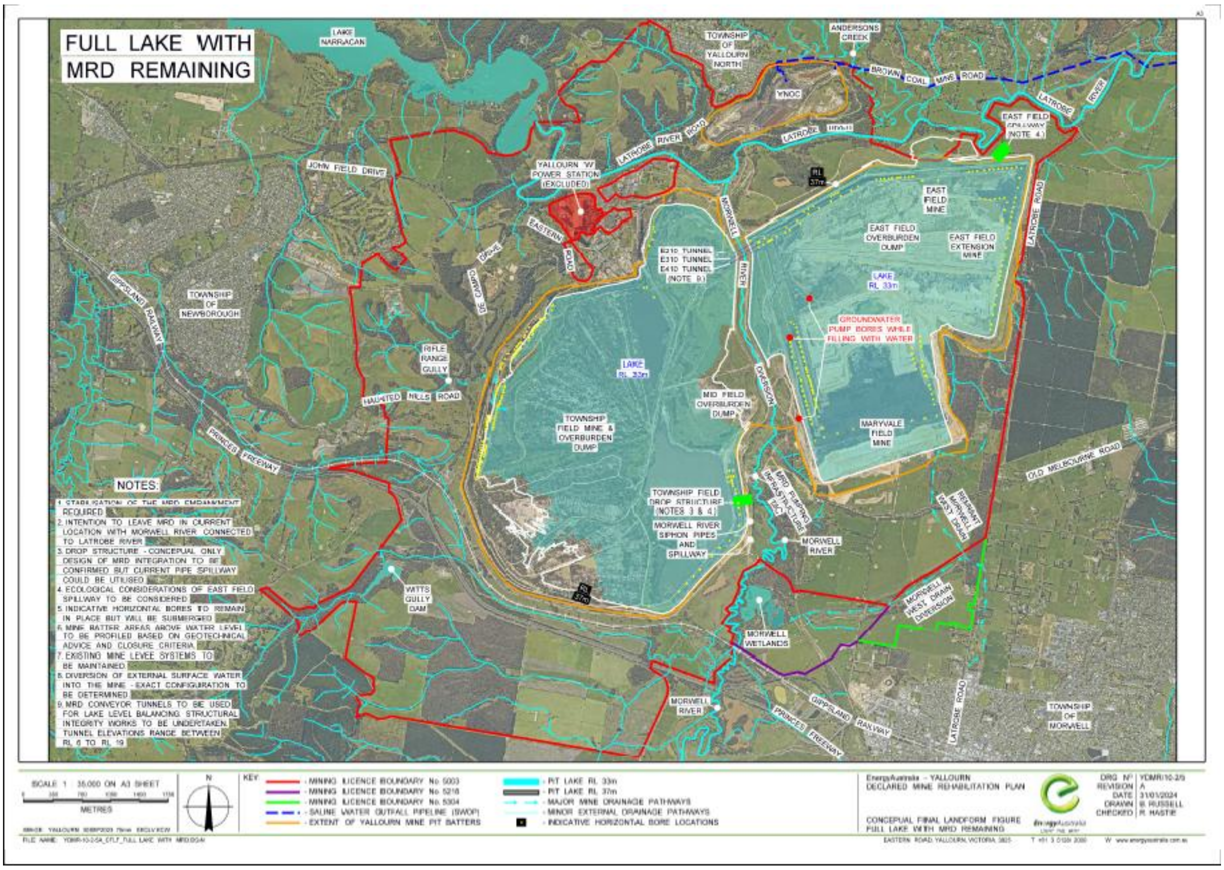

Figure 4. *Concept final landform: full lake (Note: concept only with design refinement provided in Section 3)*

The option has the benefit of creating a more robust diversion / river system through the site, with a lower risk of catastrophic failure than the Disconnected River Diversion option. This option while benefiting the structural integrity of the MRD, has the potential to result in the loss of flood events / flood flows needed to meet flow requirements within the downstream Latrobe River system.

This option would have some ongoing risk of failure. However, the likelihood of such failure would be much lower than that associated with a Disconnected Morwell River Diversion option.

Implications of pit filling water use for the Latrobe River system

A number of water sources can be considered for pit filling and pit lake operations. These sources have potential to impact on the health and functioning of the Latrobe River systems. Potential water sources include:

- Existing local sub catchments at the Yallourn site that currently discharge to the Morwell and Latrobe River.
- Groundwater.
- Bulk water entitlements from the Latrobe River system extracted from Yallourn Weir via Lake Narracan and Blue Rock Reservoir.

- Harvesting of a portion of flood events (from the Morwell and potentially Latrobe Rivers).

These sources have the potential to impact on flow components essential to the river system these flow components include:

- Summer/ autumn
    - Base flows
    - Freshes
- Winter / spring
- Base flows
    - Freshes
- Bankfull events
- Overbank events

These flow components are required in reaches that have potential to be impacted by the use of water to fill and operate a pit lake. Reaches of the Latrobe River with potential to be impacted by the use of water to fill and operate a pit lake include:

- The Tanjil River: Note that this water use is the subject of a Bulk Entitlement amendment and may not require separate assessment of impacts by EnergyAustralia Yallourn.
- The Morwell River (through the MRD) potential beneficial and adverse impacts.
- Freshwater reaches of the Latrobe River downstream of Lake Narracan .
- The Lower Latrobe River and fringing wetlands downstream of the Thomson River confluence.
- Lake Wellington and the broader Gippsland Lakes.

Recommendations arising

The geomorphic and ecological context statement provided recommendations and directions for further investigations. Recommendations for further investigations included:

- The hydrologic, geomorphic and ecological implications of the preferred design option. It was recommended that suitable hydraulic modelling e undertaken to inform the assessment and design. Hydraulic modelling of proposed design arrangement has been undertaken and is set out in Section 3) of this report.
- The risks arising from the use of water for the filling of the mine void and operation of a pit lake. It was proposed that these risks be explored with the aid of a surface water balance model. The existing DEECA surface water, water balance model is an appropriate model for such investigations. Investigations have been undertaken and are reported in Section 4) of this report.

3 Regional hydrology and hydraulics assessment

The regional hydrology and hydraulics modelling assessments have been undertaken to inform the hydrologic, geomorphic and ecological implications of the preferred design option, a *Partially Connected Morwell River*. The provision of hydrology and hydraulic modelling support for the major Morwell and Latrobe River systems can be found in:

- *Yallourn Rehabilitation Assessment – Hydrological modelling (Alluvium 2024b)* (refer Attachment B)
- *Yallourn Rehabilitation Assessment - Hydraulic Modelling and Analysis (Alluvium 2025a)* (refer Attachment C)

A summary of the outcomes of this assessment is contained below.

3.1 Regional hydrology assessment

An event based regional hydrologic model has been developed for both the Morwell and Latrobe Rivers systems. This model and the model outputs have been used to inform the hydraulic modelling task (refer to Section 3.2). The regional hydrology was split into two components.

Morwell River hydrology

The existing regional flood study, *Estimation of the flow rate and exceedance probability June 2021 flood event in the Morwell River – Detailed investigation* (Alluvium 2021), was reviewed and used to build the greater Latrobe River RORB model – see below.

Latrobe River hydrology

Model flow rates for the Morwell and Latrobe Rivers for events up to the 0.05% AEP event was required as input to the hydraulic modelling. No suitable, existing hydrological model was available for this purpose. As such a new RORB model of the Latrobe River system was built, incorporating the Morwell River existing RORB model extending downstream of the Yallourn Mine. The model was calibrated using available rainfall and gauge information on the Morwell and Latrobe systems.

Details of the model development process, the calibration and validation, and generating design flows corresponding to Annual Exceedance Probabilities (AEPs) events of 50%, 5%, 2%, 1%, 0.5%, and 0.2%, and the 0.05% AEP, as well as climate change analysis can be found in Attachment B.

Results

The combined calibrated model has been used to undertake a comparison of hydrographs at the Morwell River/Latrobe River confluence and assess timing of corresponding peak flows in the Morwell and Latrobe River. The critical flow rates and durations of all design flooding events are shown in Table 2 and Figure 4.

Table 2. Critical flow rates and durations for design flooding events

	Latrobe River @ Yallourn			Morwell River @ Yallourn		
AEP	Critical duration	Temporal pattern	Critical flow (m^3/s)	Critical duration	Temporal pattern	Critical flow (m^3/s)
50%	120 hrs	6	60	96 hrs	5	40
5%	48 hrs	6	480	48 hrs	4	240
2%	48 hrs	6	770	48 hrs	4	370
1%	48 hrs	10	1000	48 hrs	4	480
0.5	48 hrs	1	1180	36 hrs	1	560
0.2	48 hrs	1	1680	36 hrs	1	740
0.05	48 hrs	1	2600	36 hrs	1	1090

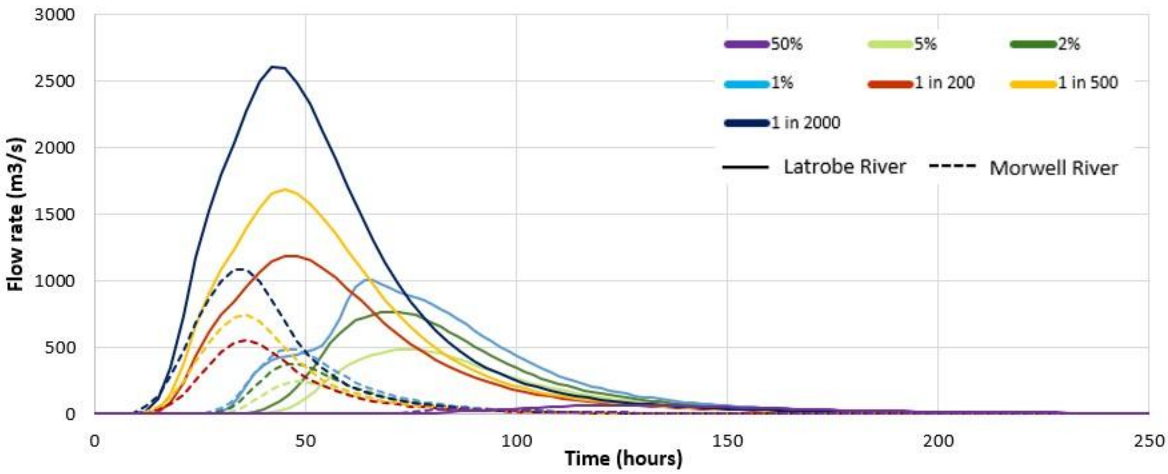

Figure 5. *Combination of the critical hydrographs, illustrating the relative magnitude of the flows between Morwell and Latrobe Rivers*

A climate change analysis has been undertaken for this study following the draft update to the Climate change considerations chapter in ARR Book 1 (DCCEEW, 2023). The RORB models for Latrobe and Morwell Rivers catchments were run with the climate change projected rainfall depths and initial losses. The peak flow rates for the Latrobe River and Morwell River catchments at Yallourn Mine for the SSP5-8.5 scenario are set out in Table 3.

Table 3. Critical flow rates in m^3/s for design flooding events with climate change scenario SSP5-8.5

	Latrobe River @ Yallourn			Morwell River @ Yallourn		
AEP	Current and near-term (m^3/s)	Medium-term (m^3/s)	Long-term (m^3/s)	Current and near-term (m^3/s)	Medium-term (m^3/s)	Long-term (m^3/s)
50%	90	110	200	60	70	120
5%	610	700	980	300	350	470
2%	930	1050	1400	450	510	670
1%	1210	1350	1760	580	640	830
0.5	1450	1640	2180	660	740	940
0.2	2020	2250	2940	860	950	1200
0.05	3080	3420	4360	1260	1380	1720

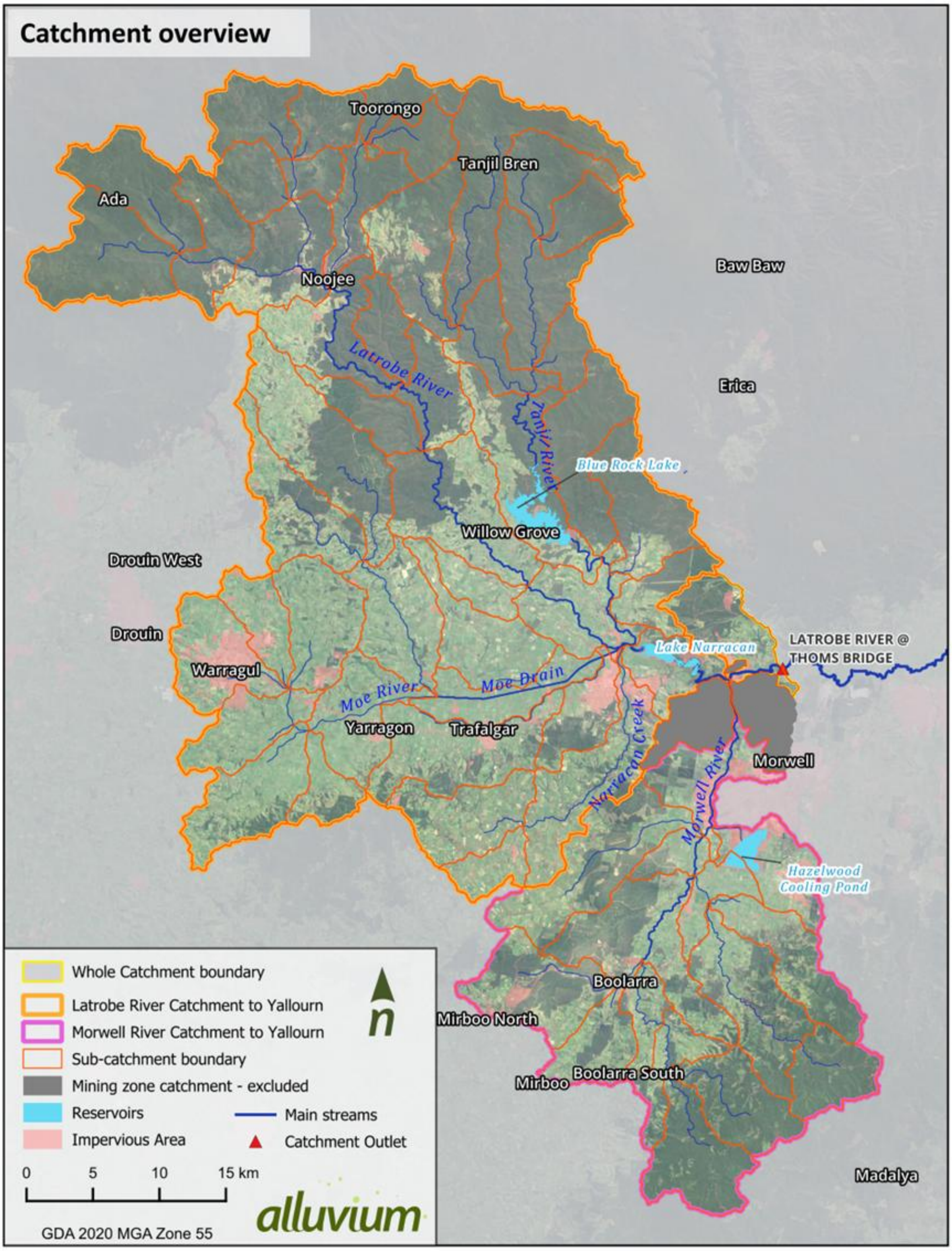

Figure 6. *Overview of Latrobe River Catchment adopted for event based hydrologic modelling for the Yallourn Mine site*

3.2 Regional hydraulic assessment

Regional hydraulic modelling has been undertaken to investigate and analyse the current flow regime and the proposed design scenario and the complex flow connections into the pits from the Morwell River, flows between the pits, and outflows from the pits. Analysis of these flow behaviours and hydraulic stream parameters (depth, elevation, shear stress and velocities) have been undertaken and used to assess the *Partially Connected Morwell River Option* against the key hydrologic, geomorphic and ecological function design principles defined in Section 2.1.

Model development

The TUFLOW model encompasses the area extending 15 km along the Morwell River and Morwell River Diversion (MRD) upstream of the Morwell and Latrobe Confluence, and 8 km of the Latrobe River. The model terminates approximately 6 km downstream of the confluence with the Morwell River. An 8-metre grid size was chosen for the model, striking a balance between computational efficiency and capturing the necessary detail of the Morwell and Latrobe River.

Model summary

Table 4. Summary of hydraulic model modifications

Item	Comments
Existing Hydraulic Models	Morwell River Diversion Hydraulic Model (HARC, 2023) This model was developed by HARC for Hazelwood which explored two scenarios, a baseline model with no offtake and no weir, and an as-built model including an existing weir and existing offtake diversion. This model would form the base for the development of the modelling for Yallourn.
Existing Hydrologic Model	A detailed hydrologic model was developed in RORB modelled the entire catchment to estimate peak flow and provide hydrographs for this hydraulic study (Alluvium, 2024).
Bathymetry	No bathymetric datasets have been used in the modelling to date within the study area. LiDAR capture have typically been captured during periods of low water inundation.
Field Survey	Field survey data have been captured at various locations within the model domain, namely: • Southern Coffer Dam • MRD South • MRD North • Eastern and Western Pits • Pump station This survey data has been used to generate surfaces at these localised sites.
LiDAR	1 m resolution LiDAR captured in 2018 was utilised by the modelling undertaken by HARC and has been retained in this model. This LiDAR was supplemented by 50 cm resolution data captured in 2020 by the Victorian Government and 2023 by the West Gippsland CMA, these areas cover the Latrobe River downstream.
Photogrammetry	In addition to the LiDAR, 10 m resolution photogrammetry DEMs from Elvis provided complete coverage of the study area in areas where there was no LiDAR coverage.
Key hydrometric data	Morwell River at Yallourn (226408), Latrobe River at Yallourn (226400B), Latrobe River at Thoms Bridge (226005) along with flow level data at the MRD Cofferdam, MRD South and MRD North.

Model verification

The updated TUFLOW model was verified by comparing model results to gauge reading for two events. The gauge readings were from two locations on the MRD. One smaller flood and one high flow event were selected to verify the hydraulic model. Gauge recordings (elevation and inferred flow sourced from data.water.vic.gov.au) were used to calibrate the model. The model calibration results for both the high and low flow events show reasonable match to the gauge readings.

Existing conditions modelling

Key points from the existing conditions modelling include;

- Peak flood depths in the Morwell River Diversion are dominated by Latrobe led events, reflecting the larger catchment area and peak flow events in the Latrobe River.
- Peak flood levels are contained within the MRD for all events tested including the 1 in 2000-year event Latrobe led event. In this event the water level rises to RL 45.3m AHD. This elevation has been identified by Energy Australia Yallourn to compromise the structural integrity of the MRD.
- While peak inundation is dominated by Latrobe led events, peak velocity and shear stress through the Morwell River diversion are highest during Morwell led events.

Table 5. Hydraulic modelling results for existing conditions

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Existing conditions peak elevation (m AHD)	Latrobe led	45.3	43.9	43.2	42.6	42.0	40.7	37.4
	Morwell led	43.3	42.3	42.3	41.3	41.0	39.7	37.5
Existing conditions peak velocity (m/s)	Latrobe led	0.9	0.9	0.9	1.0	1.7	0.2	0.7
	Morwell led	2.2	1.9	1.8	1.8	1.8	1.7	0.8
Existing conditions Peak bed shear stress (N/m^2)	Latrobe led	5.6	5.5	6.0	7.9	20.9	0.3	5.4
	Morwell led	27.8	25.6	24.0	22.8	22.3	21.2	7.4

Selection of initial layout for design configuration

A primary purpose of the hydraulic modelling was to develop and assess a potential long-term configuration for the levees and spillways for the MRD and the pits. The intent was to develop a preliminary design configuration that supports the long-term structural integrity of the levees that bound the MRD and to investigate how overflows through spillways to and from the pits behave during extreme events, while not impacting on environmental water requirements for the system.

The existing model configuration was modified via trial and error to:

1. Prevent water levels within the MRD rising above elevations that compromise the structural integrity of the MRD. A peak elevation of 42.5m AHD for the 1 in 2000-year ARI event was adopted for this purpose.
    a. Elevation: This water surface elevation was provided by EnergyAustralia Yallourn as an elevation that provides acceptable levels of confidence in the ongoing structural integrity of the existing levees adjoining the MRD.
    b. Design event: The 1in 2000 year ARI event was selected based on attainment of an acceptable level of risk given the consequence of failure of the structure. Further information on the consequence of failure of the MRD is set out in Alluvium’s review of geomorphic and ecological risks associated with the proposed rehabilitation of the Yallourn Mine site.
2. Ensure that events do not create excess differential water surface elevations between the pit lakes on the left (Township Field) and right (East Field) of the MRD. A maximum water differential water surface elevation between the Township Field and the East Field pit lakes of up to 6 metres was adopted for design. This criterion was provided by EnergyAustralia Yallourn, as that required to prevent excess lateral loads on the MRD that could result in a lateral movement of the MRD.

3. Ensure flood events do not generate erosion of the Morwell River floodplain and hence do not lead to erosion led failure of the adjoining levees and related infrastructure. A maximum velocity of 1.8m/s and shear stress of 80 N/m^2 (the maximum permissible velocity and shear stress for tall native bunch grasses, refer Fischenich 2001 Impacts of stabilisation measures) were adopted for the design.
4. Ensure that any such configuration does not divert flow from the Morwell or Latrobe Rivers that impacts on essential environmental water requirements of the Latrobe River system (including the Latrobe River). Spillways were set at elevations that ensure that flow rates in the Latrobe and Morwell River exceed 3,200 ML/day before any water is captured by the pit lake. This flow rate is required to ensure the flushing of the Latrobe River estuary of salt water at the current offtakes for the watering of the Dowd Morass and the Heart Morass on the lower Latrobe River.

The placement and sizing of the proposed spillways that control the flow in and out of the pits are presented below. The design configuration comprises

1. Two spillways from the MRD to the East Field
2. One spillway from the MRD to the Township Field
3. One Spillway from the East Field to the Latrobe River
4. Modification of the existing tunnels under the MRD to equalise water levels between the pit lakes

	Width (m)	Spill level (m AHD)
Spillway 1	50	41.5
Spillway 2	100	40
Spillway 3	50	40.5
Spillway 4	150	37

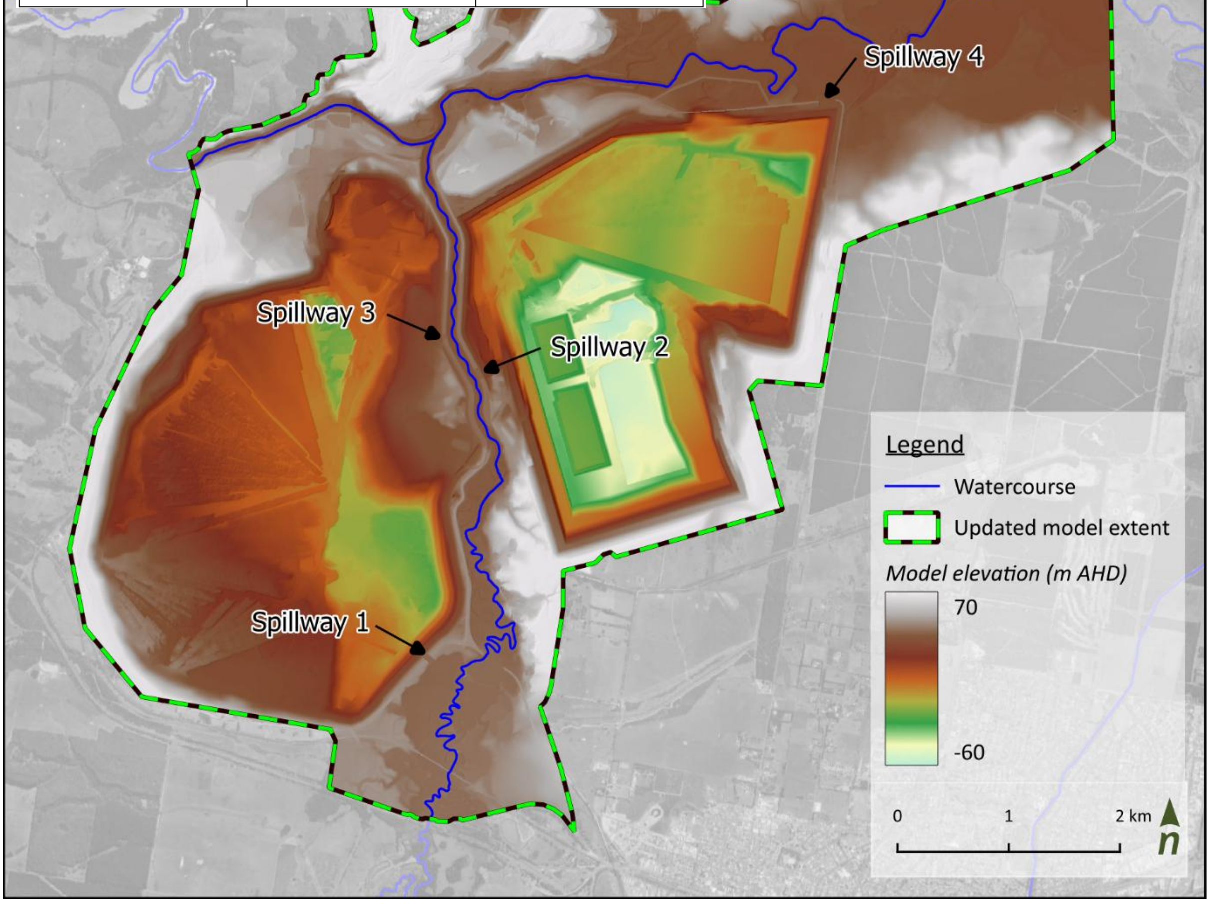

Figure 7. *Preliminary design arrangements assessed*

Preliminary design arrangement modelling results
Similar to existing conditions, the hydraulic modelling revealed flood levels to be dominated by the Latrobe led events, while the flow velocities and the resulting bed shear stresses in the MRD are more relevant during Morwell led events. The hydraulic modelling has revealed:

- Attainment of a maximum water surface elevation of approximately RL42.5m AHD for the 1 in 2000 year ARI event (Figure 8) i.e. consistent with the design criteria for maximum water levels within the MRD.
- Maximum difference in head between Township Field and The East Field pits of 3.3metres during flood events. i.e. less than that required to prevent lateral movement of the MRD
- Velocity (Figure 9) and shear stress that do not exceed:
    - That identified for the existing conditions
    - the non-scour velocity and shear stress for native bunch grasses

  Note the maximum shear stress has been quoted for the MRD floodplain not in the immediate vicinity of the proposed spillways.
- Spillway 1 being the first spillway to commence to flow. This spillway commences to flow at a 5% AEP (approx.) event in the Morwell River at 3,500ML/day (approx.). i.e. in excess of that required to flush the Latrobe River estuary of salt water at the points of inflow to the Lake Wellington fringing wetlands (Heart Morass and Dowd Morass).

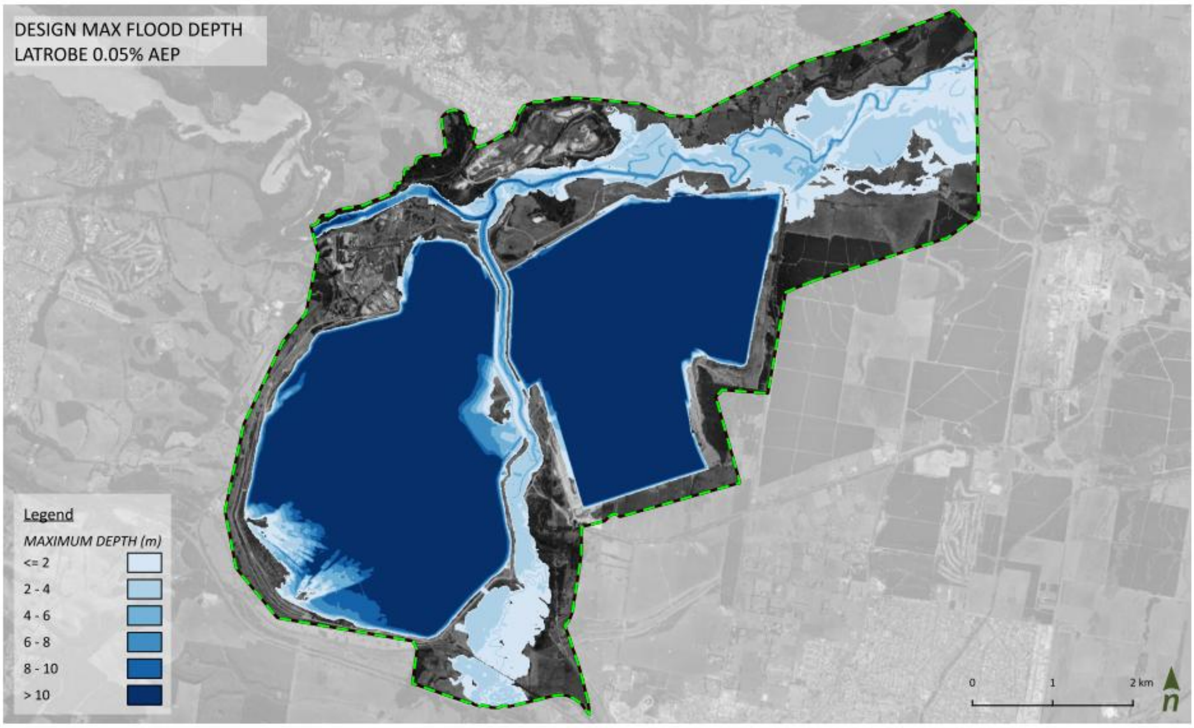

Figure 8. *0.05% AEP Latrobe River led event - Max Flood Depth – Design Conditions*

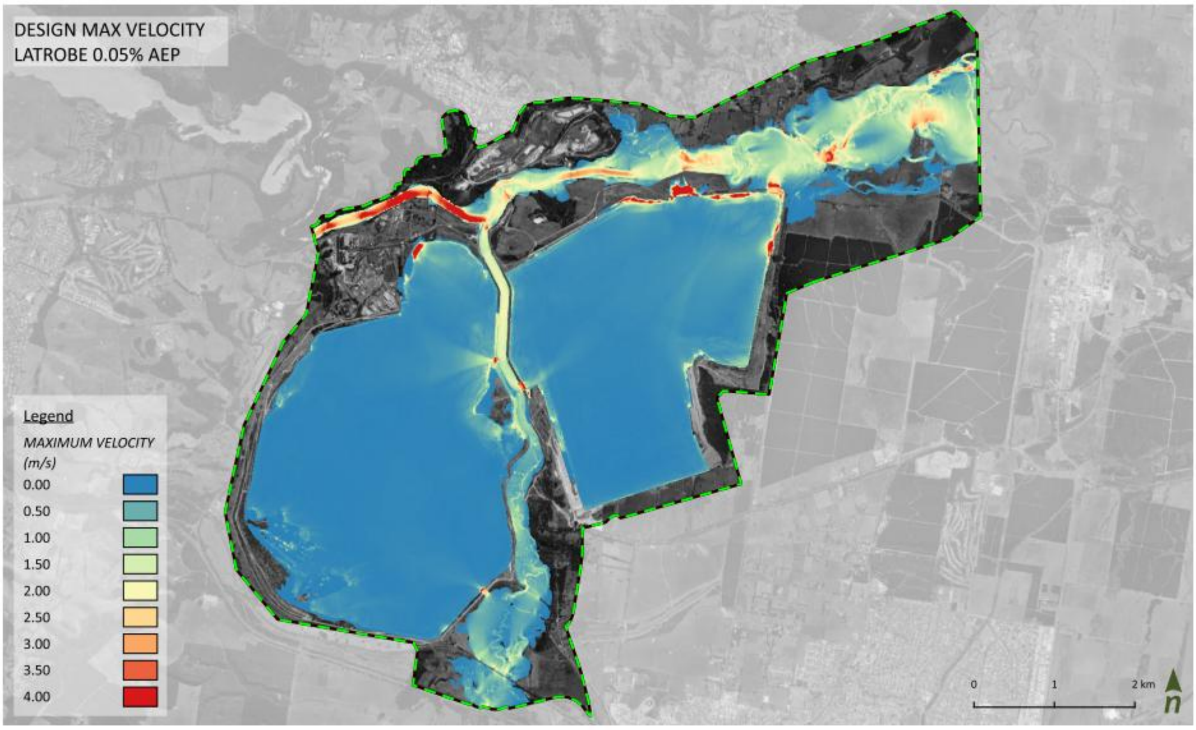

Figure 9. *0.05% AEP Latrobe River led event - Max velocities – Design Conditions*

Table 6. Hydraulic modelling results for design conditions

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Post fill conditions peak elevation (m AHD)	Latrobe led	42.5	42.1	41.7	41.4	41.1	40.4	36.9
	Morwell led	41.3	41.3	41.3	40.5	40.5	38.7	36.9
Post fill conditions peak velocity (m/s)	Latrobe led	1.5	1.1	0.8	0.5	1.3	0.1	0.6
	Morwell led	1.8	1.7	1.7	1.7	1.6	1.4	0.7
Post fill conditions Peak bed shear stress (N/m^2)	Latrobe led	12.5	7.1	5.9	7.5	19.1	0.5	5.3
	Morwell led	27.3	25.0	24.0	23.5	22.9	20.9	6.7

The hydraulic modelling has also revealed shear stress and velocity outcomes, that exceed the design criteria, over, and in the immediate vicinity of, the proposed spillways. Further assessment and design effort will be required to develop configuration arrangements that ensure the long-term performance of these structures. In addition, the velocity and shear stress criteria for existing and any proposed vegetated surfaces on the MRD floodplain are a function of the duration of events, with decreasing performance with increasing duration of inundation. Further investigations will be required to confirm the longevity of any proposed vegetative arrangements for MRD instream and floodplain erosion control, under extended flood events.

4 Environmental flow compliance assessment

The proposed Yallourn Mine Closure Plan requires an assessment of the impacts of the proposed project on waterways and wetlands of the Latrobe River catchment. The waterways and wetlands assessment has been informed by hydrologic (water balance) modelling of the Latrobe River systems. The modelling and assessment include alternate proposed water use arrangements associated with the proposed project using the 'Source' hydrologic modelling package.

The reaches assessed include those with potential to be impacted by the project and include the Morwell River, Latrobe River to Thomson River confluence, the Tanjil River and the Lower Latrobe River (downstream of the Thomson River confluence) to Lake Wellington.

4.1 Basis of design

A basis of design report was prepared to define the proposed water balance modelling approach, assumptions and scenarios to be adopted for the Yallourn Mine Closure Plan. The report was prepared to assist with the approval of proposed model runs prior to the commencement of modelling and subsequent analysis of results.

The report sets out the proposed 'base case', and 'project case' scenarios to be assessed and optional 'cumulative impacts' scenarios (if and as required). Refer to *The Latrobe River system: Water balance modelling - Basis of design (Alluvium 2024b)*.

The hydrologic model runs are set out in Table 2. The model configurations include alternate arrangements for the Hazelwood site. These alternate arrangements represent alternate potential arrangements for the Hazelwood Rehabilitation Project that are the subject of an Environmental Effects Statement (EES) process. That EES process has not been concluded and as a result two alternate Hazelwood Mine Rehabilitation arrangements have been assessed for this EnergyAustralia Yallourn project.

Further information on the configuration for each model run is shown in Table 8.

Table 7. Water balance scenarios to be modelled

Baseline/ Project	Demand profiles assessed for the fill phase	Yallourn assumptions	Hazelwood assumptions	Purpose of model configuration
Baseline	Baseline filling	Pit lake not connected Water supplied from Blue Rock under LVRRS amendment conditions, No return flows	Pit lake not connected 20 GL / annum supplied from Moondarra Reservoir No return flow	Base case for comparative analysis
Project	Project filling 1	Pit lake connected (flood inflow) Water supplied from Blue Rock under LVRRS amendment conditions No return flows	Pit lake not connected 20 GL / annum supplied from Moondarra Reservoir No return flow	To assess implications of Yallourn project under recent average use at Hazelwood and reflecting a potential Hazelwood mine void fill arrangement
	Project filling 2	Pit lake connected (flood inflow) Water supplied from Blue Rock under LVRRS amendment conditions No return flows	Pit lake Connected 30 GL / annum supplied from Moondarra Reservoir No return flow	To assess the cumulative implications of pit filling at Yallourn at the same time as a fast fill and connected pit lake arrangement at Hazelwood

Table 8. Project case configuration of demand values to run demand profile scenarios

					Assumed annual surface water demand (GL/yr)								
						Yallourn				Loy Yang			
Model Scenario name	Model Run	Model scenario prefix	Morwell Flood Harvesting - Hazelwood Connection		Hazelwood	Base Case	Dry	Med	Wet	Base Case	Dry	Med	Wet
baseline filling	**Unconnected**, water supplied from Blue Rock under LVRRS conditions No return flows	Dry/Med/Wet	Unconnected		20	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)
Project filling 1	**Connected**, water supplied from Blue Rock under LVRRS conditions no return flows	Dry/Med/Wet	Unconnected		20	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)
project filling 2	**Connected**, water supplied from Blue Rock under LVRRS conditions no return flows	Dry/Med/Wet	Connected		30	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)

4.2 Climate scenarios

Three climate change projections have been modelled and assessed, which have been previously derived as part of the LVRRS and the reference document *Climate Change Projections, Latrobe Valley Regional Rehabilitation Strategy, Method report and user guidance* (Brown, R. 2017):

- Baseline_2065 High CC (Dry condition)
- Baseline_2065 Med CC (Medium condition)
- Baseline_2065 Low CC (Wet condition)

4.3 Environmental flow compliance assessment

An environmental flow compliance assessment has been undertaken using outputs from the Source modelling. The compliance assessment has comprised a review of the hydrologic model results against environmental flow recommendations for the river reaches downstream of the project site. The timeseries of daily flow generated by the Source model have been run through eFlow predictor software (eWater 2017), using the flow recommendations from the 2020 FLOWS study for the Latrobe River system (Alluvium 2020). Compliance with flow recommendations were calculated for reaches of interest for each project scenario. The reaches of interest are:

- Tanjil River
- Morwell River at Yallourn
- Middle Latrobe River between the Morwell and Tyers Rivers confluences (Thoms Bridge)
- Lower Latrobe River downstream of the Tyers River confluence (Rosedale)
- Latrobe River estuary (Swing Bridge)

The compliance with flow recommendations have been assessed over the entire 63-year modelled period.

Note: The percentage compliance with flow recommendations is almost always less than 100%, even in unimpacted catchments with no dams or water extraction because:

- Some recommendations, such as overbank flows are not required every year for the ecosystem to be healthy
- There will naturally be dry years where flow is less, and ecological values are impacted.

The implications of the Project case 2 (Hazelwood fast fill and connected pit lake) have been discussed where these have a cumulative effect over any changes identified under the Project case 1. Impacts associated with Project Case 2 in the absence of an impact under Project Case 1 are not related to the Yallourn rehabilitation project and have not been described, assessed and discussed.

4.4 Source modelling overview

The updates that were made to the Source model to represent the Yallourn, Hazelwood and Loy Yang mines under closure and rehabilitation conditions (refer to Attachment E for breakdown of model updates) resulted in the determination of hydrologic impact of each scenario.

To represent the final site configuration of the rehabilitated mines, the Source model was modified to represent both inflows to and outflows from the pit lake. Under existing conditions, water is delivered to the mine site under the current Bulk Entitlement. However, in the rehabilitated site design, inflows are also delivered to the proposed Yallourn pit lake through a series of spillways, designed to divert overbank peak flows from the Morwell River. The proposed site design consists of 3 spillways along the Morwell River upstream of the Latrobe River confluence. These spillways have been designed to divert flow from the Morwell River to the pit lake when flows in the Morwell River exceed the following Morwell River rates:

- Spillway 1: Commence to flow at 6,048 ML/d

- Spillway 2: Commence to flow at 11,664 ML/d
- Spillway 3: Commence to flow at 19,008 ML/d

These spillway elevations have been set at an elevation high enough to limit impacts to environmental water requirements, but low enough to reduce flood event water level in the Morwell River Diversion (MRD) to assist the structural integrity of the MRD.

There is a fourth spillway out falling from Eastfield Pit to the Latrobe River, which is designed to return pit lake outflows to the system. The three inlet spillways are represented as additional demand nodes, which are configured with calculated spillway flows that are computed using weir equations that take dimensions of spillways that have been conceived with the aid of the hydraulic modelling.

4.5 Source modelling results

Flow statistics were derived from modelled daily flows for each climate case and scenario at four reference locations. As expected, the climate cases produced distinct outcomes, with the Dry case yielding lower daily flow volumes compared to the Medium and Wet cases. Assessment of scenario differences showed limited variation in the modelled median and minimum daily flows. However, notable differences were observed for the maximum and average flows under the Project Fill 2 scenario across all climate cases, Table 9. This difference between scenarios (Project Fill 1 and Project Fill 2) could be a result of the change in Hazelwood demand assumptions (30 GL/day demand from the Moondarra supply) and pit lake connectivity. The changes in Hazelwood operations shows that there is an impact on the higher flows beyond that of the impact of Yallourn.

A comparison of the project fill scenarios against the baseline for each climate case (as shown in Figure 10) shows that proposed project has been identified to have no impact on base flows or freshes in the Latrobe River system.

Table 9. Statistics for average, median, maximum, and minimum daily flows at four reference locations.

	Morwell River at Yallourn				Latrobe River at Thoms Bridge				Latrobe River at Rosedale				Latrobe River at Swing Bridge			
Flows ML/day	Avg	Med	Max	Min	Avg	Med	Max	Min	Avg	Med	Max	Min	Avg	Med	Max	Min
Dry_Baseline	336	102	14259	0.3	990	511	22395	122	1284	699	23999	171	2466	1077	69383	248
Dry_Project_Fill_1	336	102	14259	0.3	943	512	17570	122	1285	700	23999	171	2467	1077	69416	248
Dry_Project_Fill_2	295	102	9894	0.3	943	508	17462	119	1261	673	23854	170	2442	1051	69204	249
Med_Baseline	493	156	20387	3.7	1521	755	37959	222	1913	1030	36338	255	3586	1552	99191	365
Med_Project_Fill_1	493	156	20387	3.7	1409	755	26553	222	1891	1030	33921	255	3588	1552	99191	365
Med_Project_Fill_2	448	156	15220	3.7	1421	753	27469	224	1865	998	33653	254	3561	1520	98760	365
Wet_Baseline	595	191	24375	9.1	1851	926	45399	271	2328	1251	43415	315	4326	1877	118257	455
Wet_Project_Fill_1	595	191	24375	9.1	1727	926	32427	271	2303	1251	40458	315	4330	1877	118257	455
Wet_Project_Fill_2	538	191	17873	9.1	1740	925	33196	271	2277	1221	40106	315	4303	1845	117985	455

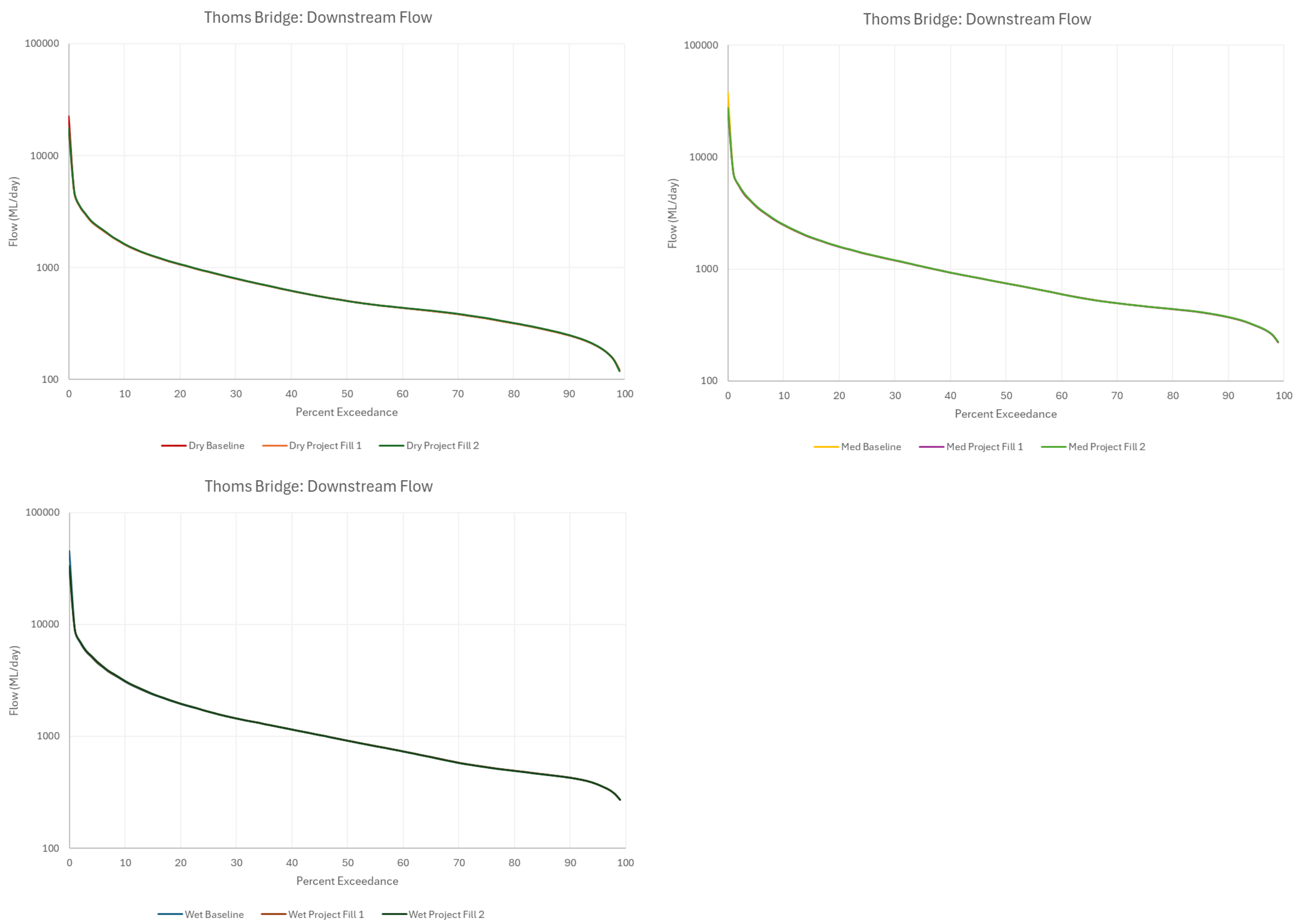

Figure 10. *Comparison of the project fill scenarios against the baseline for each climate case*

4.6 Environmental Flow Compliance Results

Tanjil River: The impact of the project scenarios on environmental flow compliance in the Tanjil River is insignificant as the project cases are identical to the base case in terms of flow regimes in the Tanjil River. No further discussion is provided on the implications for the Tanjil River.

Morwell River: The impact on environmental flow compliance in the Morwell River is insignificant as the Hazelwood offtake (u/s of the compliance point) is set at flow rate above the environmental flow recommendations for the Morwell River. The Yallourn spillways are located downstream of the compliance point on the Morwell River (Morwell River at Yallourn) and above the recommended environmental flow rates. No further discussion is provided on the implications of compliance assessment for the Morwell River.

Latrobe River at Thoms Bridge (refer Table 10): The hydrologic impact of the project is greatest in the middle Latrobe River, measured at Thoms Bridge. This compliance point is immediately downstream of the confluence with the Morwell River and is located upstream of other tributary inputs such as the Tyers River.

At Thoms Bridge, the impact of the project scenario on compliance with baseflow and fresh recommendations is minimal (Table 10). This is not surprising as the spill of water to the Yallourn pit lake occurs at flow rates above the base flow and fresh recommendations for the Latrobe River at Thoms Bridge.

However, the impact of diverting flood spills to the Yallourn pit lake, on bankfull and overbank flows may be material. The project can be expected to reduce the occurrence of bankfull events at Thoms Bridge from 27% of years to 25% of years. The cumulative impacts of flood spills into the Yallourn and Hazelwood pits reduces the occurrence of overbank events to 22% of years over the approx. 6 to 12 years where the fill phase of the Hazelwood pit lake might overlap with a fill phase for Yallourn. Rather than receiving approximately 5.4 events over a 20 year Yallourn fill period, the modelling reveals 4.7 events over the fill phase. The implication of this reduction in occurrence of bankfull events is discussed in section 7 of this report.

The impact on overbank flows is also material with the project reducing the occurrence of overbank events from 13% of years to 11% of years. Again the connection of the Morwell River at Hazelwood has a cumulative impact reducing the occurrence of overbank events at Thoms Bridge to 9% of years. Rather than receiving 2.6 overbank events in the fill phase, the Thoms Bridge site could be expected to receive 2 overbank events in a 20 year fill period. The implication of this reduction in overbank events is discussed in section 7 of this report.

Latrobe River at Rosedale (refer Table 11): The impact of spilling high flow events into the mine void diminishes downstream at Rosedale as a result of flood inputs from tributary streams (Table 11). The project is not expected to have a material impact on the Latrobe River at Rosedale under a medium climate change projection.

Latrobe River at Swing Bridge (refer Table 12): This reach of river comprises the lower Latrobe Estuary. The modelling has revealed the project to not have any material impact on baseflows, freshes or bankfull events i.e. the events needed to flush salt from the adjoining Sale Common, Heart Morass and Dowd Morass wetland regulating structures. As such the project is not expected to have an impact on the watering of the adjoining wetlands. However, the project has the potential to reduce the occurrence of overbank events from 50% of years to 48% of years. The implication of this change is discussed in Section 6.3. The Hazelwood rehabilitation project does not create a cumulative impact on these overbank events.

Table 10. Environmental flow compliance (%) for the Latrobe River at Thoms Bridge during the filling phase (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 440 ML/d baseflow	65	65	65
summer & autumn 980 ML/d fresh	82	82	81*
winter & spring 1500 ML/d baseflow	37	37	37
winter & spring 6000 ML/d fresh	42	42	43*
annual 10000 ML/d bankfull	27	25	22
annual 15000 ML/d overbank	13	11	9

*Note: As noted in Section 4.4 flows of at least 6058 ML/d are bypassed through the MRD with no diversion, thus results for Project Case 2 are expected to be an impact associated with Hazelwood works. We acknowledge the inconsistency in results, possibly a rounding issue, which is to be further explored. This is not expected too fundamentally change the outcomes of this assessment for Yallourn.

Table 11. Environmental flow compliance (%) for the Latrobe River at Rosedale during the filling phase (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 380 ML/d baseflow	89	89	89
summer & autumn 1400 ML/d fresh	55	55	52
winter & spring 1800 ML/d baseflow	45	45	44
winter & spring 3000 ML/d fresh	83	83	81
annual 8000 ML/d bankfull	56	56	56
annual 10000 ML/d overbank	36	36	36*

*Note: We acknowledge the inconsistency in results between Latrobe River at Thoms Bridge and Latrobe River at the Rosedale, which is to be rectified as part of future scenario testing. This is not expected too fundamentally change the outcomes of this assessment.

Table 12. Environmental flow compliance (%) for the Latrobe River at the Swing Bridge (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 1100 ML/d baseflow	41	41	39
summer & autumn 2200 ML/d fresh	24	24	23
summer & autumn 3200 ML/d fresh	27	27	27
winter & spring 1100 ML/d baseflow	90	90	89
winter & spring 3200 ML/d fresh	47	47	46
winter & spring 4500 ML/d fresh	35	35	35
annual 9500 ML/d bankfull	51	51	50*
annual 14000 ML/d overbank	50	48	48

*Note: We acknowledge the inconsistency in results between Latrobe River at Rosedale and Latrobe River at the Swing Bridge, which is to be rectified as part of future scenario testing. This is not expected too fundamentally change the outcomes of this assessment.

4.7 Findings

The proposed project has been identified to have no impact on base flows or freshes in the Latrobe River system. These events are required for essential instream habitat, the maintenance of water quality and the provision of triggers for fish movement. This outcome is not surprising as the flow rates at which the proposed spillways at the Yallourn mine site (above 6000ML/d), were set are above that required for these environmental flow requirements.

Similarly, the modelling has revealed the project to not have an impact on the base flow and freshes required for the Latrobe estuary. These flow rates are required not only for the Latrobe River estuary but to remove salt water from the estuary in the vicinity of the regulating structures used to water the Ramsar listed fringing wetlands, Sale Common, Heart Morass and Dowd Morass. As such the project is not expected to have an impact on the watering of the subject wetlands.

However, the project has been identified as having the potential to impact on the occurrence of bankfull and overbank events. These events are required for the watering of floodplain vegetation, to maintain channel form and to limit terrestrial vegetation encroachment into the channel. The project is expected to reduce the occurrence of these events. These changes are most notable at Thoms Bridge where reductions in the occurrence of events were identified for bankfull in all climate change projections assessed and overbank events for the medium and wet climate projections. Impacts on overbank events were also identified for Rosedale under a dry climate projection and the Swing Bridge for the medium climate change projection. While reductions in the occurrence of bankfull and overbanks have been identified to occur, the investigation has revealed that the project will result in only a small change to the occurrence of events over the 20 year (approx.) duration of the fill phase. As an example, the expected reduction in the occurrence of overbank events at Thoms Bridge from approximately 5.4 events to 4.7 events over the duration of the fill phase is not expected to have a material impact on the vegetation community or channel form over this period. Further testing of this implication will be required.

5 Other considerations

5.1 Fish passage

Migratory fish species are found in the Latrobe River system. The spillway arrangements have the potential to result in the movement of fish into the pit lakes. Once in the pit lakes there is potential for migratory fish to become stranded in the pit lake and not complete life cycles.

Further investigations will be required to identify the potential for such stranding of native migratory fish. However, mitigation measures can be included into proposed works that reduce the potential for such movement into the pit lake (e.g. dark culverts at the site of the outflow spillway – Spillway 4) and/ or provide a mechanism for the movement of fish out from the pit lake (fish ladders at inflow spillways).

As there are suitable mitigation measures available, and subject to further investigation, design and implementation of such measures (if and as required), we do not foresee significant risks to native fish movement associated with the proposed arrangements.

5.2 Pit lake water quality implications for the Latrobe River system

Five constituents have been found by RGS (2025) to have potential to be at elevated levels in the proposed pit lakes:

- Copper
- Aluminium
- Manganese
- Zinc and
- pH (likely)

These five constituents have potential to be released to the Latrobe River via spillway 4 during flood events in the post fill phase. Spillway 4 has potential to release water from the pit lakes in major events that trigger spillway inflows or in local catchment events if pit lake levels are at or near the Spillway 4 crest elevation at the time of the inflow to the pit lake.

Copper and zinc levels are elevated (relative to conservative guidelines) throughout the catchment, and region and according to RGS 2025 are present in rainfall at concentrations of approx. 50 µg/L, possibly due to burning of coal at power stations throughout the valley. According to RGS 2025 this rainfall contribution is, most likely to be, a major source of copper and zinc in the pit lakes. The speciation of copper and zinc in the lakes has not been modelled, but very high concentrations in the Morwell River relative to guideline values, and the presence of aquatic fauna throughout the Latrobe system suggest that its bioavailability is low.

As copper and zinc do not appear to be bio available and as a reduction in the burning of coal in the Latrobe Valley will reduce their supply to the system, we do not foresee significant risk with the copper or zinc. None the less, due to the high concentrations of dissolved (total) copper and zinc and the uncertainty regarding speciation and bioavailability, we recommend numerical analysis of expected copper and zinc concentrations in the Latrobe River downstream of Spillway 4 and further investigation into the speciation of copper and zinc in the Morwell River, Latrobe River and local rainfall.

High aluminium concentrations have also been identified for the pit lakes. However aluminium is likely to be present in colloidal form, which is not biologically available and commonly passes through the 45 µm filter used to sample water (RGS 2025). Further investigations are required into the expected aluminium concentrations downstream of Spillway 4 and its bioavailability. It should also be highlighted that aluminium is elevated (relative to freshwater quality ecosystem guidelines) in nearly all water inputs to the RGS modelling (e.g. Morwell River, Latrobe River, Moondarra Reservoir, groundwater etc.).

In addition to copper, zinc and aluminium further investigations are required into other constituents including manganese, addressing their source, expected concentrations in the Latrobe River downstream of Spillway 4, their bio availability and potential for adverse impacts on the Latrobe River and Gippsland Lakes Ramsar site.

In addition to the above there may be potential for nutrient inputs to the pit lakes to contribute to algal blooms. Such algal blooms have the potential to be released to the Latrobe River system via spillway 4. Further lake water quality modelling will be required to identify the occurrence of such events and subsequent investigations into the potential for releases to have an adverse impact on the Latrobe River and Gippsland Lakes.

Investigations will be required to identify appropriate mitigation measures in the event that further assessments reveal unacceptable water quality risks arising from pit lake discharges via Spillway 4. Mitigation measures to limit any potential adverse impacts could include provision of a top up strategy and or outlet works that limits discharge via Spillway 4 to only occur when induced by inflows from flood events in the Morwell or Latrobe Rivers.

6 Conclusion

A preliminary spillway design arrangement has been developed and assessed for the site based on the Partially Connected Morwell option and its potential to meet key hydrologic, geomorphic and ecological criteria outlined in *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine (Alluvium 2024)*.

Event based hydrologic modelling was undertaken to inform (TUFLOW) hydraulic modelling. The hydraulic modelling was used to develop and assess a preliminary design configuration for the site.

The preliminary design configuration comprised

1. Two spillways from the MRD to the East Field
2. One spillway from the MRD to the Township Field
3. One Spillway from the East Field to the Latrobe River
4. Modification of the existing tunnels under the MRD to equalise water levels between the pit lakes

Regional water balance modelling was undertaken using the Latrobe Source model to identify the implications of water use on the environmental water requirements for the Latrobe River system (and tributaries). The assessment was based on reducing the risks of elevated water levels in the MRD during the fill phase and hence the operation of the spillways during the fill phase.

The performance of the proposed arrangement has been assessed against the design principles set out in the geomorphic and ecological context statement discussed in Section 2.1 of this report:

Hydrologic regime.
Criteria: The arrangement should provide for both:

- longitudinal hydrologic connectivity
- lateral floodplain connectivity

Outcome: The spillways have been set at elevations that ensure that flow rates in the Latrobe and Morwell River exceed 6000 ML/day before any water is captured by the pit lake. This flow rate provides for both longitudinal continuity of flow and ongoing floodplain inundation through the MRD following the construction and operation of the proposed spillways. However, it noted that the project has the potential to reduce the occurrence of floodplain inundation at Thoms bridge during the fill phase. This is discussed under ecological condition and processes.

Geomorphic processes.
Criteria: The arrangement should:

- not be subject to accelerated high rates of erosion and deposition
- be robust i.e. resistant to change and have the ability to adapt and repair following change without comprising the other values and outcomes
- provide for ongoing longitudinal and lateral bed load sediment movements

Outcome:

- Erosion: The proposed arrangements have been found to not increase peak velocity and shear stress beyond that present in the existing conditions. The proposed arrangements result in a reduction in the peak velocity and shear stress in the MRD and retention of velocity and shear stress within the range that can be accommodated by nature based (vegetative) erosion control works. However, it is noted that the performance of such erosion control measures declines with increasing duration of events. The long-term success of nature-based erosion control works will require further assessment and design. Further, more specific design development is required for the proposed spillways to ensure their enduring performance.

- Robustness: The maximum water surface elevation of approximately RL42.5m AHD for the 1 in 2000-year ARI event, meets the design criteria, and represents a 3 metre (approx.) reduction from peak water elevations under the current conditions and increased confidence in the long-term performance of the MRD.
- Sediment transport: The proposed spillways increase the confidence in the long-term functioning the MRD and hence the long-term potential to provide ongoing bed load sediment transport to the Latrobe River. The proposed spillways while increasing the confidence in the longevity of the MRD have the potential to reduce sediment transport when compared to existing conditions. However, as events up to the 5% event in the Morwell River are not impacted by the spillway operation, any reduction in long term sediment transport is likely to be insignificant. Further investigations will be required to confirm the change in bed load sediment transport capacity of the MRD and the implications of any such change on sediment deposition on the stability and longevity of the MRD.

Ecological condition and processes

Criteria: The arrangement should:

- Provide for ongoing benthic ecological processes
- Meet instream and riparian habitat and transfer (e.g. fish passage) requirements

Outcomes: The proposed arrangements do not impact on the environmental flow requirements of the Tanjil River or Morwell River. Further, the proposed arrangements do not impact the:

1. Base flow or fresh requirements of the freshwater reaches of the Latrobe River system or
2. The occurrence of events required to displace the salt wedge from the Latrobe River estuary and hence the capacity to provide freshwater to the lower Latrobe fringing wetlands (Heart Morass and Dowd Morass).

These outcomes are not surprising as the proposed spillways do not intercept flows below that to meet these environmental water requirements. However, the proposed arrangements have the potential to reduce the occurrence of some bankfull and overbank events through the Latrobe River, under alternate climate projections. Reductions in the occurrence of bankfull events were found in the mid Latrobe River (at Thoms Bridge) during the fill phase for all climate projections, and for overbank events at Thoms Bridge (medium and wet climate projections), Rosedale (dry climate projection only) and at the Swing Bridge (medium climate projection only). The consequence of the reduction to bankfull (Thoms Bridge) and overbank events has not been fully assessed. A preliminary review suggests that the changes to the occurrence of bankfull and overbank events is not likely to be material over the duration of the fill phase. However further investigations are required to confirm (or otherwise) these findings.

While there is some impact on bankfull and overbank events during the fill phase at Thoms Bridge, such adverse impacts are not anticipated in the post fill phase. In the post fill phase, spillway inflows to the pit lakes are expected to pass through the pit lake (subject to top up arrangements) and contribute to downstream bankfull and overbank events. Modelling and flow compliance analysis will be required to confirm this outcome. The investigations should explore the implications of a connected pit lake arrangement at Yallourn on regional water resources, environmental flow compliance and water quality for the waterways and wetlands including Lake Wellington.

Further the investigation has not sought to identify the impact of the proposed arrangements on other related matters including sediment transport in the lower Morwell River and fish passage. These matters will require investigation and assessment.

Flood water captured because of a partially connected arrangement is 'Above cap' water that is part of the Latrobe system environmental water entitlements. While use of such water may have limited impacts, it may be necessary to provide some form of offset (provision of water or otherwise) as compensation for such capture. The requirement for, and form of, any such offset is beyond the scope of this assessment and report and should be the subject of subsequent investigations.

Further investigations will be required to support the assessment and design of the proposed rehabilitation arrangements at the Yallourn open cut mine site. Investigations that will rely on the water balance modelling will include but may not be limited to:

- Water use strategy: Further work is required to develop a water use strategy that maximises delivery of water to fill the mine lake and to represent that strategy in the Source model. This will require iterative manipulation of the Source model. This is required for an accurate estimation of the filling period and likelihood of a major shortfall in environmental flow compliance.
- Environmental compliance in the pit fill phase: The environmental risk associated with reductions in compliance with bankfull and overbank flow recommendations at Thoms Bridge and elsewhere should be assessed. This will require an assessment of the ecological consequence of not complying with recommendations for nominated intervals and the likelihood of those intervals occurring during the filling phase.
- Environmental compliance and related waterway and wetland assessments for the post fill phase: Water balance and environmental flow compliance assessments are required to assess the implications of the project in the post fill phase. These assessments will need to be informed by the expected pit outflows to the Latrobe River as determined by pit lake water balance modelling.
- Water quality assessments: The post fill phase assessment should also include water quality assessments. This regional water quality assessments should be informed by the output of pit lake water balance and water quality modelling, regional water balance modelling and regional water quality data.
- Morwell River sediment transport assessment: The results of the water balance modelling will also be important to identify the implications of the proposed arrangements on bed load sediment transport through the Morwell River in the vicinity of and downstream of the proposed pit lake inlet spillways.

Attachment A_ The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine (Alluvium 2024a)

The Latrobe River system: A context statement for Energy Australia Yallourn to inform rehabilitation of the Yallourn Open Cut mine

July 2024

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

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

This report has been prepared by Alluvium Consulting Australia Pty Ltd for EnergyAustralia Yallourn under the contract titled 'Surface water modelling assessment'.

Authors: Ross Hardie
Review: Stuart Cleven
Approved: Ross Hardie

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Contents

Figures

1 Introduction

This report has been prepared for EnergyAustralia Yallourn to inform decisions regarding the closure and rehabilitation of the Yallourn Open Cut Mine.

The Latrobe River (Durt-Yowan) system, including its wetlands, floodplains and estuary, supports a wide range of social, environmental, economic and cultural values and assets. Environmental values include native fish populations, vegetation communities, and the internationally significant wetlands of the Gippsland Lakes that are listed under the Ramsar convention (including some of the lower Latrobe wetlands and all of Lake Wellington). The river system also supports a diversity of recreational (e.g., boating and angling), cultural and amenity values.

Taken together, these values, and the opportunities they present, are becoming increasingly important to the Latrobe valley and its communities.

However, since European settlement, the Latrobe River system has been subjected to significant modification and environmental degradation. Water resources have been developed through dam and weir construction, and diverted for use in agriculture, power generation, industry and urban uses. As a result, the river is hydrologically stressed and its freshwater dependent values – including floodplains and wetlands and the biodiversity they sustain – have been compromised. Riparian vegetation over much of the river system has been cleared and modified, and the structure and habitat values of some river reaches has changed due to historic channel realignment and snag removal. Water quality has also been impacted, mainly by land-based sources of pollution. In the lower Latrobe wetlands, a combination of factors is contributing to rising salinity levels that threaten to change their ecological character.

The rationale for healthy rivers extends well beyond biodiversity outcomes. A healthy river system also provides opportunities to improve individual and community wellbeing, to deliver meaningful reconciliation with Aboriginal people, and to deliver employment, economic development and tourism benefits. A healthy river system also contributes toward social cultural and economic outcomes.

Planning is underway for a transition away from coal-based power production in the Latrobe Valley. This transition includes the planned closure and rehabilitation of the Yallourn open cut mine site. The proposed rehabilitation of the Yallourn mine includes establishment of a pit lake and requires decisions on issues that impact on the both the site and the broader Latrobe River system. Management decisions impacting on the wider Latrobe River system include;

1. the management of the Morwell River Diversion through the site, and
2. the use of water resources to fill the mine void and maintain the pit lake

These decisions have the potential to adversely impact and benefit the water and waterway related values of the Latrobe River system and communities that rely on these values.

1.1 Project scope and objectives

This report documents the current hydrologic and ecological condition of the Morwell and Latrobe River systems and the implications of these conditions on options for the Yallourn Mine closure planning. Further the report provides preliminary commentary on a preferred option identified by EnergyAustralia Yallourn for the rehabilitation of the site including the management of the MRD.

The site is shown in Figure 1 and the broader system in Figure 2.

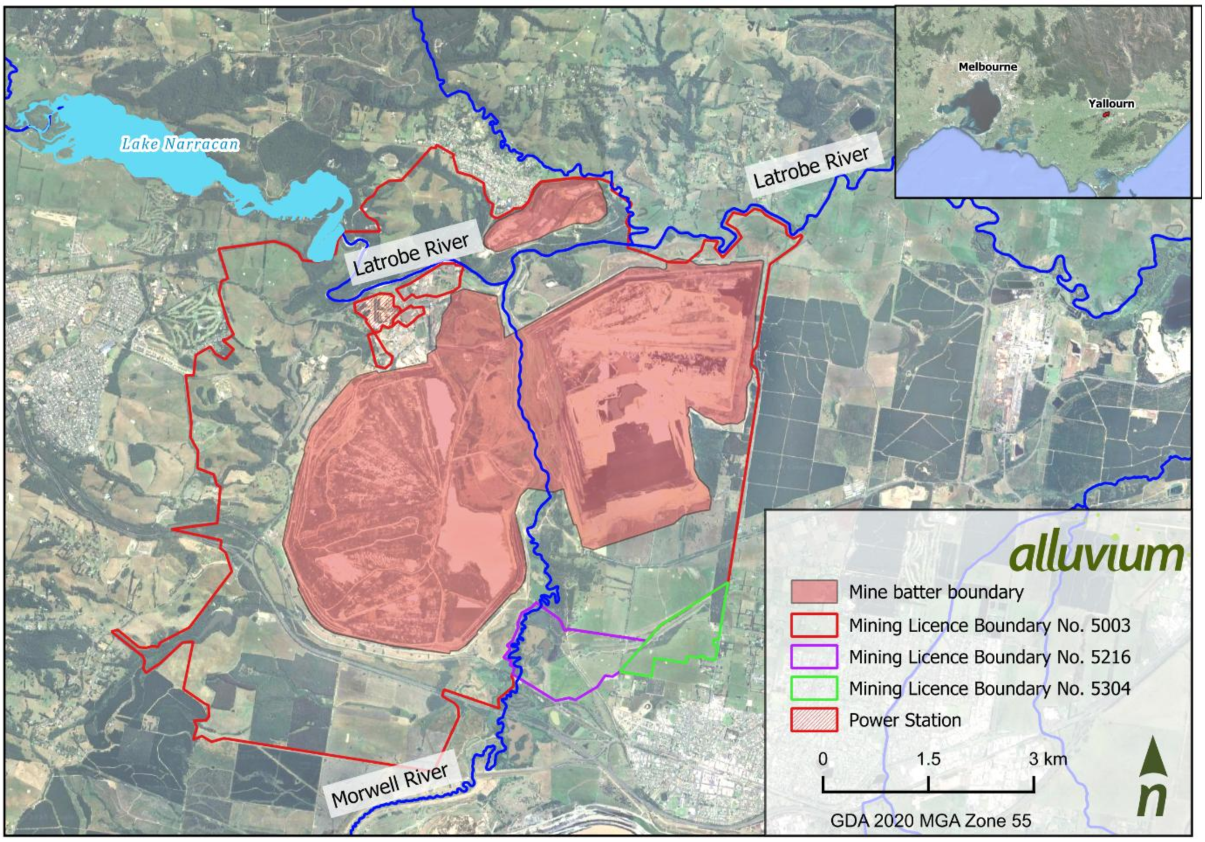

Figure 1 *The subject site*

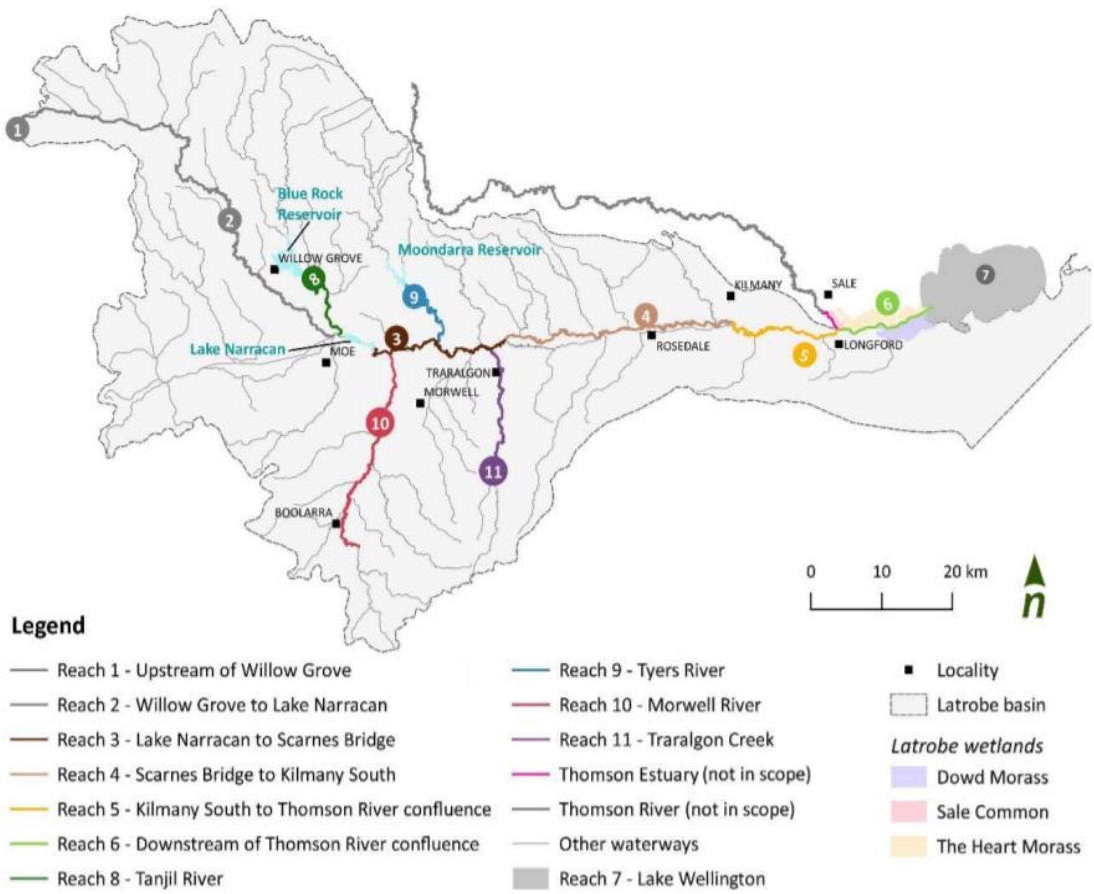

Figure 2. *Reaches of the Latrobe River System and important tributaries (source: Alluvium, 2020)*

Document review

The project, and this report, considered relevant work that has been undertaken. This included:

- Recent studies of water supply including: The updated FLOWS study (Alluvium, 2020), including a quantitative shortfalls analysis (Alluvium 2021) and the development of interim water recovery targets for consideration in the Central and Gippsland Sustainable Water Strategy discussion draft[1] (DELWP, 2021a)
- Latrobe Valley Regional Water Study – Ecological Effects Assessment (Hale et al., 2020)
- The Latrobe Valley Regional Rehabilitation Strategy (LVRRS) and the associated technical work undertaken for its implementation (DELWP, 2020a; DJPR, 2020a)
- The report on changed conditions and likely futures for the Ramsar-listed Lake Wellington and its fringing wetlands (Hale & Boon, 2021).

Investigations into the impacts and risks to groundwater and surface were explored, where appropriate.

2 Background and context

2.1 The Latrobe River System and its current condition

The Latrobe basin is located between the Strzelecki and Baw Baw Ranges in West Gippsland, Victoria. With tributaries originating in the Baw Baw plateau and northern Strzelecki ranges, the Latrobe River flows through a

[1] Interim waterway recovery targets were reviewed by the West Gippsland Catchment Management Authority and an expert panel, and updated in the final strategy.

mainly agricultural landscape before merging with the Thomson River (Carran Carran) and flowing into Lake Wellington (Figure 3).

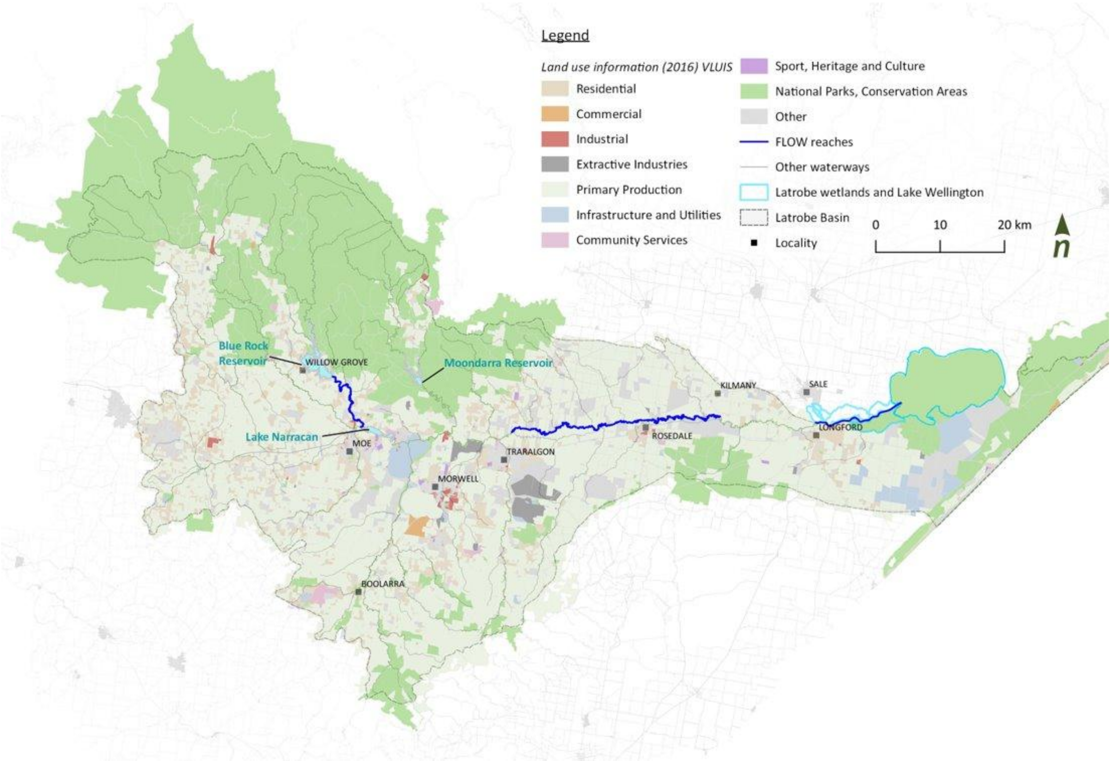

Figure 3. *Land use across the Latrobe River system (source: Alluvium, 2020)*

3 The Latrobe River: Management following European settlement

3.1 Agricultural development

The Latrobe River riparian zones, floodplains and wetlands have been subjected to clearing of native vegetation and grazing for over a century. While vegetation clearing has been controlled through the implementation of Victoria's Native Vegetation Retention Controls, ongoing grazing prevents the regeneration of vegetation from riparian zones. Remnant native riparian vegetation through the Latrobe River and tributary streams is an important natural asset within the Latrobe River system.

3.2 The opening of the Gippsland Lakes

Reductions in freshwater flows in the Latrobe River and the ongoing effects of the opening of a permanent entrance to the Gippsland Lakes has led to increasing salinity in the lower Latrobe wetlands. Parts of these wetlands are internationally recognised under the Ramsar Convention, but they have been degraded and altered from their original freshwater condition. The conservation of the wetlands, under the terms of the Ramsar convention, protecting the character of the wetlands at the time of listing is dependent upon the provision of adequate inflows of freshwater from the Latrobe and Thomson Rivers to not only water the wetlands, but to flush out saline intrusions arising from the opening of the Gippsland Lakes.

3.3 River improvements: Desnagging and meander cutoffs

The Latrobe River system has been substantially modified since European settlement. Much of the physical management of the system has been in response to the low and flat topography adjoining the Latrobe River. This swampy nature, while characteristic of the landscape was problematic for agricultural production and transport. '*…for the most part the roads and tracks hugged the higher ground above the KooWeeRup swamp but* *the track included the wet ground around Longwarry, Yarragon and Trafalgar. These areas became known as the "Glue Pots" due to the never-ending sticky mud that sucked at the feet of both man and beast*'. (www.oddhistory.com.au).

Meander cut-offs were constructed on the Latrobe River between 1930's to the 1970's, downstream of Lake Narracan to reduce the occurrence of Latrobe River floodplain inundation and increase agricultural production. It has been estimated that between 66 and 77 meander cut-offs were constructed on the Latrobe River.

Channel changes on the lower Latrobe River since the late 1800s include a 25per cent reduction in channel length due to artificial meander cutoffs. The meander cutoffs and reduced channel length have resulted in increased mean channel width, increased channel instability and incision of up to 1.05 m. Hydraulic changes at the Rosedale gauge include increases in bankfull flow velocity and a 67per cent increase in channel capacity, resulting in a threefold reduction of overbank flow duration.

The reduced overbank inundation and increased channel instability have led to increased fine (suspended) sediment and nutrient production and transport to Gippsland Lakes. The incision has contributed to poor stream condition in the Latrobe River (downstream of Lake Narracan) and to ongoing water quality problems in the Gippsland Lakes.

3.4 Water resource development

The use of water from the Latrobe River for consumptive demands in the energy sector, urban use, industry and agriculture has contributed to a current flow regime that fails to meet environmental requirements. Not only has the amount of water provided to the river decreased but the amount of water required to meet flow requirements has increased due to channel incision process. The channel incision process has resulted in an increase the flow rate needed to create floodplain inundation. Floodplain inundation is required in the Latrobe River system to protect remnant vegetation communities adversely impacted by reduced flows and by the channel incision process. The Latrobe River system is currently over-extracted: the environment flows study for the Latrobe River[2] identified a shortfall of 37 GL to meet environmental requirements. The shortfall in environmental water is likely to increase as a result of climate change.

In water resource terms, the Latrobe is a fully allocated system with several bulk entitlements allocated to Southern Rural Water, Gippsland Water and other consumptive uses, as well as two bulk entitlements for environmental purposes. The system includes three water reservoirs: the Blue Rock Lake (Tanjil River), Moondarra reservoir (Tyers River) and Lake Narracan (Latrobe River), with storage capacities of 198 gigalitres (GL), 30 GL and 7 GL, respectively (Figure 4). These storages service urban water supply, irrigated agriculture, power generation, and other industrial and environmental water demands (DELWP, 2021a). Yallourn weir, located directly downstream from Lake Narracan, is another in-stream structure worth noting. In addition to existing consumptive bulk entitlements (BEs), essential service industries, urban users and other entitlement holders can also obtain additional water supplies through the Latrobe Reserve bulk entitlement (established in 2011), which provides up to 37.4 GL from Blue Rock Reservoir during drought periods to help manage such shortfalls (DELWP, 2021a).

Some of these modifications, particularly river regulation through dams and weirs, were undertaken to support development of water resources for agriculture, coal mining and related power generation, and industrial and urban uses. Previous studies have reported the Latrobe River system as being hydrologically stressed and over-extracted (Alluvium, 2009; Alluvium, 2020; DELWP, 2020c). Development and use of water resources has impacted on the volume and variability of flows in the river system, altering sediment transport dynamics and disconnecting floodplains across the system (EarthTech 2005; Tilleard et al. 2009).

Environmental water bulk entitlements cover entitlement held in Blue Rock Reservoir (Blue Rock Environmental Entitlement 2013) and provision for the Lower Latrobe Wetlands (Lower Latrobe Wetlands Entitlement 2010).

3.5 Coal based power production

Mining activity in support of coal-based power production on floodplain adjoining the Latrobe and Morwell Rivers have threatened stream condition through water extraction and repeated diversions of the Latrobe River and in particular the Morwell River. These threats are set to continue compromising the health of the system pending and depending on mine closure plans.

Over many decades, Latrobe water resources have supported, and continue to support, significant brown coal-based power production in the Latrobe Valley. In 2019/20, 63.7 GL was used for this purpose (DELWP, 2021b). This power production has been supported by three open-cut coal mines: Hazelwood, Loy Yang (servicing the Loy Yang A and Loy Yang B Power Stations) and Yallourn (Figure 4). The mines are large, each extending over 12 km^2 in total, with a combined void space at closure projected to be 2800 GL (Hale et al., 2020). All of these power stations are scheduled for phased closure over the next 25 years. Hazelwood has ceased power production and is currently in the process of completing an Environmental Effects Statement relating to its mine void rehabilitation plans.

3.6 Climate change

The future trajectory of the Latrobe River system based on a business-as-usual scenario and a mid-range climate change scenario is one of an ongoing decline in condition, particularly for the Lower Latrobe and adjoining wetlands. The condition of the lower Latrobe wetlands is on serious course of decline due to rising salinity. Salinity in these wetlands is still adjusting to the opening of a permanent entrance to the Gippsland Lakes and is also affected by contemporary and future threats such as declining streamflow and sea level rise.

3.7 Summary of changes following European settlement

A summary of the physical changes to the river system arising from management of the system post European settlement include:

- Channel straightening and desnagging.
- Channel instability and incision and widening.
- Reduced instream flow within the Latrobe River system.
- Increased salinity of the Gippsland lakes, Lower Latrobe River and the fringing freshwater wetlands of the Lower Latrobe River.
- Reduced occurrence of overbank inundation.
- Reduced bedload sediment supply.
- Increased fine sediment and nutrient transport to the Gippsland Lakes.
- Loss of instream habitat.
- Reduced riparian vegetation.
- Reduced and limited fish passage.

In turn these physical changes have led to declines in:

- Instream habitat.
- Water quality.
- Instream ecology.
- Floodplain and wetland ecology.
- Instream and riparian species diversity and richness.

4 The implications of these changes for the ecological functioning of the Latrobe River system

These changes to the river system have had significant impacts on the ecological functioning of the Latrobe River system. Some of these impacts include:

Gippsland Lakes and fringing wetlands

The Australian government has an obligation to protect and preserve the ecological character of the Gippsland Lakes and fringing wetlands under the terms of the Ramsar Convention. The lakes have been recognised as internationally significant representing natural or near-natural wetland condition and providing important habitat to large communities of waterbirds. The lakes also have social and economic value in recreation, tourism, and fishing.

Since the permanent opening and dredging of Lakes Entrance in 1889, the lower Latrobe wetlands and estuary have experienced a long-term trajectory of change. The permanent opening of this entrance, combined with increasing demands on the water resources of the Latrobe and Thomson-Macalister rivers and climate change/vulnerability, has led to rising salinity levels in the Lower Latrobe River and adjoining wetlands including Heart and Dowd morasses. resulted in both chronic and episodic (acute) saline intrusions into the Gippsland Lakes, fringing wetlands and tributary streams. Although the impacts of salinity were probably evident within the first few decades of the opening, it may take centuries for the full ecological effects to be manifest. The functioning of the Lower Latrobe River and wetlands prior to European settlement would be described as an intermittently closed and open lagoon system supporting freshwater lacustrine (lake) and palustrine (march/morass) features. This system is now transitioning to an open marine-estuarine system (DSEWPC, 2010). The negative effects of increased salinity on aquatic ecosystems in the Lower Latrobe wetlands has been exacerbated by surface water extraction for resource uses, sea level rise associated with climate change, and land use activities in the mid and upper Latrobe River (Boon et al., 2008; Hale et al., 2021; Raulings et al., 2021). Therefore, Heart Morass and Dowd Morass are now classified to be in a brackish-water wetland condition with some pockets of higher levels of freshwater (Hale & Boon, 2021). Salinity in these wetlands is predicted to increase under future climate conditions as freshwater inflows decrease and sea level rises (DEWLP, 2021a; Hale & Boon, 2021; Jacobs, 2017). Sale Common is the only remaining freshwater wetland in the lower Latrobe wetland complex on public land, and although it is relatively small, it supports high freshwater biodiversity values.

Environmental flows in the form of releases and flood events will provide valuable fresh water to these systems. Changes in flow regimes that reduce the occurrence and duration of events that flush the saline wedge from the lower Latrobe River can be expected to have an adverse impact on the Lower Latrobe River.

The ecological character and values of the Gippsland Lakes are also threatened by elevated sediment and nutrient loads from tributary streams. The Latrobe River contributes a significant proportion of sediment and nutrients to the lakes and particularly dominates sediment and nutrient loads to Lake Wellington. The source of the increased sediment and nutrient loads has been the subject of several investigations and is most likely to be due to a combination of agricultural land use activities, urban sewage effluent and ongoing channel erosion triggered by meander cut-offs. Activities and or events that result on increased fine sediment and nutrient deliveries to the Latrobe River system will exacerbate these impacts. Programs and projects that reduce the supply of fine sediment and nutrients to the lower Latrobe River and Gippsland Lakes would be advantages to the system.

Endangered species

The Australian grayling (*Prototroctes maraena*) is listed as vulnerable under the Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act and the Victorian Flora and Fauna Guarantee (FFG) Act. Australian Grayling are known to have inhabited the Thomson and Latrobe river systems. The lower Latrobe and Thomson Rivers are identified as important for the Australian grayling under the National Recovery Plan for the

Australian Grayling[3]. The Victorian government has agreed to and has obligations under this Recovery Plan. However, protection of, and provision for, Australian Grayling in these systems is threatened by fish barriers, flow regulation and poor water quality.

Fish passage through the Latrobe River system is impaired and blocked by:

- Lake Narracan and other physical barriers
- Poor river health including poor quality riparian vegetation and instream habitat. These poor conditions exist in the diversion of the Morwell River at Yallourn.
- Elevated temperature and restricted habitat diversity downstream of Lake Narracan
- Flow regulation.

In addition to the above, outcomes for Australian Grayling in the Latrobe River system are limited as a result of limited availability of preferred gravel bed habitat in the Latrobe River system upstream of the Thomson River confluence. Significant area of habitat is only available in the Tyres River downstream of Moondarra Reservoir and in the upper Reaches of the Morwell River. The improved health and functioning of the Morwell River including the existing river diversions will be essential for any expansion of Australian Grayling habitat.

Remnant vegetation

The Victorian and Australian governments are committed to the retention and protection of Australia's remnant native vegetation. Native vegetation along riparian lands through the Latrobe River system, including riverbank and wetland vegetation, has important habitat values and provides functions for aquatic ecosystems such as shading and organic inputs. Vegetated riparian corridors can provide connectivity of ecosystems along the river and through the catchment.

Ongoing uncontrolled stock access to waterways and riparian lands in the Latrobe River system is a threat to the condition of remnant riparian vegetation. However, flow regulation and meander cut-offs (and accompanying channel incision) have also contributed to a decline in the condition of riparian vegetation in the Latrobe River downstream of Lake Narracan. Degradation of riparian zones leads to increased stream temperatures, reduced organic input to aquatic ecosystem, reduced riparian habitat and connectivity along the river, and increased channel erosion.

Summary

The ecological condition of the Latrobe River system is spatially heterogenous with the upper reaches (e.g., the Upper Latrobe, the Tanjil and Tyers Rivers) in good condition with high quality instream and riparian biodiversity. The condition of the river then deteriorates downstream from the Blue Rock and Moondarra storages. The reach of the Latrobe River between Lake Narracan and Rosedale, as well as the heavily modified lower reach of the Morwell River and Traralgon Creek, support only small remnants of instream and riparian vegetation and limited faunal diversity. They also suffer from poor water quality, and the effects of modifications to channel structure and in-stream habitats and barriers to fish migration. The environmental condition of the lower reaches of the Latrobe River improves downstream from Rosedale, and again from Kilmany township, where some meanders have been reinstated and extensive remnant floodplain forest and wetlands exist.

Despite these challenges, the Latrobe River retains some natural flow variability, and is relatively stable from a geomorphic perspective. In this regard, considerable scope exists to rehabilitate and improve the ecological condition of the Latrobe River through an integrated suite of waterway management initiatives. The lower reaches of the Latrobe River (downstream of the Rosedale and Kilmany townships) are a prime example demonstrating the recovery potential of the river. The Latrobe Estuary (from Swing Bridge to the delta of Lake Wellington) is classified as a permanently open salt-wedge (Hale et al., 2020) and supports freshwater, estuarine and diadromous fish species and salt-tolerant vegetation communities. Salinity in the estuary is governed by

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[3] Backhouse, G., Jackson, J. and O'Connor, J. 2008a. National Recovery Plan for the Australian Grayling *Prototroctes maraena*. Department of Sustainability and Environment, Melbourne.

water levels (and salinity) in Lake Wellington and the volumes of freshwater inflows from the Thomson and Latrobe Rivers.

Maintaining the health and condition of the Latrobe River, its tributaries, wetlands and floodplains are important for supporting a diverse range of environmental, economic, social and Aboriginal cultural values (DELWP, 2020b). Identified shortfalls in environmental water and a general decline in water availability due to over extraction of water for urban, electricity and agricultural uses can lead to a loss of biodiversity and decline in environmental values across the Latrobe system. These impacts are predicted to be exacerbated under drier future climate conditions but can be mitigated if more water is made available to maintain minimum environmental flow targets (Alluvium, 2021; DELWP, 2021a).

In summary, the health and condition of the Latrobe River system continues to be threatened by multiple stressors. Acknowledging that improvements to waterway health may be achieved through increased environmental water and improved flow regimes, there is also considerable scope for other river management initiatives, such as removing barriers to fish passage (Kingfisher Research, 2016) to complement and add value to available environmental water, and to play an important role in achieving waterway health outcomes and improving the character and condition of the Latrobe River system.

5 The Morwell River Diversion at Yallourn

5.1 Description

The Morwell River Diversion (MRD) at Yallourn is located immediately upstream of the Morwell River confluence with the Latrobe River, with this confluence located approximately 4km downstream from Lake Narracan and 1km downstream of the Yallourn Weir. The existing site is shown in Figure 4. This figure also sets out conceptual arrangements for the proposed rehabilitation of the site.

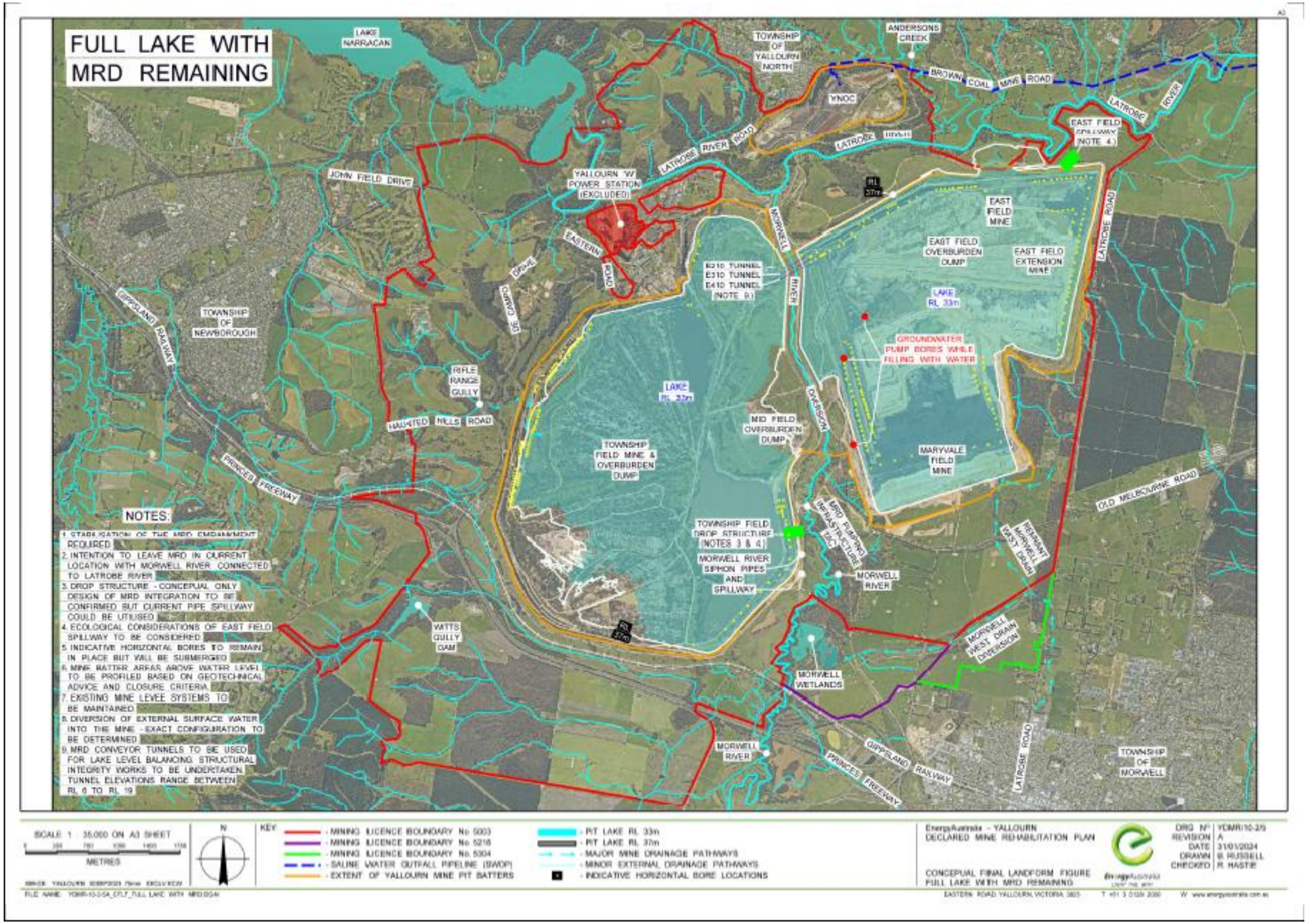

Figure 4 *Concept final landform: full lake (Note that final arrangements for individual project elements have not been determined and may not be included or significantly modified from that shown*

The MRD was constructed in 2005 and replaced a pre-existing single pipe culvert and overlying floodway-based river diversion. The MRD was constructed to enable access to the East Field Extension and Maryvale Field coal deposits and comprises an open meandering river channel with the upstream section (Southern Crossing) constructed though natural cut. Downstream of this section is compacted earth fill placed on internal overburden dump (Township Field), followed by a synthetic and clay lined section as it flows downstream into another cut section and then reporting to the Latrobe River in its northern reach.. As such the MRD operates as an aqueduct with open cut mine voids (Township Field and East Field) on both sides.

The MRD, river channel is a compound channel comprising a low flow waterway that contains flows up to the 5 year ARI (20% AEP) event at the southern (upstream extent) of the structure, and an adjoining narrow floodplain. The capacity of the diversion channel decreases in a downstream direction, in part as a result of backwater effects from the Latrobe River. Levees either side of the limited floodplain were included in the arrangement and intended to contain flows up to the 1 in 10,000year ARI event. This storage capacity has reduced since commissioning due to ongoing settlement to about 1 in 5000 ARI event, as assessed following the 2012 MRD remediation. The MRD is approximately 3,300m in length and was constructed at a grade of approximately 0.00076m/m. As a result, the diversion falls 2.3 metres through/ across the Yallourn site.

The MRD embankment collapsed in 2012, resulting in both the Morwell River and flow from the Latrobe River discharging into the open cut pit. The embankment collapse was subsequently repaired and put back into service. The repairs included multiple liner systems along a 800m section of the river diversion, comprising of geo-composite, geosynthetic and clay liners.

In 2021 following a major rainfall event, cracks were identified in the southern section of MRD that placed the MRD, open cut pit and power production at risk. Temporary emergency works were installed to divert future high flows (following the June 2021 event) into the upstream Hazelwood mine site to protect the downstream Yallourn mine, power production and to facilitate the remediation works along MRD southern section. The repairs included recompacting the upper layer of the High Flow Channel (HFC), regarding the floodplain in the remediation zone and reconstructed sections of the Low Flow Channel (LFC) with compacted clay and rock erosion protection. The river flows in the LFC were reinstated in April 2022, with all repairs to the HFC completed by May 2022.

Despite the recent repairs, the MRD remains vulnerable requiring targeted monitoring and ongoing management.

5.2 Implications of the current MRD on river health and function

The MRD poses significant risk to the health and function of the Morwell and Latrobe Rivers. These risks are largely associated with a potential catastrophic failure / collapse of the MRD. A discussion on the hydrologic, water quality, geomorphic and ecological implications of a catastrophic failure (collapse) of the MRD is provided in Attachment No. 1. These potential impacts are framed around a longer-term failure of the MRD following filling of the pit lake with freshwater. This attachment also sets out a number of mitigation measures that could be undertaken to reduce the consequence of such a catastrophic failure.

However, there are additional risks (potential) associated with a shorter term MRD failure prior to the completion of the filling of the mine voids with water to form a pit lake. These short-term risks are set out below. A failure of the MRD, prior to the filling of the mine voids with water could lead to the following outcomes, notably the outcomes would vary depending on the scale of occurring event:

1. Capture of some or all the Morwell River flow and Latrobe River flows into the Open cut pits could occur. Such capture would lead to the loss of downstream flow until the pit was filled with water and or emergency works installed to prevent further loss of flow.
2. Emergency works would necessitate cessation of releases from Lake Narracan to prevent loss of flow into the open cut pit and related erosion. Lake Narracan has a relatively small capacity and is typically operated at or near full supply. The cessation of flow from Lake Narracan would only be for a short period of time and any cessation in flow would result in downstream impacts to water dependent

ecological values. Despite such constraints, past experience has demonstrated current management ability to limit losses in the event of such failures.

3. The capture of a significant proportion of flows from the Morwell River would result in;
    a. Loss of bed load sediment transport from the Morwell River to the Latrobe River, exacerbating the existing sediment starvation and accelerated rates of bank erosion the Latrobe River (following reinstatement of flow regimes)
    b. loss of benthic process in the Morwell River system
    c. loss of fish passage through the Morwell River
4. Headward erosion in the Morwell River and potentially in the Latrobe River. Active management intervention is necessary, as there is a risk headward erosion in the Morwell River could lead to potentially catastrophic upstream impacts in the worst case, such as large-scale Morwell River channel deepening and widening that could threaten river health, gauging stations, transport infrastructure (road and railway) and the upstream Morwell River wetlands and Morwell River diversion at Hazelwood.
5. Following the filling of the pit with uncontrolled flows from the Morwell River, ongoing Morwell River erosion could lead to ongoing elevated rates of fine sediment and nutrient delivery to the Latrobe River and Gippsland Lakes.

The MRD contains many elements of an ecologically functioning river corridor including low rates of erosion and deposition, non woody vegetation cover such as emergent reeds, habitat logs and a pool and riffle bed form. However, in many places the current MRD lacks a structurally diverse riparian corridor consistent with an ecologically healthy river system. The absence of a structurally diverse riparian corridor that includes woody vegetation has been necessary to protect the integrity of the clay liners that prevent the seepage of river water from the river channel into the open cut void. Such seepage control is necessary to prevent the piping of sediments and collapse of the MRD. While the absence of a woody riparian corridor is necessary to prevent seepage losses and the potential for related MRD collapse, this risk management should be balanced with the ecological needs required to preserve and maintainecological values for the Morwell River and its function within the broader Latrobe River system.

5.3 Landscape rehabilitation outcomes

EnergyAustralia Yallourn seek the establishment of a stable landscape at the Yallourn site that meets regulatory requirements and community aspirations. To this end EnergyAustralia Yallourn propose the filling of the Yallourn pit with freshwater. This filling of the pit will aid the stability of the pit walls and contribute to the stabilisation of the Morwell River Diversion. The mass of water within the pit lake will contribute to supporting the excavated pit walls and the fill material used to construct the MRD.

It is understood that EnergyAustralia seek to relinquish their mining license. It would be expected that licence relinquishment will require the demonstration that any river diversion, or alternate arrangement, operates and meets the hydrologic, geomorphic and ecological functioning of a river system and the social and cultural expectations of the community, consistent with the current and future context of the Latrobe River system. Such hydrologic, geomorphic and ecological functioning and social and community expectations have not yet been fully defined, but are likely to include elements such as:

- Hydrologic, geomorphic and ecological functioning.
    - Hydrologic regime. The arrangement should provide for both
        - longitudinal hydrologic connectivity
        - lateral floodplain connectivity
    - Geomorphic processes. The arrangement should
        - not be subject to accelerated high rates of erosion and deposition

        - be robust i.e. resistant to change and have the ability to adapt and repair following change without comprising the other values and outcomes
        - provide for ongoing longitudinal and lateral bed load sediment movements
    - Water quality: The arrangement should
        - enables essential carbon and nutrient longitudinal and lateral transfers
        - not be subject to pollutant loads that adversely impact on beneficial uses
    - Vegetation community: The arrangement should contain a vegetation community that
        - Supports geomorphic robustness
        - Provides a long-term source of large wood to the reach
        - Provides shade for instream temperature control, instream habitat and fish passage
    - Ecological condition and processes
        - Provides for ongoing benthic ecological processes
        - Meets instream and riparian habitat and transfer (e.g. fish passage) requirements
- Social and cultural expectations
    - Provision of site access
    - Visual amenity

These conditions are partially supported by the present MRD. Further enhancements may be required to meet broader expectations of the community. .

5.4 Options for management

Within this context and for the purpose of this assessment, options have been explored for the Morwell River Diversion at Yallourn. The option currently contemplated by EnergyAustralia Yallourn for the site comprises filling of the adjoining Township Field and East Field voids with freshwater (refer Figure 4). This water would provide structural support to the MRD and reduce the likelihood and consequence and hence risk of collapse.

Various alternatives could be considered for the MRD within this filled mine void arrangement including:

1. Fully connected Lake and MRD i.e. a flow through pit lake whereby the MRD is decommissioned, and all flow directed through a pit lake
2. Disconnected Morwell River Diversion: Morwell River diversion retained but remain hydrologically disconnected from the pit lake
3. Partially connected Morwell River: Morwell River diversion retained for passing of the environmental flows and modified via a high flow connection to pit lake

EnergyAustralia Yallourn has indicated a preference for the partially connected arrangement. A discussion on geomorphic and ecological implications of this option is provided in below.

A further option, that the Morwell River Diversion is replaced by an alternate Morwell River Diversion around the pit lake is not under consideration by EnergyAustralia Yallourn.

6 Morwell River Diversion preferred option: Partially connected MRD

This option is included in the conceptual arrangement for the site (refer Figure 4) and seeks to increase the robustness of the existing diversion channel and river by not confining flood events within the diversion structure. This option would seek to provide a controlled spill of floodwater from the Morwell River (and or

Diversion) channel to the pit lake, and the subsequent return of the flood water to the Morwell and / or Latrobe Rivers via a return flow spillway/ floodway.

The option has the benefit of creating a more robust diversion / river system through the site, with a lower risk of catastrophic failure than the Disconnected River Diversion option. The Partially connected MRD option has the added benefit of potentially enabling additional native vegetation establishment within the diversion alignment and the accompanying benefits including:

- Streambank erosion control
- A long-term source of large wood
- Shading of the waterway for temperature control, instream habitat and to aid fish passage.

This option while benefiting the structural integrity of the MRD, has the potential to result in the loss of flood events / flood flows needed to meet flow requirements within the Latrobe River system. This impact could be avoided via the provision of an alternate source of water to maintain lake levels and thereby ensure ongoing flows to the Latrobe River and Gippsland Lake system.

The option also has potential to impact on fish passage. Further assessment and refinement of the option will be required to address ecological habitat and fish passage requirements.

This option would have some ongoing risk of failure. However, the likelihood of such failure would be much lower than that associated with a Disconnected Morwell River Diversion option. The implications of and management options for a failure of the Morwell River Diversion into a full pit are set out in Attachment 1 appended to this report.

Further investigations will be required into the hydrologic, geomorphic and ecological implications of the preferred option. Such investigations should inform further development and refinement of the preferred option.

While this review of the preferred option has focussed on the post filling (operation) phase, consideration can and should be given to the fill phase. The risk of diversion failure would be reduced if floodwater was removed from the MRD during the fill phase. Work to enable such diversion of flood flow could form a component of the Partially connected MRD arrangement. An investigation into the impact of filling of the pit lake including the harvesting of floodwater should be the focus of a separate hydrologic investigation. Such floodwater forms a part of the environmental flow regime in the river system. The harvesting of flood water to reduce the risk of diversion failure may require mitigation measures. Such mitigation measures have not yet been examined.

7 Implications of pit filling water use for the Latrobe River system

A number of water sources can be considered for pit filling and pit lake operations. These sources have potential to impact on the health and functioning of the Latrobe River systems. Potential water sources include:

- Existing sub catchments at the Yallourn site that currently discharge to the Morwell and Latrobe River.
- Groundwater.
- Bulk water entitlements from the Latrobe River system extracted from Yallourn Weir via Lake Narracan and Blue Rock Reservoir.
- Harvesting of a portion of flood events (from the Morwell and potentially Latrobe Rivers).

These sources have the potential to impact on flow components essential to the river system these flow components include:

- Summer/ autumn
    - Base flows

    - Freshes
- Winter / spring
    - Base flows
    - Freshes
- Bankfull events
- Overbank events

These flow components are required in reaches that have potential to be impacted by the use of water to fill and operate a pit lake. Reaches of the Latrobe River with potential to be impacted by the use of water to fill and operate a pit lake include:

- The Tanjil River: Note that this water use is the subject of a Bulk Entitlement amendment and may not require separate assessment of impacts by Energy Australia Yallourn.
- The Morwell River (through the MRD) potential beneficial and adverse impacts.
- 2 x reaches of the Latrobe River.
- The Lower Latrobe River and fringing wetlands downstream of the Thomson River confluence.
- Lake Wellington and the broader Gippsland Lakes.

The risks arising from the use of water for the filling of the mine void and operation of a pit lake can be explored with the aid of a surface water balance model. The existing DEECA surface water, water balance model would be an appropriate model for such investigations.

8 Conclusion

This report aims to provide a context for the exploration of rehabilitation options for the Yallourn mine site and MRD. The report also provides a brief discussion on a preferred MRD rehabilitation arrangement and on water supply options and their implications for hydrologic, geomorphic, and ecological objectives for the Latrobe River system.

The issues identified in this report will need to be tested through appropriate assessments to inform the development of the preferred arrangement for site and the identification and assessment of any mitigation measures.

Attachment No. 1: The implications of, and management options for, a longer-term failure of the Morwell River Diversion at Yallourn

Implications of a failure of the Morwell River Diversion

A failure of the Morwell River Diversion into an adjoining full pit lake is likely to result in the following outcomes:

1. **Channel incision**: We would expect to see channel incision in the Morwell River. Depending on the location of the failure, we would expect up to 2 metres of incision. This incision would lead to uncontrolled upstream erosion including channel widening and channel meander development and in the absence of management intervention could;
    - destroy instream channel form and habitat in the Morwell River upstream of the MRD impacting on the upstream ecology of the Morwell River
    - destroy streambank and riparian vegetation and dewater adjoining wetlands including the Morwell Wetlands.
    - impact on upstream infrastructure assets such as any telecommunications cables, pipelines and potentially the foundations for the upstream railway and freeway.
    - impact on the stability of the diverted course of the Morwell River adjoining the Hazelwood mine site.
    - create downstream water quality issues and in particular lead to high levels of suspended sediment delivery to the Latrobe River and Gippsland Lakes
    - form an effective barrier to fish migrations including the migration of the critically endangered Australian Grayling. The barrier to fish migration would persist until any incision does not include headcuts in the channel bed and a stable bed form and habitat reestablish in the Morwell River.
2. **Cessation of Bedload sediment supply and benthic processes**: We would expect a cessation of bedload sediment transport through the Morwell River to the Latrobe River. The Latrobe River is bed load sediment starved as a result of past incision and the presence of Lake Narracan and Yallourn Weir immediately upstream of the Morwell River confluence with the Latrobe River. This starvation can lead to accelerated rates of channel change (meander development). The failure of the MRD would also lead to the cessation of riverine benthic processes and continuity in the Latrobe River system. Similar to the above, the collapse of the MRD would lead to a loss of riverine benthic processes from the Latrobe River system.
3. **Cessation of baseflows to Latrobe River system:** catastrophic failure of the levee and an uncontrolled breach in the river diversion has the potential to consume all summer baseflow in the Morwell River to offset lake evaporative losses. This loss of baseflow could lead to increased salinity in the Gippsland Lakes and decline in river health. This impact would be avoided via the provision of an alternate source of water to maintain lake levels and thereby ensure ongoing flows to the Latrobe River and Gippsland Lake system.

Several of the issues arising from a potential failure of the MRD arise as a result of the close proximity of Lake Narracan and Yallourn Weir (on the Latrobe River) with confluence of the Morwell and Latrobe Rivers. Lake Narracan and Yallourn Weir form an effective barrier to fish migrations, bedload sediment transport and riverine benthic processes. A failure of the Morwell River to provide these services, would render the complete loss of these services from Latrobe River system upstream of the Morwell River confluence.

Management options to reduce the consequence of an MRD failure

Mitigation measures that can reduce the **likelihood** of an MRD failure include the provision of a full pit lake and flood spillways as currently proposed by Energy Australia (Yallourn).

Mitigation measures that can reduce the **consequence** of a failure of the MRD include:

1. **Instream provisional grade control:** Structures such as piled rock bars can be installed into the bed of the Morwell River during the mine rehabilitation phase in anticipation of and to limit the scale and spatial extent of any channel incision that would occur in the event of an uncontrolled failure of the MRD**.** Similar structures were installed into the bed of the Cann River in 1999 in anticipation of potential channel incision. Such incision has since occurred in the Cann River, and the structures have performed their intended function to limit headward erosion. Any such structures installed in the Morwell River in anticipation of a failure of the MRD would only serve as an interim measure to limit channel change pending implementation of longer-term management interventions such as permanent grade control structures or the establishment of a meandering channel alignment.
2. **Vegetation establishment in the Latrobe River system:** The implication of reduced bed load sediment supply in the Latrobe River and potential for channel erosion can be reduced by reducing the sediment transport capacity of the Latrobe River and increasing the resistance of the Latrobe River to erosion. A program of stock exclusion and revegetation through the Latrobe River and in particular through the reach downstream of the Morwell River to the Tyres River confluence would assist in the protection of the reach from long term erosion arising from any long term cut to bedload sediment supply to the Latrobe River arising from the a catastrophic failure of the MRD..
3. **Decommissioning of Lake Narracan and Yallourn Weir:** As set out above the implications of a failure of the MRD are compounded by the presence of Lake Narracan and Yallourn Weir. Consideration should be given to the longer-term decommissioning of Lake Narracan and Yallourn Weir. Lake Narracan and Yallourn Weir largely services the water supply needs of the Yallourn and Loy Yang sites. Following the closure and rehabilitation of Yallourn and Loy Yang, Lake Narracan and Yallourn Weir is unlikely to be required for these water supply needs. The decommissioning of Lake Narracan and Yallourn Weir would benefit fish passage and sediment transport processes in the Latrobe River. Such benefits would be significantly greater in the event of a failure of the MRD.
4. **The Pit Lake:** The pit lake acts as a preventative control by balancing hydraulic pressures and forces, but it also limits consequence of failure through similar means. With potential energy removed, a failure will not have the driving force to generate significant erosion. Failure will be smaller in scale and repairable compared to a large-scale failure into a dry void. Failure will also not consume river flows as these will pass through the lake and into the Latrobe River.

Attachment B_ Yallourn Rehabilitation Assessment – Hydrological modelling (Alluvium 2024b)

Yallourn Rehabilitation Assessment – Hydrological modelling

June 2024

alluvium

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

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **EnergyAustralia Yallourn** under the contract titled 'Yallourn Rehabilitation Assessment – Hydrological modelling'.

Authors: Stuart Cleven, Suresh Hettiarachchi, Ha Nguyen
Review: Stuart Cleven
Approved: Ross Hardie

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Cover image: abstract river image, Shutterstock

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Executive summary

This report documents the approach and outcomes of a hydrological assessment of the Latrobe and Morwell Rivers within the context of the Yallourn Mine. This report effectively supersede all previous reports on the regional hydrologic analysis for this site. The assessment involved hydrological modelling of the entire catchment to estimate peak flow and hydrographs. The purpose of the investigation was to develop the hydrologic model that will be used to estimate peak flow rates to inform subsequent hydraulic assessment of the project area. The hydrologic model was built in RORB for ~2600 km^2 catchment of the Latrobe River extending to Latrobe Thoms Bridge gauge downstream of Yallourn Mine.

Key components of the assessment:

1. **Hydrologic model development for the whole catchment for calibration and validation**

    - A detailed hydrologic model was developed in RORB for the entire ~2600 km^2 catchment area of the Latrobe River extending to Latrobe Thoms Bridge gauge downstream of Yallourn Mine.
    - This model was calibrated and validated against actual historical flooding events in 2015, 2016, and 2021 to ensure accuracy and reliability.

2. **Design event modelling**

    - The calibrated whole catchment model served as the foundation for developing separate models for the Latrobe River catchment (~1940 km^2) and the Morwell River catchment (612 km^2) within the Yallourn Mine context.
    - These separated models were used to simulate various design events with Annual Exceedance Probabilities (AEPs) of 50%, 5%, 2%, 1%, 1 in 200, 1 in 500, and 1 in 2000.
    - The critical flow in m^3/s at the Latrobe River @ Yallourn and Morwell River @ Yallourn stations for various design events are shown in the table and figure below.

AEP	50%	5%	2%	1%	1 in 200	1 in 500	1 in 2000
Latrobe River @ Yallourn	60	480	770	1000	1180	1680	2600
Morwell River @ Yallourn	40	240	370	480	560	740	1090

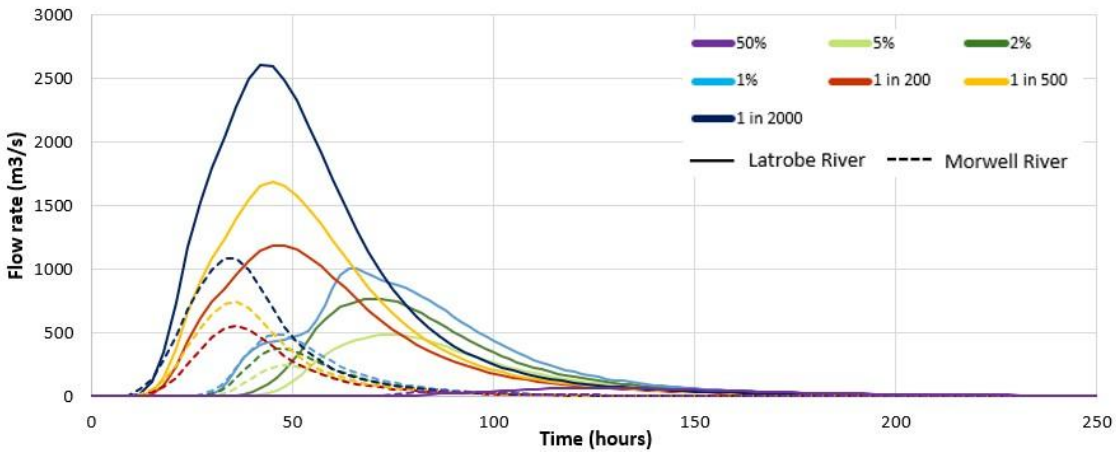
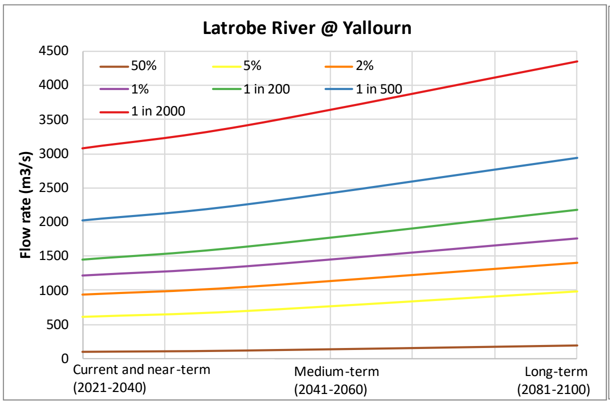
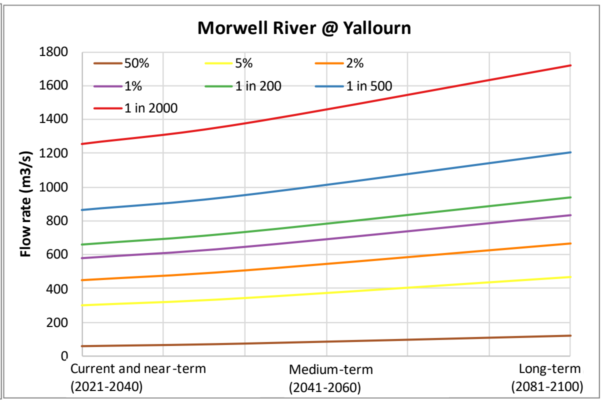


Figure shows the design flow hydrographs for Morwell and Latrobe Rivers

3. Peak flow estimates based on Climate change scenarios

- The impact of climate change on the design events was modelled for the near, medium, and long-term projections up to 2100. These scenarios were based on the very high Shared Socioeconomic Pathways (SSP5-8.5).
- The peak flow rates under the very high Shared Socioeconomic Pathways (SSP5-8.5) scenario are shown in the figure below.





Contents

Figures

Tables

1 Introduction

Pells Sullivan Meynink: Geotechnical & Engineering Services (PSM) is currently engaged in supporting EnergyAustralia Yallourn (EAY) in the development of mine rehabilitation arrangements, addressing a spectrum of concerns, notably the geotechnical and hydro geotechnical stability of long-term mine batters. In addition, RGS has been engaged to conduct the pit water balance to service the mine rehabilitation plan. To augment these efforts, Alluvium has been engaged to provide assistance to EAY, PSM and RGS in conducting regional surface water and water balance modelling. This modelling is crucial for informing decisions related to landform and mine rehabilitation planning.

This document presents the approach and outcomes of a hydrological assessment of the Latrobe and Morwell Rivers within the context of the Yallourn Mine (Figure 1). **This report effectively supersede all pevious reports on the regional hydrologic analysis for this site**.The assessment involved hydrological modelling of the entire catchment to estimate peak flow and hydrographs. The purpose of the investigation was to develop the hydrologic model that will be used to estimate peak flow rates to inform subsequent hydraulic assessment of the project area. The hydrologic model was built in RORB for 2600 km^2 catchment of the Latrobe River extending to Latrobe Thoms Bridge gauge downstream of Yallourn Mine.

This report specifically centres on the hydrological assessment of the Latrobe and Morwell Rivers within the context of the Yallourn Mine. The assessment involved three main parts

1. Hydrological modelling of the entire catchment extending to Thoms Bridge Gauge to calibrate and validate the hydrological model responses to the actual flood events of August 2015, July 2016, and June 2021.
2. Hydrological modelling of the separated Latrobe River and Morwell River catchments extending to Yallourn Mine to estimate design peak flow and hydrographs, which will inform the subsequent hydraulic assessment of the project area.
3. Hydrological modelling of climate change scenarios on the Latrobe River and Morwell River catchments to identify the impact on the design events.

This report discusses the model development process, the calibration and validation, and generating design flows corresponding to Annual Exceedance Probabilities (AEPs) events of 50%, 5%, 2%, 1%, 0.5%, and 0.2%, and the 1:2000 year Average Recurrence Interval (ARI) event. The climate change scenarios were modelled for the very high Shared Socioeconomic Pathways (SSP5-8.5) with the near-, medium-, and long-term projections up to 2100.

2 Background

The Yallourn Mine is located in the Latrobe Valley, approximately 130 km southeast of Melbourne (refer to Figure 1). Positioned astride the Morwell River, the mine is immediately upstream of its presently diverted confluence with the Latrobe River. The Morwell River's upstream drainage basin spans 612 km^2, while the Latrobe River's catchment extends to a size of up to 1940 km^2. Approximately 3.5 km upstream from their confluence lies Lake Narracan on the Latrobe River.

The hydrology of the Latrobe and Morwell Rivers has undergone prior scrutiny. The Morwell River Flood Study (Alluvium, 2021) examined the impact of Morwell River flooding on the Yallourn Mine during the June 2021 flood event, utilizing RORB modelling. The modelled area covered a 612 km^2 catchment extending from upstream of the Morwell River to the Morwell River Gauge near Yallourn Mine. For the Latrobe River, the Latrobe Flood Study (Cardno, 2015) employed the URBS hydrological model provided by BOM, incorporating six sub-models to study the entire Latrobe River Catchment. The parameters utilized in these earlier studies will serve as a reference for establishing the model setup and for comparison with the current model.

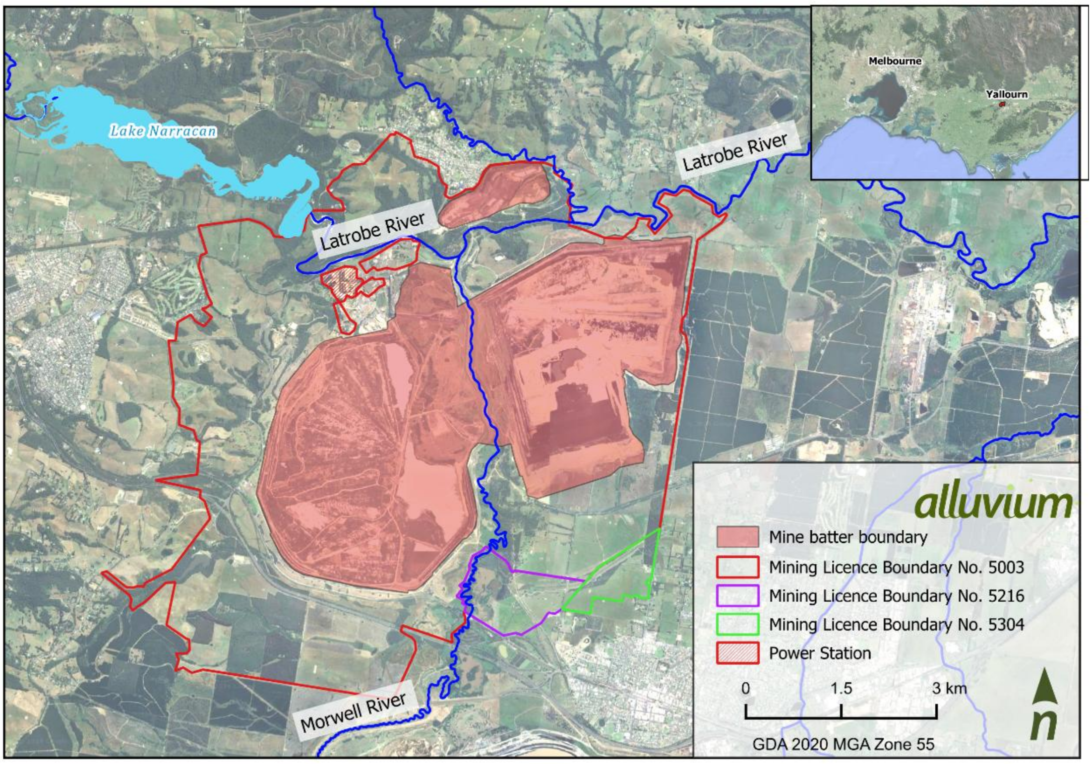


Figure 1. *Yallourn Mine site context*

3 Catchment description and hydrological model setup

The catchment delineation was undertaken using CatchmentSIM, relying on VicMap's 10-meter resolution Digital Elevation Model (DEM). The catchment area of the Latrobe River up to Thoms Bridge Gauge, the first discharge gauge station downstream of Yallourn Mine, totals approximately 2600 km^2. The catchment main waterways include the Latrobe River along with its principal tributaries Tanjil River, Moe River/Drain, Narracan Creek, and Morwell River (Figure 2). Key reservoirs within the catchment include Blue Rock Lake on the Tanjil River, Hazelwood Cooling Pond on Eel Hole Creek (a tributary of the Morwell River), and Lake Narracan on Latrobe River.

The hydrological model was first developed for the entire 2600 km^2 Latrobe River catchment up to Thoms Bridge Gauge. The entire catchment was partitioned into 63 sub-catchments, with areas ranging from 14 to 80 km^2 and an average of 42 km^2. Imperviousness within these sub-catchments spans from 0 to 32.6%. Refer to Figure 2 for a visual representation of the catchment layout and delineation. Runoff routing and hydrograph generation for studied rainfall events were executed using RORB software Version 6.45. Sub-catchment details, including area, imperviousness, and connections, were imported into RORB from CatchmentSIM results. Most reaches were modelled as 'natural,' except for those connecting the reservoirs, which were defined as 'drown.'

The discharge relations for Blue Rock Lake and Lake Narracan were modelled in RORB using the weir formula and water elevation-storage relations obtained from the Southern Rural Water website, along with measurements from the DEM. The Hazelwood Cooling Pond was modelled using a storage formula following the Morwell Flood Study (Alluvium, 2021). Lake Narracan was excluded from the model due to its relatively negligible storage volume in comparison to its catchment size. We assumed Lake Narracan to be fully open during the designated events, given its gated spillways closely matching flows in flood scenarios. Refer to Table A1 in Appendix A for reservoir input details, and Figure A4 in Appendix A for the RORB model layout.

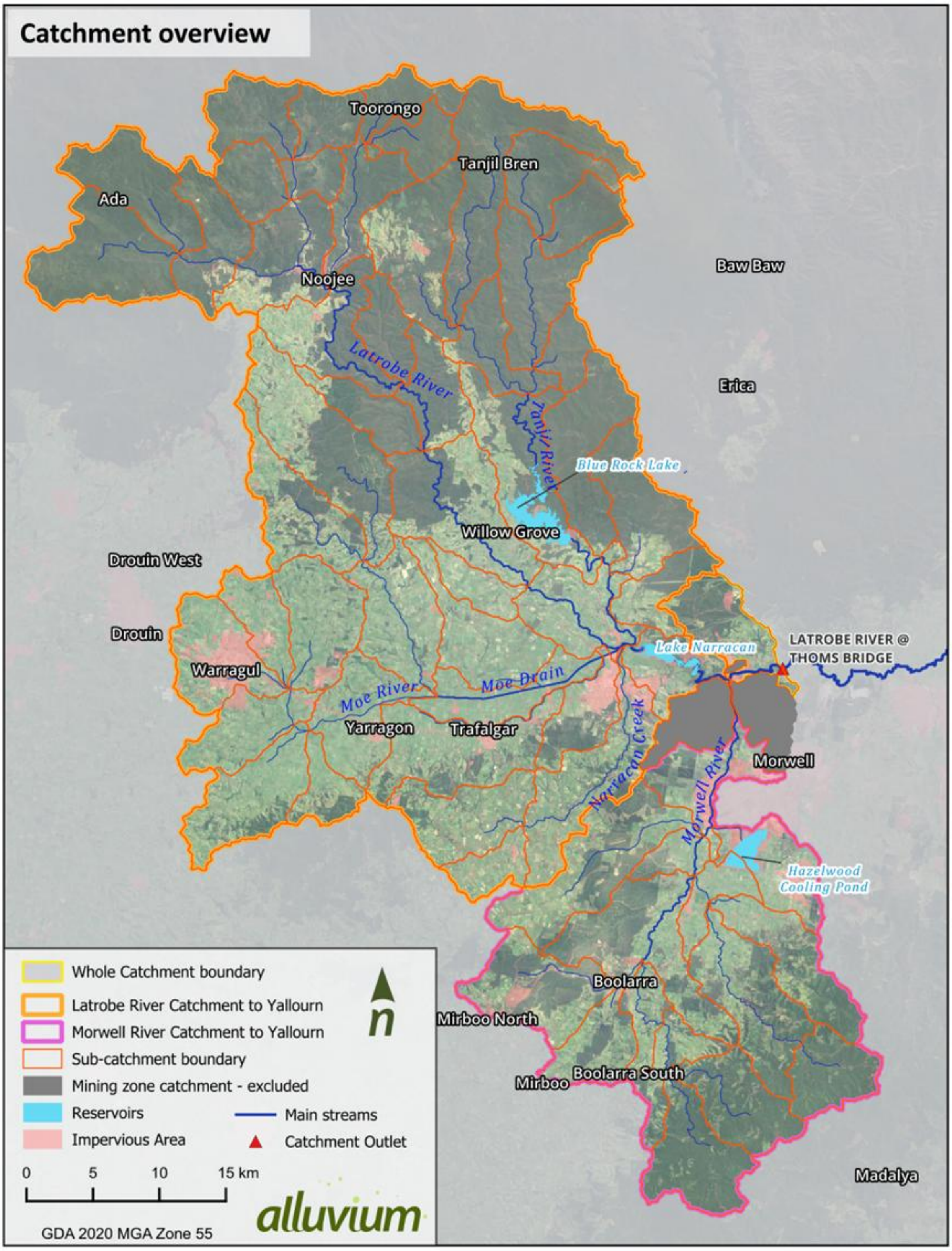


Figure 2. *Overview of Latrobe River Catchment through Yallourn Mine*

4 Model calibration and validation

Calibration and validation of hydrologic models endeavours to generate a verified set of parameters reflecting the catchment's runoff and routing response to an actual rainfall event. The calibrated parameters include:

- Initial loss (IL) and continuous loss (CL), representing catchment storage and influencing rainfall-excess hyetograph and runoff-routing.
- Reach storage coefficient (k_c) and exponent (m) parameters, governing reach storage in the equation $S = kQ^m$ (S: reach storage, Q: discharge, k: function of k_c), were calibrated. The exponent (m) largely depends on channel's cross-section shape and can generally have an average value of 0.8. The value of k_c hinges on channel characteristics like roughness, cross-section shape, bed-slope, and length, affecting storage volume and lag time between rainfall and discharge. Increasing k_c reduces discharge and extends the lag time.

We calibrated the RORB model of the entire catchment to two events in 2015 and 2016 to find the most suitable set of parameters for each event. The average for each of the parameters within the two sets for years 2015 and 2016 were then validated to the event in 2021.

4.1 Calibrating and validating events

The event of 2015 (25 to 30 August), 2016 (21 to 27 July) were selected as the calibration events. While these events are not among the largest flood occurrence on record, the discharge data obtained at the gauging stations exhibited completeness. We also focused on years prior to 2021 and decided not to use the flood that occurred in 2022 as there were upstream diversions during the flood based on local information provided by EAY. The flood that occurred in June 2021 initiated remedial and corrective works at the mine that were completed in 2022. As a resulted of these works and modifications, high flows were diverted upstream of the mine that then affected flows measured at the gauges. Hence the reason to focus on years prior to 2021 for calibration. In addition, both 2015 and 2016 are independent events without immediate antecedent precipitation. Additionally, we selected 2015 and 2016 as the winter season (Southern) in both these years can be considered wetter than average with regular and frequent rain events during the months from June to September. Selecting wetter conditions results in more conservative estimate for modelling parameters.

The event of 2021 (7 to 14 June) was chosen as the validated event because it is the one of the largest events occurring in the area. Although the discharge recorded at some of the gauging stations exhibited bypassing, we can still use the data from some important gauges to validate the appropriateness of the calibrated parameters. Details of the events are listed in Table 1. We also had access to infilled data from previous work done by Alluvium (Alluvium, 2021) that provided data at critical locations for comparison.

The calibration and validation input rainfall depths, temporal and spatial distribution from actual events and compare the resulted hydrographs to the actual hydrographs. The data used for calibration and validation are presented in the following sections.

Table 1. Calibration and validation events

Event	**2015**	**2016**	**2021**
Purpose	Calibration	Calibration	Validation
Rainfall duration	00:00 25/8 to 23:00 30/8	00:00 21/7 to 23:00 27/7	00:00 7/6 to 23:00 14/6
Mean total rainfall (mm)	62.3	62.0	174.9
Discharge duration	00:00 25/8 to 23:00 1/9	00:00 21/7 to 23:00 29/7	00:00 7/6 to 23:00 16/6

4.2 Rainfall spatial distribution

The singular non-uniform spatial pattern for a catchment area exceeding 20 km² was estimated through the design rainfall grids method, as outlined in Chapter 6 Book 2 of ARR 2019 (Jordan et al., 2019). Three spatial patterns corresponding to three actual rainfall events in 2015, 2016 and 2021 were used in this study to calibrate and validate the hydrological model.

To complete this task, we first identified the available rainfall gauges within and around the catchment zone from Water Data Online (BOM, 2024) and Surface Water Monitoring Data (VIC DELWP, 2024). There are two types of rainfall data: daily rainfall records (daily and sometimes accumulated) and pluviometer records (every 15 minutes). We used the rainfall data from pluviometer records in this study to be consistent with the pluviographs for the temporal patterns we used in the later step. The distribution of pluviometer (continuous) rain gauges is presented in Figure 3 with sources, and total rainfall for each event listed in Table A1 - Appendix A.

Next, total rainfall depths from the rainfall event duration were calculated for all 28 pluviometer rain gauges identified. These rainfall depths were then spatially interpolated over the catchment using the Inverse Distance method with a 300 m grid cell size. The resulting spatial pattern was averaged to delineate total rainfall depths in the sub-catchments. The spatial distribution of rainfall for the sub-catchments is visually represented in Figure 4.

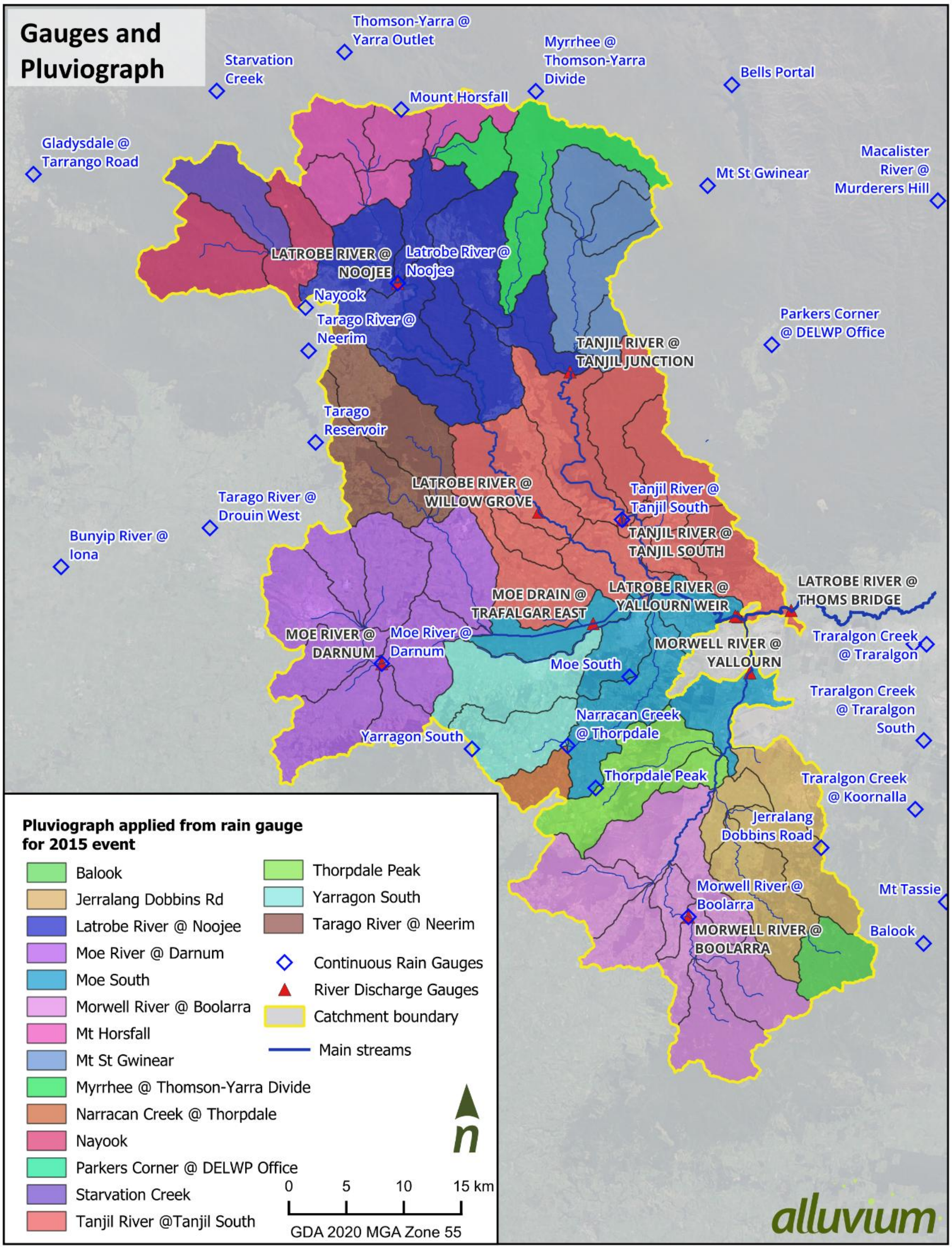


Figure 3. *Available continuous rain gauges and river discharges gauges in the catchment area and distribution of pluviographs used in the 2015 event calibration*

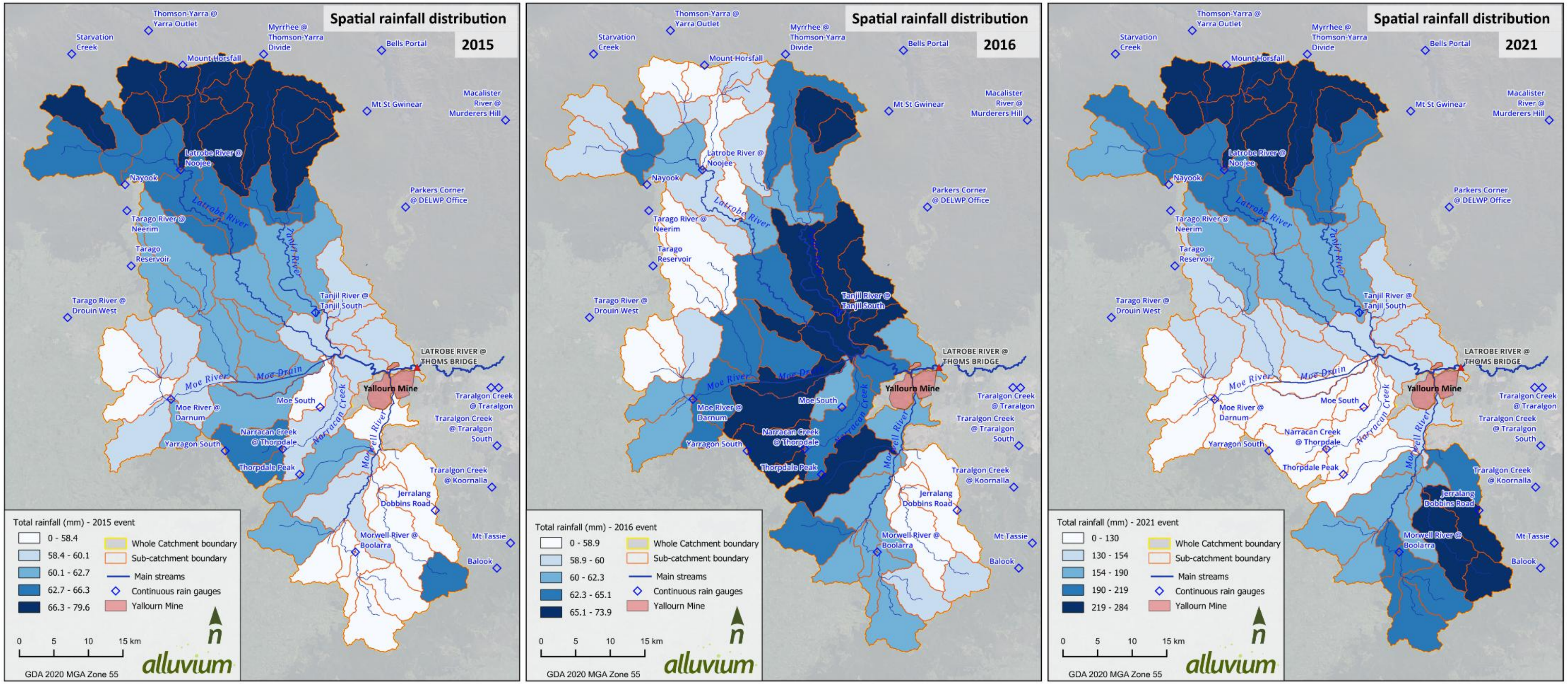


Figure 4. *Rainfall spatial distribution for the calibration and validation events*

4.3 Rainfall temporal distribution

Hourly rainfall pluviographs from the pluviometer rain gauges were used as the temporal patterns for the calibration events. The pluviographs were appropriately distributed across the 63 sub-catchments based on the proximity of a gauge to a sub-catchment centroid, as illustrated in Figure 3 for the 2015 event. The use of some gauges varies for different events due to their inconsistent availability. Details of the pluviographs used for each event are provided in Table A1 - Appendix A and the pluviographs are shown in Figure 5 for the 2015 event and in Figure A1 and Figure A2 for the 2016 and 2021 events.

4.4 Flow hydrographs

Measured flow hydrographs from 10 discharge gauges (see Figure 3) were used to compare the modelled hydrographs. A selection of the gauges used are discussed in more detail below.

There are three gauges around Latrobe River at Yallourn Mine with discharge data available from different sources as detailed in Figure 5. Gauge 226400 location is shown from the BOM and VIC DELWP websites to be upstream of the Narracan Lake. Gauge 226400B is upstream of the Yallourn Weir and Gauge 226400A is downstream of the Yallourn Weir. Figure A3 – Appendix A shows these gauge discharges during a few events together with the Latrobe River @ Thoms Bridge gauge. We see that the data for 226400A is similar to 226400B suggesting the actual location of 226400A is similar to 226400B. Notably, the discharge of 226400A is even higher than the flow at Latrobe @ Thoms Bridge gauge, showing that data from this gauge can be affected by the weir and is not suitable for calibration. Although the 226400B gauge is immediately upstream of the weir near Yallourn Mine and its hydrographs have some flat sections reflecting the weir interference, its data still looks reasonable. Therefore, the data of gauge 226400B was used in this study to represent the hydrograph at Latrobe River @ Yallourn with consideration of the weir interference during high flows.

We selected to use the infilled data developed for the Morwell flood study (Alluvium, 2021) at the Morwell River @ Yallourn gauge for calibration and validation The infilled data developed for the 2021 flood study (Figure A7) for this gauge is at a daily interval for events prior to 2018 and at 15-minute time step for the June 2021 event (8 to 23 June). The reason for making this choice is that we think the infilled data has a better representation of flows during larger flows conditions at this gauge (Figure A7). In addition, the Alluvium (2021) study completed infilling data at the Latrobe River @ Yallourn Mine 226400B gauge, which addressed a known gauging issue during the 2021 event, which was also used during model validation.

The hydrograph data were obtained and run with a one-hour time step. The hydrograph duration for each event was two days longer than the rainfall events. Baseflow data were estimated as constant baseflow for each of the discharge gauge. Details of the gauges are shown in Table A2 – Appendix A.

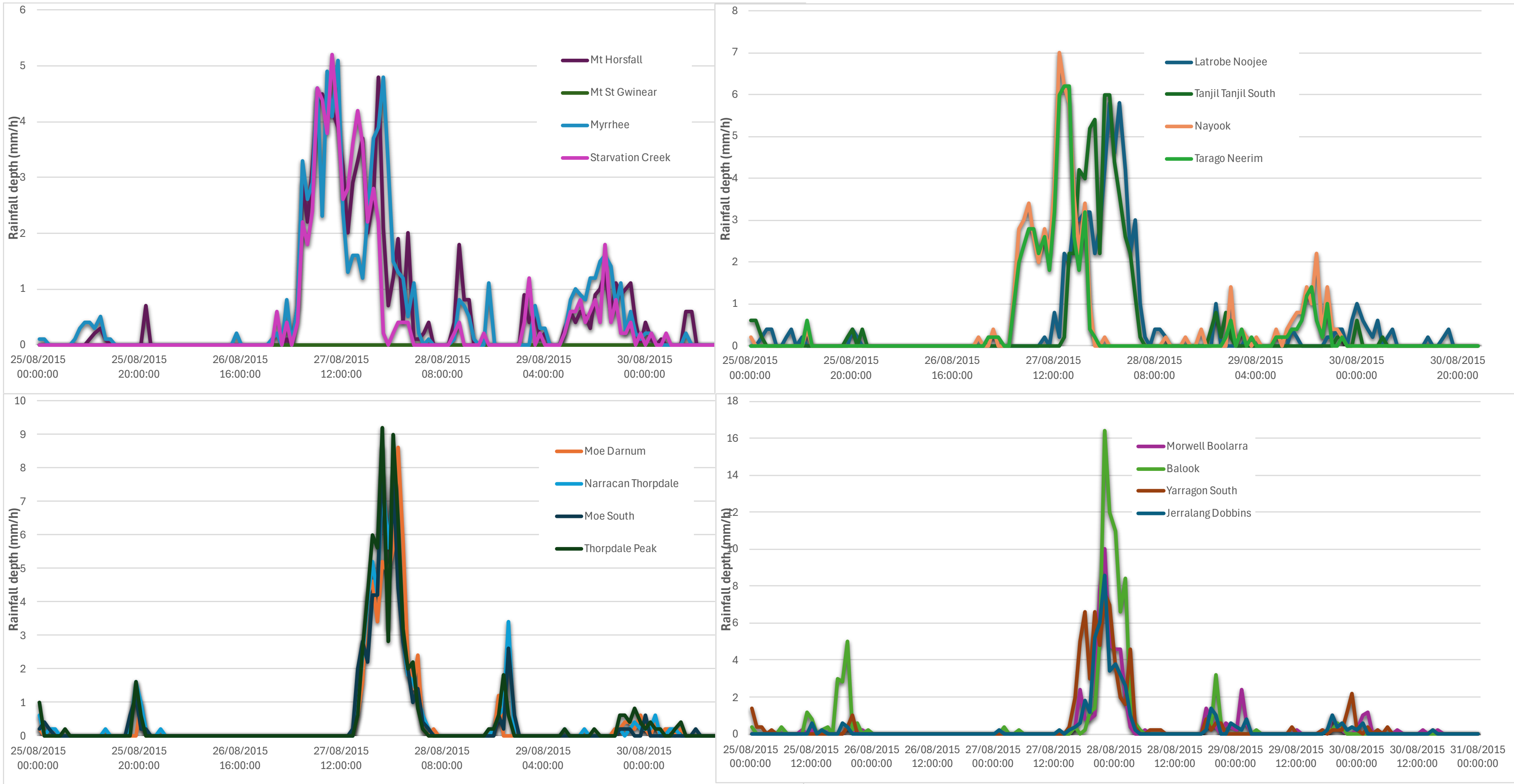


Figure 5. *Pluviographs used in model calibration for the 2015 events; upper panel: northern gauges, lower panel: southern gauges.*

4.5 Calibration procedure and results

The calibration process involved a comparison between the observed hydrographs from 10 gauging stations and the hydrographs calculated by the model for the specified calibration events. A critical aspect of this calibration is the careful adjustment of various routing and loss parameters. This parameter tuning extended to 10 interstation areas, corresponding to the 10 gauging stations. The sequence of calculations and calibrations is systematically presented in Figure A4 - Appendix A.

Figure 6 and Figure 7 present the calculated and actual hydrographs, along with the associated rainfall-excess hyetographs at the gauging stations for the 2015 and 2016 events. The calculated and actual hydrographs align well for most of the gauging stations with some exceptions for the low discharge stations. The calculated hydrographs for Morwell River @ Yallourn have significantly higher peak than the actual gauging hydrographs and have closer matches with the infilled data for both events. The gauges with high flow values, Latrobe @ Yallourn and Latrobe @ Thoms Bridge, demonstrated a good alignment between the calculated and observed hydrographs. During the calibration, the reaches parameters kc and m, were deliberately kept constant for both calibration events because these factors are not rainfall dependent. The calibrated model parameters are documented in Table 2.

4.6 Validation procedure and results

The calibrated parameters for the two events were averaged and applied to the 2021 event (see Table 2). The resulted calculated and actual hydrographs are presented in Figure 8. The calculated hydrographs for some gauging stations match very well with the actual hydrographs, including two stations on Tanjil River and Latrobe River @ Thoms Bridge. The validation results may suggest that the model is overestimating the Latrobe River gauges and underestimating the Morwell River gauges. However, given that the 2021 event is one of the largest events in the history of the gauge and that the gauge discharge was obtained from the rating curves against observed water levels, which were built using much lower events than this event, it is considered appropriate.

It is also noted that three gauges on the Latrobe Rivers except for the Latrobe River @ Thoms Bridge gauge had a bypass issue. In addition, the rating curve at Morwell River @ Boolarra gauge shows that the highest discharge data ever captured in this curve is approximately 2000 ML/day or 23 m^3/s, while the peak flow rate for the 2021 event is 140 m^3/s (see Figure A6). The record for Latrobe River @ Thoms Bridge gauge rating curve, however, has value quite close to the 2021 peak flow (see Figure A6). We also consider the hydrographs for both Morwell River @ Yallourn and Latrobe River @ Yallourn based on the infilled data that was developed in the previous study (Alluvium, 2021). The model results at these locations matched the infilled data within reasonable margins. Therefore, the model parameters were considered appropriate and validated, which is supported by the close match for Latrobe River @ Thoms Bridge for the 2021 event.

Table 2. Routing and losses parameters resulting from model calibration and used for validation and design events

			2015		2016		2021 validation and design events	
Interstation Area	kc	m	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Latrobe River @ Noojee	**50**	**0.8**	38	2.7	19.5	2.1	**28.75**	**2.4**
Latrobe River @ Willow Grove	**50**	**0.8**	35	1.4	17.5	2.2	**26.25**	**1.8**
Moe River @ Darnum	**40**	**0.8**	18	1.2	18	1.5	**18**	**1.35**
Moe Drain @ Trafalgar East	**60**	**0.8**	24	1.2	17	0.84	**20.5**	**1.02**
Tanjil River @ Tanjil Junction	**30**	**0.8**	20	2.1	32	1.55	**26**	**1.825**
Tanjil River @ Tanjil South	**30**	**0.8**	25	2.5	32	2.5	**28.5**	**2.5**
Latrobe River @ Yallourn	**40**	**0.8**	35	3	35	2.2	**35**	**2.6**
Morwell River @ Boolarra	**40**	**0.8**	20	1.8	15	1.7	**17.5**	**1.75**
Morwell River @ Yallourn	**40**	**0.8**	30	1.8	20	1.3	**25**	**1.55**

Latrobe River @ Thoms Bridge	**80**	**0.8**	20	3	10	1	**15**	**2**

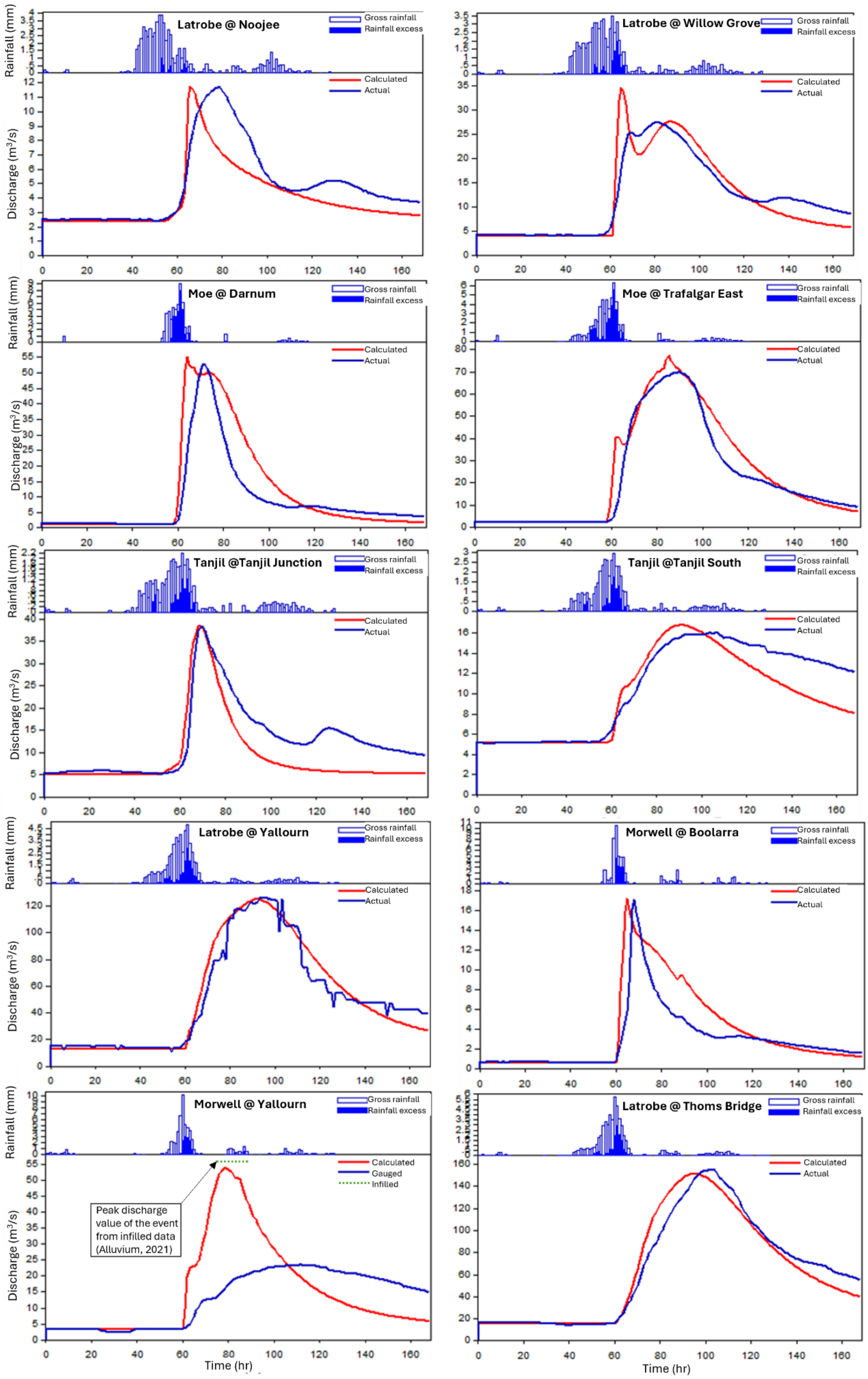


Figure 6. *Calculated (red line) versus actual/gauged (blue line) and infilled (green line) hydrographs at gauging stations used in model calibration for the 2015 event.*

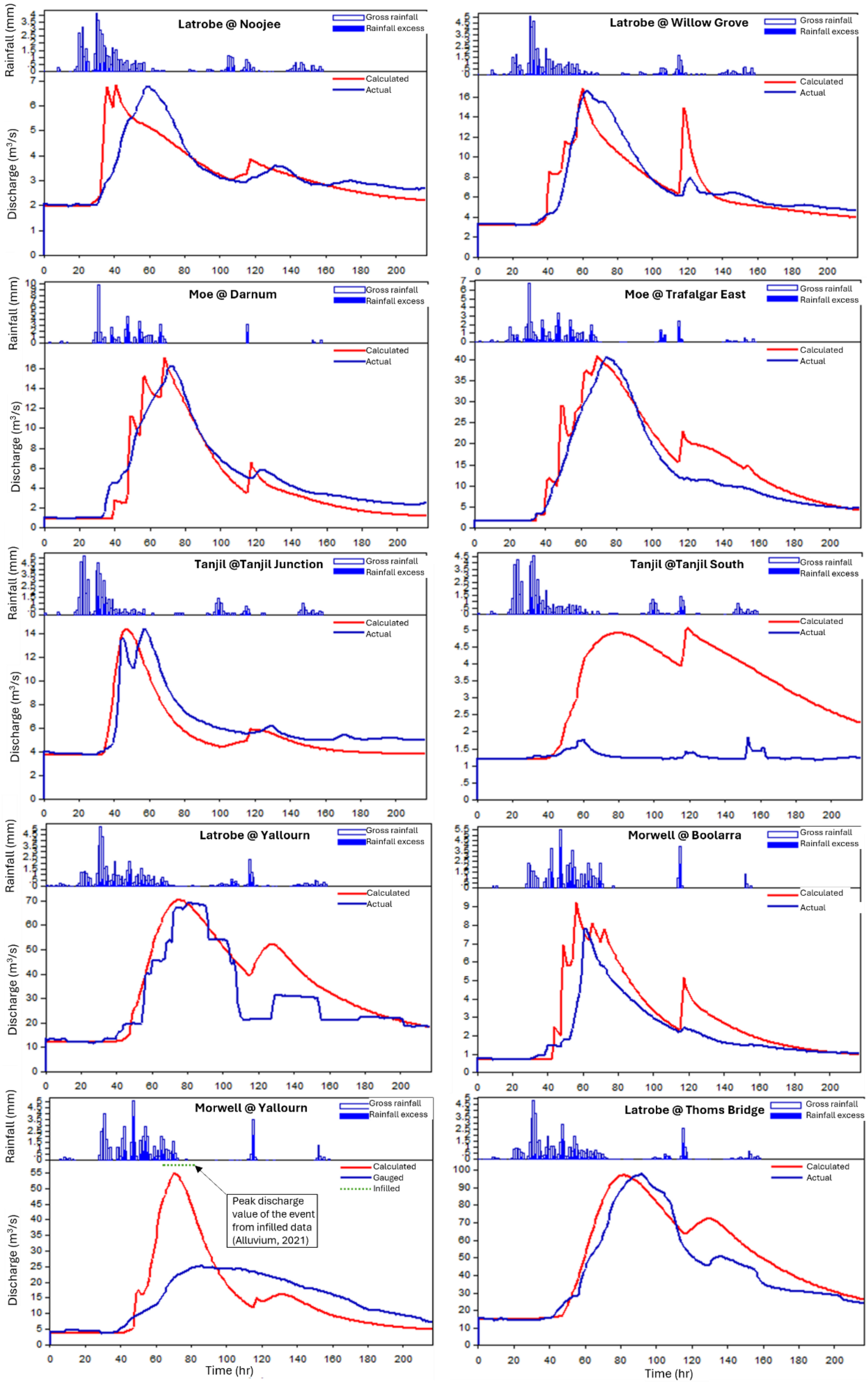


Figure 7. *Calculated (red line) versus actual/gauged (blue line) and infilled (green line) hydrographs at gauging stations used in model calibration for the 2016 event.*

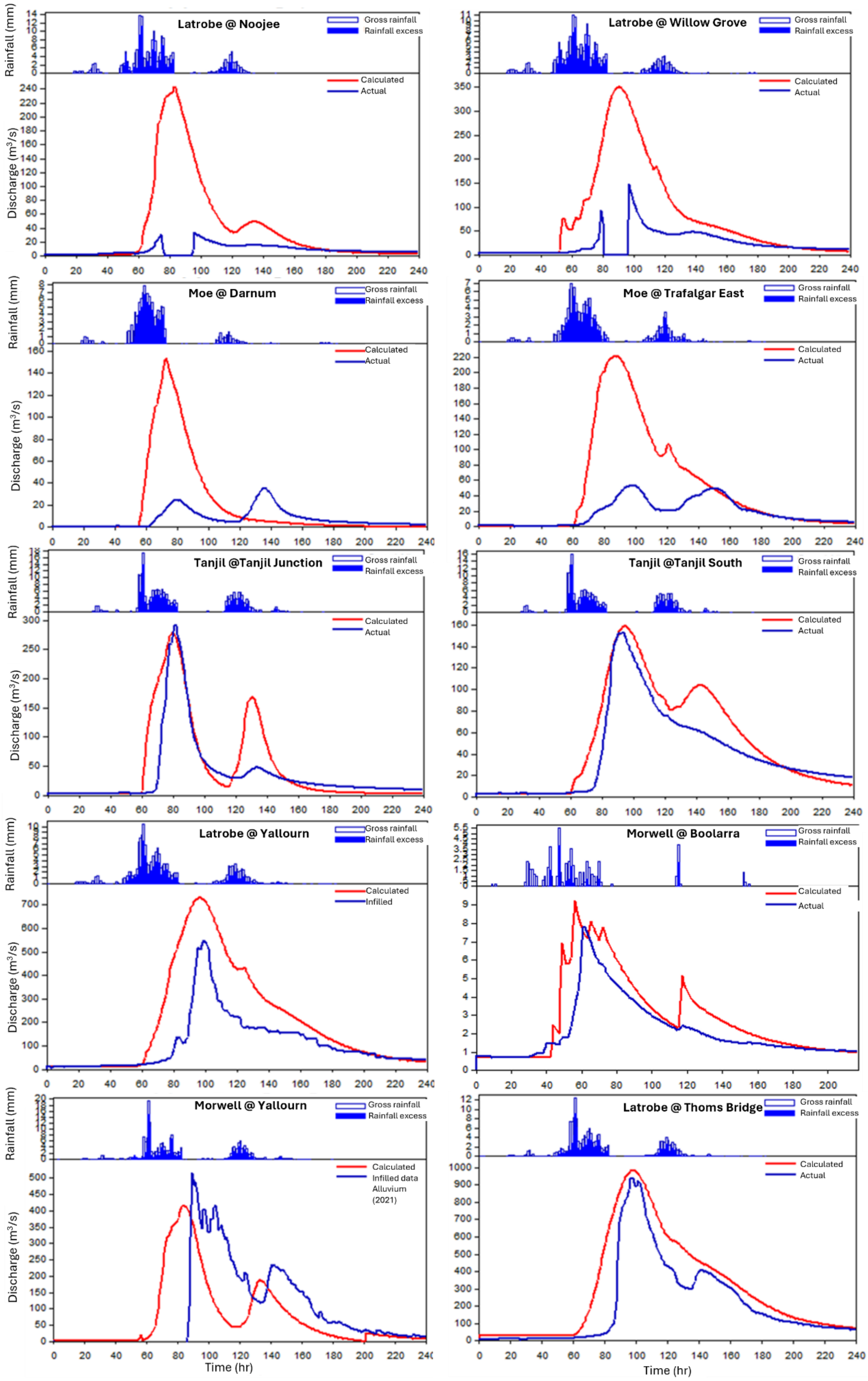


Figure 8. *Calculated (red line) versus actual/gauged (blue line) and infilled (green line) hydrographs at gauging stations used in model validation for the 2021 event.*

5 Design event flow analysis

The design event flow analysis was conducted for the separated catchments of the Latrobe River and Morwell River within the context of Yallourn mine. The separation of the catchments for the Latrobe and Morwell Rivers are indicated in Figure 2. The following sections will describe the model set up for the separated catchments and the design event modelling procedure for a spectrum of Annual Exceedance Probabilities (AEPs) events, including frequent to rare (50%, 5%, 2%, 1%), and very rare to extreme (1 in 200, 1 in 500, and 1:2000) events following the ARR2019 guidelines.

5.1 Model setup

The validated RORB model for the entire catchment was separated for the Latrobe River catchment and the Morwell River catchment. The hydrologically significant geometrical features, the sub-catchment areas, reach lengths, and land use imperviousness are the same as the original model. The Latrobe River catchment on its own includes 47 sub-catchments with the total area of about 1940 km^2, while the Morwell River catchment includes 15 sub-catchments with the total area of about 612 km^2. The two model outlets are at the confluence of the two rivers.

The interstation gauges in the RORB models were kept unchanged with corresponding catchment parameters, maintained from the validated whole catchment model (Table 2). This one set of catchment parameters is applied throughout all design events with the assumption that catchment behaviours across different events exhibit a consistent pattern, allowing the application of calibrated parameters for all the design event models.

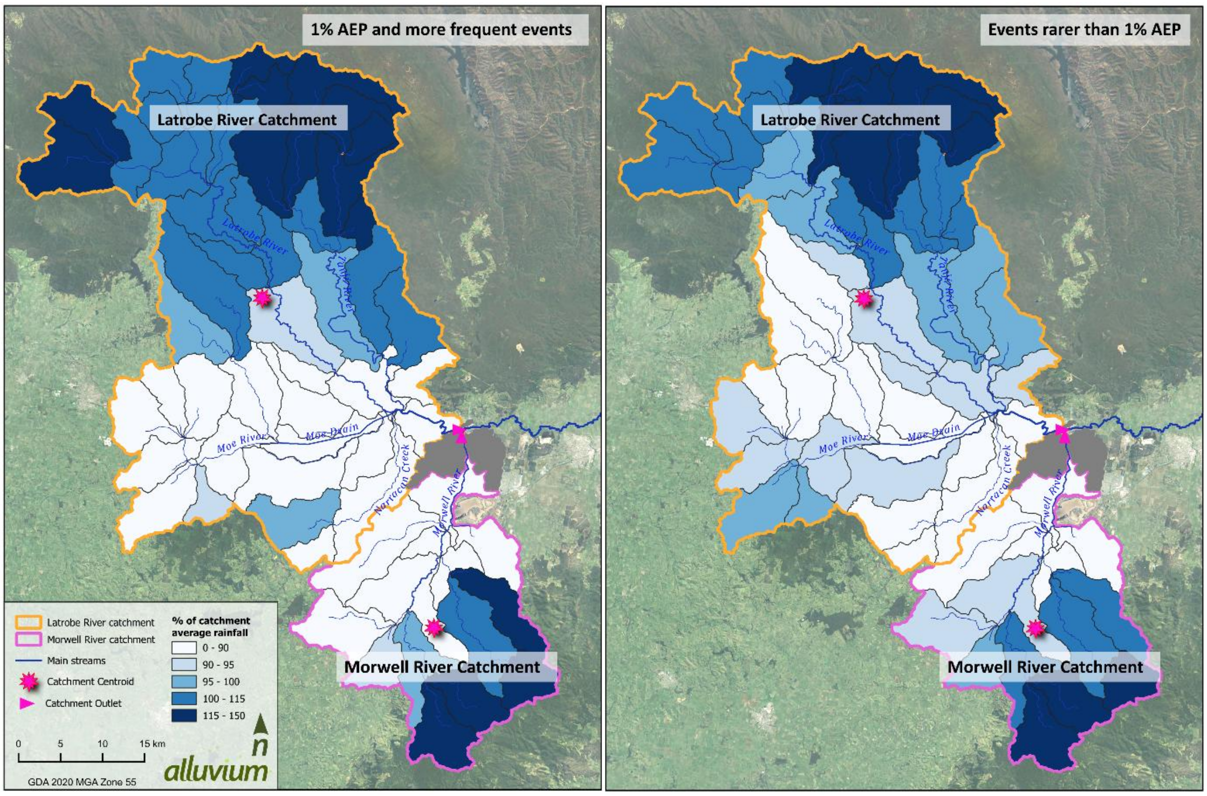


Figure 9. *Spatial patterns for the Infrequent to Rare events (left) and Very Rare to Extreme events (right) of the Latrobe and Morwell Rivers catchments in relation to the catchment average rainfall*

5.2 Design events modelling procedure

Infrequent to rare events

Design event analysis for the infrequent events follows Book 2 - Chapter 3: Design rainfall of the ARR2019 guidelines (Green et al., 2019). For the infrequent to rare events, i.e., 50%, 5%, 2% and 1% AEP, the gridded rainfall data for the 1% AEP event was first obtained from BOM Design Rainfall Data System (BOM, 2016) for various durations, and then weighted-averaged to sub-catchment rainfall. The rainfall spatial pattern expressed as sub-catchment percentages against the catchment average rainfall for various durations were calculated and applied to all infrequent to rare events (See Figure 9 left panel).

The Intensity Frequency Duration (IFD) information for each catchment centroid were obtained and areal temporal patterns specific to the Southern Slope (Vic/NSW) zone was applied (Geoscience Australia, 2022). Areal Reduction Factors (ARFs), in line with ARR 2019 recommendations for catchments ranging between 1000 and 30,000 km² were selected (Babister et al., 2019). The median pre-burst depths were applied within the RORB model.

An ensemble of rainfall durations spanning from 12 hours to 168 hours were systematically analysed for each catchment to identify the critical hydrographs. First, the 60th percentile peak flow rate of all hydrographs with the same duration was extracted from the results to represent the flow rate of a duration. Then, the highest peak flow rate among the durations was selected as the critical flow rate of the given design event. The hydrographs and durations corresponding to the critical flow rates are the critical hydrographs and critical durations, respectively.

Very rare to extreme events

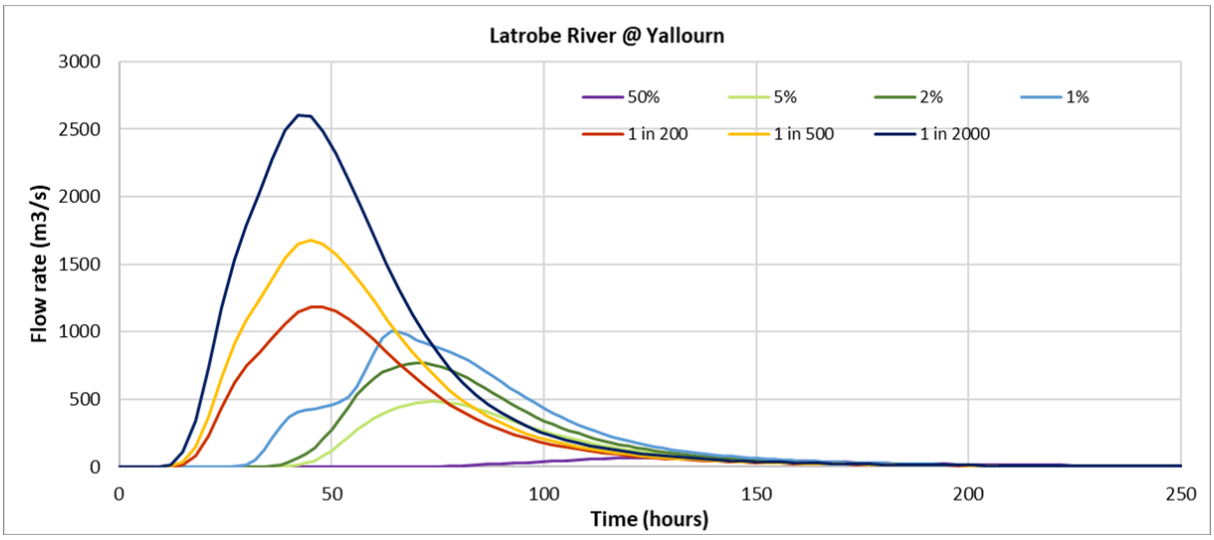
The 1 in 200, 1 in 500 and 1 in 2000 year events were modelled based on the very rare to extreme events methodology (ARR 2019 Book 8 - Nathan & Weinmann, 2019). The Latrobe and Morwell River catchments are within the Generalised Southeast Australia Method (GSAM) – Coastal Zone. The rainfall spatial pattern was derived from the Topographic Adjustment Factor (TAF) from the GSAM method. The gridded TAF was converted to spatial pattern in a similar way to the infrequent to rare events (See Figure 9 right panel). The coastal GSAM temporal patterns with durations from 24 to 96 hours with a 3-hour time step for a reference catchment size of 2500 km^2 and 500 km^2 provided in AR&R were used for Latrobe and Morwell catchments, respectively.

The IFD information for each catchment centroid for these events was also obtained. As there was only one temporal pattern for each duration, the hydrograph with the highest peak flow among all durations is the critical hydrograph of a design events rated as rare to extreme.

The critical flow rates and durations of all design flooding events are shown in Table 3 and critical hydrographs are shown in Figure 10. Figure A8 in the appendix illustrates the relative magnitude of the flows in the Morwell and Latrobe Rivers.

Table 3. Critical flow rates and durations for design flooding events

	Latrobe River @ Yallourn			Morwell River @ Yallourn		
AEP	Critical duration	Temporal pattern	Critical flow (m³/s)	Critical duration	Temporal pattern	Critical flow (m³/s)
50%	120 hrs	6	60	96 hrs	5	40
5%	48 hrs	6	480	48 hrs	4	240
2%	48 hrs	6	770	48 hrs	4	370
1%	48 hrs	10	1000	48 hrs	4	480
1 in 200	48 hrs	1	1180	36 hrs	1	560
1 in 500	48 hrs	1	1680	36 hrs	1	740
1 in 2000	48 hrs	1	2600	36 hrs	1	1090



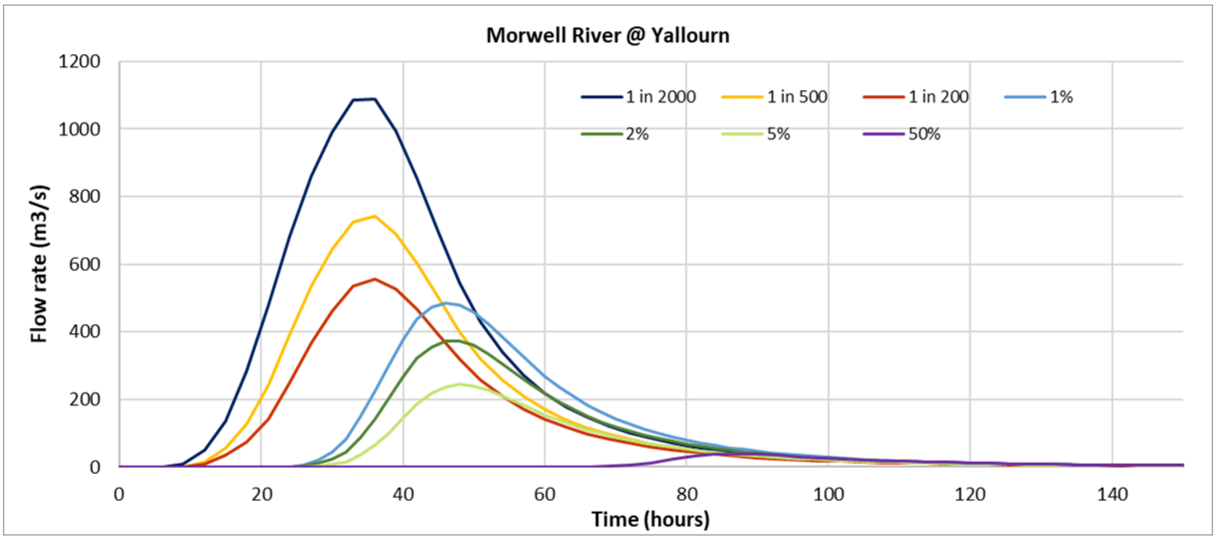


Figure 10. *Critical hydrographs of the series of AEP flood events evaluated at Latrobe River and Morwell River at Yallourn.*

6 Climate change analysis

A climate change analysis has been undertaken for this study following the draft update to the Climate change considerations chapter in ARR Book 1 (DCCEEW, 2023). The approach to account for climate change is consistent with other studies that are on=going and complete for this project. There are four-climate related factors that are typically considered during a climate change scenario analysis: (1) a design storm of a given AEP and duration, (2) temporal pattern, (3) spatial pattern, and (4) loss parameters that represent soil moisture conditions. Among them, the impact on temporal pattern is mostly significant for short events (i.e., less than 24 hours) and the impact on spatial pattern is uncertain from current research. Therefore, we maintained the spatial patterns that were used in the design storm analysis as presented in Figure 2. In this study, the climate change impacts on rainfall intensity and loss parameters were considered based on the very high Shared Socioeconomic Pathways (SSP5-8.5).

As per the undated guidelines, the projected rainfall depth I_p is estimated as

$$I_p = I \times \left(1 + \frac{\alpha}{100}\right)^{\Delta T}$$

where α is the rate of change, *I* is the design rainfall depth for a given AEP, and ΔT is the most up to date estimate of global temperature projection for the design period. In this study, α = 8 (%/°C) is the median estimate for event duration from 24 hours and longer. The median ΔT were used for each period, ΔT = 1.4 °C for current and near-term (2021-2040), ΔT = 2.3 °C for medium-term (2041-2060), ΔT = 4.5 °C for long-term (2081-2100).

Current literature suggests that the initial loss (IL) will increase with increasing temperature due to dryer soil conditions and the updated guidelines provides estimates for adjustments to these parameters. For the Southern Slope cluster where the catchments are located, the median rate of change in IL is 3.9 (%/°C).

The ratio of projected rainfall depth (Ip) to current design event (I) values and the ratio projected initial loss (ILp) to the calibrated IL are shown in Table 4.

Table 4. Changes in rainfall depth and initial loss with climate change scenario SSP5-8.5

	ΔT (°C)	Ip/I	ILp/IL
Current and near-term (2021-2040)	1.4	1.11	1.05
Medium-term (2041-2060)	2.3	1.19	1.09
Long-term (2081-2100)	4.5	1.41	1.18

The RORB models for Latrobe and Morwell Rivers catchments were run with the climate change projected rainfall depths and initial losses. The peak flow rates for the Latrobe River and Morwell River catchments at Yallourn Mine for the SSP5-8.5 scenario are set out in Figure 11 and Table 5.

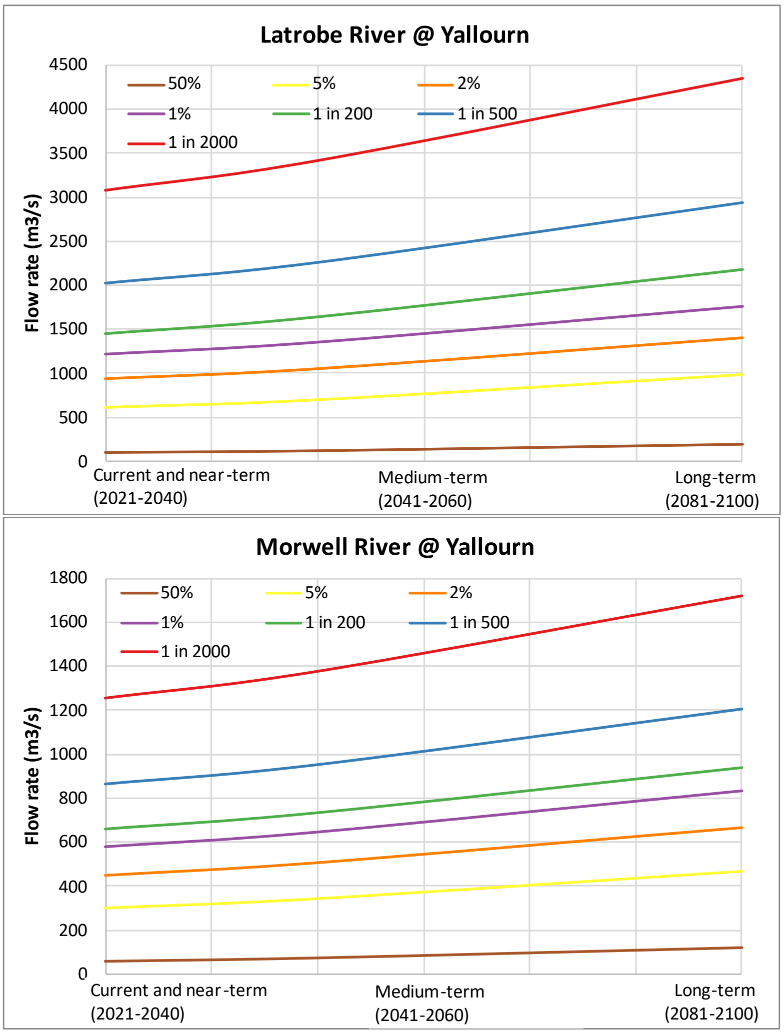


Figure 11. *Critical flow rates at Latrobe River and Morwell River at Yallourn with climate change scenario SSP5-8.5.*

Table 5. Critical flow rates in m³/s for design flooding events with climate change scenario SSP5-8.5

	Latrobe River @ Yallourn			Morwell River @ Yallourn		
AEP	**Current and near-term (m³/s)**	**Medium-term (m³/s)**	**Long-term (m³/s)**	**Current and near-term (m³/s)**	**Medium-term (m³/s)**	**Long-term (m³/s)**
50%	90	110	200	60	70	120
5%	610	700	980	300	350	470
2%	930	1050	1400	450	510	670
1%	1210	1350	1760	580	640	830
1 in 200	1450	1640	2180	660	740	940
1 in 500	2020	2250	2940	860	950	1200
1 in 2000	3080	3420	4360	1260	1380	1720

7 Reference

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Nathan, R. & Weinmann E. (2019). Book 2 - Estimation of Very Rare to Extreme Floods in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

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Appendix A
RORB model setup and data

Table A1. Continuous rain gauge details and application for calibration and validation events

		Total rainfall (mm)			Pluviuograph used in sub-catchments		
Gauge	**Data source**	**2015**	**2016**	**2021**	**2015**	**2016**	**2021**
Macalister Murderers Hill	VIC DELWP	51.4	19.6	190.4			
Latrobe Noojee	VIC DELWP	65	57.2	216.6	6,7,8, 11,13,14,52,53	6,7,8, 11,13,14,19,20,23, 52,53	6,7,8, 11,13,14,52,53
Moe Darnum	VIC DELWP	56.4	60.6	107.6	38,39,40,41,42,43,44,45	38,39,40,41,42,43,44,45	38,39,40,41,42,43,44,45
Tanjil Tanjil South	VIC DELWP	57.8	76.2	125.6	1,2,3,46,51,54,55,56,57	1,2,3,46,51,54,55,56,57	1,2,3,46,51,54,55,56,57
Narracan Thorpdale	VIC DELWP	63.2	75.2	102.6	59	59	59
Morwell Boolarra	VIC DELWP	53.2	61.2	205.2	25,26,27,28,29,30,63	25,26,27,28,29,30,63	25,26,27,28,29,30,63
Traralgon Koornalla	VIC DELWP	52.8	66.8	229.2			
Traralgon Traralgon South	VIC DELWP	52.4	49.2	149.8			
Mt Tassie	VIC DELWP	68.8	60.2	327.8			
Traralgon EPA	VIC DELWP	50.4	44.4	88.4			
Balook	VIC DELWP	87.2	74.8	287.2	62	62	62
Moe South	VIC DELWP	55.8	59.4	80.2	37,47,48,49,50	37,47,48,49,50	37,47,48,49,50
Yarragon South	VIC DELWP	67.8	79.4	142.2	58,60	58,60	58,60
Thorpdale Peak	VIC DELWP	66.4	65.6	109.2	34,35	34,35	34,35
Jerralang Dobbins	VIC DELWP	48.8	42.4	278.2	31,32,33,36	31,32,33,36	31,32,33,36
Bells Portal	BOM	-	-	146.2			
Tarago Reservoir	BOM	64	49.4	127.2			
Tarago Drouin West	BOM	49.8	42.2	98.4			
Mt Horsfall	BOM	84	0	293.8	19,20,21,22,24		19,20,21,22,24
Mt St Gwinear	BOM	-	79.2	233.6	9,10,17,18	9,10,12,17,18	10,17,18
Myrrhee	BOM	84.8	0	329.4	12,23		12,23
Nayook	BOM	67.6	70.2	171.6	16,61	16,61	16,61
Tarago River at Neerim	BOM	56.6	59.2	162.2	4,5	4,5	4,5
Thomson Yarra	BOM	68.8	56	391.7		21,22,24	
Parkers Corner	BOM	-	-	186.4			9

Starvation Creek	BOM	66.8	60.2	194.8	15	15	15
Bunyip Iona	BOM	52.4	40.8	51			
Gladysdale Tarrango	BOM	67	44	201.4			

Table A2. Discharge gauge details

	Data Source		
Gauge	**2015**	**2016**	**2021**
Latrobe River @ Noojee	VIC DELWP		
Latrobe River @ Willow Grove	VIC DELWP		
Moe River @ Darnum	VIC DELWP		
Moe Drain @ Trafalgar East	VIC DELWP		
Tanjil River @ Tanjil Junction	VIC DELWP		
Tanjil River @ Tanjil South	VIC DELWP		
Latrobe River @ Yallourn	226400B BOM	226400B BOM	Infilled data (Alluvium 2021)
Morwell River @ Boolarra	VIC DELWP		
Morwell River @ Yallourn	Infilled data (Alluvium 2021) - daily		Infilled data (Alluvium 2021) - continuous
Latrobe River @ Thoms Bridge	VIC DELWP		

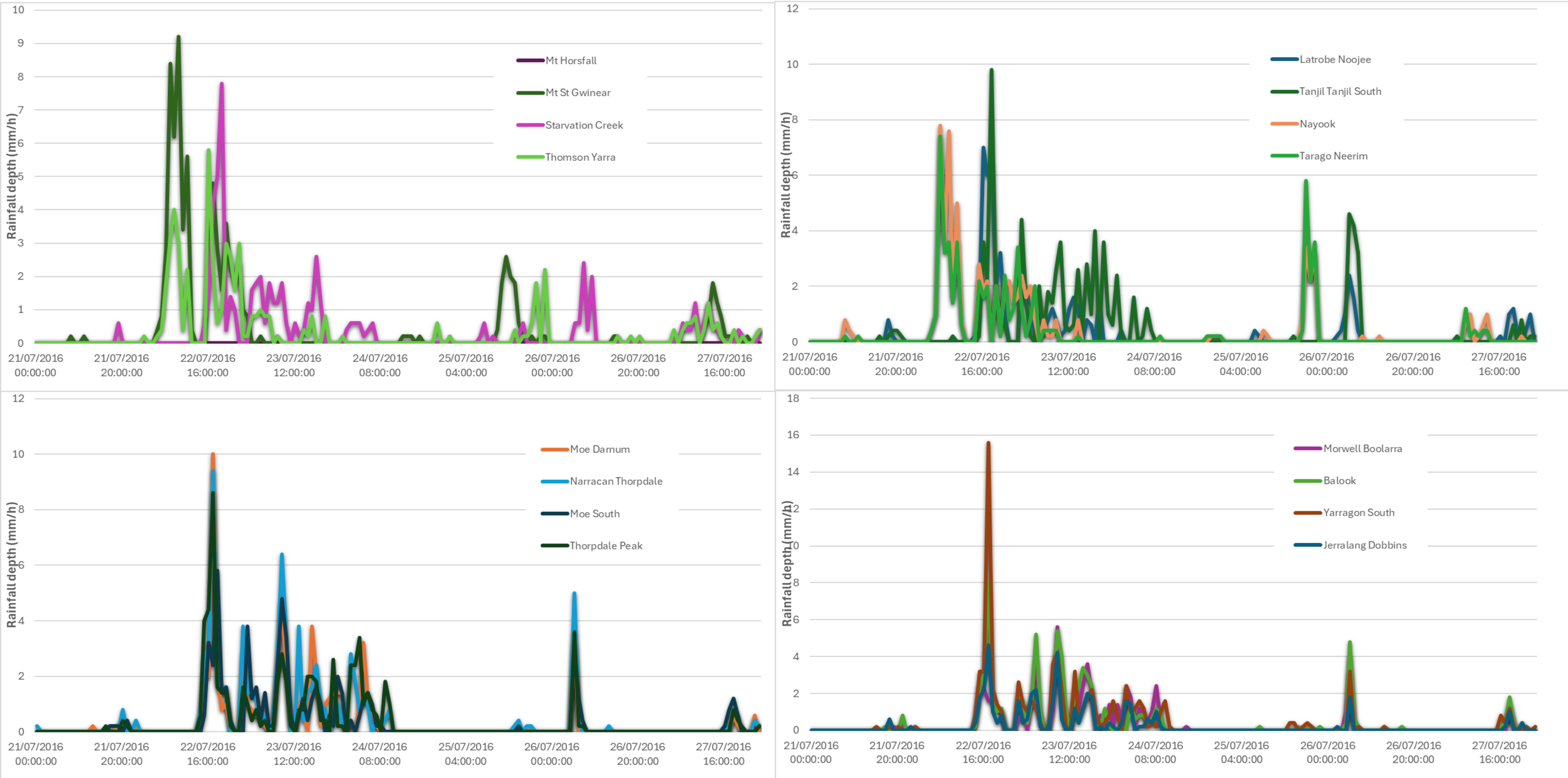


Figure A1. *Pluviographs of various gauges for the 2016 event*

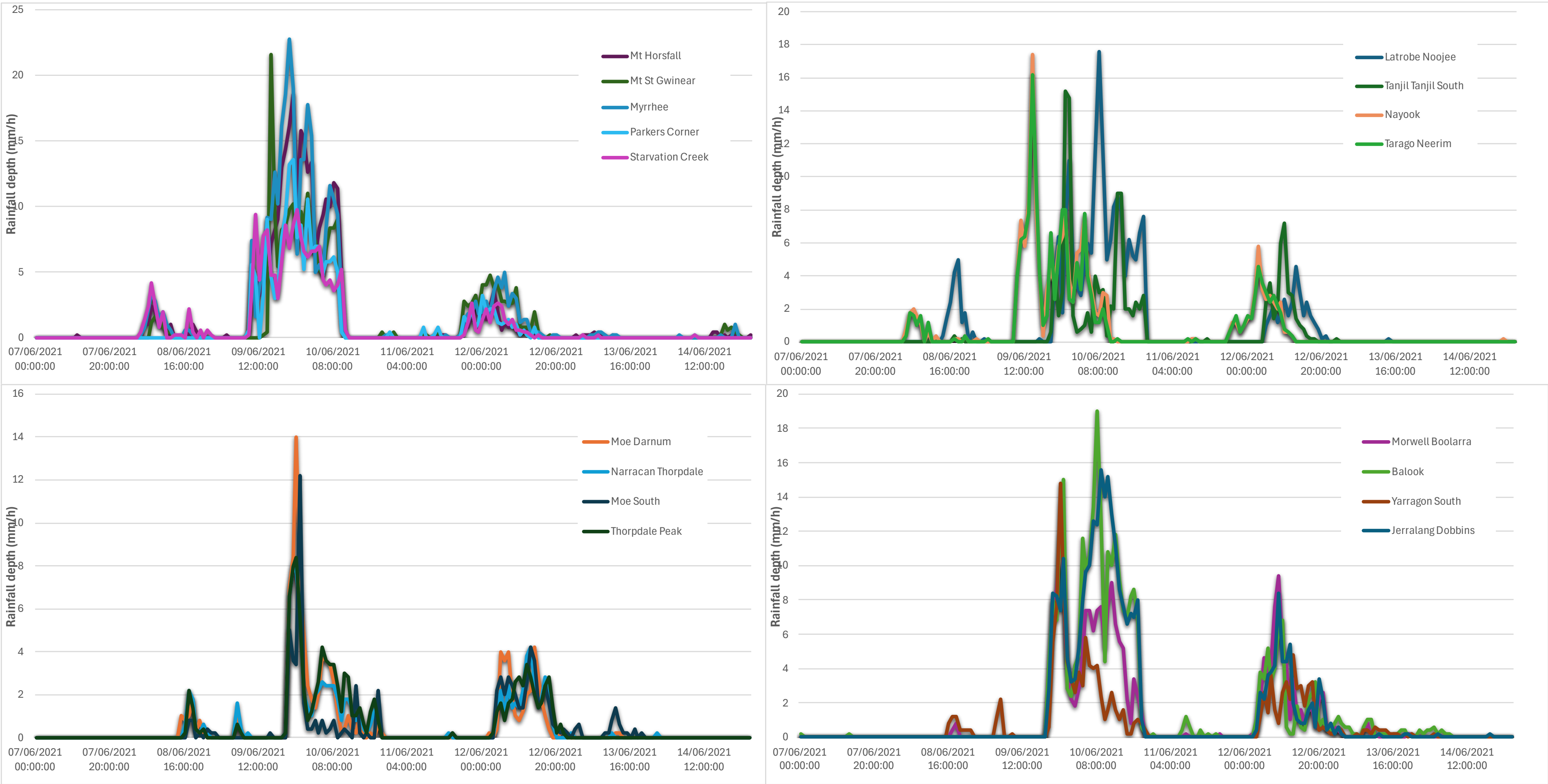


Figure A2. *Pluviographs of various gauges for the 2021 event*

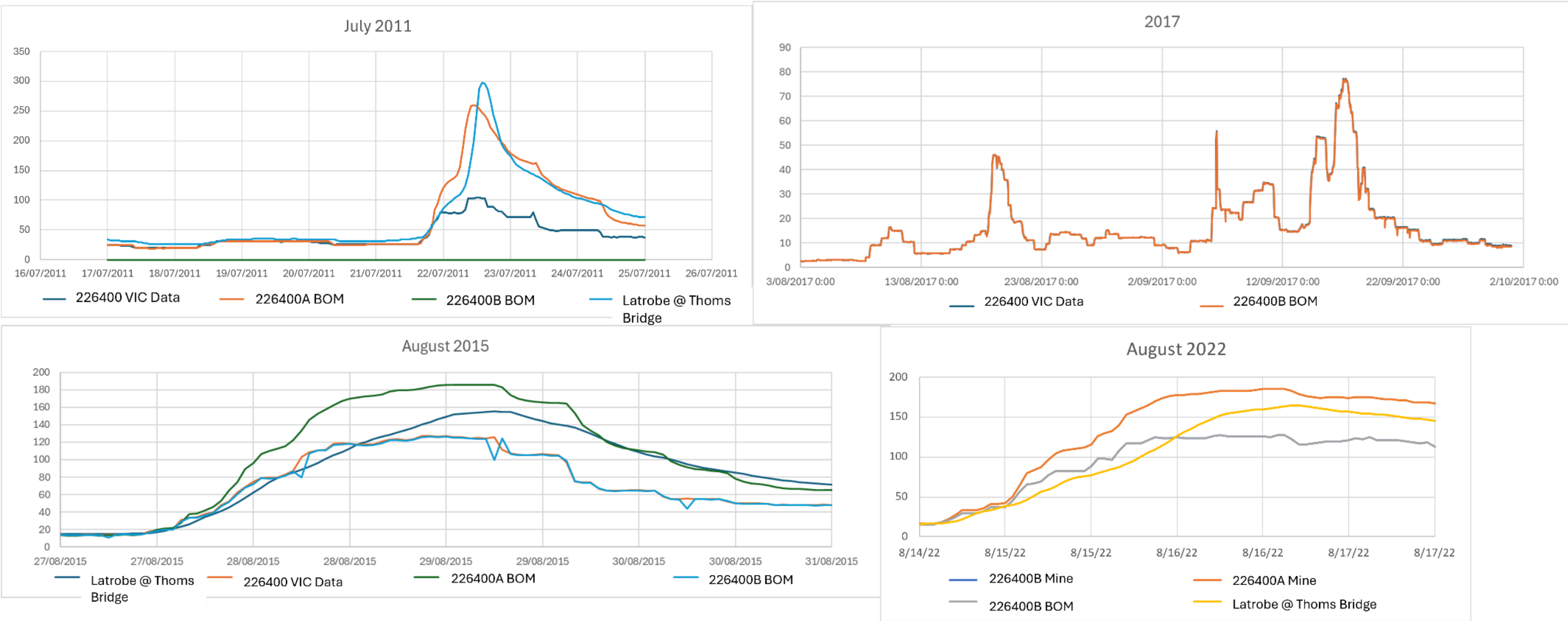
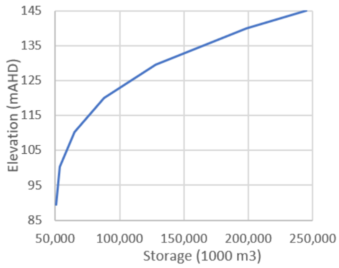
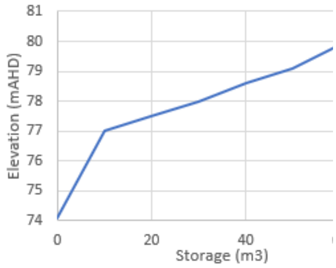


Figure A3. *Comparison of discharges gauges on Latrobe River in context of Yallourn Mine*

Table A3. Reservoir details in RORB models

Reservoir	Blue Rock Lake	Hazelwood Cooling Pond
Discharge relation method	Weir Formula Only	Storage Formula $S = 3600\ k_s Q^{m_s}$
Parameters	1 spillways Kw = 2 Crest elevation = 47.7m Effective length = 16 m	$k_s = 4$; $m_s = 1$
Elevation-Storage Relation		

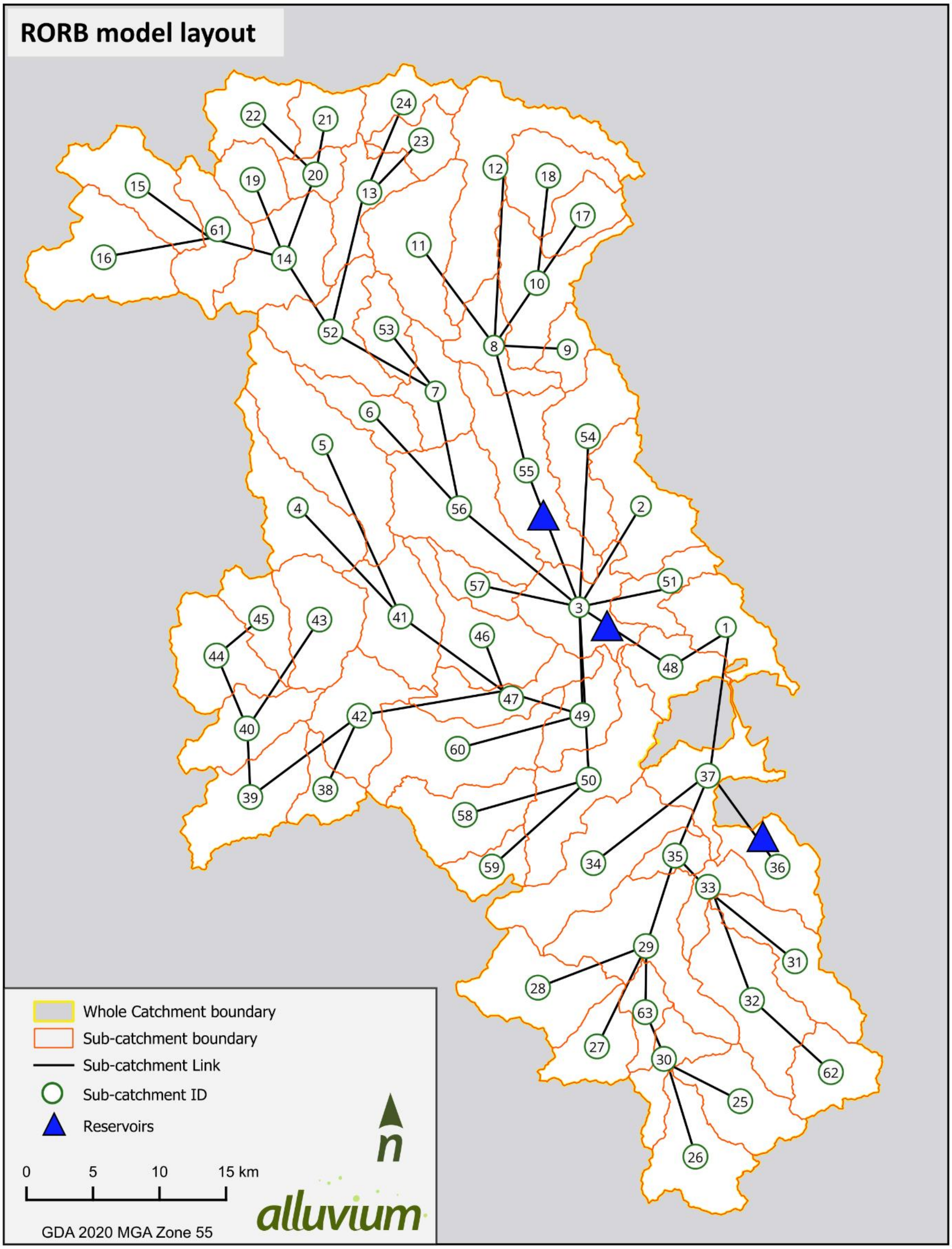


Figure A4. *RORB model layout*

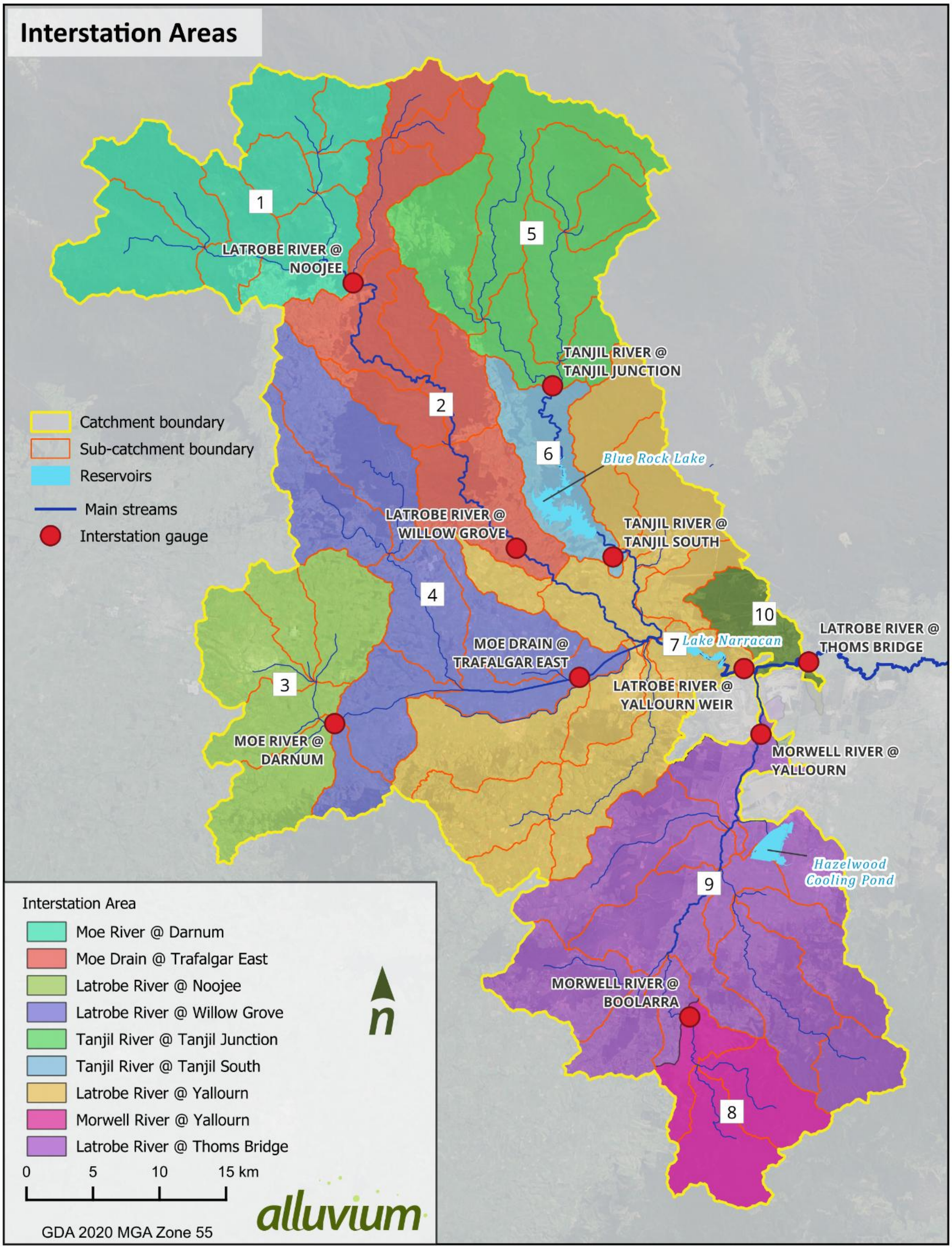
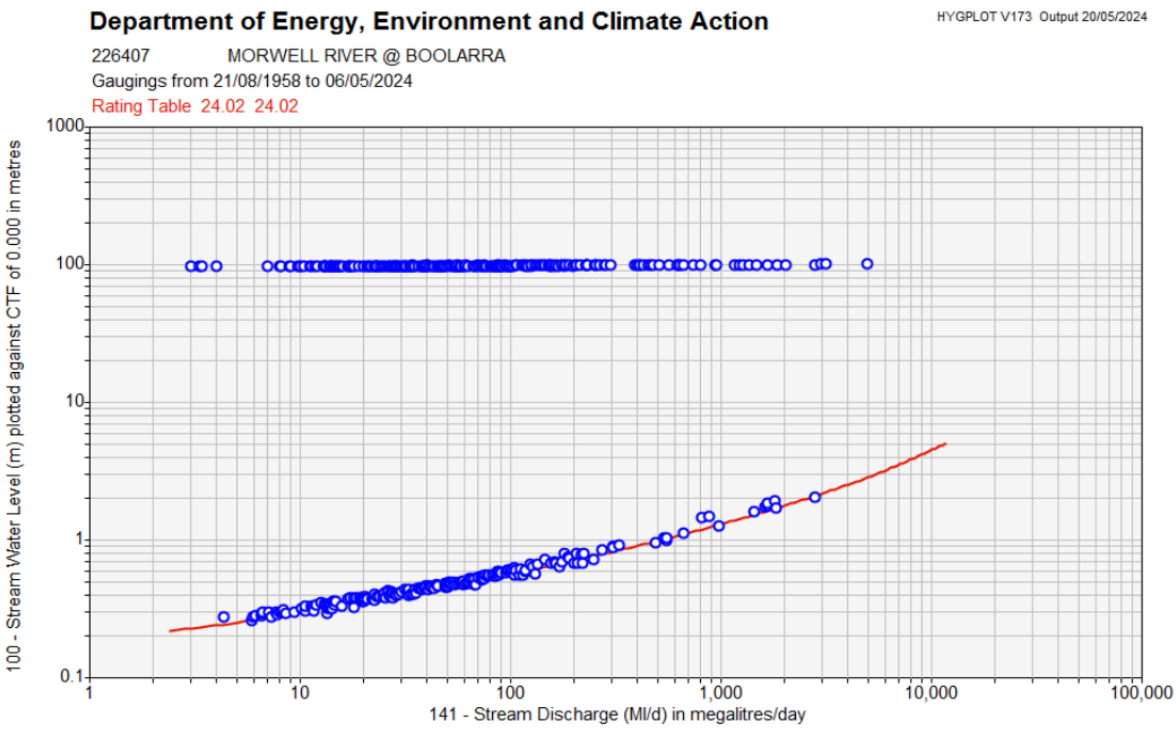


Figure A5. *Interstation areas details*



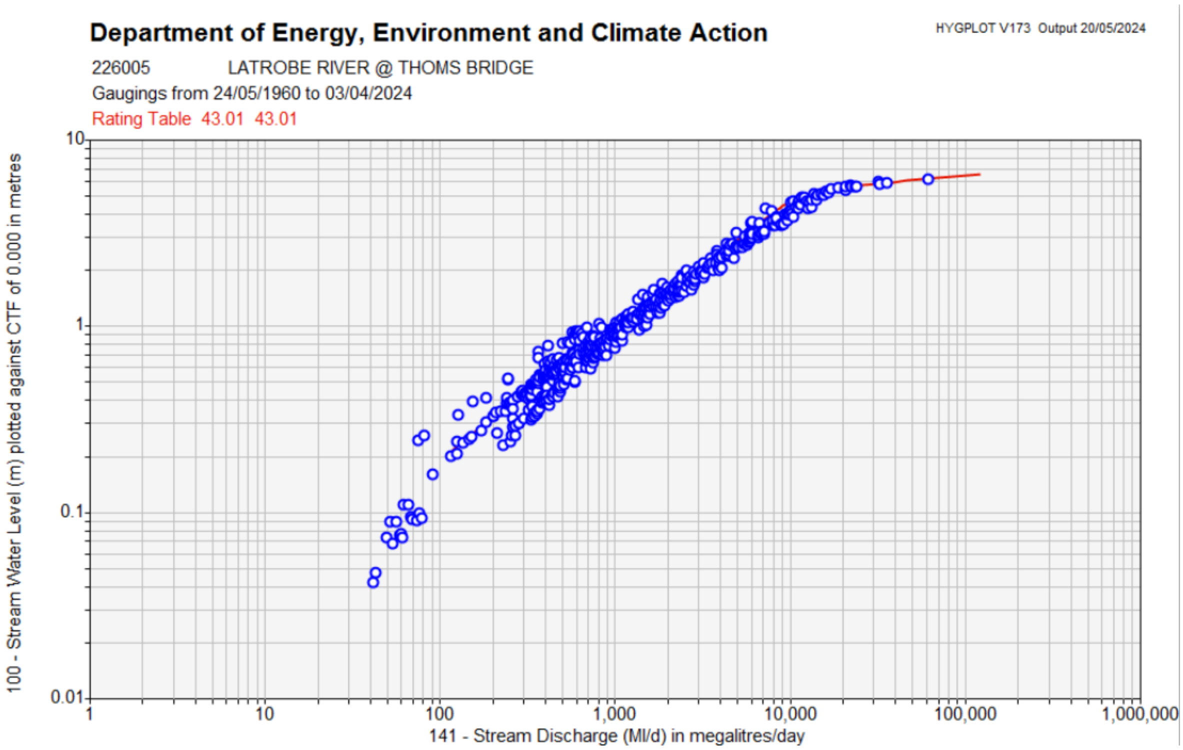


Figure A6. *Rating curves of the Morwell @ Boolarra (upper) and Latrobe @ Thoms Bridge (lower) discharge gauges*

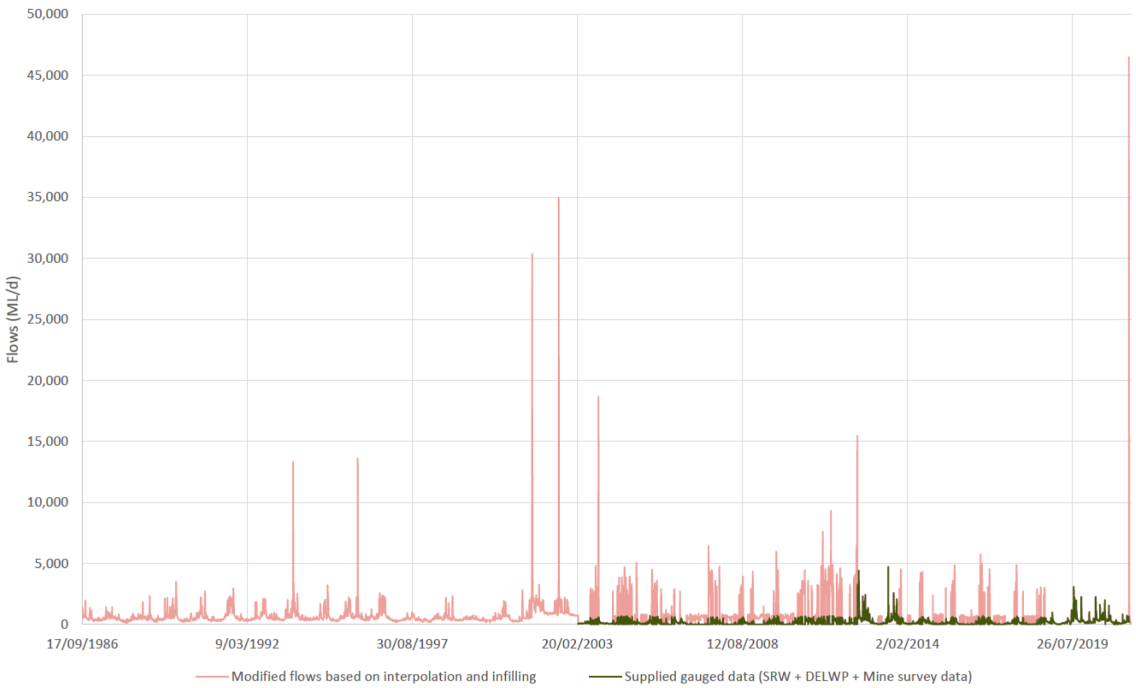


Figure A7. *Copy of Figure 11 in Alluvium (2021) showing the infilled data compared with the gauge data for Morwell @ Yallourn gauge.*

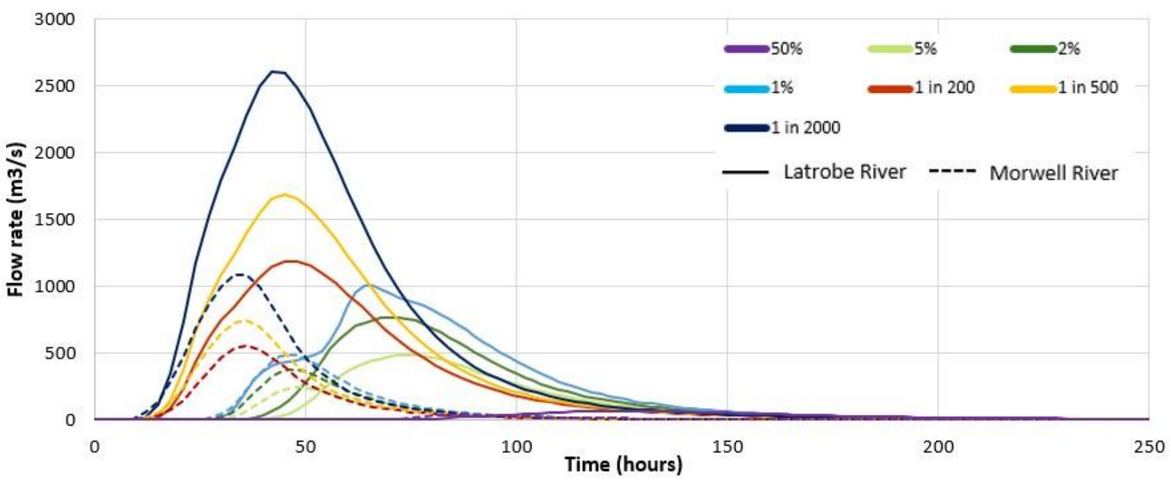


Figure A8 *Combination of the critical hydrographs shown in figures 9 and 10, illustrating the relative magnitude of the flows between Morwell and Latrobe Rivers*

Attachment C_ Yallourn Rehabilitation Assessment - Hydraulic Modelling and Analysis (Alluvium 2025a)

Yallourn Rehabilitation Assessment - Hydraulic Modelling and Analysis

FINAL REPORT

March 2025

alluvium

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

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **Energy Australia Yallourn** under the contract titled 'Surface water modelling assessment'.

Authors: Prawi Woods/Suresh Hettiarachchi/Nicholas Heaney

Review: Stuart Claven
Approved: Stuart Claven

Version: 1d (Final)
Date issued: March 2025
Issued to: Sid Rastogi and Keith Halford, Energy Australia
Citation: Confidential-do not cite this report

Cover image: abstract river image, Shutterstock

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Contents

Figures

Tables

Executive Summary

Alluvium has been engaged by Energy Australia Yallourn (EAY) to investigate surface water matters with respect to proposed mine closure options at the Yallourn mine site, Victoria. This report sets out the approach to and results from hydraulic modelling completed by Alluvium focussed on surface flooding from the Latrobe and Morwell River. This report is presented in the following sections;

1. Introduction
2. Design principles and hydraulic modelling assessment criteria
3. Model update and build
    a. Geometry updates to reflect existing conditions and an extension of the model domain.
    b. Model verification.
4. Results and analysis
    a. Existing conditions modelling results and discussion.
    b. Model iterations and selection of design configuration.
    c. Design conditions modelling results and discussion
5. Existing and design condition comparative analysis
6. Conclusions.

An existing TUFLOW hydraulic model for the Morwell River was adopted and modified for the investigation. The TUFLOW model encompasses the area extending 9 km along the Morwell River and Morwell River Diversion (MRD) upstream of the Morwell and Latrobe Confluence, and 2.5 km of the Latrobe River (upstream of the confluence). The model terminates approximately 9 km downstream of the confluence with the Morwell River. An 8-metre grid size was chosen for the model, striking a balance between computational efficiency and capturing the necessary detail of the Morwell and Latrobe River.

Model summary

Table 1. Summary of hydraulic model modifications

Item	Comments
Existing Hydraulic Models	**Morwell River Diversion (Hazelwood) Hydraulic Model (HARC, 2023)** This model was developed by HARC for Hazelwood Rehabilitation Project. The model explored two scenarios, a baseline model with no offtake weir into the Hazelwood Pit, and a model including an offtake diversion. This model would form the base for the development of the modelling for Yallourn.
Existing Hydrologic Model	A detailed hydrologic model was developed in RORB which modelled the entire catchment to estimate peak flow and provide hydrographs for this hydraulic study (Alluvium, 2024).
Bathymetry	No bathymetric datasets have been used in the modelling to date within the study area. LiDAR capture have typically been captured during periods of low water inundation.
Field Survey	Field survey data have been captured at various locations within the model domain, namely: • Southern Coffer Dam • MRD South • MRD North • Eastern and Western Pits • Pump station This survey data has been used to generate surfaces at these localised sites.
LiDAR	1 m resolution LiDAR captured in 2018 was utilised by the modelling undertaken by HARC and has been retained in this model. This LiDAR was supplemented by 50 cm resolution data captured in 2020 by the Victorian Government and 2023 by the West Gippsland CMA, these areas cover the Latrobe River downstream.
Photogrammetry	In addition to the LiDAR, 10 m resolution photogrammetry DEMs from Elvis provided complete coverage of the study area in areas where there was no LiDAR coverage.
Key hydrometric data	Morwell River at Yallourn (226408), Latrobe River at Yallourn (226400B), Latrobe River at Thoms Bridge (226005) along with flow level data at the MRD Cofferdam, MRD South and MRD North.

Model verification

The updated TUFLOW model was verified by comparing model results to gauge reading for two events. The gauge readings were from two locations on the MRD. One smaller flood and one high flow event were selected to verify the hydraulic model. Gauge recordings (elevation and inferred flow sourced from data.water.vic.gov.au) were used to calibrate the model. The model calibration results for both the high and low flow events show reasonable match to the gauge readings.

Existing conditions modelling

The key findings from the existing conditions modelling results are:

- Peak flood depths in the Morwell River Diversion are dominated by Latrobe led events, reflecting the larger catchment area and peak flow events in the Latrobe River.
- Peak flood levels are contained within the MRD for all events tested including the 0.05% AEP (1 in 2000 year ARI).
- While peak inundation is dominated by Latrobe led events, peak velocity and shear stress through the Morwell River diversion are highest during Morwell led events.

Table 2. Hydraulic modelling results for existing conditions

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Existing conditions peak elevation (m AHD)	Latrobe led	45.3	43.9	43.2	42.6	42.0	40.7	37.4
	Morwell led	43.3	42.3	42.3	41.3	41.0	39.7	37.5
Existing conditions peak velocity (m/s)	Latrobe led	0.9	0.9	0.9	1.0	1.7	0.2	0.7
	Morwell led	2.2	1.9	1.8	1.8	1.8	1.7	0.8
Existing conditions Peak bed shear stress (N/m^2)	Latrobe led	5.6	5.5	6.0	7.9	20.9	0.3	5.4
	Morwell led	27.8	25.6	24.0	22.8	22.3	21.2	7.4

Selection of initial layout for design configuration

A primary purpose of the hydraulic modelling was to develop and assess a potential long-term configuration for the levees and spillways for the MRD and the pits. The intent was to develop an initial configuration that supports the long-term structural integrity of the levees that bound the MRD and investigate how overflows through spillways to and from the pits behave during extreme events. Additionally, consideration is given to not adversely impact environmental water requirements for the system.

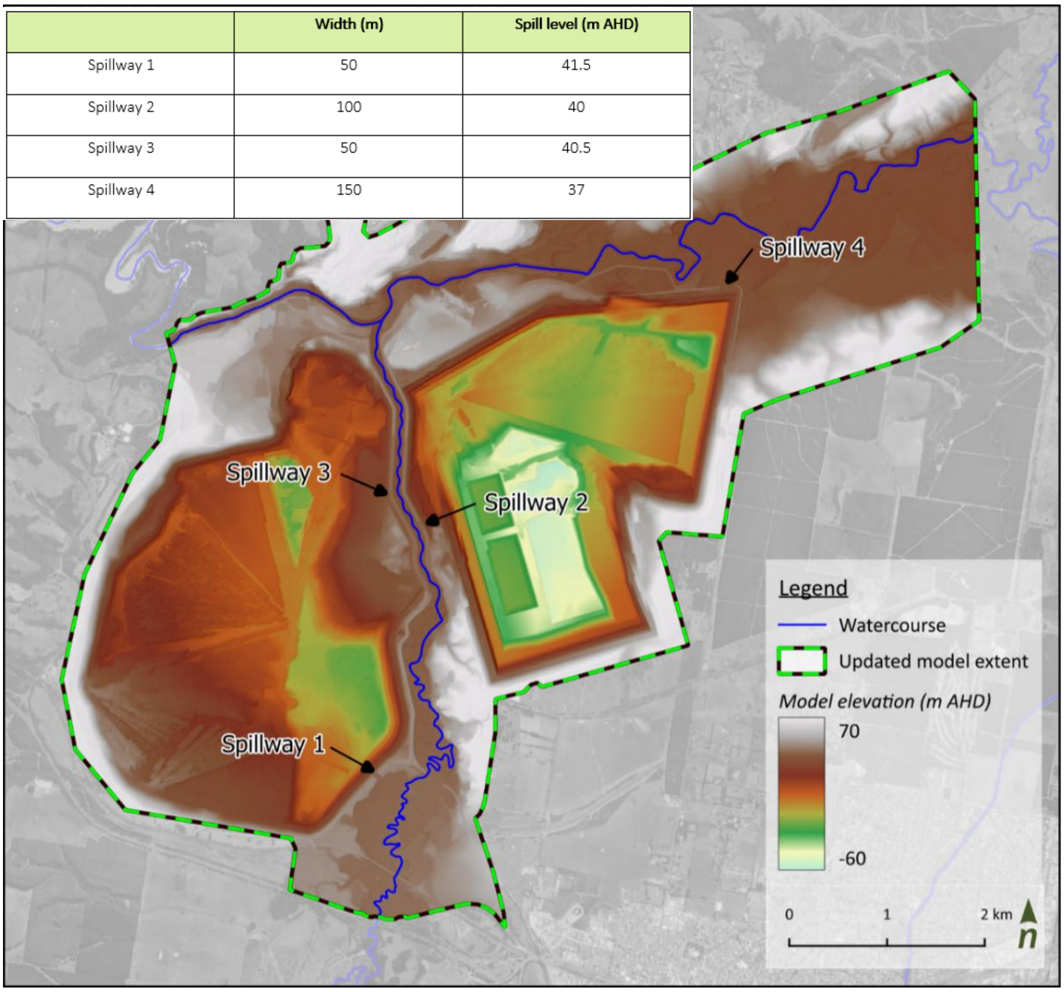
The existing model configuration was modified via trial and error to:

1. Prevent water levels within the MRD rising above elevations that compromise the structural integrity of the MRD. A peak elevation of 42.5m AHD for the 0.05% AEP (1 in 2000 year ARI) event was adopted for this purpose.
    a. Elevation: This water surface elevation was provided by Energy Australia (Yallourn) as an elevation that provides for the ongoing structural integrity of the existing levees adjoining the MRD.
    b. Design event: This design event was selected based on attainment of an acceptable level of risk given the consequence of failure of the structure. Further information on the consequence of failure of the MRD is set out in Alluvium's review of geomorphic and ecological risks associated with the proposed rehabilitation of the Yallourn Mine site.

2. Ensure that events do not create excess differential water surface elevations between the pit lakes on the left (Township Field) and right (East Field) of the MRD. A maximum water differential water surface elevation between the Township Field and the East Field pit lakes of up to 6 metres was adopted for design. This criterion was provided by Energy Australia Yallourn, as that required to prevent excess lateral loads on the MRD that could result in a lateral movement of the MRD.
3. Ensure flood events do not generate erosion of the Morwell River floodplain and hence do not lead to erosion led failure of the adjoining levees and related infrastructure. A maximum velocity of 1.8m/s and shear stress of 80 N/m^2 (the maximum permissible velocity and shear stress for tall native bunch grasses, refer Fischenich 2001 Impacts of Stabilisation Measures) were adopted for the design.
4. Ensure that any such configuration does not divert flow from the Morwell or Latrobe Rivers that impacts on environmental water requirements of the Latrobe River system (including the Latrobe River). Spillways to be set at elevations that ensure that flow rates in the Latrobe and Morwell River exceed 3,200 ML/day before any water is captured by the pit lake. This flow rate is required to ensure the flushing of the Latrobe River estuary of salt water at the current offtakes for the watering of the Dowd Morass and the Heart Morass on the lower Latrobe River.

The placement and sizing of the proposed spillways that control the flow in and out of the pits are presented below (Figure 1). The design configuration comprises

1. Two spillways from the MRD to the East Field
2. One spillway from the MRD to the Township Field
3. One Spillway from the East Field to the Latrobe River
4. Modification of the existing tunnels under the MRD to equalise water levels between the



	Width (m)	Spill level (m AHD)
Spillway 1	50	41.5
Spillway 2	100	40
Spillway 3	50	40.5
Spillway 4	150	37

Figure 1. *Preliminary design configuration arrangements that were assessed*

Preliminary design arrangement modelling results

Similar to existing conditions, the hydraulic modelling revealed flood levels to be dominated by the Latrobe led events, while the flow velocities and the resulting bed shear stresses in the MRD are more relevant during Morwell led events. The hydraulic modelling has revealed:

- Attainment of a maximum water surface elevation of approximately RL42.5m AHD for the 0.05% AEP (1 in 2000 year ARI) event i.e. consistent with the design criteria for maximum water levels within the MRD.
- Maximum difference in head between Township Field and the East Field pits of 3.3 metres during flood events. i.e. less than that required to prevent lateral movement of the MRD
- Velocity and shear stress that do not exceed:
  - that identified for the existing conditions
  - the non-scour velocity and shear stress for native bunch grasses

  Note the maximum shear stress in the following tables has been quoted for the MRD floodplain not in the immediate vicinity of the proposed spillways.
- Spillway 1 being the most upstream along the MRD and is engaged at 50% AEP (approx.) event in the Morwell River at 3,500ML/day (approx.). i.e. in excess of that required to flush the Latrobe River estuary of salt water at the points of inflow to Lake Wellington's fringing wetlands (Heart Morass and Dowd Morass). Note that current modelling assumes a coincidental 50% AEP flow in the Latrobe River, which provides and additional level of a conservative estimate.

Table 3. Hydraulic modelling results for design conditions

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Preliminary design conditions peak elevation (m AHD)	Latrobe led	42.5	42.1	41.7	41.4	41.1	40.4	36.9
	Morwell led	41.3	41.3	41.3	40.5	40.5	38.7	36.9
Preliminary design conditions peak velocity (m/s)	Latrobe led	1.5	1.1	0.8	0.5	1.3	0.1	0.6
	Morwell led	1.8	1.7	1.7	1.7	1.6	1.4	0.7
Preliminary design conditions Peak bed shear stress (N/m^2)	Latrobe led	12.5	7.1	5.9	7.5	19.1	0.5	5.3
	Morwell led	27.3	25.0	24.0	23.5	22.9	20.9	6.7

The hydraulic modelling has also revealed shear stress and velocity outcomes on, and in the immediate vicinity of the proposed spillways that exceed the design criteria. Further assessment and design effort will be required to develop configuration arrangements that ensure the long-term performance of these structures. In addition, the velocity and shear stress criteria for vegetated surfaces are a function of the duration of events, with decreasing performance with increasing duration of inundation. Further investigations will be required to confirm the event longevity of any proposed vegetative arrangements for MRD instream and floodplain erosion control.

1 Introduction

Alluvium has been engaged by EnergyAustralia Yallourn (EAY) to investigate surface water arrangements associated with the Morwell River Diversion (MRD) at Yallourn as part of wider investigations undertaken by EAY with respect to the proposed rehabilitation and closure of the Yallourn mine site, Victoria. This report sets out the approach and results from hydraulic modelling completed by Alluvium focussed on surface flooding from the Latrobe and Morwell Rivers (Figure 2).

Alluvium is one of several engineering, environmental, geotechnical and academic service providers engaged in supporting the development of mine closure land arrangements works at the site. The group is addressing a spectrum of concerns, notably the geotechnical and hydro geotechnical stability of long-term mine batters during flooding conditions along with maintaining minimum environmental flows through the Mowell River Diversion (MRD).

For the purposes of this report, the hydraulic modelling extents include the Morwell River Diversion, the Township Field and East Field pits and the Latrobe River in the vicinity of the Morwell River confluence (refer Figure 2). The hydraulic model inflows have been based on catchment hydrologic modelling developed by Alluvium (refer 'Yallourn Rehabilitation Assessment – Hydrological modelling', June 2024). The hydraulic modelling has been used to inform decisions related to landform and mine rehabilitation options. This document presents the development of the hydraulic model within the context of the Yallourn Mine Rehabilitation Project along with results and analysis for existing and proposed design configurations. The hydraulic model builds on an existing model created for the Morwell River Diversion at Hazelwood (HARC, 2023)(Figure 3).

The hydraulic model (HARC, 2023) was modified and extended to include the section of the reach where the Morwell River enters the Latrobe River as well as extending the Latrobe River reach 9 km downstream from the confluence (Figure 2). Hydraulic structures, including crest lines and relevant culverts, as well as updated LiDAR data were integrated to update the previous model. The model also utilises the most recent TUFLOW solver and employs sub grid sampling which increases the accuracy and speed of the model runs. Further information on the data used, model domain expansion, hydraulic structures, terrain data, and TUFLOW solver upgrades are set out in the report. The model was verified using historic flood data along the MRD and Latrobe River. The verified existing conditions model was run for a series of design events after which the model was modified to reflect an initial layout of the design conditions. The design condition model was also run for the same series of design events to build a matrix of modelling results showing depth, velocity and bed shear stress along the MRD.

2 Design principles and hydraulic modelling assessment criteria

The hydraulic modelling set out in this report has been undertaken to investigate and analyse the existing hydraulic conditions and a proposed design scenario for the MRD. The modelling has including the complex flow connections into the pits from the Morwell River, flows between the pits, and outflows from the pits. Analysis of these flow behaviours and hydraulic parameters (depth, elevation, shear stress and velocities) have been undertaken and used to assess a *Partially Connected Morwell River Option* against the key hydrologic, geomorphic and ecological function design principles defined in in *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine* (Alluvium 2024b). These include:

- Hydrologic, geomorphic and ecological functioning.
  - Hydrologic regime. The arrangement should provide for both:
    - longitudinal hydrologic connectivity
    - lateral floodplain connectivity
  - Geomorphic processes. The arrangement should:
    - not be subject to accelerated high rates of erosion and deposition
    - be robust i.e. resistant to change and have the ability to adapt and repair following change without comprising the other values and outcomes
    - provide for ongoing longitudinal and lateral bed load sediment movements
  - Ecological condition and processes
    - Provides for ongoing benthic ecological processes
    - Meets instream and riparian habitat and transfer (e.g. fish passage) requirements

Additionally, a number of key design stability conditions have been identified through EnergyAustralia Yallourn led risk workshops including the potential for the catastrophic failure / collapse of the MRD associated with ongoing channel and embankment stability. The purpose of the proposed modifications to the MRD is to increase the robustness of the MRD to increase confidence in its ongoing functionality as part of the rehabilitated landscape at Yallourn. The adopted hydraulic intent and performance criteria for the MRD are set out below.:

1. Prevent water levels within the MRD rising above elevations that compromise the structural integrity of the MRD. A peak elevation of 42.5m AHD for the 1 in 2000 year ARI event was adopted for this purpose.
   a. Elevation: This water surface elevation was provided by Energy Australia (Yallourn) as an elevation that provides for the ongoing structural integrity of the existing levees adjoining the MRD.
   b. Design event: This design event was selected based on attainment of an acceptable level of risk given the consequence of failure of the structure. Further information on the consequence of failure of the MRD is set out in Alluvium's review of geomorphic and ecological risks associated with the proposed rehabilitation of the Yallourn Mine site.
2. Ensure that events do not create excess differential water surface elevations between the pit lakes on the left (Township Field) and right (East Field) of the MRD. A maximum water differential water surface elevation between the Township Field and the East Field pit lakes of up to 6 metres was adopted for design. This criterion was provided by Energy Australia Yallourn, as that required to prevent excess lateral loads on the MRD that could result in a lateral movement of the MRD.
3. Ensure flood events do not generate erosion of the Morwell River floodplain and hence do not lead to erosion led failure of the adjoining levees and related infrastructure. A maximum velocity of 1.8m/s

and shear stress of 80 N/m^2 (the maximum permissible velocity and shear stress for tall native bunch grasses, refer Fischenich 2001 Impacts of stabilisation measures) were adopted for the design.

4. Ensure that any such configuration does not divert flow from the Morwell or Latrobe Rivers that impacts on environmental water requirements of the Latrobe River system (including the Latrobe River). Spillways to be set at elevations that ensure that flow rates in the Latrobe and Morwell River exceed 3,200 ML/day before any water is captured by the pit lake. This flow rate is required to ensure the flushing of the Latrobe River estuary of salt water at the current offtakes for the watering of the Dowd Morass and the Heart Morass on the lower Latrobe River.

Investigations have been undertaken to assess the proposed project against these criteria.

3 Model Build/update

3.1 TUFLOW model Overview

This study employed TUFLOW (build 2023-03-AC) for hydraulic modelling of the Morwell and Latrobe River in the context of the Yallourn Mine. Due to the desired fine grid resolution and efficient simulation times, the model was run using the HPC (Heavily Parallelised Computing) numerical scheme. The HPC scheme allows for an adaptive timestep determined based on three control factors: Courant Number, Shallow Wave Celerity Number, and Diffusion Number. These factors ensure numerical stability and accuracy during the simulation.

An additional feature employed in the model is TUFLOW Sub-Grid Sampling. This allows the model to incorporate the detailed information from the underlying LiDAR data, even when using a coarser grid size overall. This improves the model's ability to represent the conveyance and storage characteristics of the Morwell and Latrobe River. TUFLOW is an industry standard hydraulic modelling platform in Australia and was deemed suitable for this project. The following sections document the updates to the existing hydraulic model and presents preliminary results from design event simulations.

3.2 Data updates

Table 4 provides a summary of the relevant existing datasets available in the study area.

Table 4. Summary of data collected

Item	Comments
Existing Hydraulic Models	Morwell River Diversion Hydraulic Model (HARC, 2023) This model was developed by HARC for Hazelwood which explored two scenarios, a baseline model with no offtake weir, and a model including an offtake diversion. This model has formed the base for the development of the modelling for Yallourn.
Existing Hydrologic Model	A detailed hydrologic model was developed in RORB modelled the entire catchment to estimate peak flow and provide hydrographs for this hydraulic study (Alluvium, 2024).
Bathymetry	No bathymetric datasets have been used in the modelling to date within the study area. LiDAR capture have typically been captured during periods of low water inundation.
Field Survey	Field survey have been captured at various locations within the model domain, namely: • Southern Coffer Dam • MRD South • MRD North • Eastern and Western Pits • Pump station This survey data has been used to generate surfaces at these localised sites.
LiDAR	1 m resolution LiDAR captured in 2018 was utilised by the modelling undertaken by HARC and has been retained in this model. This LiDAR was supplemented by 50 cm resolution data captured in 2020 by the Victorian Government and 2023 by the West Gippsland CMA, these areas cover the Latrobe River downstream.
Photogrammetry	In addition to the LiDAR, 10 m resolution photogrammetry DEMs from Elvis provided complete coverage of the study area in areas where there was no LiDAR coverage.
Key hydrometric data	Morwell River at Yallourn (226408), Latrobe River at Yallourn (226400B), Latrobe River at Thoms Bridge (226005) along with flow level data at the MRD Cofferdam, MRD South and MRD North.

3.3 Details of model domain and topography

Figure 2 shows the updated hydraulic model boundary for this study. The TUFLOW model encompasses the area extending 9 km along the Morwell River upstream of the Morwell and Latrobe Confluence, and 2.5 km of the Latrobe River (upstream of the confluence). The model terminates approximately 9 km downstream of the confluence. An 8-metre grid size was chosen for the model, striking a balance between computational efficiency and capturing the necessary detail of the Morwell and Latrobe River.

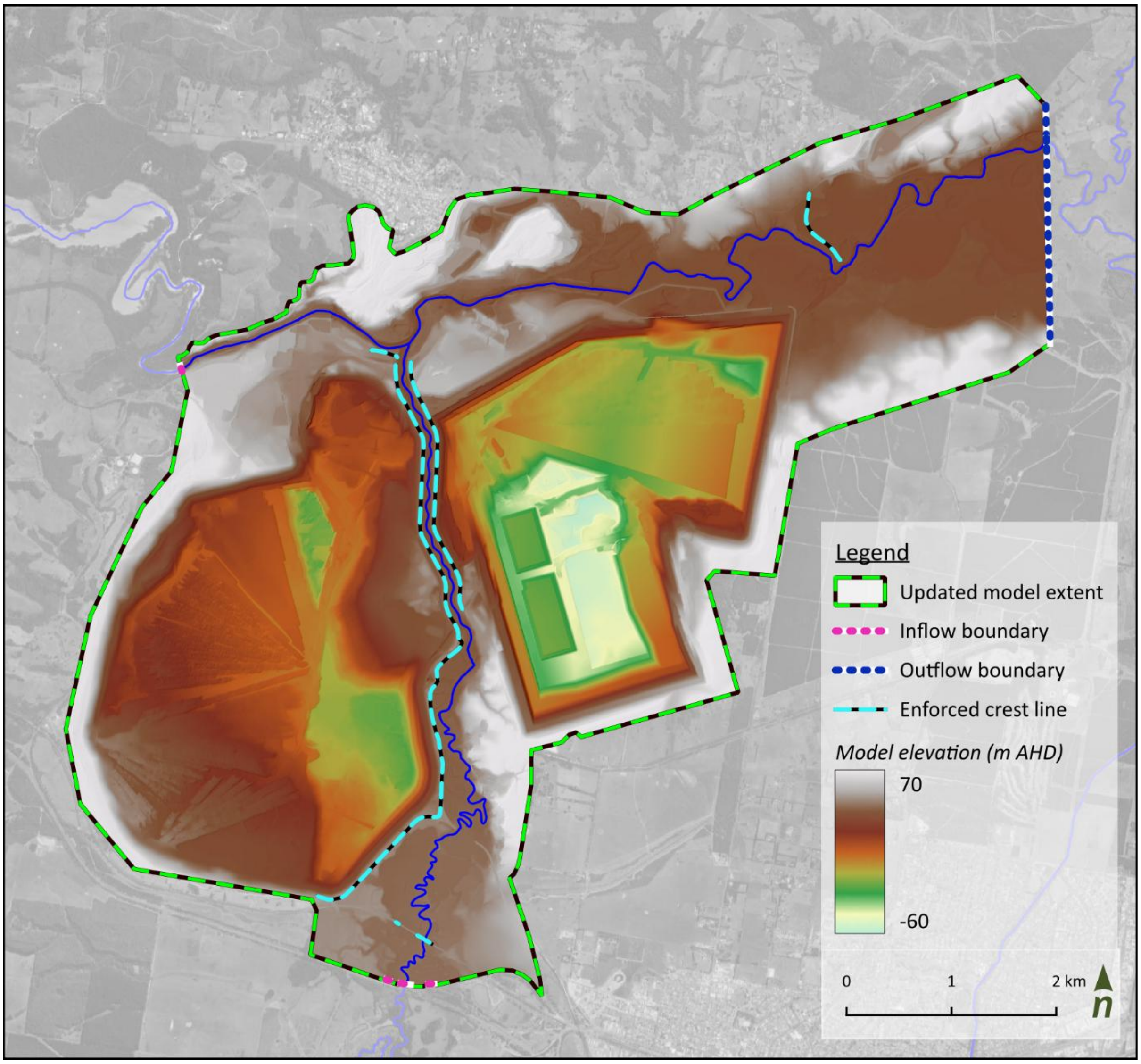


Figure 2. *Model topography and locations of hydraulically enforced crest lines*

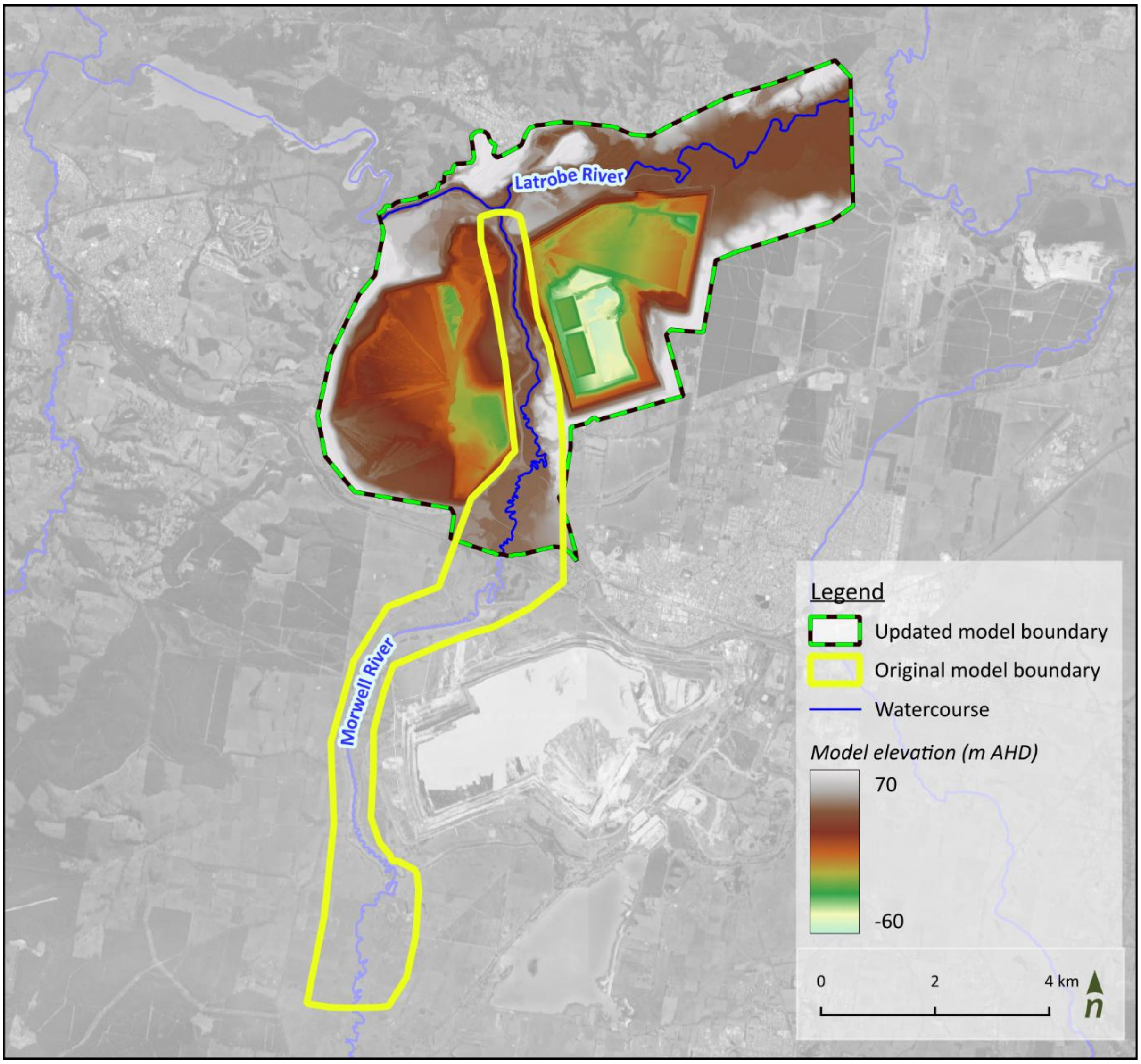


Figure 3. *Original and updated TUFLOW model boundary (Model developed to assess hydraulics within the Morwell River Diversion (MRD))*

3.4 Sub-grid sampling

To leverage the high-resolution LiDAR data within the model, TUFLOW Sub-Grid Sampling was employed with a sampling frequency of 9. Sub-grid sampling allows the model to more accurately represent the storage and conveyance that is possible within the system being modelled.

3.5 Initial estimate of Manning's 'n' values

Initial estimates of Manning's n coefficients, which represent surface roughness, were assigned to different land cover types within the model (refer to Table 5 and Figure 4 for details). The manning's values were parameterised based on values provided in Book 6 of ARR 2019 (Ball et al, 2019). These values are:

Table 5. Initial Manning's n values

Description	Manning's n
Residential	0.35
Pasture/Cultivated area	0.03
Light brush and trees	0.06
Forested	0.12
Body of water	0.035
Gravel	0.03
Waterway	0.03

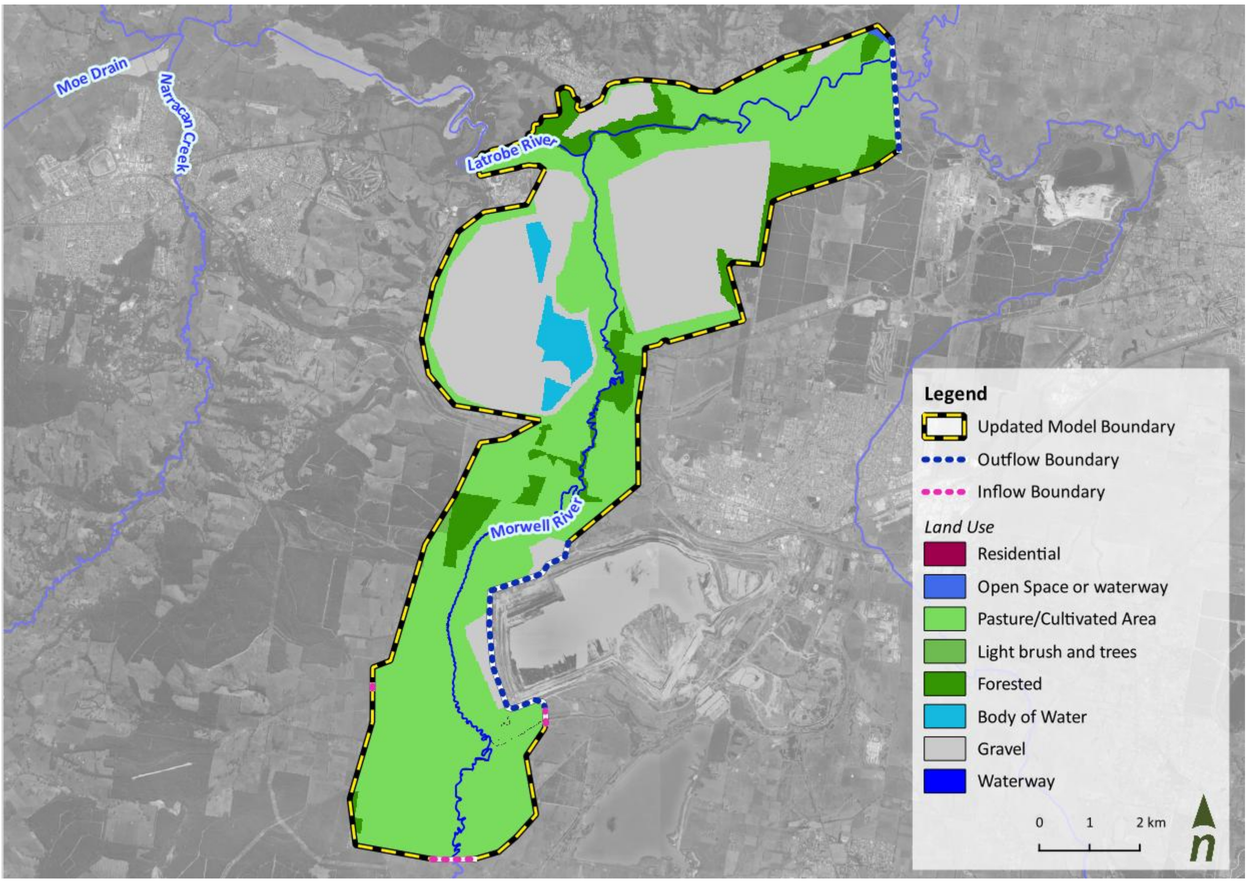


Figure 4. *Assigned landuse*

3.6 Topographic modifications

Hydraulically significant crest lines were incorporated into the model to ensure that embankments are adequately represented in the model and prevent premature spilling, particularly along the Morwell embankments to the adjacent pits.

Table 6. Modelling setup summary

Parameter	Description	Value/Source
Modelling software	Hydraulic modelling software	TUFLOW (build 2023-03-AC)
Numerical scheme	Model simulation scheme	Heavily Parallelised Compute (HPC) with Sub Grid Sampling (SGS)
Timestep control factors	Factors for Adaptive Timestep	Courant Number, Shallow Wave Celerity Number, Diffusion Number
LiDAR Data Source	Source of topographic information	1 metre resolution LiDAR captured in 2018 supplemented with high resolution 50 cm LiDAR along the Latrobe captured in 2020 and 2023
Inflow data	Modelled Inflow Values	Design RORB hydrographs 50% AEP, 5% AEP,2% AEP,1% AEP, 0.5% AEP (1 in 200 year ARI), 0.2% AEP (1 in 500 year ARI), 0.05% AEP (1 in 2000 year ARI)
Vegetation data source	Source of Land Cover Information	Aerial imagery
Model domain	Geographic Extent	18 km upstream of the Morwell and Latrobe confluence, capturing 9 km of the Latrobe River downstream.
Grid size	Model cell resolution	8 metres
Sub-grid sampling frequency	Sampling resolution for LiDAR Data	9 (Approx. 1 meter sampling distance)
Topographic modifications (survey data, spillways and crest lines)	Representation in Model	Z shapes for hydraulically sensitive topographical features and spillways. Survey data for features such as MRD and pump station converted to surfaces and incorporated into model.

As noted in Table 6, details of the Southern Crossing (SC) and Northern Crossing (NC) were added to the model. The culvert crossings detailed were provided by EA and were added as 1D model elements. The locations of the NC and SC are shown in Figure 5.

Figure 5. *Model topography at region around MRD with crossing locations shown*

3.7 Model Verification

Model verification (calibration) is undertaken to ensure that the hydraulic model produces results that reflect that which can be expected in the field. The process for model verification is to iterate the model by adjusting model parameters until modelled results are consistent with observed results. Our modelling experience has shown that Manning's n roughness values are the primary parameter that needs to be varied during TUFLOW model verification. Mannings 'n' roughness values are associated with the land cover data used in the model and indicate the level of resistance to flow during flood events. Secondary factors that are considered are downstream boundary conditions and accuracy of model representation and losses at hydraulic structures.

We used both a low flow and a high flow event for the model verification process to ensure that the model is suitable for assessment of low flow conditions as well as flood flows. The inflow hydrographs used for model verification were extracted from gauges located upstream of the project site while depth gauge data provided by EAY was also used to verify model results for the selected events. The process and steps followed for model verification is described below.

Selection of verification flood events

One smaller flood in September 2017 and one higher flood event in June 2021 were selected to calibrate and verify the hydraulic model. Available gauge station recordings of flow depth and inferred flow rate (data.water.vic.gov.au) were used as inputs to the model for both the Morwell River and Latrobe River (Figure 6 and Figure 7). Depth data on the MRD were extracted from two gauges that are located at the norther and southern crossing (NC and SC respectively) to calibrate the model. It is worth noting that the event of June 2021 was the largest event on record for the area.

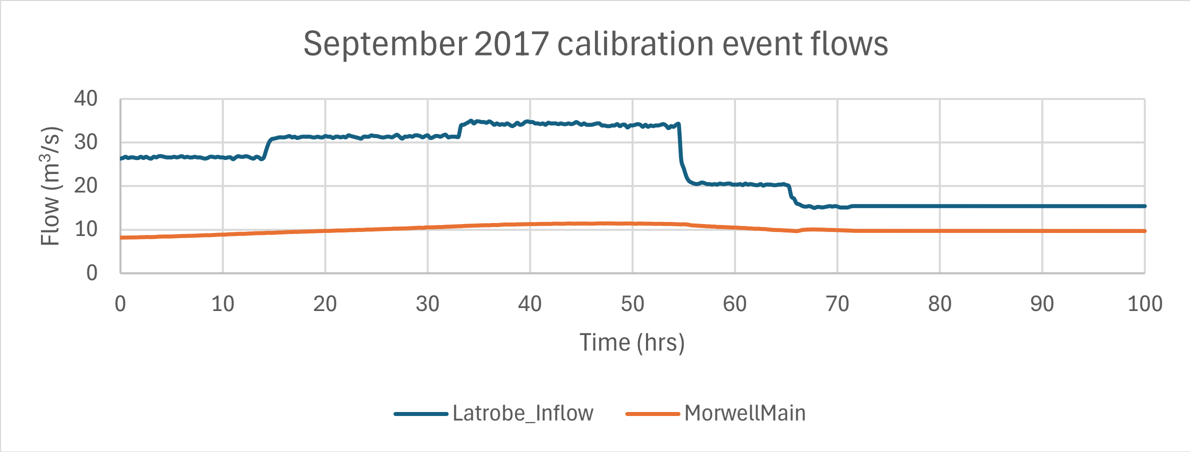


Figure 6. *September 2017 inflow hydrographs on the Latrobe and Morwell rivers*

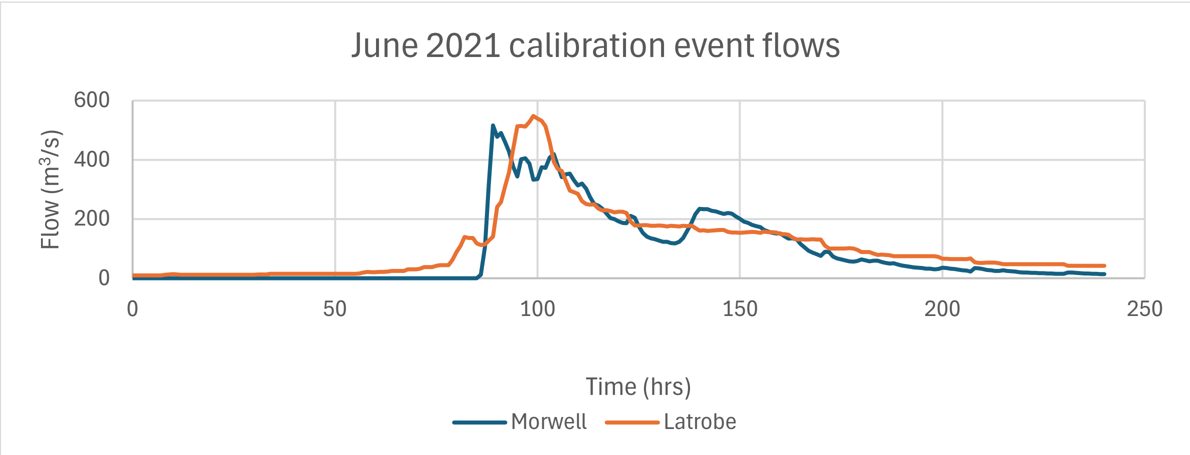


Figure 7. *June 2021 Flow hydrographs for Latrobe and Morwell rivers*

Model verification for 2021 event

Initial modelling results for the 2021 event indicated higher levels when compared to the gauge reading at the SC and NC. After checking and updating to make sure that the geometry of the model accurately represented the modelling conditions, Manning's n for the land cover layer was adjusted. The antecedent conditions were also considered by looking at the flow and depth data for a period prior to the June flood event. The gauge data indicated that it was most likely dry over an extended period that would result in less vegetation in the area. Review of aerial images confirmed that there was a lower level of vegetation, and forested area during the period prior to this event. As such manning's n values were refined to better represent the ambient conditions during and prior to the flood event (Table 7). Knowing that the levels in the MRD is highly influenced by the flood levels on the Latrobe River, the Manning's n values along the floodplain of the Latrobe River were also carefully refined to reflect the land cover conditions for June 2021. The geometry of the bridges/structures and flow restrictions along the Latrobe River downstream of the confluence were also refined. Subsequent to these adjustment to Manning's n values, the modelling results were a close match to the gauge readings at the NC, with some discrepancies at the SC (Figure 8).

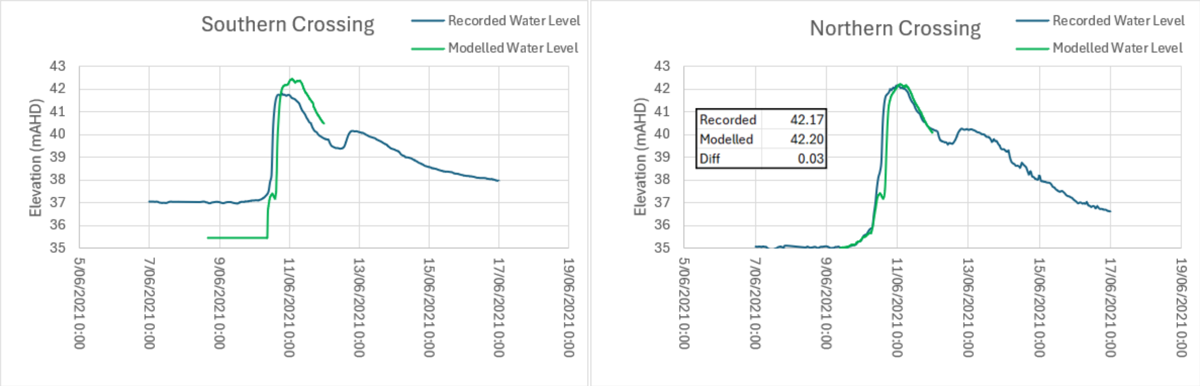


Figure 8. *Comparison of modelled and gauge levels during June 2021 event at the SC and NC*

Table 7. Adjusted Mannings n values used for June 2021 event modelling

Description	Manning's n AR&R 2019	Manning's n June 2021
Pasture/Cultivated area	0.35	0.03
Light brush and trees	0.03	0.055
Forest	0.06	0.08
Dense Forest	0.12	0.12
Body of water	0.035	0.035
Gravel	0.03	0.03
Waterway (MRD)	0.03	0.03
Waterway (Latrobe)	0.35	0.035

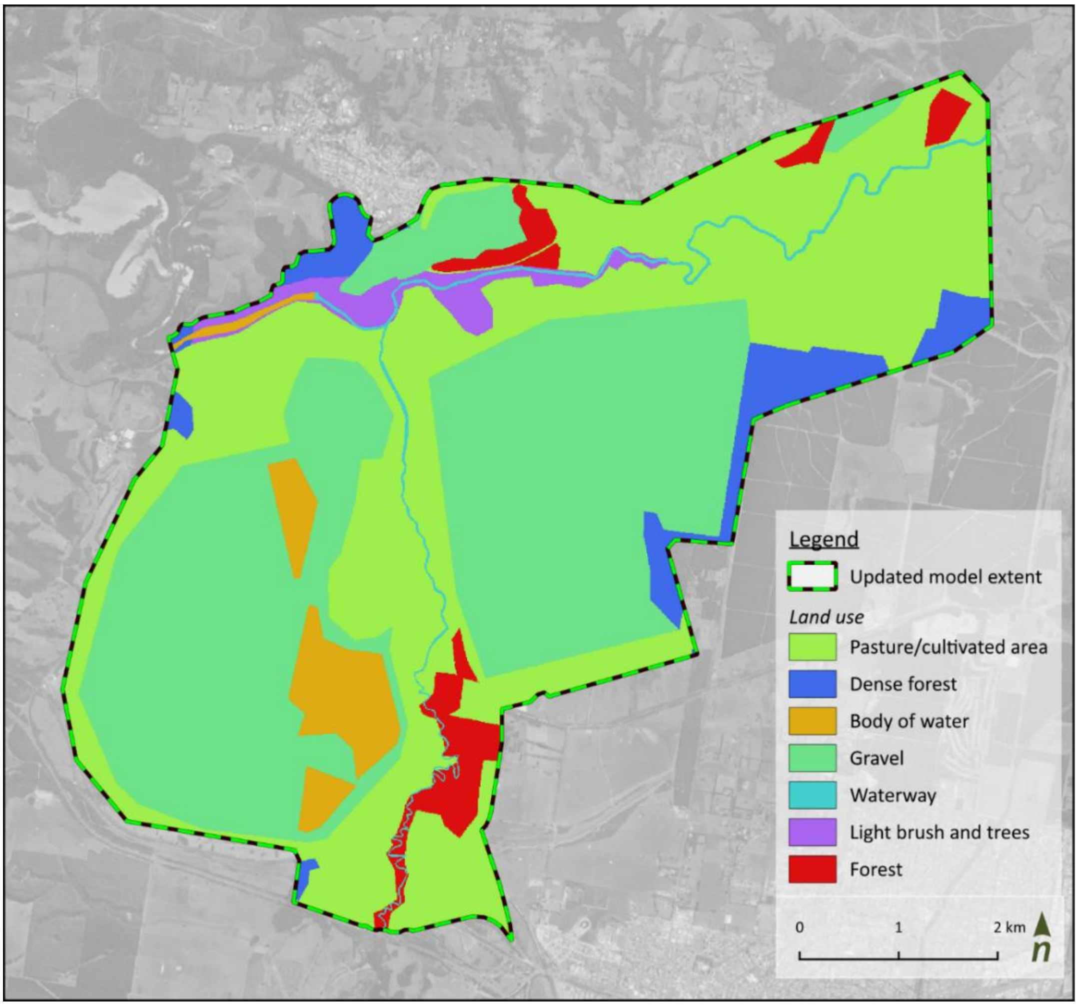


Figure 9. *Land use areas used for the validation, existing conditions and design conditions modelling*

As part of the calibration exercise, we also investigated a potential data anomaly between SC and NC. NC is located downstream of SC and we expected water levels at SC to be higher than NC. For the June 2021 event the recorded water surface elevations at SC were lower than NC (Figure 10). This is opposite to what would be expected. Examination of long term gauge readings showed that the head loss between the SC and the NC is typically between 2 and 2.5 m during low flow events (as indicated in the early part of June in Figure 10) and that it varies between 0 to 0.5 m during larger flood events that are influenced by the Latrobe River. We attributed the anomaly in the June 21 event to a possible misreading at the gauge. Since the gauge level and the modelling results with the adjusted n values were within acceptable margines at the NC and the model showed the appropriate level to account for expected head loss at the SC (equivalent to head loss of 0.2-0.4 m), the model results were accepted for the June 2021 event.

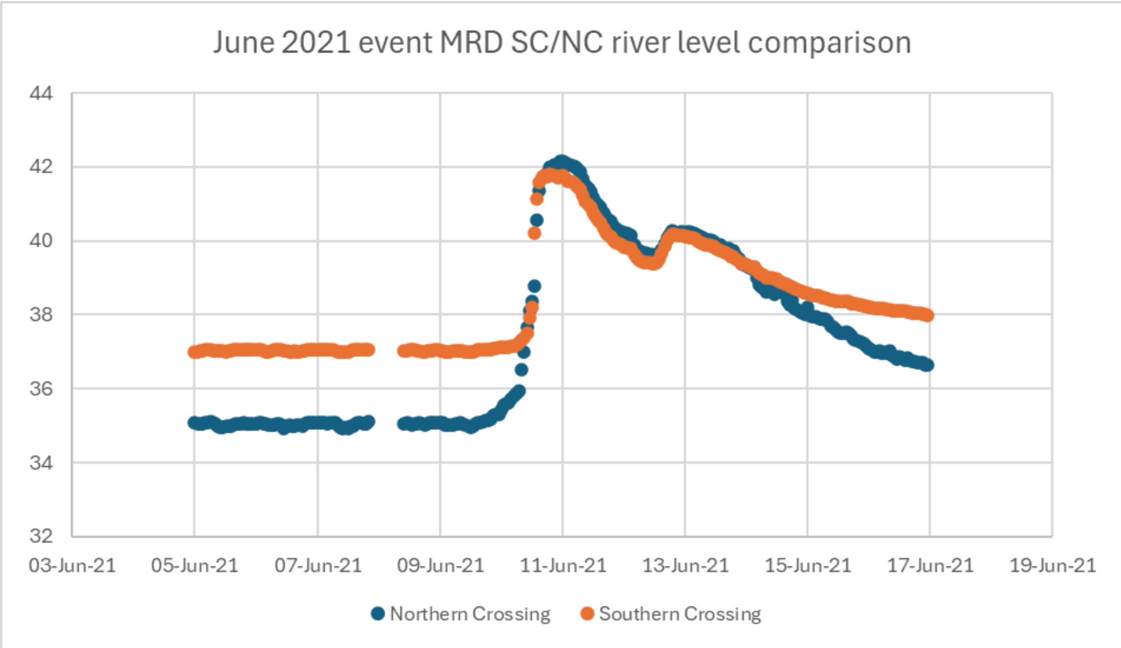


Figure 10. *Guage reading at NC and SC for the June 2021 event showing reversed head differential*

Model verification for the September 2017 event

As discussed, we modelled a smaller flood event to make sure that the model was robust and would provide reliable results for a range of flood events. As noted, the Manning's n values used for the June 2021 event had to be reduced to reflect the prevailing dry low vegetated conditions at the time. One of the underlying assumptions when modelling design events is that the antecedent conditions are reflective of average conditions. Hence, the Manning's n values were re-adjusted to reflect average conditions and vegetation conditions in the floodplain when modelling the 2017 event. A good estimate of average Manning's n values is important to avoid under estimating flood levels during design event modelling. Results show that model and gauge results are within 0.3-0.4 m indicating a fair correspondence between modelled levels and gauge levels at both SC and NC for the 2017 event (Figure 11).

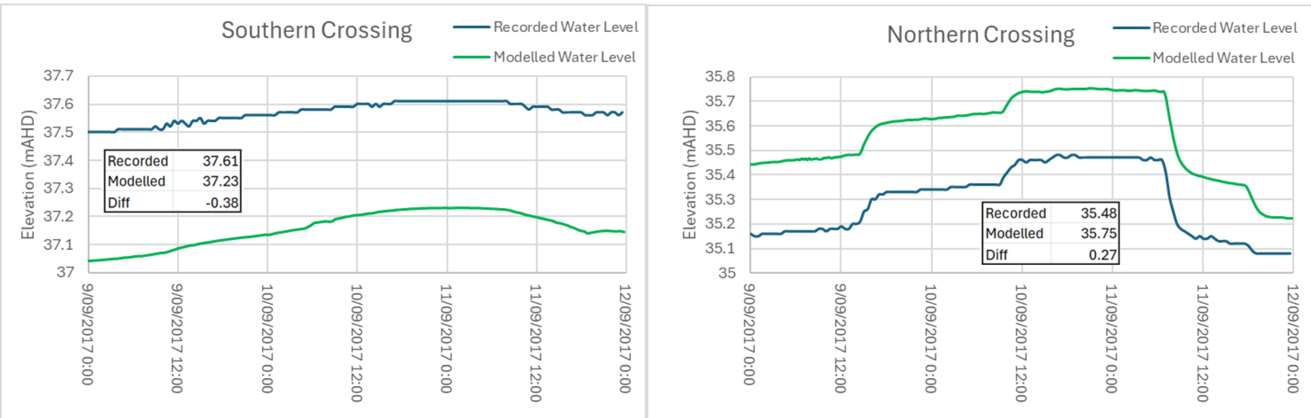


Figure 11. *Comparison of modelled and gauge levels during Sept 2017 event.*

The 2017 event model calibration Mannings's n values were adopted for the design event modelling. These values are shown in Table 8 together with the other values used in the derivation of the adopted Mannings n values.

Table 8. Mannings n values trialled including 2017 event calibration proposed for design event modelling

Description	Manning's n AR&R 2019	Manning's n June 2021	Manning's n Sept 2017*
Pasture/Cultivated area	0.35	0.03	0.03
Light brush and trees	0.03	0.055	0.06
Forest	0.06	0.08	0.085
Dense Forest	0.12	0.12	0.12
Body of water	0.035	0.035	0.035
Gravel	0.03	0.03	0.03
Waterway (MRD)	0.03	0.03	0.035
Waterway (Latrobe)	0.35	0.035	0.035

*Adopted for existing and design model runs

4 Design event modelling and results

4.1 Coincident design events

The study area covers the confluence of the Morwell and Latrobe Rivers, necessitating analysis of coincident design events due to the potential for differing flood mechanisms. As the size of the catchment of the Latrobe River at the mine is approximately three times larger than the catchment of the Morwell River, it is unlikely that the effective AEP of the flood flows in both rivers will be the same. Hence, a series of possible coincident flows have been developed to represent probable flood events in each river that can coincide with the other river. Essentially enabling testing of which river has greater influence on flood levels at the site. For this method, we considered the following primary flooding pathways:

- Mainstream flooding led by the Morwell River: Driven by high flows directly within the Morwell River.
- Mainstream flooding led by the Latrobe River: Flooding of the Latrobe River can cause elevated water levels that propagate upstream into the MRD, leading to backwater flooding.

To determine which mechanism governs flood levels under various scenarios, a suite of coincident design flows was developed and simulated. Table 9 outlines the combinations of annual exceedance probability (AEP) for both rivers. An envelope of the maximum flood results was then taken to represent the worst-case flood conditions for each AEP combination.

Table 9. Summary of coincident design events analysed for both Rivers (leading event in bold, coincident event in regular text*)*

Scenario			
Latrobe R led event with coincident Morwell R event		Morwell R event with coincident Latrobe R event	
Latrobe	Morwell	**Morwell**	Latrobe
%AEP	%AEP	**%AEP**	%AEP
0.05	1	**0.05**	1
0.2	2	**0.2**	1
0.5	2	**0.5**	1
1	5	**1**	5
2	5	**2**	5
5	50	**5**	50
50	50	**50**	50

4.2 Existing conditions assessment

Peak flood levels, velocities and shear stress for the MRD at the reference site (located within the MRD adjacent to Spillway 2 - refer to Figure 5) for the range of design events, from the 50% AEP to the 0.05% AEP (1 in 2000 year ARI) event are presented in Table 10 and Attachment 1.

The results show that the flood waters are typically contained within the banks of the MRD for all events up to the 0.05% AEP (1 in 2000 year ARI) event. Key points from the existing conditions modelling include:

- Peak flood depths in the Morwell River Diversion are dominated by Latrobe led events, reflecting the larger catchment area and peak flow events in the Latrobe River.
- Peak flood levels are contained within the MRD for all events tested including the 1 in 2000-year event Latrobe led event. In this event the water level rises to RL 45.3m AHD. This elevation has been identified by Energy Australia Yallourn to compromise the structural integrity of the MRD.
- While peak inundation is dominated by Latrobe led events, peak velocity and shear stress through the Morwell River diversion are highest during Morwell led events.

Table 10. Design event modelling results existing condition (@ Spillway 2, refer to Figure 5)

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Existing conditions peak elevation (m AHD)	Latrobe led	45.3	43.9	43.2	42.6	42.0	40.7	37.4
	Morwell led	43.3	42.3	42.3	41.3	41.0	39.7	37.5
Existing conditions peak velocity (m/s)	Latrobe led	0.9	0.9	0.9	1.0	1.7	0.2	0.7
	Morwell led	2.2	1.9	1.8	1.8	1.8	1.7	0.8
Existing conditions Peak bed shear stress (N/m^2)	Latrobe led	5.6	5.5	6.0	7.9	20.9	0.3	5.4
	Morwell led	27.8	25.6	24.0	22.8	22.3	21.2	7.4

Note on data comparison: the data presented in Table 10 and Figure 11 to Table 16 are all extracted from the same point on the floodplain close to spillway 2 (shown in Figure 5). This point was chosen as a location experiencing typical maximum values of velocity and bed shear stress occurring on the floodplain of the MRD. For comparison purposes this point remained consistent across all model events and scenarios. It is therefore important to note that the maximum velocity and bed shear stress values are indicative and do not always represent the highest values present across the entire model as shown in Figures A15 to A84 in Attachment 1.

4.3 Design conditions assessment

One of the main tasks for this modelling effort is to develop and assess a initial layout of the levees and spillways for the MRD and the pits that will reflect long term arrangements at the site. Here the intent is to develop an initial configuration that will provide adequate levels of protection to the levees that bound the MRD as well as investigate how overflows through spillways to and from the pits behave during extreme events. The current levees that form the banks of the MRD were modified (lowered) based geotechnical stability requirements (designed by others) which will have an impact on the safe levels and flow velocities that can be allowed. Hence, multiple iterations were considered prior to developing the design conditions assessed and reported in this document. The following sections presents the model updates that represents the initial design configuration and modelling results.

A primary purpose of the hydraulic modelling was to develop and assess a potential long-term configuration for the levees and spillways for the MRD and the pits. The intent was to develop an initial configuration that supports the long-term structural integrity of the levees that bound the and investigate how overflows through spillways to and from the pits behave during extreme events, while not impacting on environmental water requirements for the system

Design intent and criteria

As set out in the introduction to this report a set of MRD hydraulic design criteria were developed for the project . The hydraulic criteria for the MRD are summarised in Table 11.

Table 11 MRD Hydraulic design criteria

Intent	Criteria	Metric
Maintain the integrity of residual levees that maintain the flow regime in the MRD	Peak water surface elevation in the MRD	RL42.5m in the 1 in 200 yr ARI event
Prevent lateral movement of the MRD as a form of failure of the MRD	Differential water surface between Township Field and East Field	Max 6metres
Avoid floodplain erosion as a potential cause of failure of the MRD levees and related infrastructure	Floodplain velocity and shear stress	Max floodplain velocity less than 1.8m/s Max floodplain shear stress less than $80N/m^2$
Not adversely impact on the environmental water requirements of the Latrobe River system	Minimum flow rate in the MRD before water is diverted via spillways to the pit lakes	3,200ML /day equivalent to the flow rate required to flush salt from the Lower Latrobe River in the vicinity of the inlets to the Heart and Dowd Moras.s

Design configuration

The existing model configuration was modified via trial and error to meet the design intent and criteria. The primary features included into the MRD and modified to achieve the design intent comprised:

- Two spillways from the MRD to the East Field
- One spillway from the MRD to the Township Field
- One Spillway from the East Field to the Latrobe River
- Modification of the existing tunnels under the MRD to equalise water levels between the pits

	Width (m)	Spill level (m AHD)
Spillway 1	50	41.5
Spillway 2	100	40
Spillway 3	50	40.5
Spillway 4	150	37

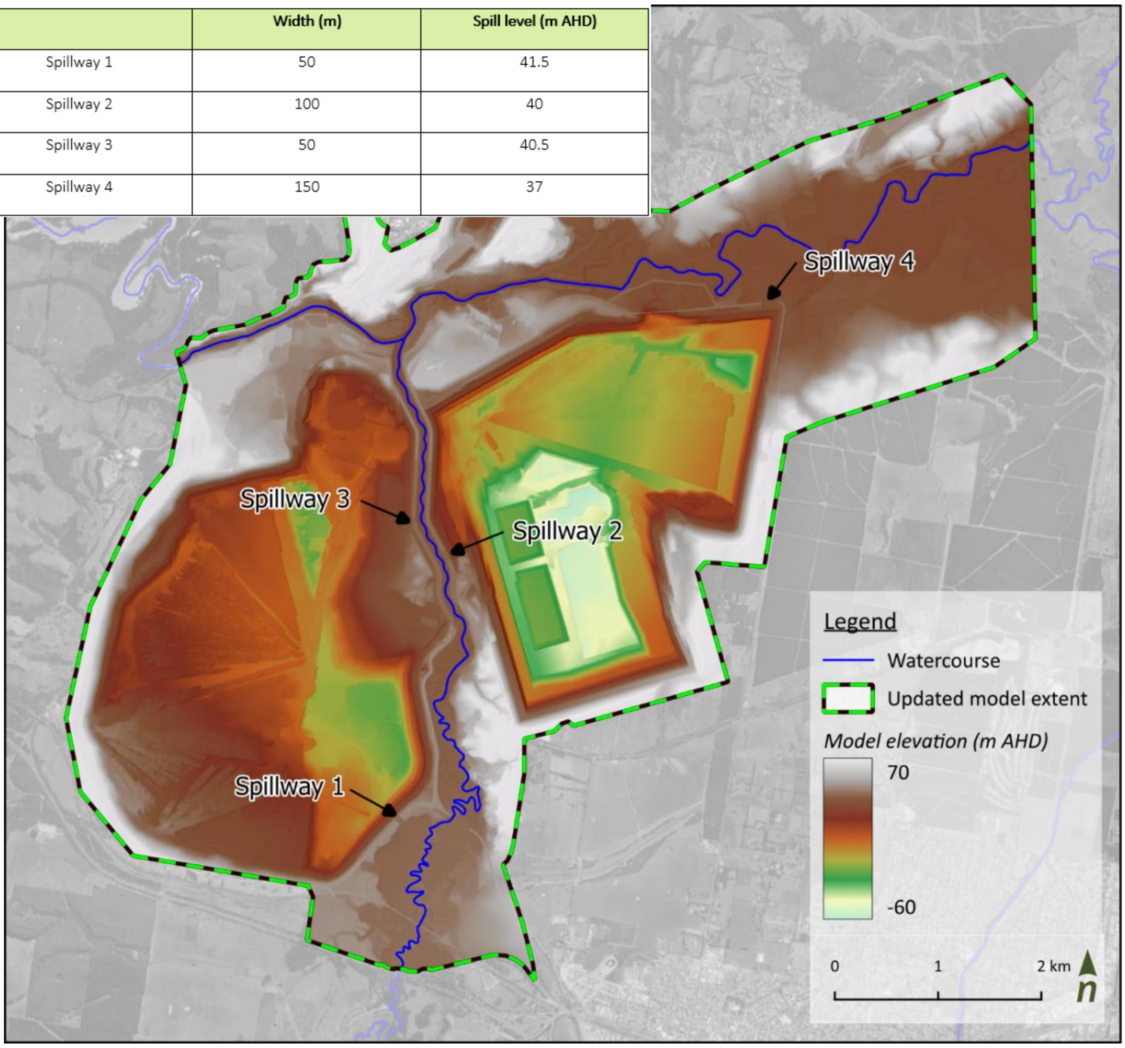


Figure 12. *Preliminary design arrangements assessed*

Preliminary modelling results of design conditions

Similar to existing conditions, the hydraulic modelling revealed flood levels to be dominated by the Latrobe led events, while the flow velocities and the resulting bed shear stresses in the MRD are more relevant during Morwell led events. The hydraulic modelling has revealed:

- Attainment of a maximum water surface elevation of approximately RL42.5m AHD for the 1 in 2000 year ARI event (refer to Attachment 1 for results mapping) i.e. consistent with the design criteria for maximum water levels within the MRD.
- Maximum difference in head between Township Field and The East Field pits of 3.3 metres during flood events. i.e. less than that required to prevent lateral movement of the MRD
- Velocity (refer to Attachment 1 for results mapping) and shear stress that do not exceed:
  - That identified for the existing conditions
  - the non-scour velocity and shear stress for native bunch grasses

  Note the maximum shear stress has been quoted for the MRD floodplain not in the immediate vicinity of the proposed spillways.
- Spillway 1 being the first spillway to commence to flow. This spillway commencing to flow at a 5% AEP (approx.) event in the Morwell River at 3,500ML/day (approx.). i.e. in excess of that required to flush the Latrobe River estuary of salt water at the points of inflow to the Lake Wellington fringing wetlands (Heart Morass and Dowd Morass).

Table 12. Design event modelling results design configuration (@ Spillway 2, refer to Figure 5)

		0.05% AEP	0.2 % AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	50% AEP
Preliminary design conditions peak elevation (m AHD)	Latrobe led	42.5	42.1	41.7	41.4	41.1	40.4	36.9
	Morwell led	41.3	41.3	41.3	40.5	40.5	38.7	36.9
Preliminary design conditions peak velocity (m/s)	Latrobe led	1.5	1.1	0.8	0.5	1.3	0.1	0.6
	Morwell led	1.8	1.7	1.7	1.7	1.6	1.4	0.7
Preliminary design conditions Peak bed shear stress (N/m^2)	Latrobe led	12.5	7.1	5.9	7.5	19.1	0.5	5.3
	Morwell led	27.3	25.0	24.0	23.5	22.9	20.9	6.7

Table 13 provides spot peak velocity and shear stress at each of the spillways for the 0.05% AEP (1 in 2000 year ARI) Latrobe led event. The hydraulic modelling results show shear stress and velocity outcomes over, and in the immediate vicinity of, the proposed spillways exceed the design criteria. Further assessment and design effort will be required to develop configuration arrangements that ensure the long-term performance of these structures. In addition, the velocity and shear stress criteria for existing and any proposed vegetated surfaces on the MRD floodplain are a function of the duration of events, with decreasing performance with increasing duration of inundation. Further investigations will be required to confirm the longevity of any proposed vegetative arrangements for MRD instream and floodplain erosion control, under extended flood events.

Table 13. Peak spot velocity and shear stress over the spillways for the 0.05% AEP Latrobe led event

Spillway	Peak velocities	Peak shear stress
	(m/s)	(N/m^2)
1	5.4	380
2	6.1	430
3	5.8	500
4	5.2	280

5 Comparison and discussion of existing and design configuration

With the modelling completed for both existing and design conditions, here we compare and discuss the results and the implications for the MRD design configuration. As mentioned before, the results and comparisons are based on an indicative reference point along the MRD at Spillway 2. It is important to note that the results can vary along the channel reach. A spatial distribution of flood depths and velocities are presented in the figures in the Appendices that are provided as separate attachments. Referring to Table 14 the flood levels along the MRD decrease for all Latrobe led events and maintains the level at or below RL 42.5. Though flood levels are below the spillway levels for the 50% events, the flood levels at Spillway 1 for these events are at a level that still activated Spillway 1(see Table S1 in Supplementary information). Hence resulting in a decrease in flood levels in the MRD. Similar decrease in flood levels, though at a lesser magnitude close to 1 m, are shown for Morwell led events which indicates that Spillway 1 is activated for all the modelled events.

Table 14. Comparison of Peak flood level (@ Spillway 2, refer to Figure 5)

		Peak elevation (m AHD)		
		Existing	Design	Change in design
Latrobe led	0.05% AEP	45.3	42.5	-2.8
	0.2% AEP	43.9	42.1	-1.8
	0.5% AEP	43.2	41.7	-1.5
	1% AEP	42.6	41.4	-1.2
	2% AEP	42.0	41.1	-1.0
	5% AEP	40.7	40.4	-0.2
	50% AEP	37.4	36.9	-0.5
Morwell led	0.05% AEP	43.3	41.3	-2.0
	0.2% AEP	42.3	41.3	-1.0
	0.5% AEP	42.3	41.3	-1.0
	1% AEP	41.3	40.5	-0.8
	2% AEP	41.0	40.5	-0.5
	5% AEP	39.7	38.7	-1.0
	50% AEP	37.5	36.9	-0.7

Comparison of peak velocities (Table 15) at the reference points presents some interesting results that indicate the dynamic nature of flood behaver along the MRD. Existing velocities in the MRD for the Latrobe led event are close to half that of the velocities experienced during Morwell led events even though flood levels are lower for the Morwell led events. This is primarily due to the fact that the higher flood levels are impacted by backwater effects along the MRD when large events occur in the Latrobe River resulting in the level pool type flow in the MRD. This effect of backwater is demonstrated for the 2% and 50% AEP events where we see an increase in velocity with decrease in flood magnitude. Here the event in the Latrobe is smaller but the coincident flow modelled in the Morwell is the same as for the 1% AEP (5% AEP modelled in the Morwell (Table 9)). The lower flow in the Latrobe results in a lower flood level at the confluence and thus a larger head loss through the MRD allowing for flow rates to increase. The similar effect is shown for the Latrobe led 50% AEP event.

The velocities for the Latrobe led events increase in the design configuration as flows from the Latrobe backflow along the MRD due to activation of Spillways 2 and 3 during the two largest flood events. The velocities for the Morwell led events are minimally impacted by the added spillways for the design configuration. The only impact is due to activation of Spillway 1 at the upstream end of the MRD. It is important to note that the velocities presented are based on the reference point and intended to be indicative and for comparison purposes. The value are also from the peak and do not represent the duration of events and the level of sustained impact along the MRD. Further analysis is required to ascertain the duration of velocities above relevant thresholds.

Table 15. Comparison of peak velocity (@ Spillway 2, refer to Figure 5)

		Peak Velocity (m/s)		
		Existing	Design	Change
Latrobe led	0.05% AEP	0.9	1.5	0.6
	0.2% AEP	0.9	1.1	0.2
	0.5% AEP	0.9	0.8	-0.1
	1% AEP	1.0	0.5	-0.5
	2% AEP	1.7	1.3	-0.3
	5% AEP	0.2	0.1	0.0
	50% AEP	0.7	0.6	-0.1
Morwell led	0.05% AEP	2.2*	1.8*	-0.3
	0.2% AEP	1.9	1.7	-0.2
	0.5% AEP	1.8	1.7	-0.1
	1% AEP	1.8	1.7	-0.1
	2% AEP	1.8	1.6	-0.1
	5% AEP	1.7	1.4	-0.3
	50% AEP	0.8	0.7	-0.2

*peak velocity values

Figure 13 (also included in Appendix B) shows the spatial distribution of peak velocities throughout the model domain for the Latrobe led 0.05% AEP (1 in 2000 year ARI) event. Though the velocities are based on peak instantaneous values, Figure 13 provides a snapshot of the dynamic nature of flood behaviour through the MRD and the pits. It is interesting to note the high velocities over the spillways and along the 'choke; area in the river reaches as well as the diffusion of these velocities within the pits. We see that the velocities in general are less than 2 m/s through the MRD channel. Consistent with the Table 15, and within acceptable levels when appropriate erosion protection is applied through the MRD. The overflow/outflow at Spillway 4 in the northeast of the east pit also indicates high velocities over the spillway. Similar to the spillway within the MRD, the outlet spillway will also need protective treatment as well as providing a safe stable channel through the floodplain of the Latrobe River. Note that the high velocities indicated along the northern edges of the pits are an artefact of possible model instability at a hard boundary and TUFLOW interaction with DEM and should be ignored at this point as there are no overflows or breaches along those locations.

Figure 13. *Peak velocity distribution for the design configuration*

Considering the resulting shear stresses, Table 16 shows peak spot shear stresses at the reference point. Similar to the velocity results, higher shear values are prevalent for Morwell led events at the reference point. As discussed above, the shear stresses are within tolerable levels when appropriate levels of erosion protection is applied along the MRD channel (shear stress of 80 N/m^2 (the maximum permissible velocity and shear stress for tall native bunch grasses, refer Fischenich 2001 Impacts of stabilisation measures)). There is minimal impact on the shear stress with the design configuration as only Spillway 1 is minimally activated during Morwell led events.

Table 16. Peak shear stress for Morwell led events (@ Spillway 2, refer to Figure 5)

		Peak Shear Stress (pa)		
		Existing	Design	Change
Latrobe led	0.05% AEP	5.6	12.5	7.0
	0.2% AEP	5.5	7.1	1.7
	0.5% AEP	6.0	5.9	-0.1
	1% AEP	7.9	7.5	-0.4
	2% AEP	20.9	19.1	-1.8
	5% AEP	0.3	0.5	0.2
	50% AEP	5.4	5.3	-0.1
Morwell led	0.05% AEP	27.8	27.3	-0.5
	0.2% AEP	25.6	25.0	-0.6
	0.5% AEP	24.0	24.0	0.0
	1% AEP	22.8	23.5	0.7
	2% AEP	22.3	22.9	0.6
	5% AEP	21.2	20.9	-0.3
	50% AEP	7.4	6.7	-0.6

6 Conclusion

A preliminary spillway design arrangement has been developed and assessed for the site based on the Partially Connected Morwell option and its potential to meet key hydrologic, geomorphic and ecological criteria outlined in *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine (Alluvium 2024)*.

Event based hydrologic modelling was undertaken to inform (TUFLOW) hydraulic modelling. The hydraulic modelling was used to develop and assess a preliminary design configuration for the site.

The preliminary design configuration comprised

1. Two spillways from the MRD to the East Field
2. One spillway from the MRD to the Township Field
3. One Spillway from the East Field to the Latrobe River
4. Modification of the existing tunnels under the MRD to equalise water levels between the pit lakes

The performance of the proposed arrangement has been assessed against the specific hydraulic criteria set out in Table 11. The outcome against these criteria are set out in Table 17. The proposed arrangements have been found to meet these criteria.

Table 17 MRD Hydraulic design criteria

Intent	Criteria	Metric	Outcome
Maintain the integrity of residual levees that maintain the flow regime in the MRD	Peak water surface elevation in the MRD	RL42.5m in the 1 in 200 yr ARI event	RL 42.5m AHD for 1 in 2000 yr ARI event
Prevent lateral movement of the MRD as a form of failure of the MRD	Differential water surface between Township Field and East Field	Max 6metres	3. 3metres
Avoid floodplain erosion as a potential cause of failure of the MRD levees and related infrastructure	Floodplain velocity and shear stress	Max floodplain velocity less than 1.8m/s Max floodplain shear stress less than 80N/m^2	1.8m/s in the 1 in 2000 yr Morwell led event 30N/m2 (approx.) in the 1 in 2000 yr Morwell led event
Not adversely impact on the environmental water requirements of the Latrobe River system	Minimum flow rate in the MRD before water is diverted via spillways to the pit lakes	3,200ML /day equivalent to the flow rate required to flush salt from the Lower Latrobe River in the vicinity of the inlets to the Heart and Dowd Morass	3,500ML/day

In addition, and based on attainment of the specific hydraulic design criteria the arrangements have been assessed against the design principles set out in the geomorphic and ecological context statement discussed in Section 0 of this report and

Hydrologic regime.
Criteria: The arrangement should provide for both:

- o longitudinal hydrologic connectivity
- o lateral floodplain connectivity

Outcome: The spillways have been set at elevations that ensure that flow rates in the Latrobe and Morwell River exceed 3,200 ML/day before any water is captured by the pit lake. This flow rate provides for both longitudinal continuity of flow and ongoing floodplain inundation through the MRD following the construction and operation of the proposed spillways. However, it noted that the project has the potential to reduce the occurrence of floodplain inundation at Thoms bridge during the fill phase. This is discussed under ecological condition and processes.

Geomorphic processes.
Criteria: The arrangement should:

- o not be subject to accelerated high rates of erosion and deposition
- o be robust i.e. resistant to change and have the ability to adapt and repair following change without comprising the other values and outcomes
- o provide for ongoing longitudinal and lateral bed load sediment movements

Outcome:

- Erosion: The proposed arrangements have been found to not increase peak velocity and shear stress beyond that present in the existing conditions. The proposed arrangements result in a reduction in the peak velocity and shear stress in the MRD and retention of velocity and shear stress within the range that can be accommodated by nature based (vegetative) erosion control works. However, it is noted that the performance of such erosion control measures declines with increasing duration of events. The long-term success of nature-based erosion control works will require further assessment and design. Further, more specific design development is required for the proposed spillways to ensure their enduring performance.
- Robustness: The maximum water surface elevation of approximately RL42.5m AHD for the 1 in 2000-year ARI event, meets the design criteria, and represents a 3 metre (approx.) reduction from peak water elevations under the current conditions and increased confidence in the long-term performance of the MRD.
- Sediment transport: The proposed spillways increase the confidence in the long-term functioning the MRD and hence the long-term potential to provide ongoing bed load sediment transport to the Latrobe River. The proposed spillways while increasing the confidence in the longevity of the MRD have the potential to reduce sediment transport when compared to existing conditions. However, as events up to the 5% event in the Morwell River are not impacted by the spillway operation, any reduction in long term sediment transport is likely to be insignificant. Further investigations will be required to confirm the change in bed load sediment transport capacity of the MRD and the implications of any such change on sediment deposition on the stability and longevity of the MRD.

In addition to that set out above, any further modelling for the development and refinement of the design configuration should also consider:

- Impacts of climate change that can occur through the design life of the mine and MRD.
- Refinement of spillway sizing and positioning along the MRD in association with the point above, mine rehabilitation landform design and proposed modifications to the MRD levee system.
- Further analysis of velocity and shear durations and spatial variability, the proposed rehabilitation design and amendments that may be required.
- Further analysis of coincidental flows between the Latrobe and Morwell Rivers and its impact on system stability and design arrangements.

References

Alluvium, 2024a. *Yallourn Rehabilitation Assessment – Hydrologic Modelling.* Report prepared for Energy Australia Yallourn.

Alluvium, 2024b. *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine* (Alluvium 2024b). Report prepared for Energy Australia Yallourn.

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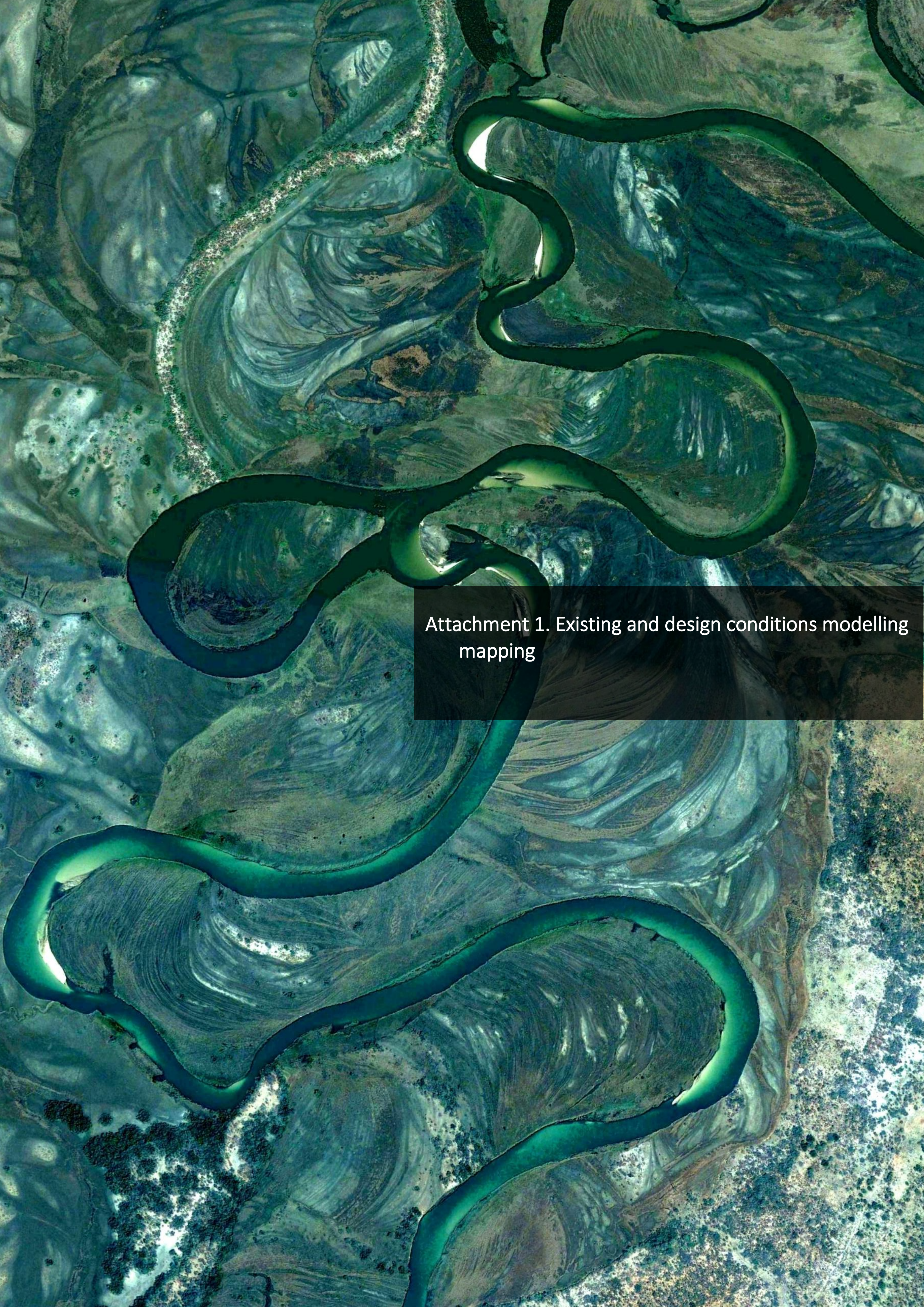
HARC, 2023, *Morwell River Diversion Hydraulic Impact Analysis – Memo*

Attachments

Maximum flood depth, velocity and shear stress maps for the modelled area are provided separately as an attachment (Attachment 1) to this report.

Note on result maps: high velocity and bed shear stress values have been observed at the northern most edges of the mine pits (see results A15 to A84 (Attachment 1). These high values are a modelling artefact. Similarly, water present in the pits in the existing conditions results is another artefact of the model. The water does not come from flows from either river and doesn't change throughout the existing conditions model runs.



Attachment 1. Existing and design conditions modelling mapping

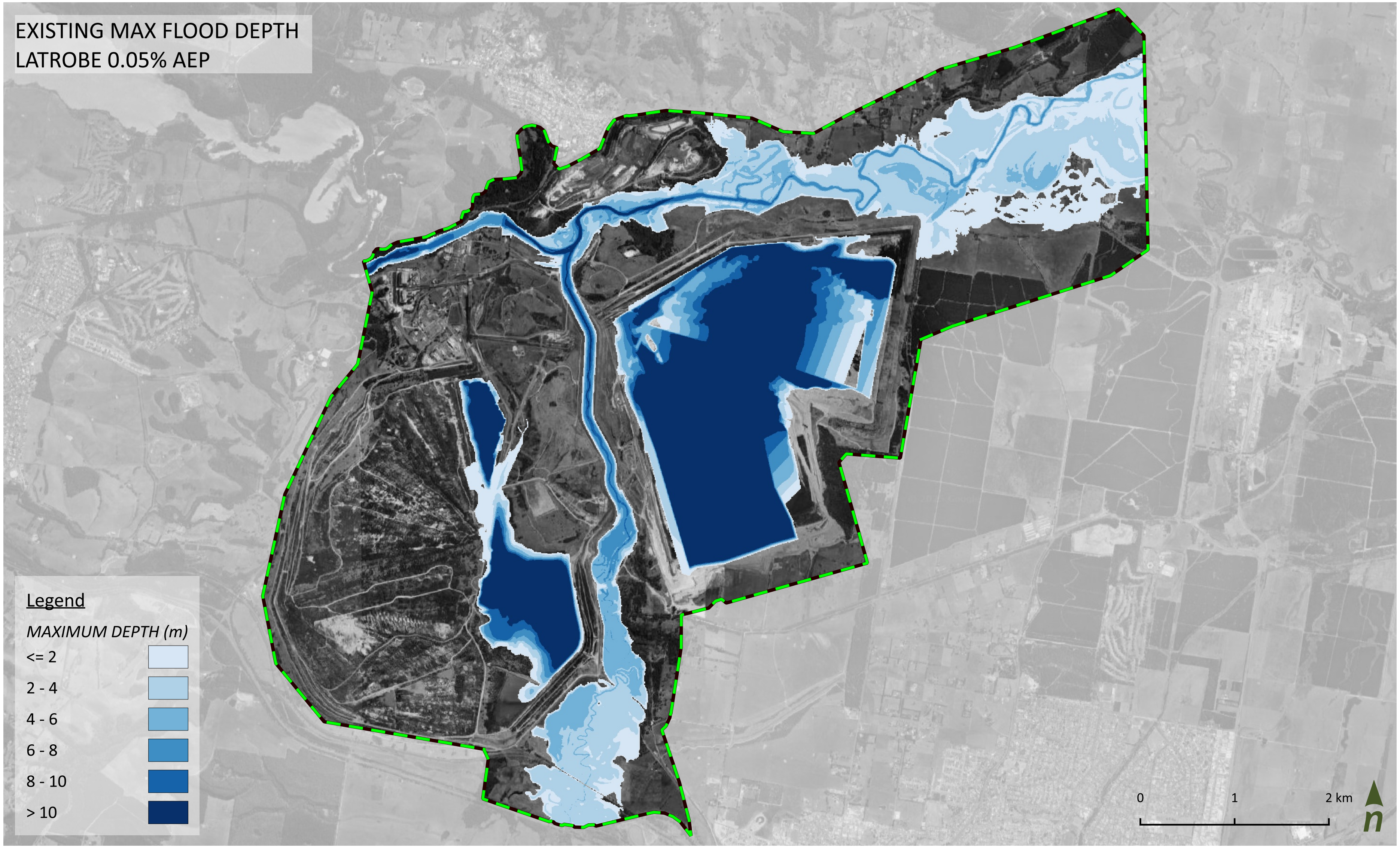


FIGURE A1. EXISTING MAX FLOOD DEPTH LATROBE 0.05% AEP

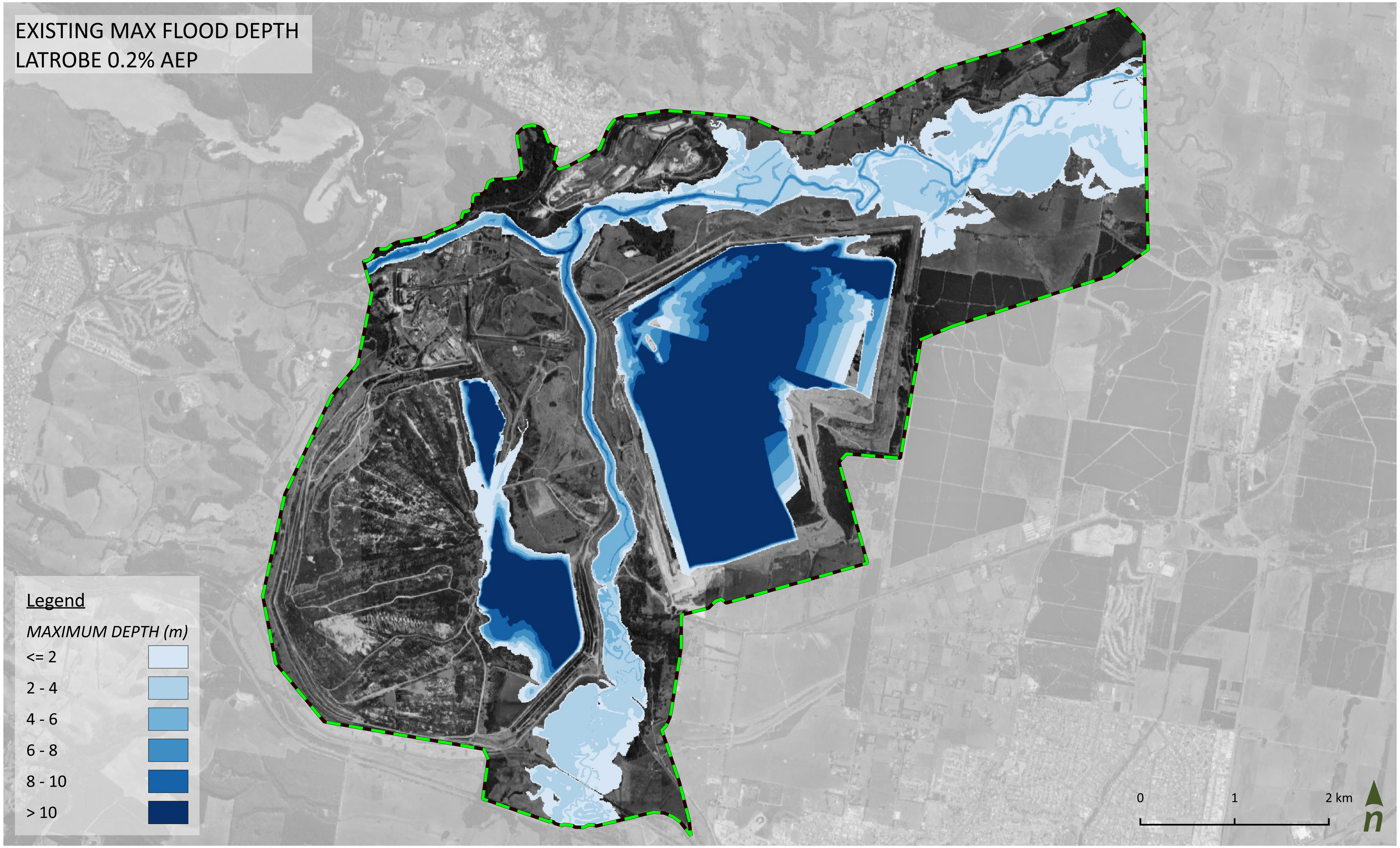


FIGURE A2. EXISTING MAX FLOOD DEPTH LATROBE 0.2% AEP

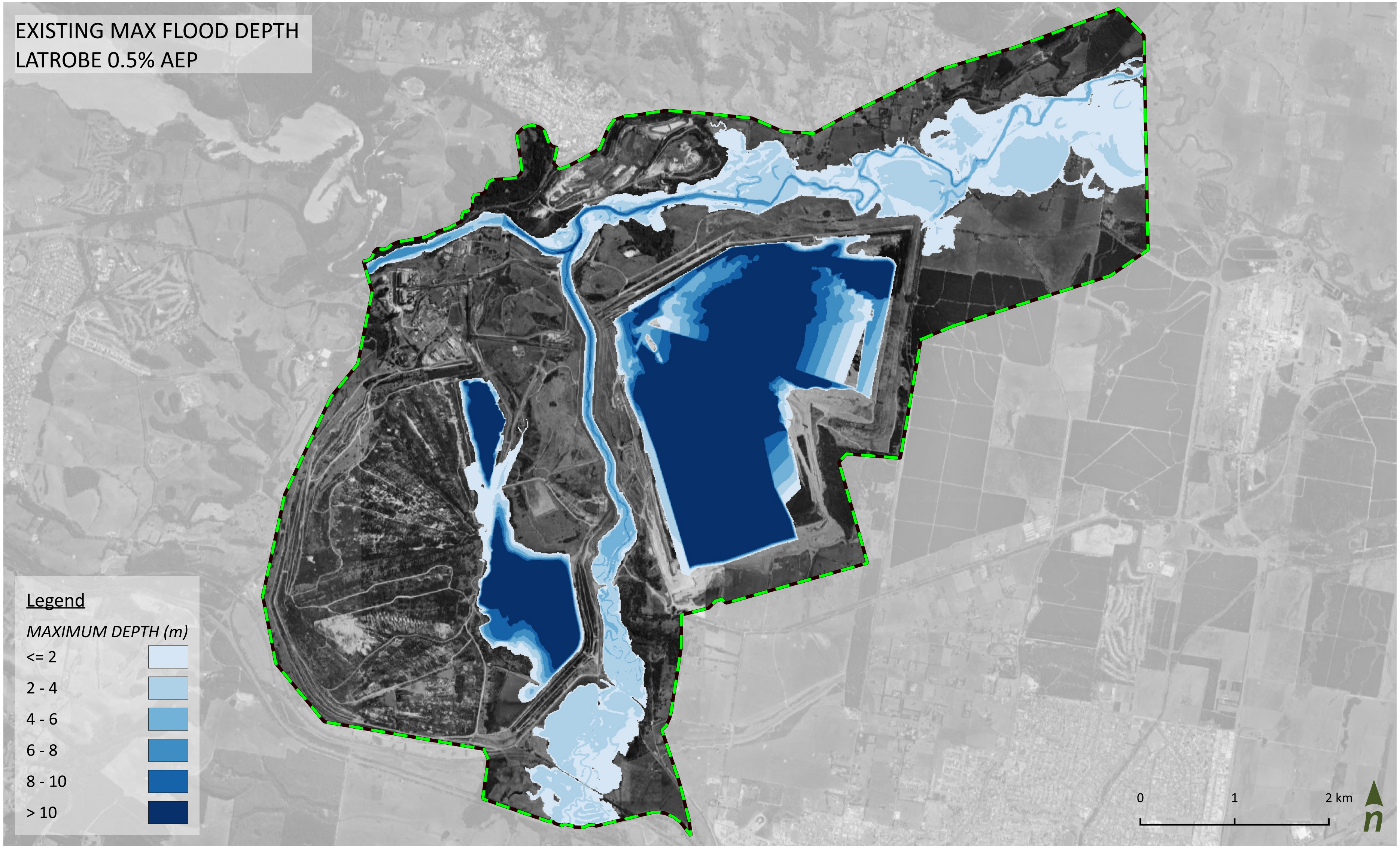


FIGURE A3. EXISTING MAX FLOOD DEPTH LATROBE 0.5% AEP

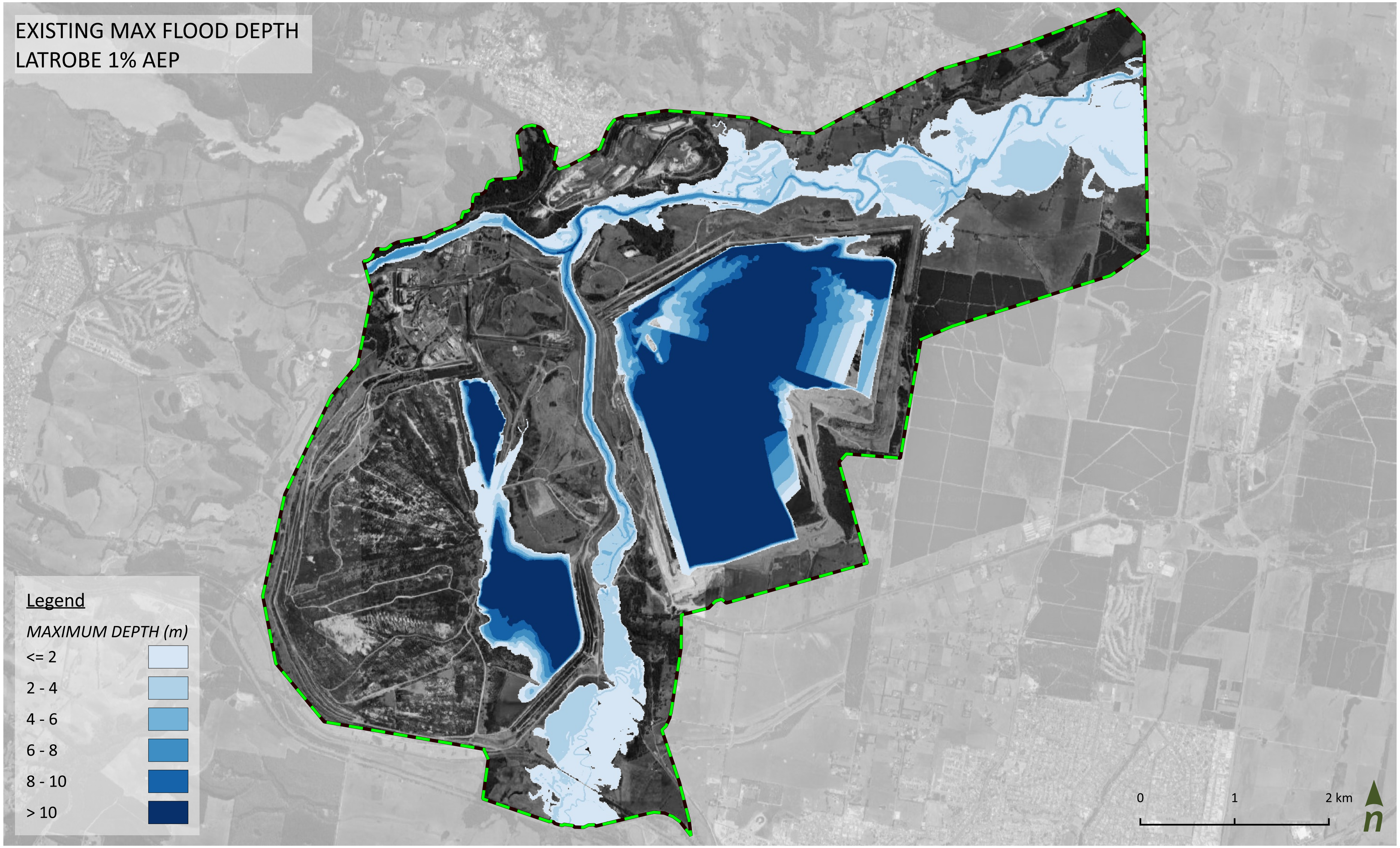


FIGURE A4. EXISTING MAX FLOOD DEPTH LATROBE 1% AEP

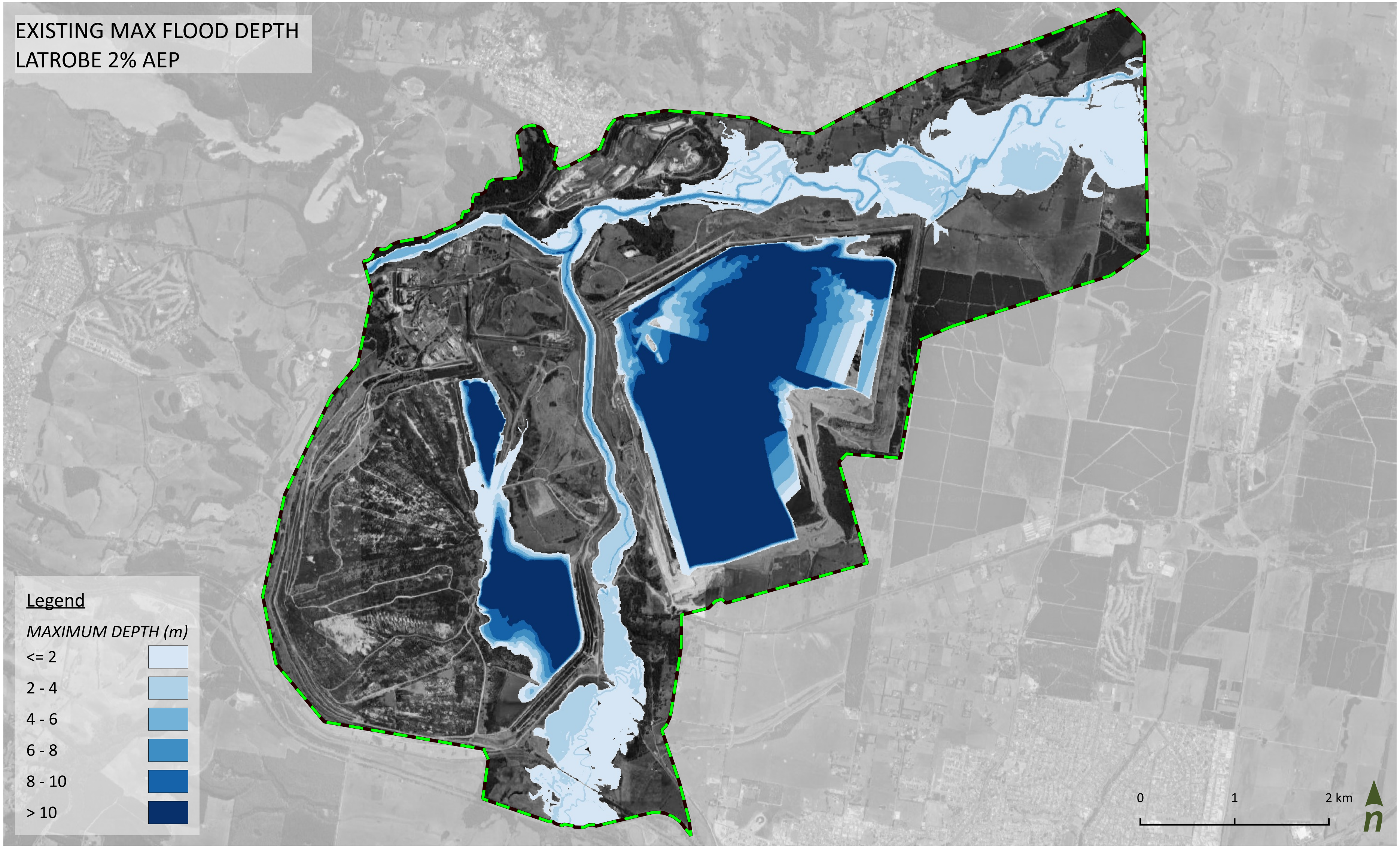


FIGURE A5. EXISTING MAX FLOOD DEPTH LATROBE 2% AEP

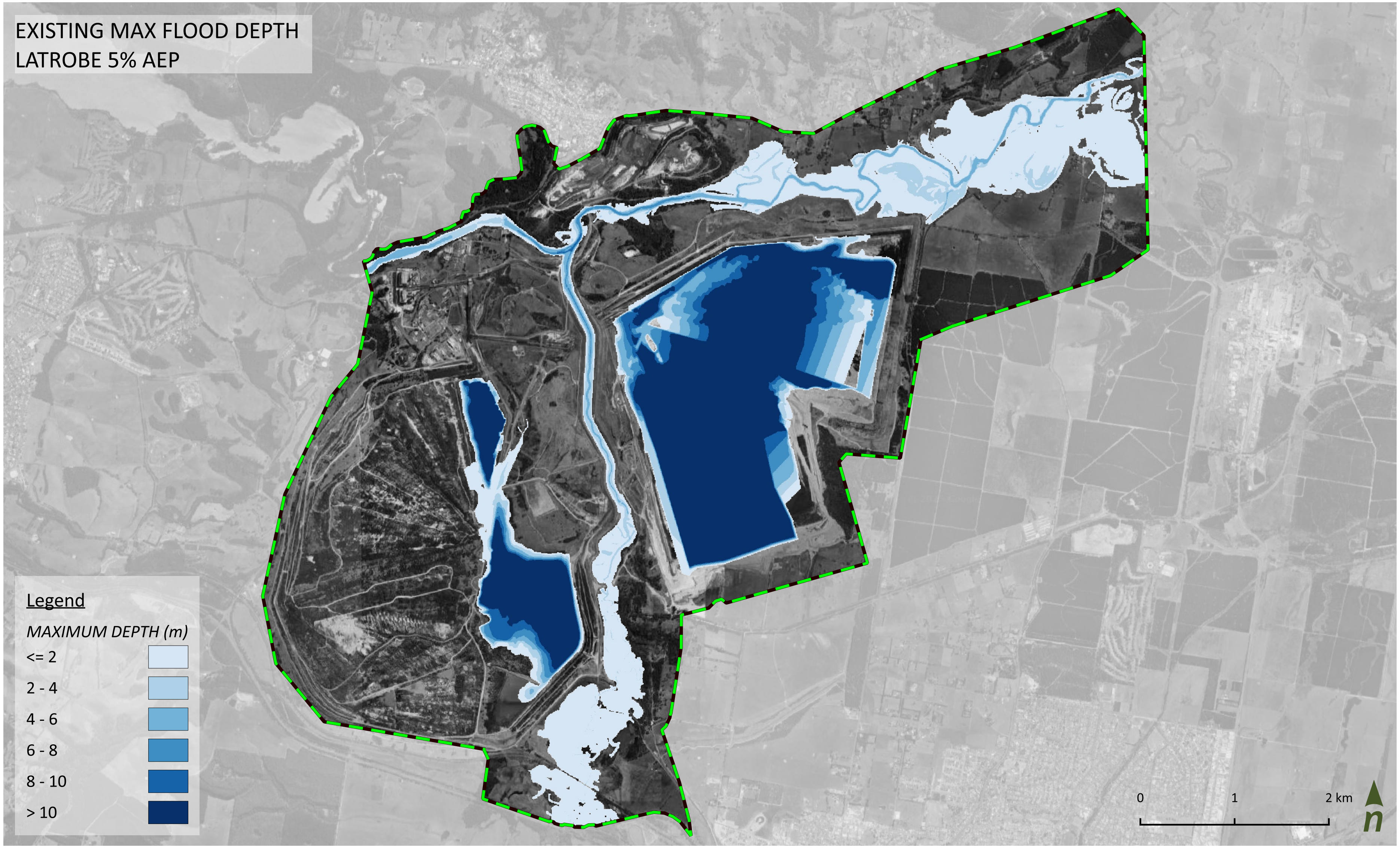


FIGURE A6. EXISTING MAX FLOOD DEPTH LATROBE 5% AEP

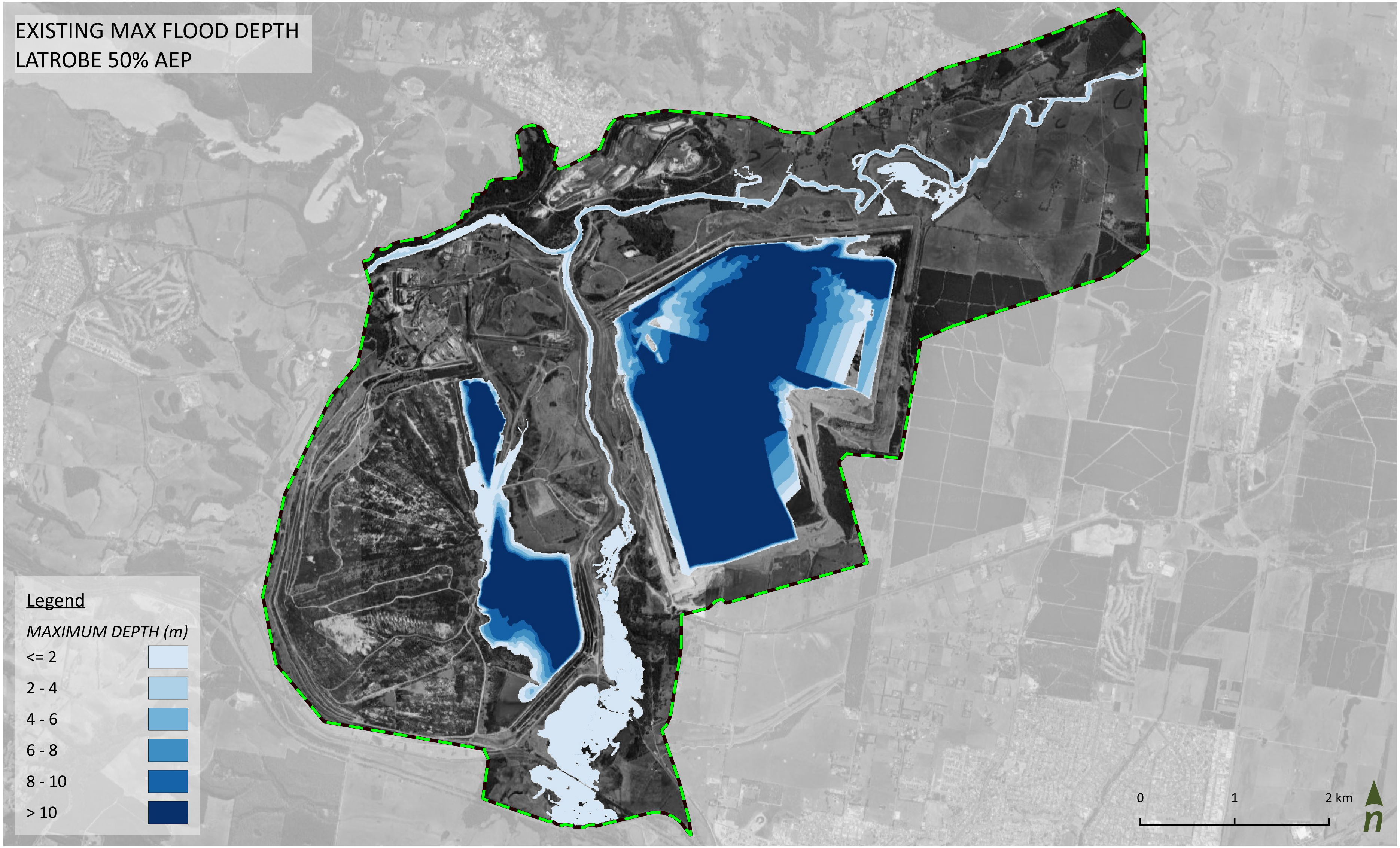


FIGURE A7. EXISTING MAX FLOOD DEPTH LATROBE 50% AEP

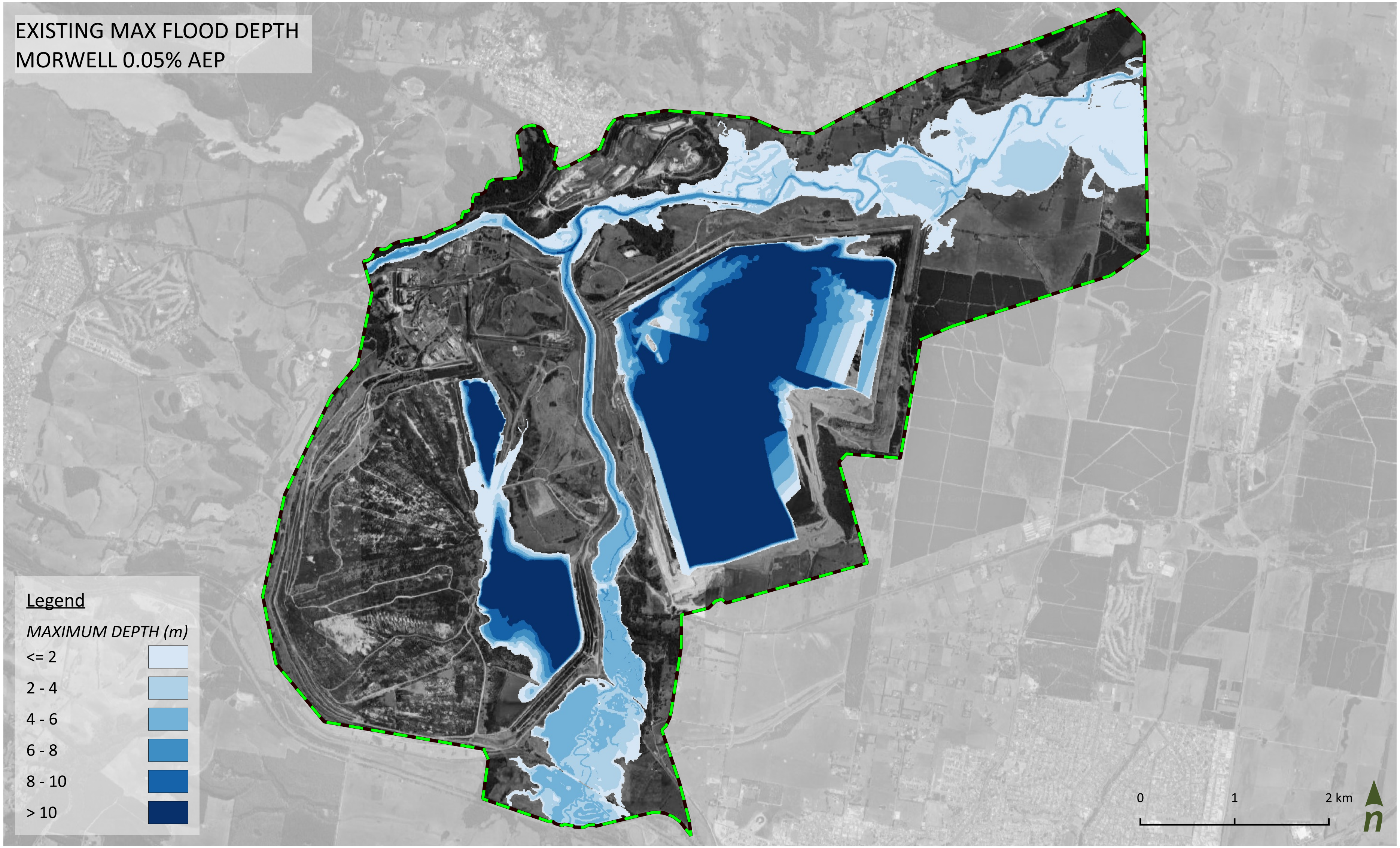


FIGURE A8. EXISTING MAX FLOOD DEPTH MORWELL 0.05% AEP

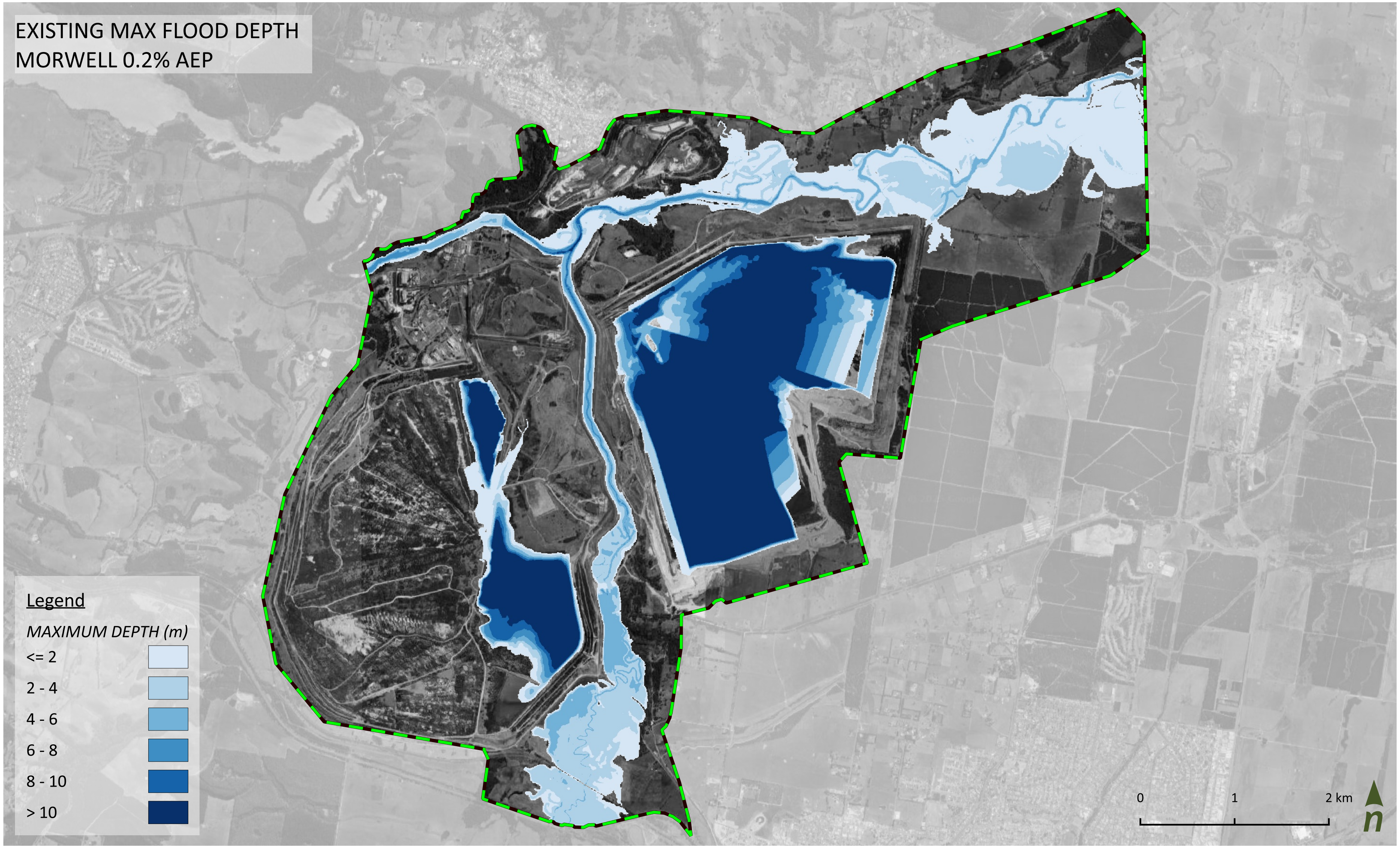


FIGURE A9. EXISTING MAX FLOOD DEPTH MORWELL 0.2% AEP

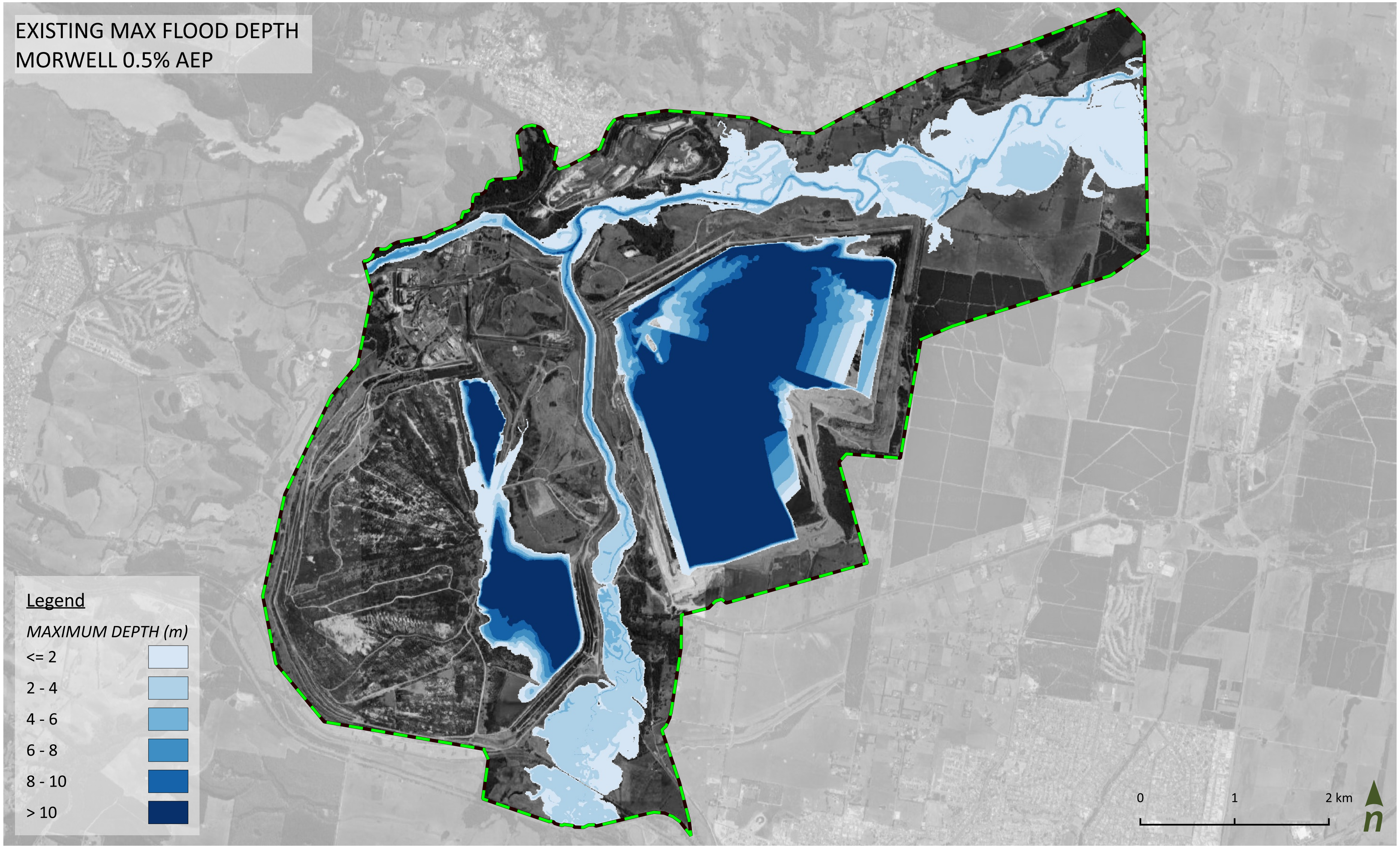


FIGURE A10. EXISTING MAX FLOOD DEPTH MORWELL 0.5% AEP

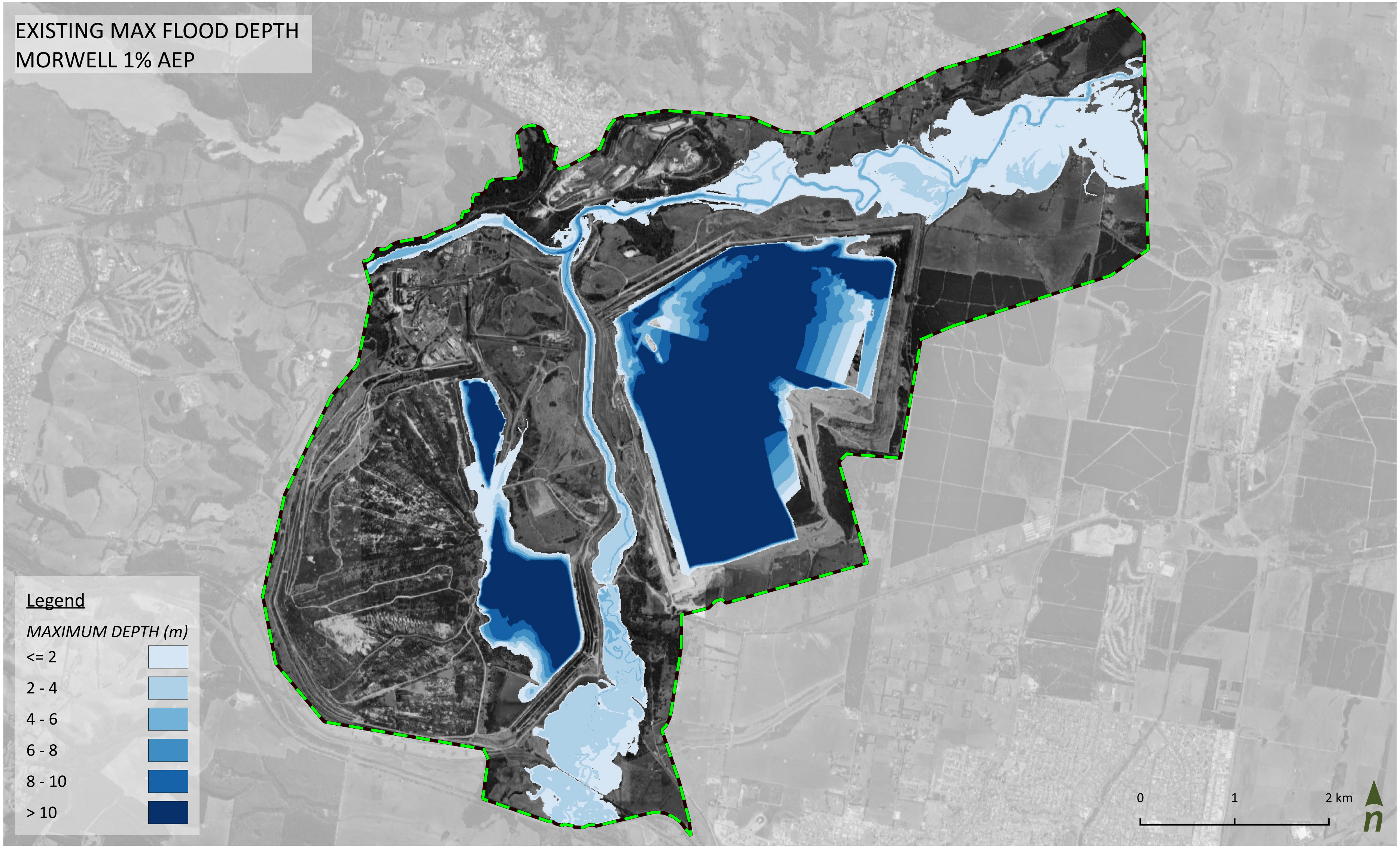


FIGURE A11. EXISTING MAX FLOOD DEPTH MORWELL 1% AEP

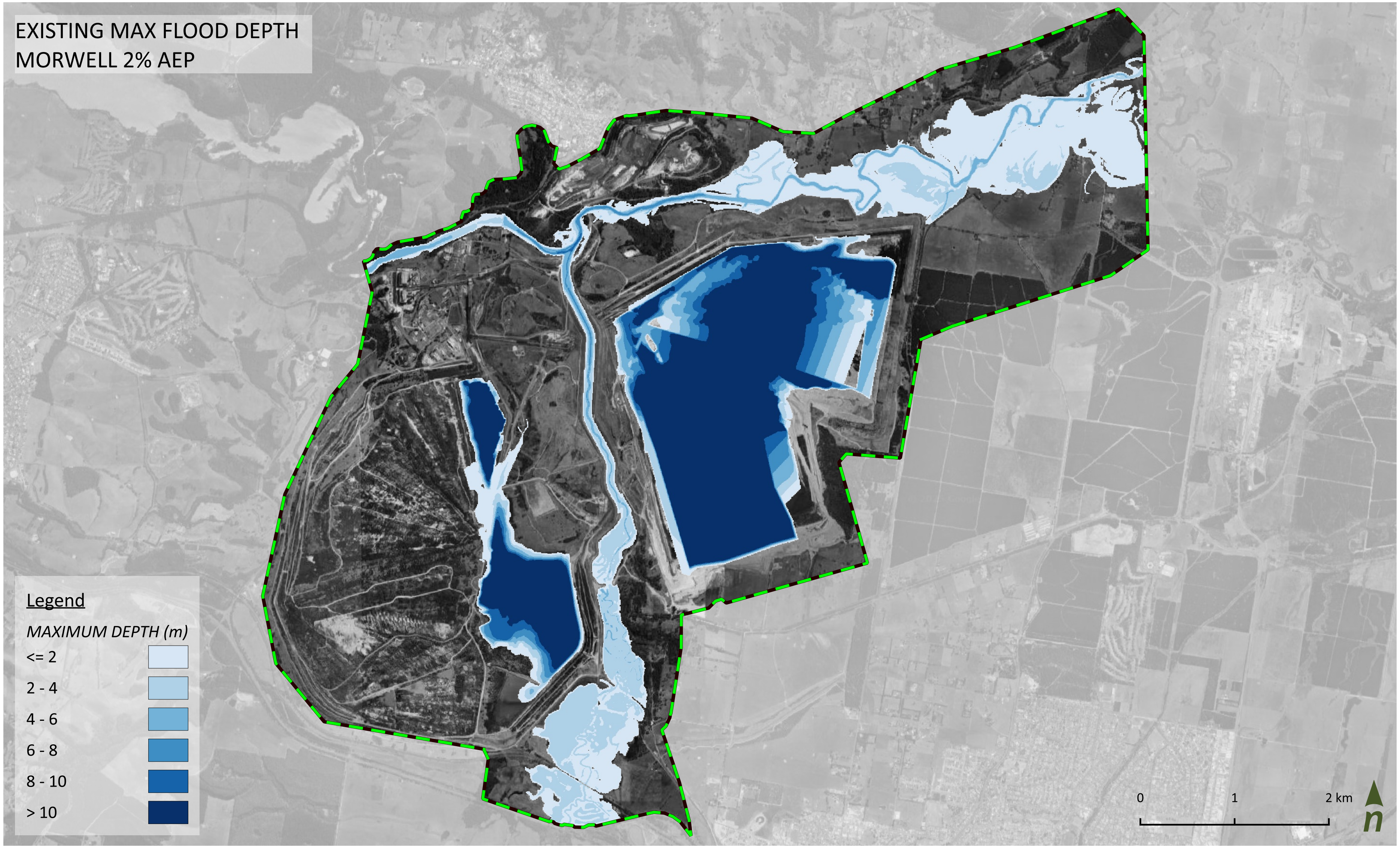


FIGURE A12. EXISTING MAX FLOOD DEPTH MORWELL 2% AEP

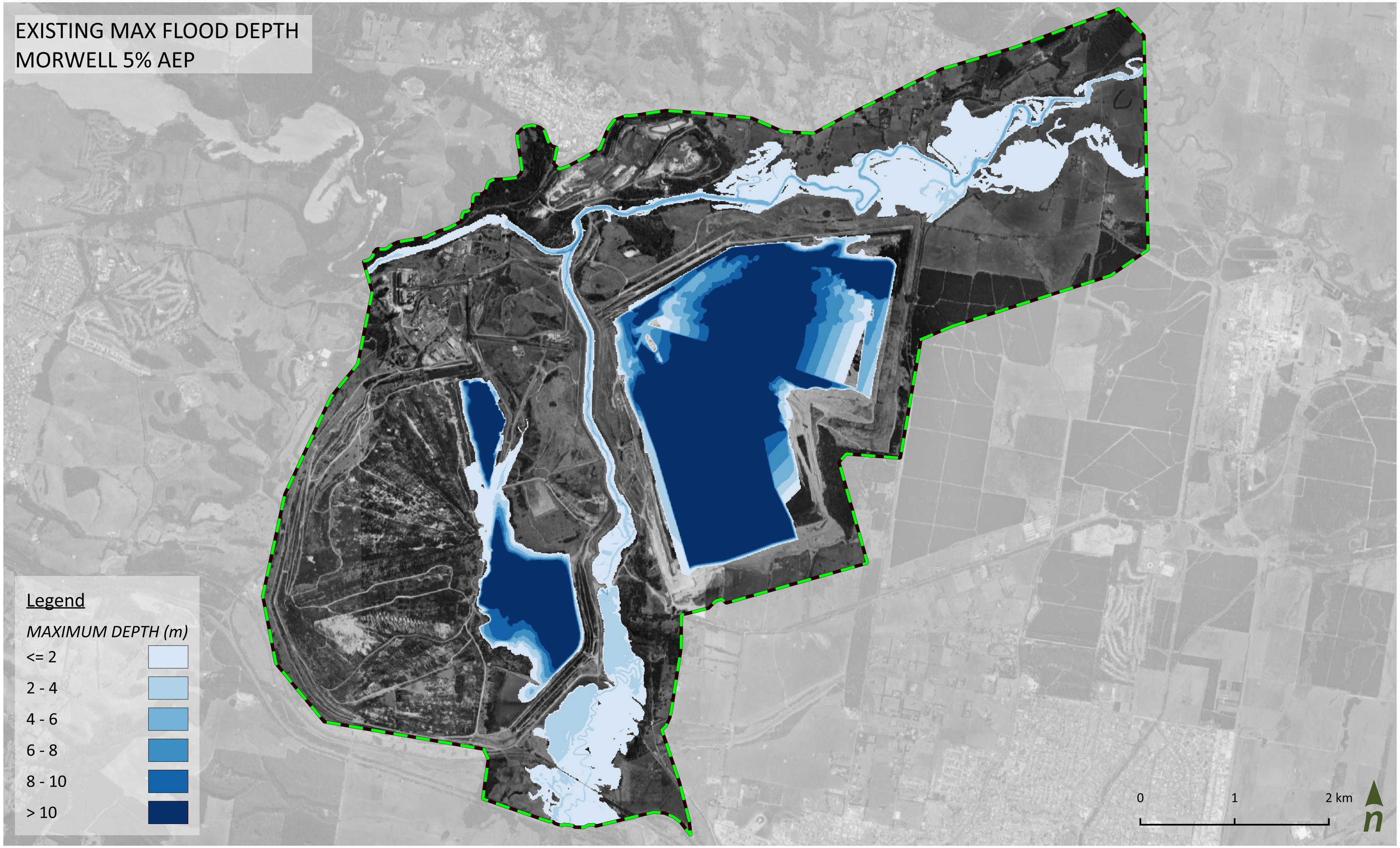


FIGURE A13. EXISTING MAX FLOOD DEPTH MORWELL 5% AEP

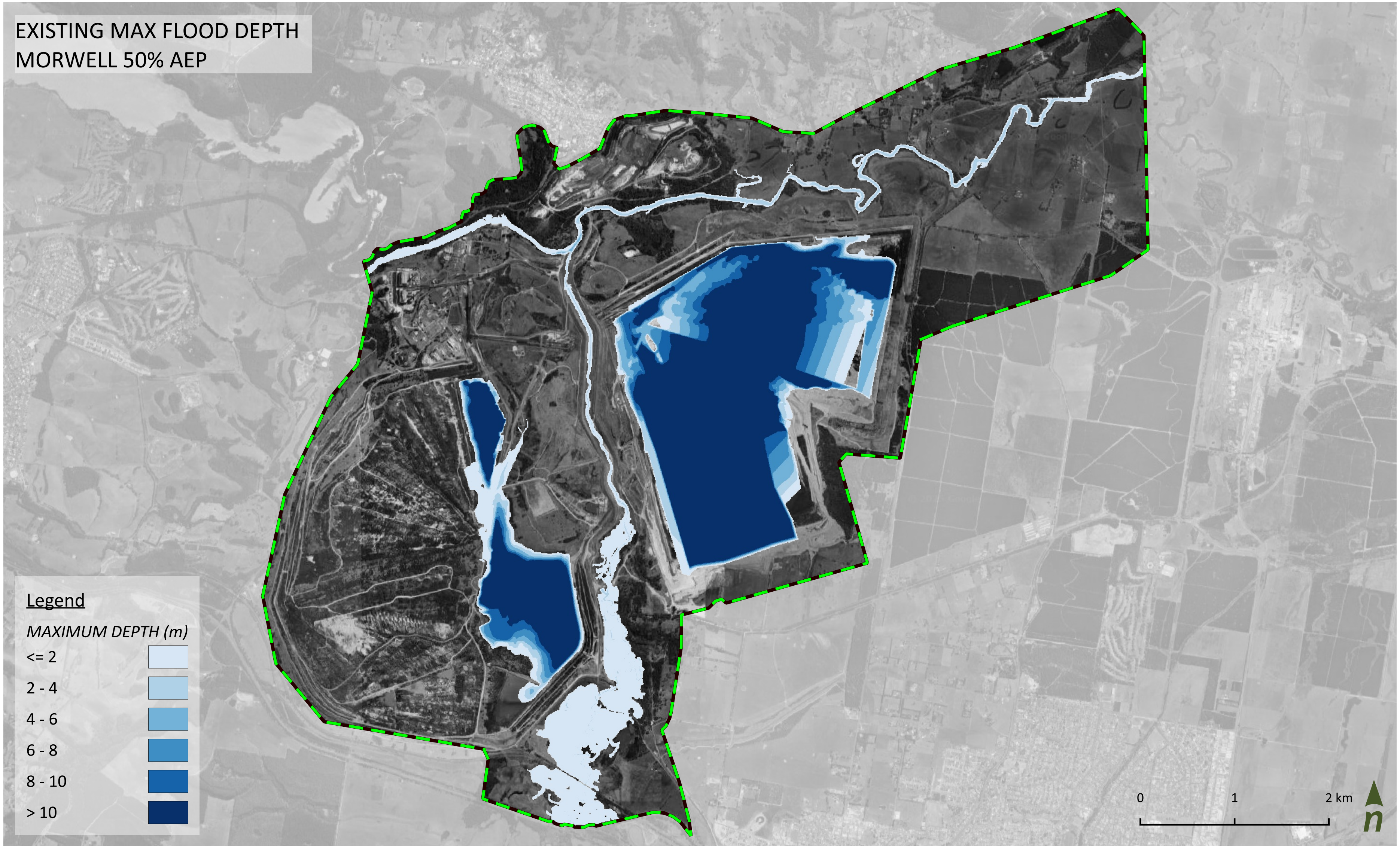


FIGURE A14. EXISTING MAX FLOOD DEPTH MORWELL 50% AEP

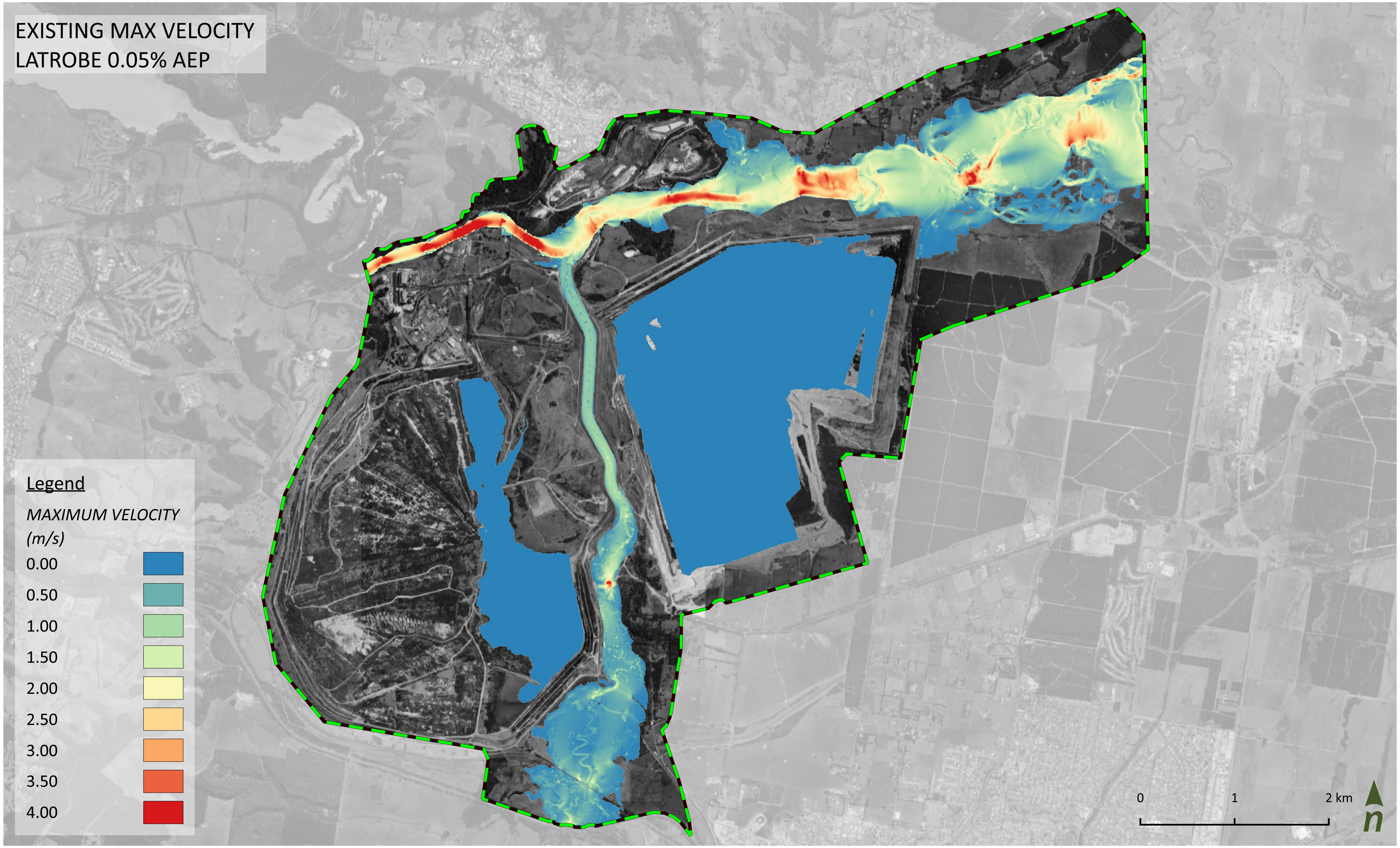


FIGURE A15. EXISTING MAX VELOCITY LATROBE 0.05% AEP

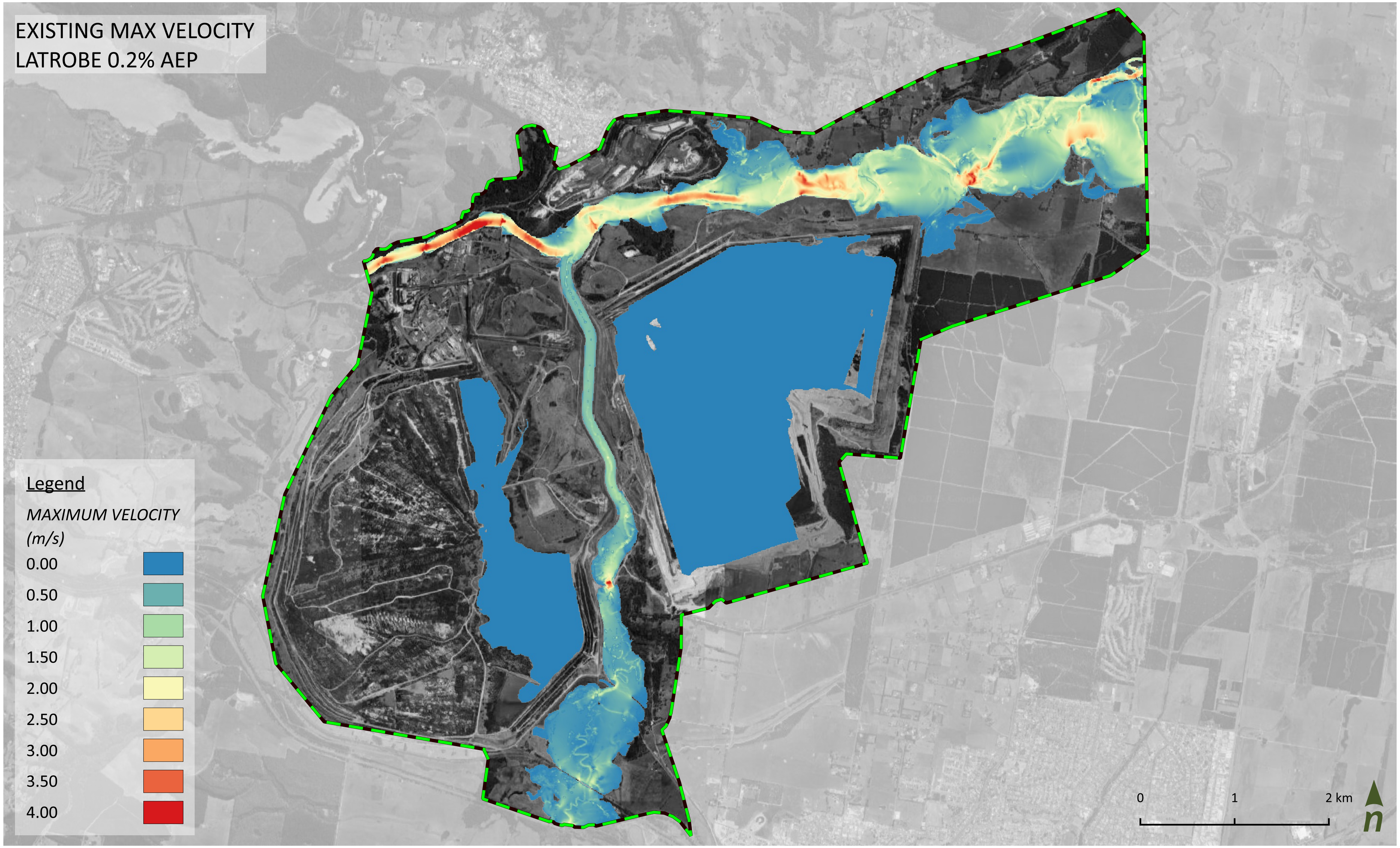


FIGURE A16. EXISTING MAX VELOCITY LATROBE 0.2% AEP

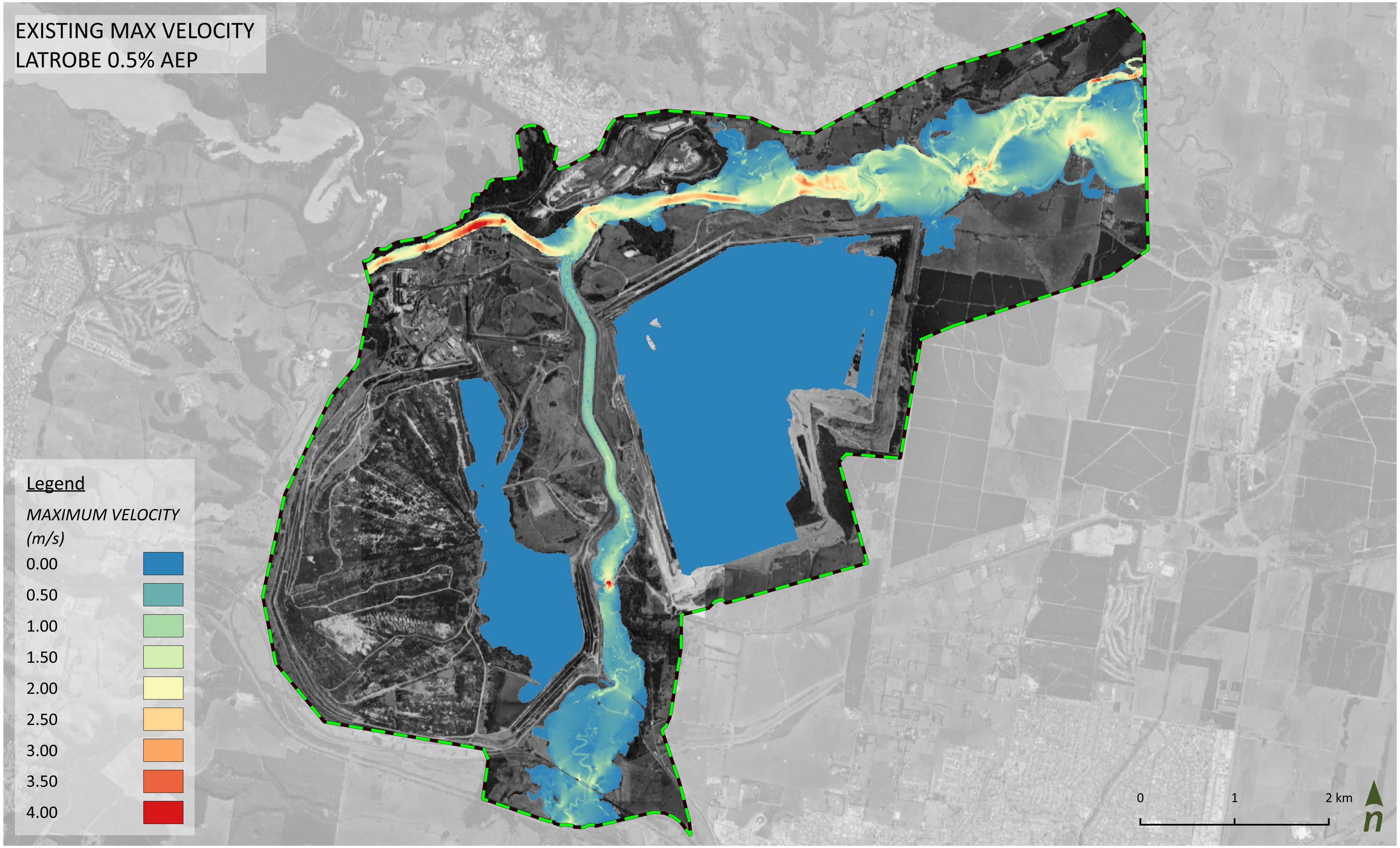


FIGURE A17. EXISTING MAX VELOCITY LATROBE 0.5% AEP

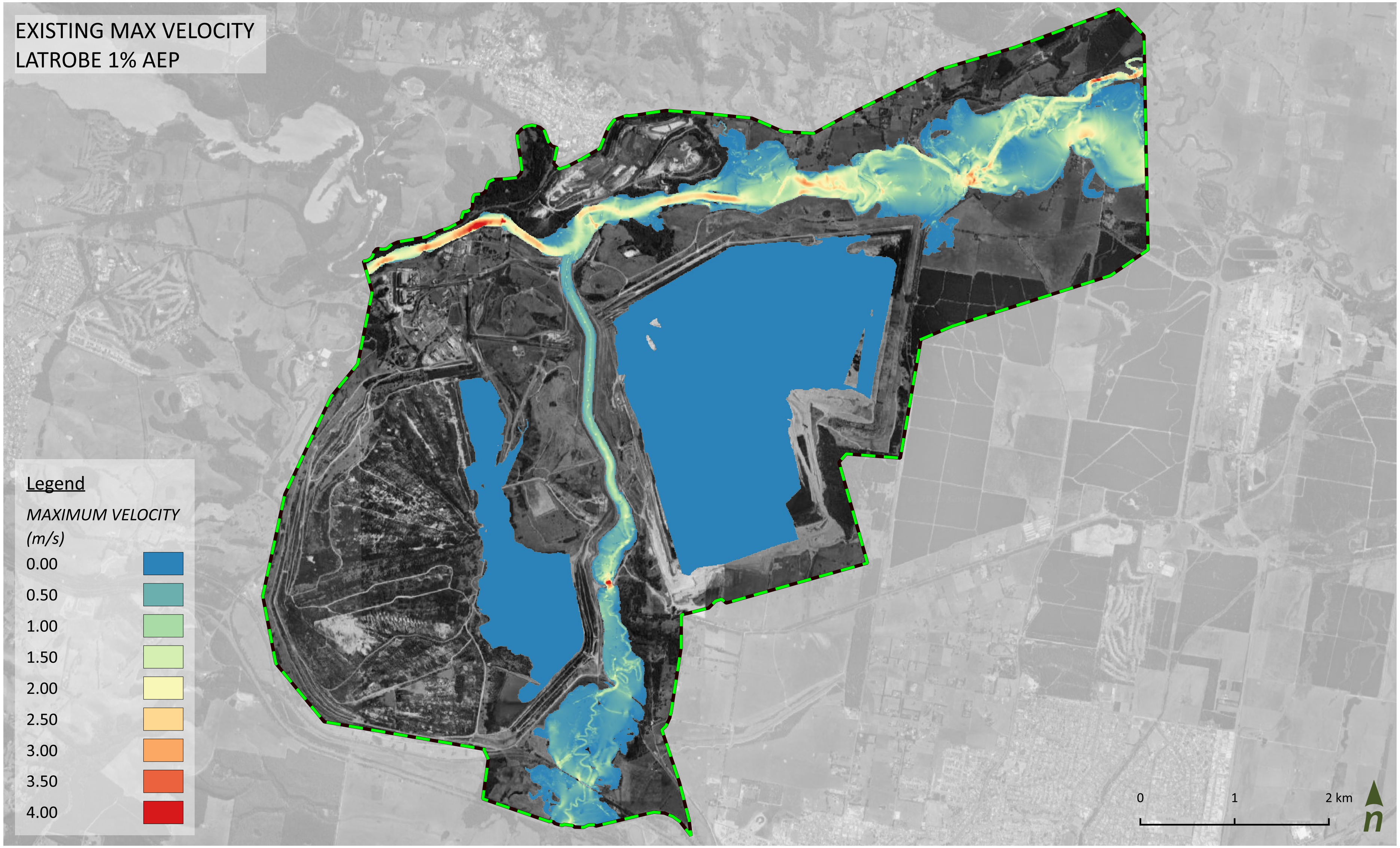


FIGURE A18. EXISTING MAX VELOCITY LATROBE 1% AEP

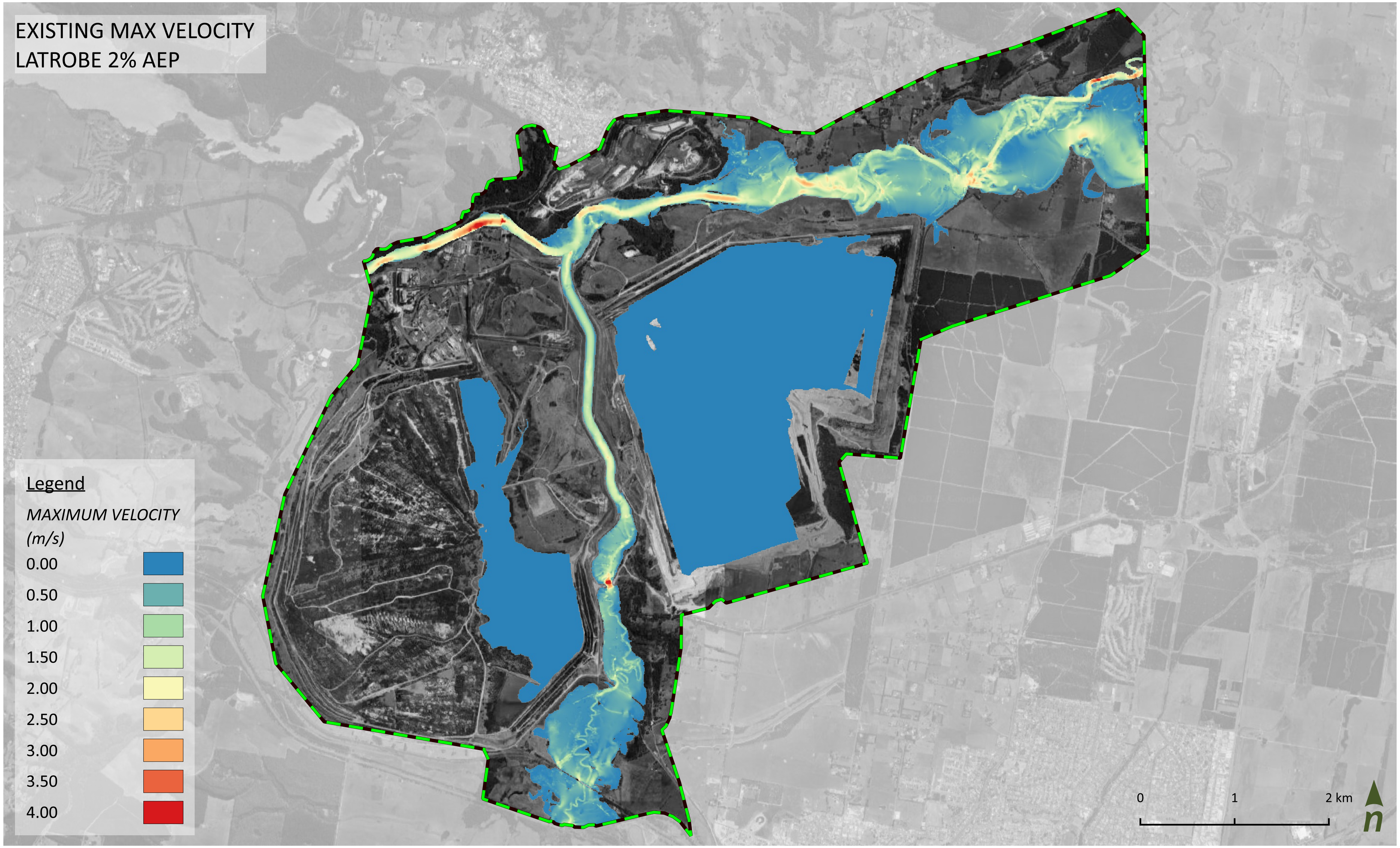


FIGURE A19. EXISTING MAX VELOCITY LATROBE 2% AEP

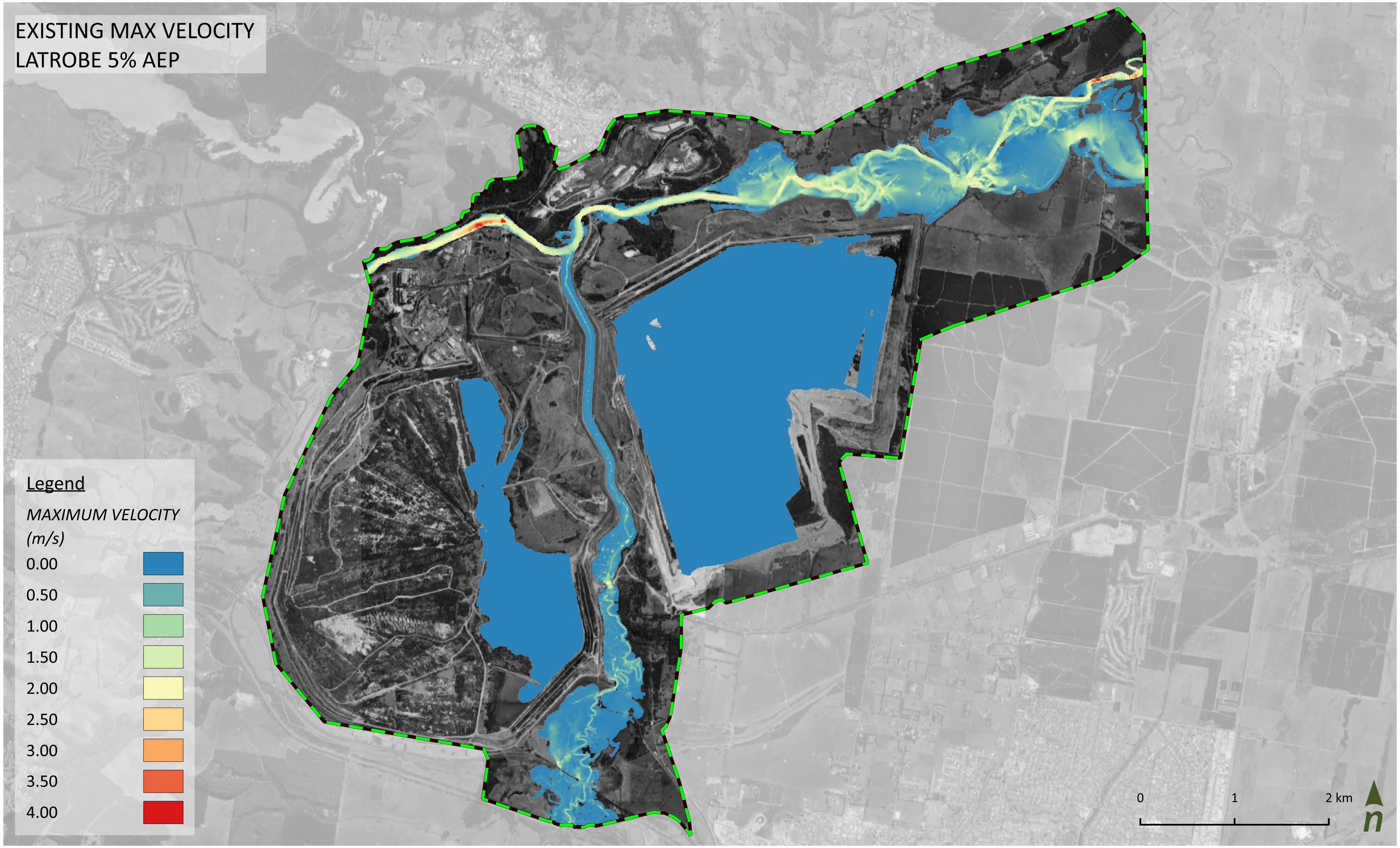


FIGURE A20. EXISTING MAX VELOCITY LATROBE 5% AEP

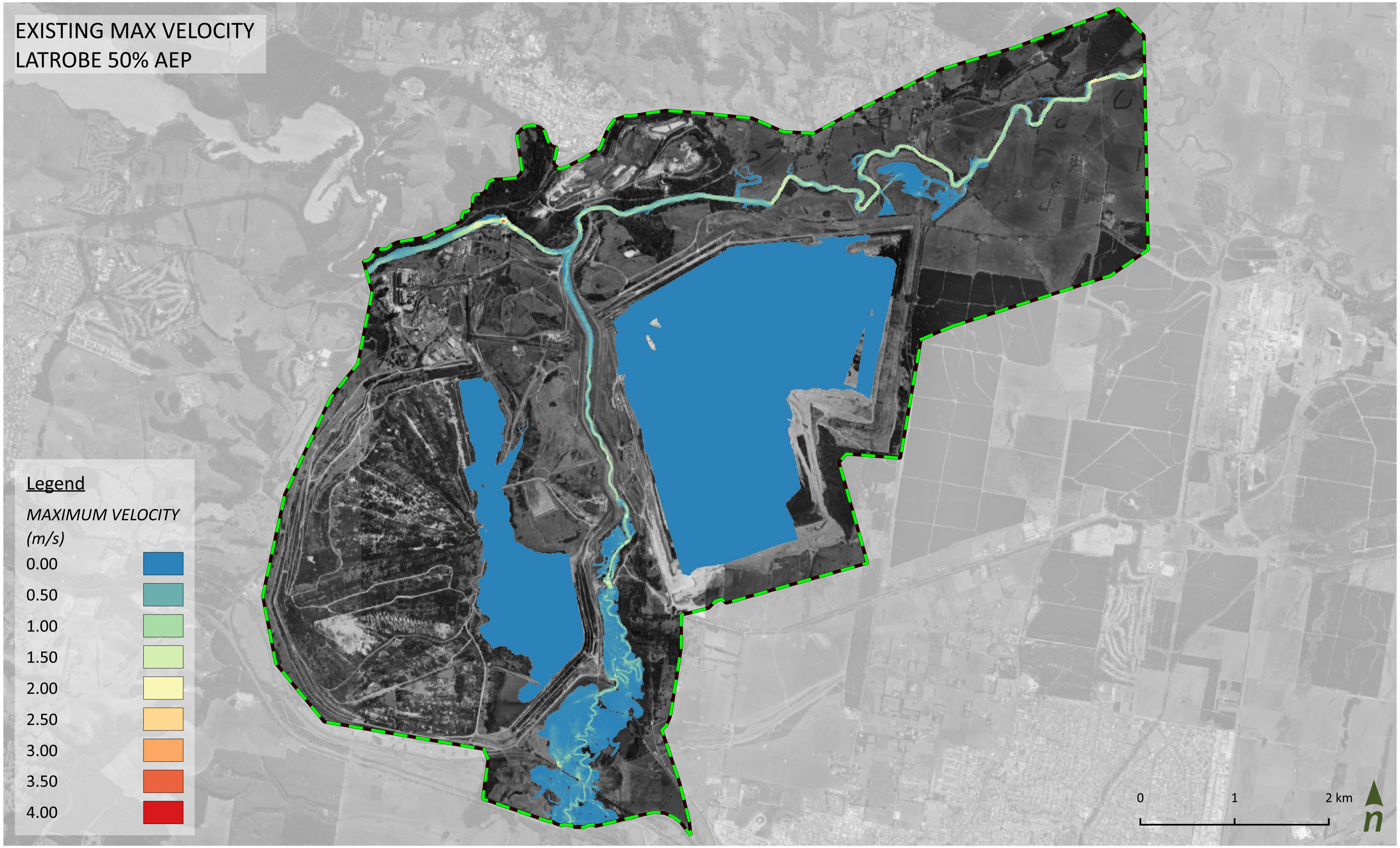


FIGURE A21. EXISTING MAX VELOCITY LATROBE 50% AEP

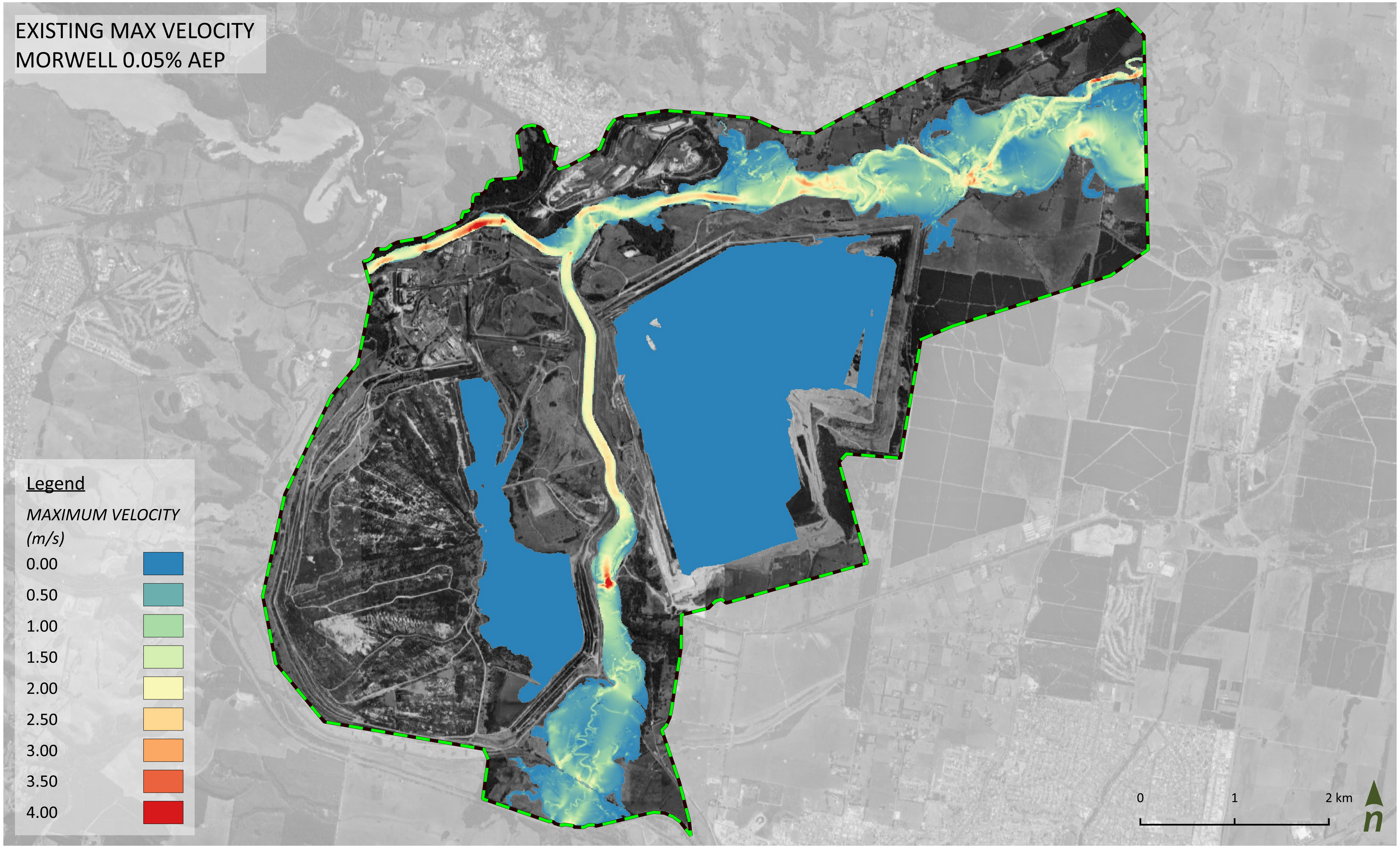


FIGURE A22. EXISTING MAX VELOCITY MORWELL 0.05% AEP

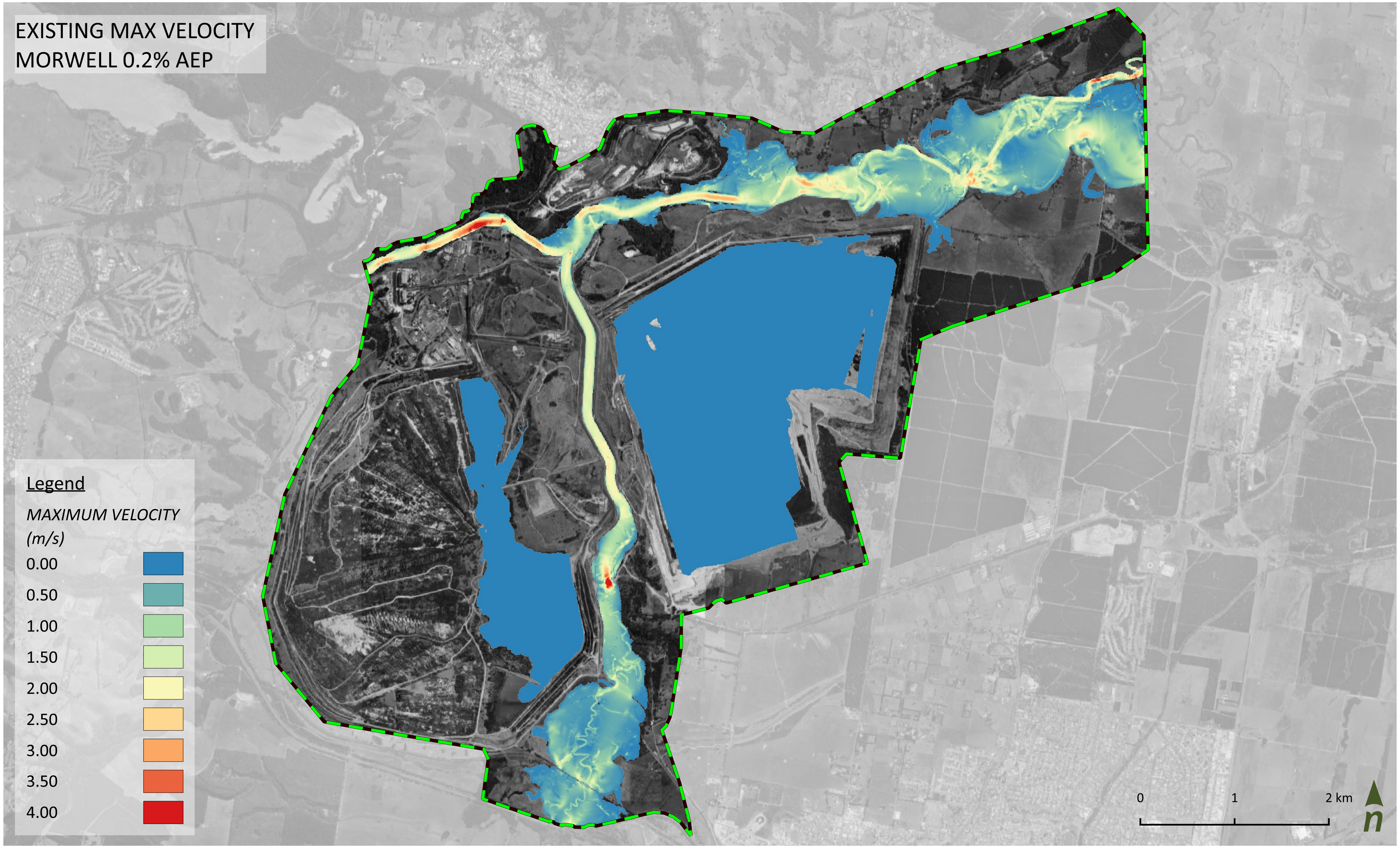


FIGURE A23. EXISTING MAX VELOCITY MORWELL 0.2% AEP

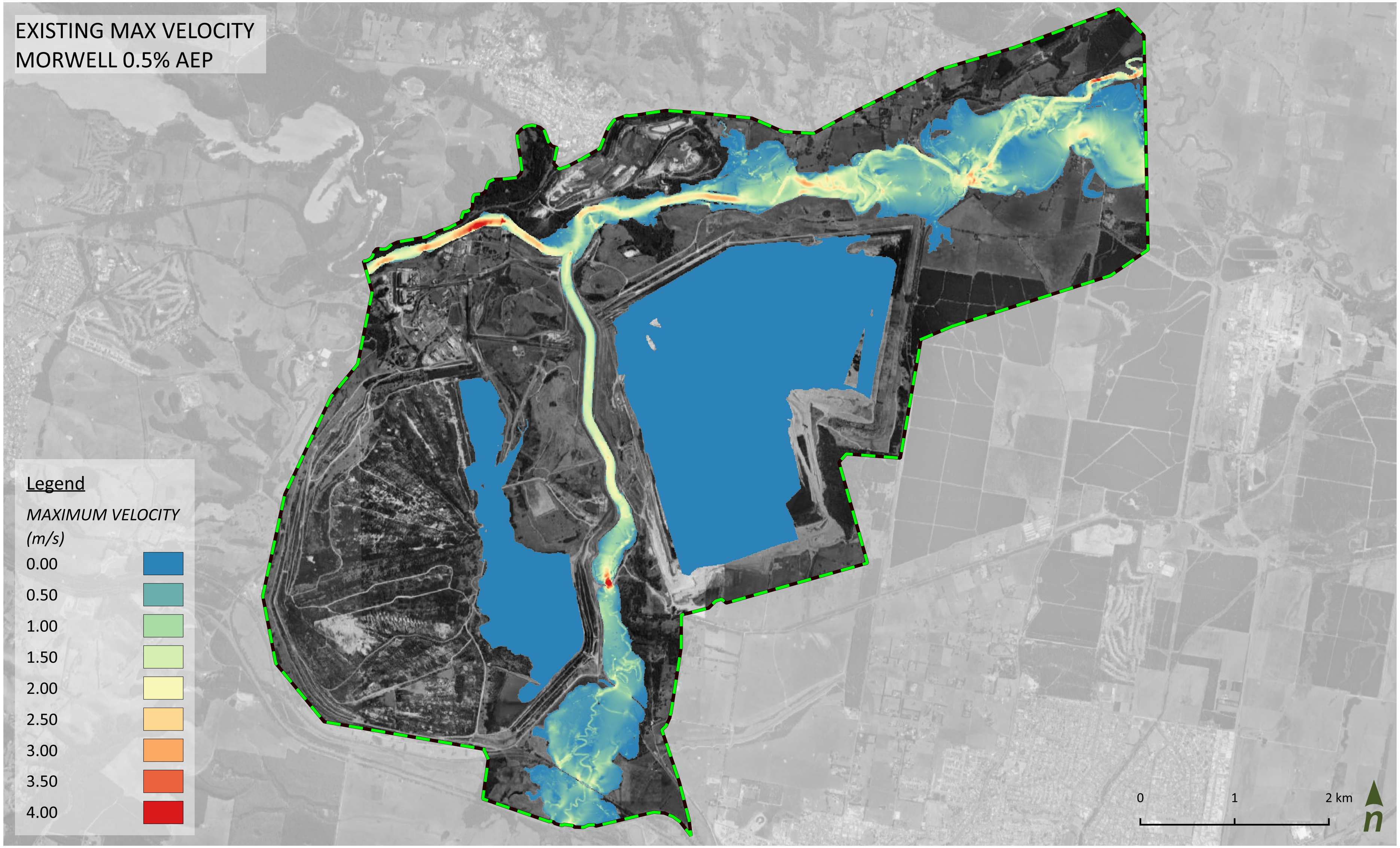


FIGURE A24. EXISTING MAX VELOCITY MORWELL 0.5% AEP

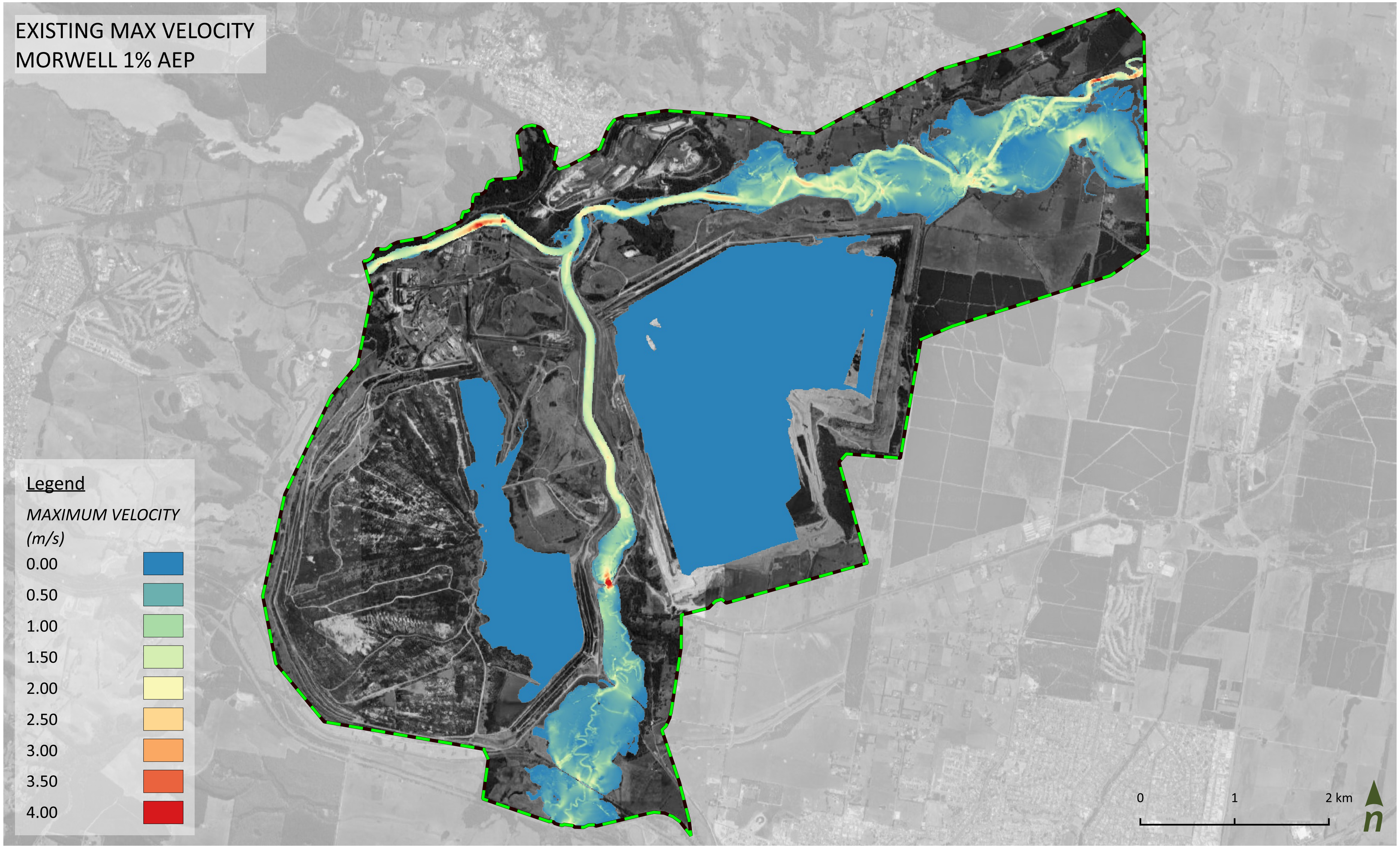


FIGURE A25. EXISTING MAX VELOCITY MORWELL 1% AEP

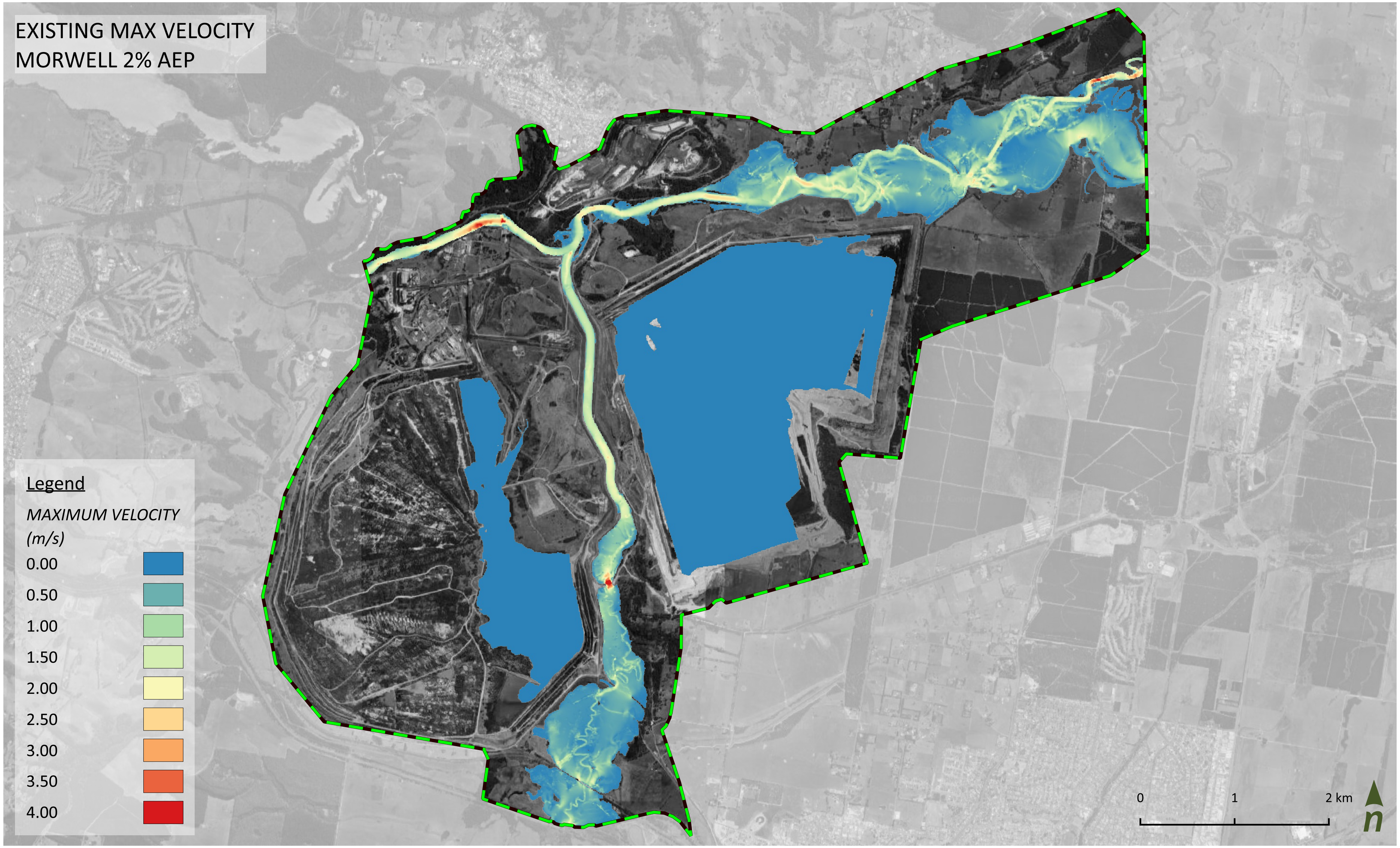


FIGURE A26. EXISTING MAX VELOCITY MORWELL 2% AEP

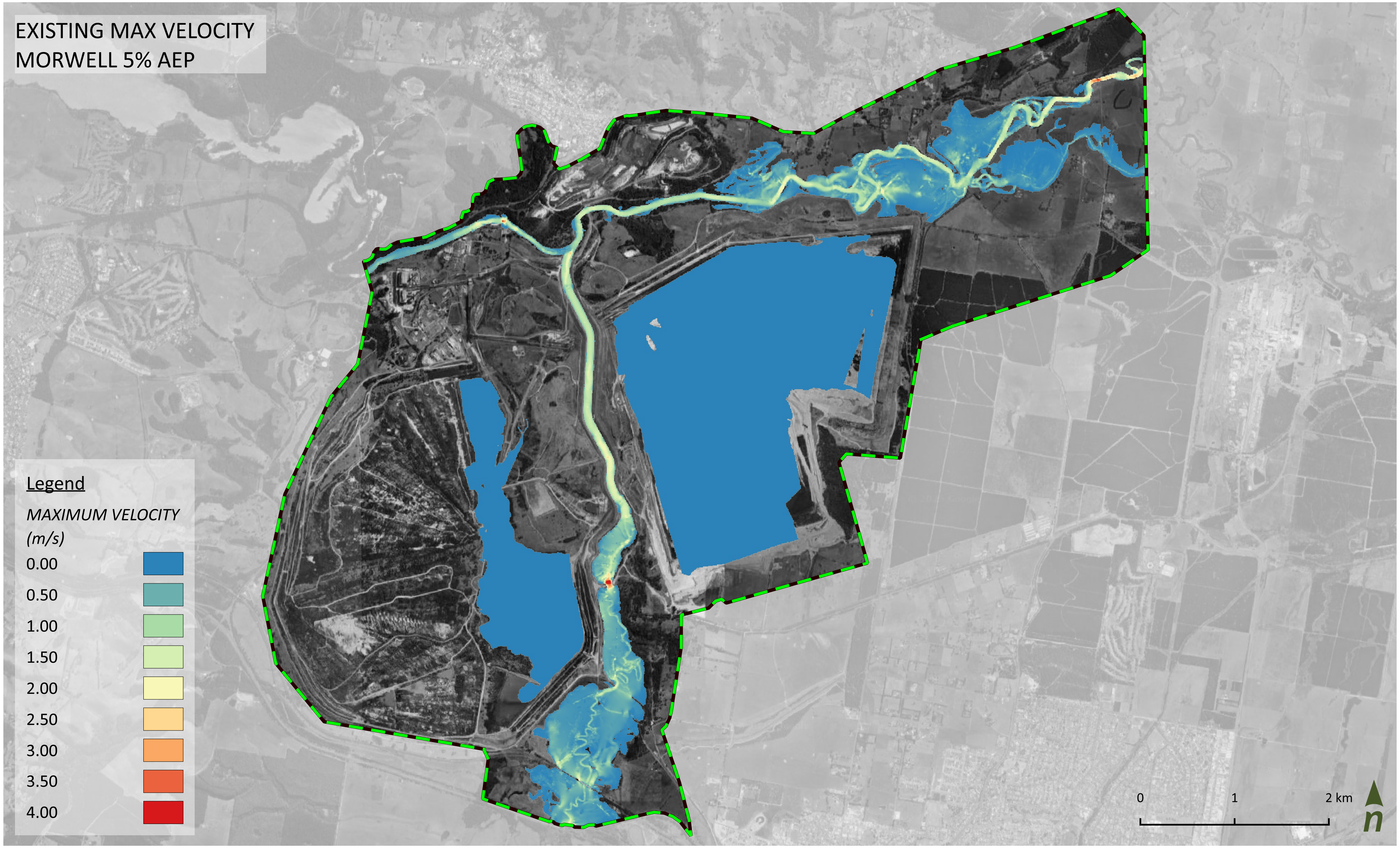


FIGURE A27. EXISTING MAX VELOCITY MORWELL 5% AEP

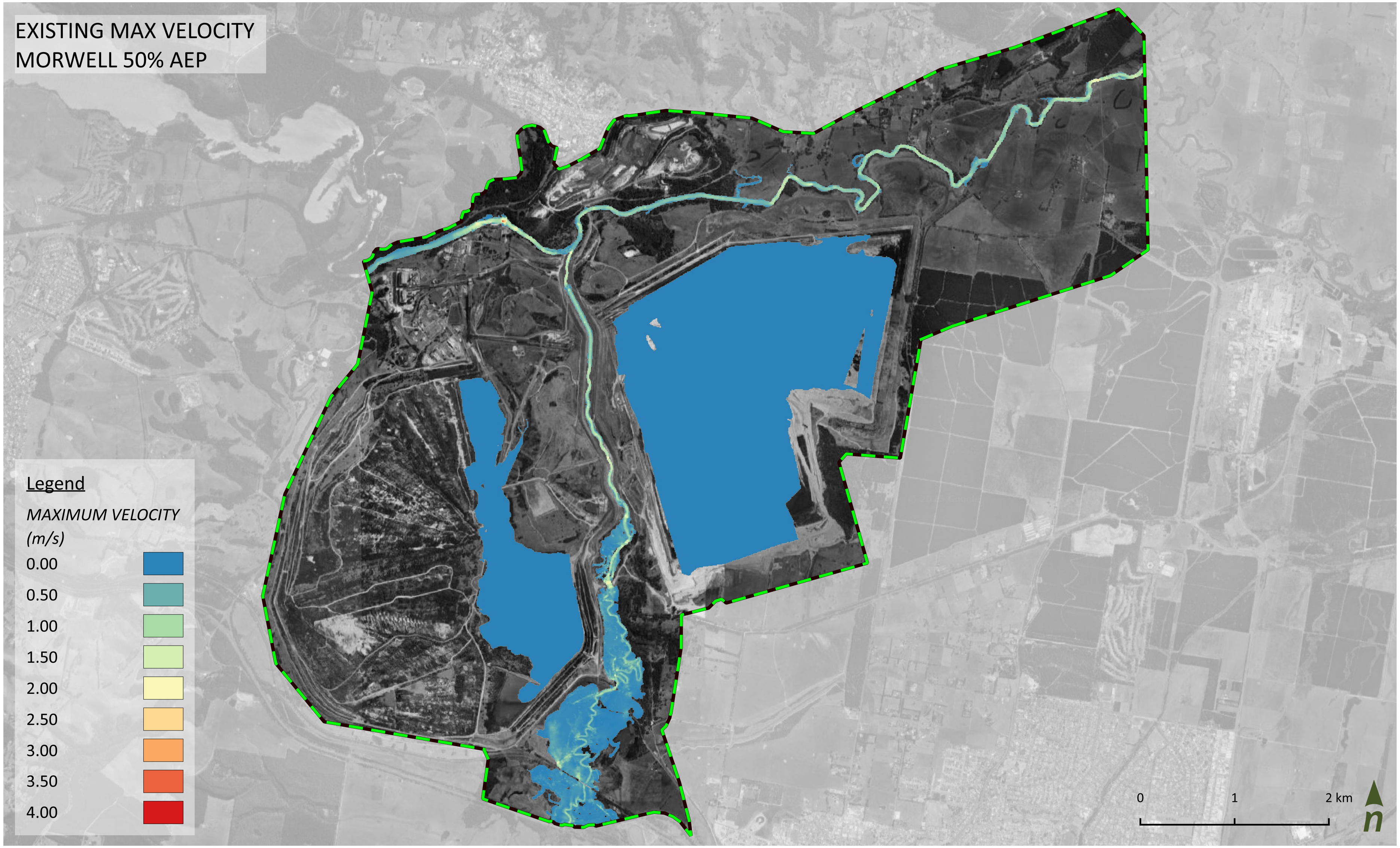


FIGURE A28. EXISTING MAX VELOCITY MORWELL 50% AEP

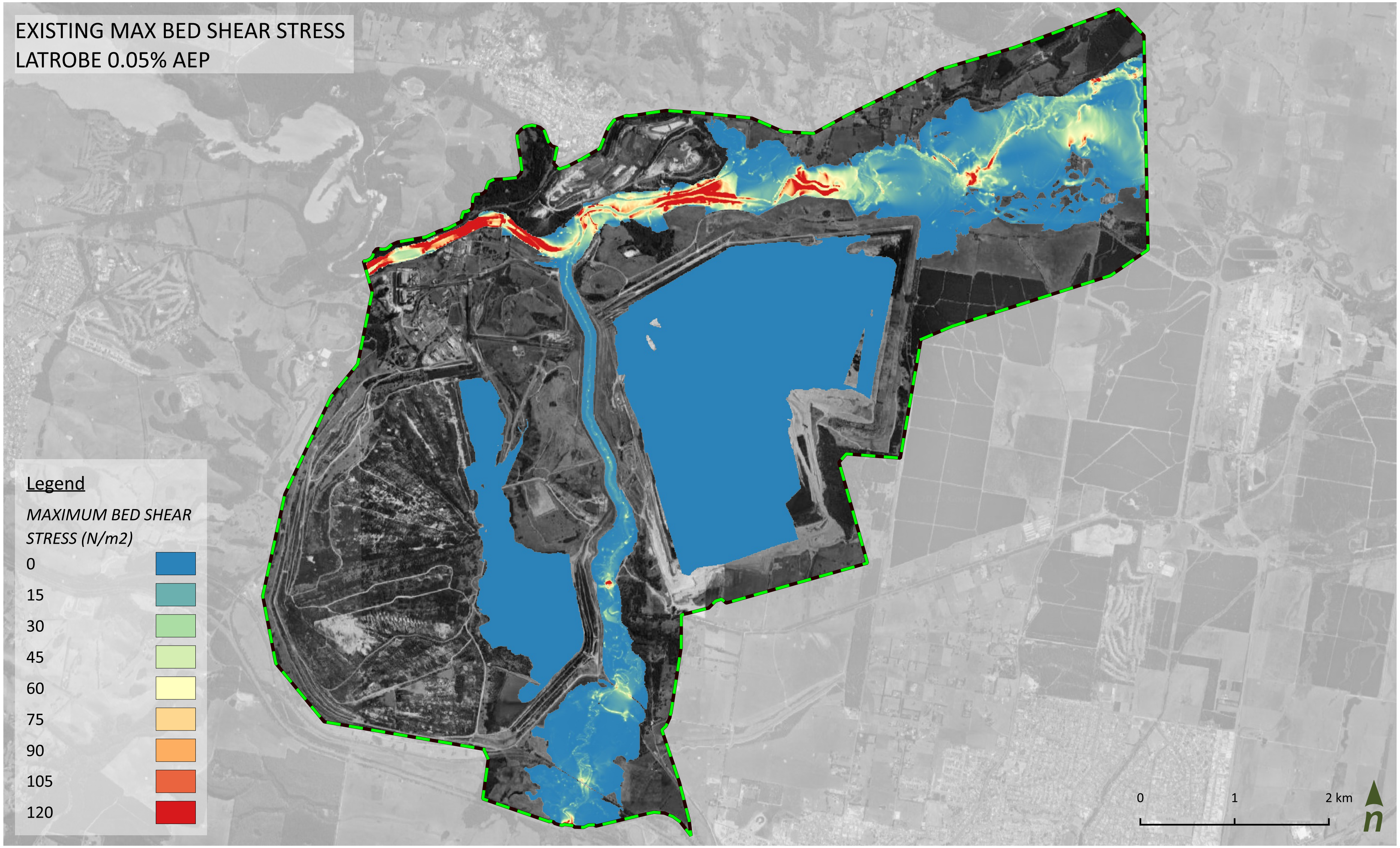


FIGURE A29. EXISTING MAX BED SHEAR STRESS LATROBE 0.05% AEP

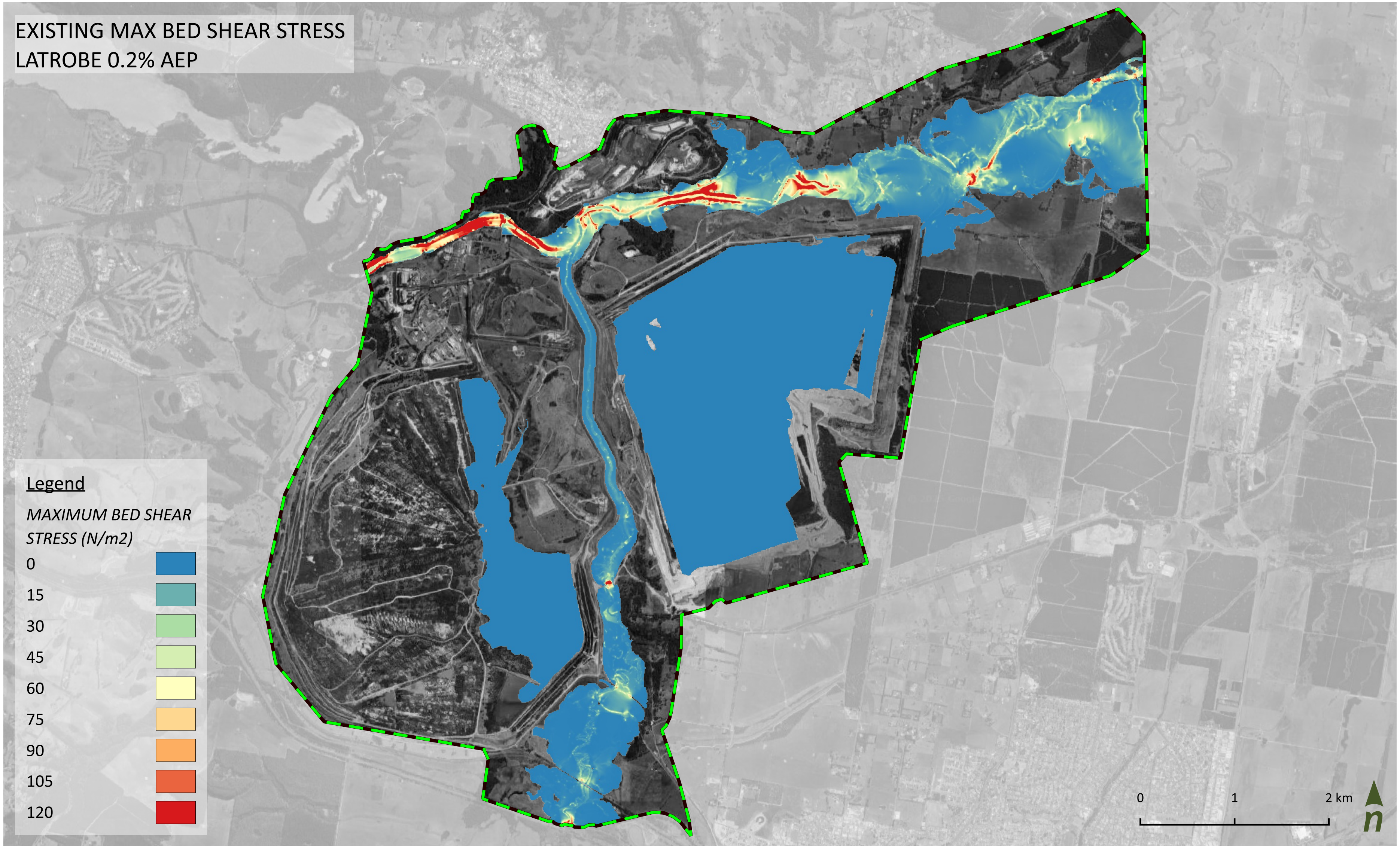


FIGURE A30. EXISTING MAX BED SHEAR STRESS LATROBE 0.2% AEP

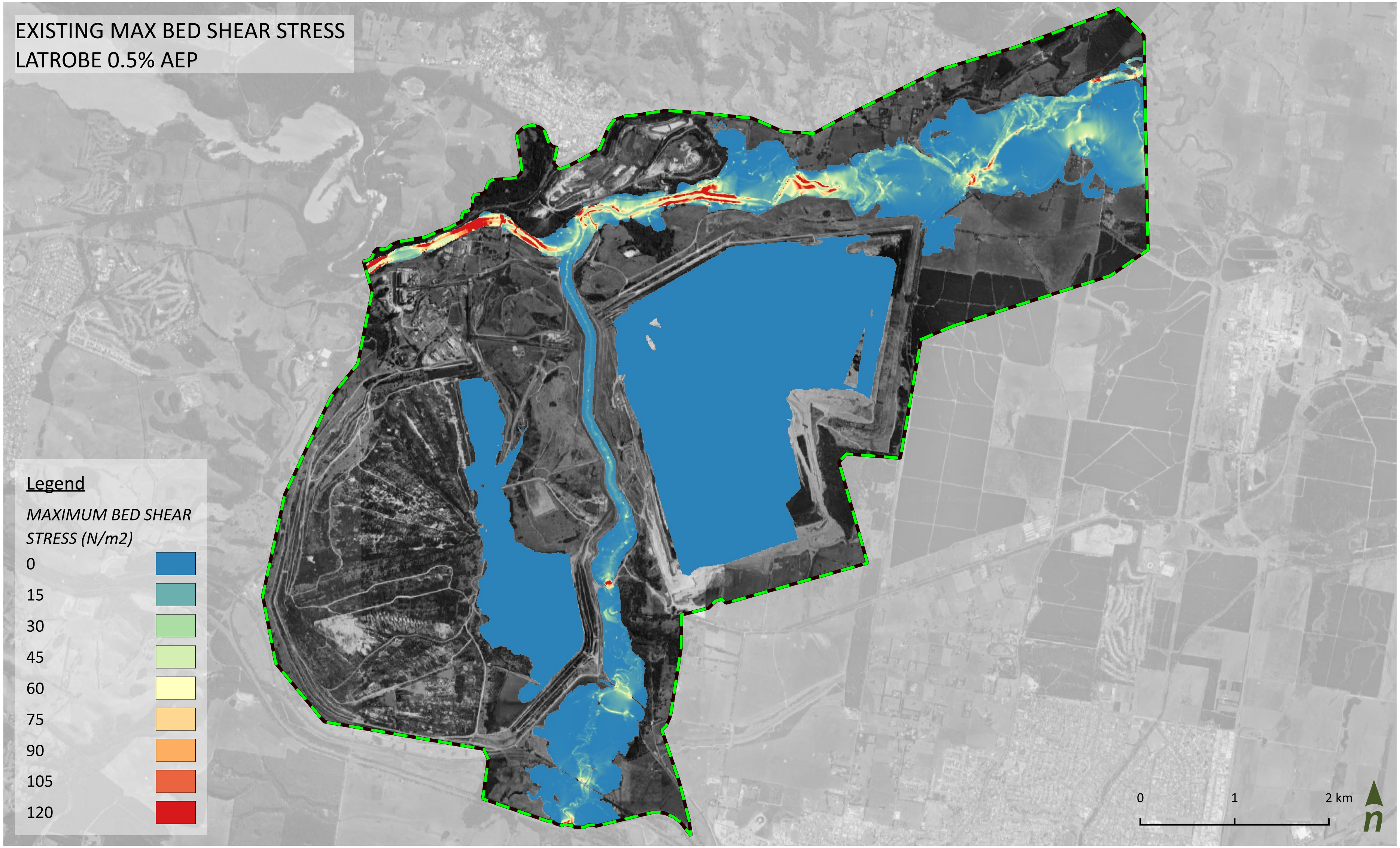


FIGURE A31. EXISTING MAX BED SHEAR STRESS LATROBE 0.5% AEP

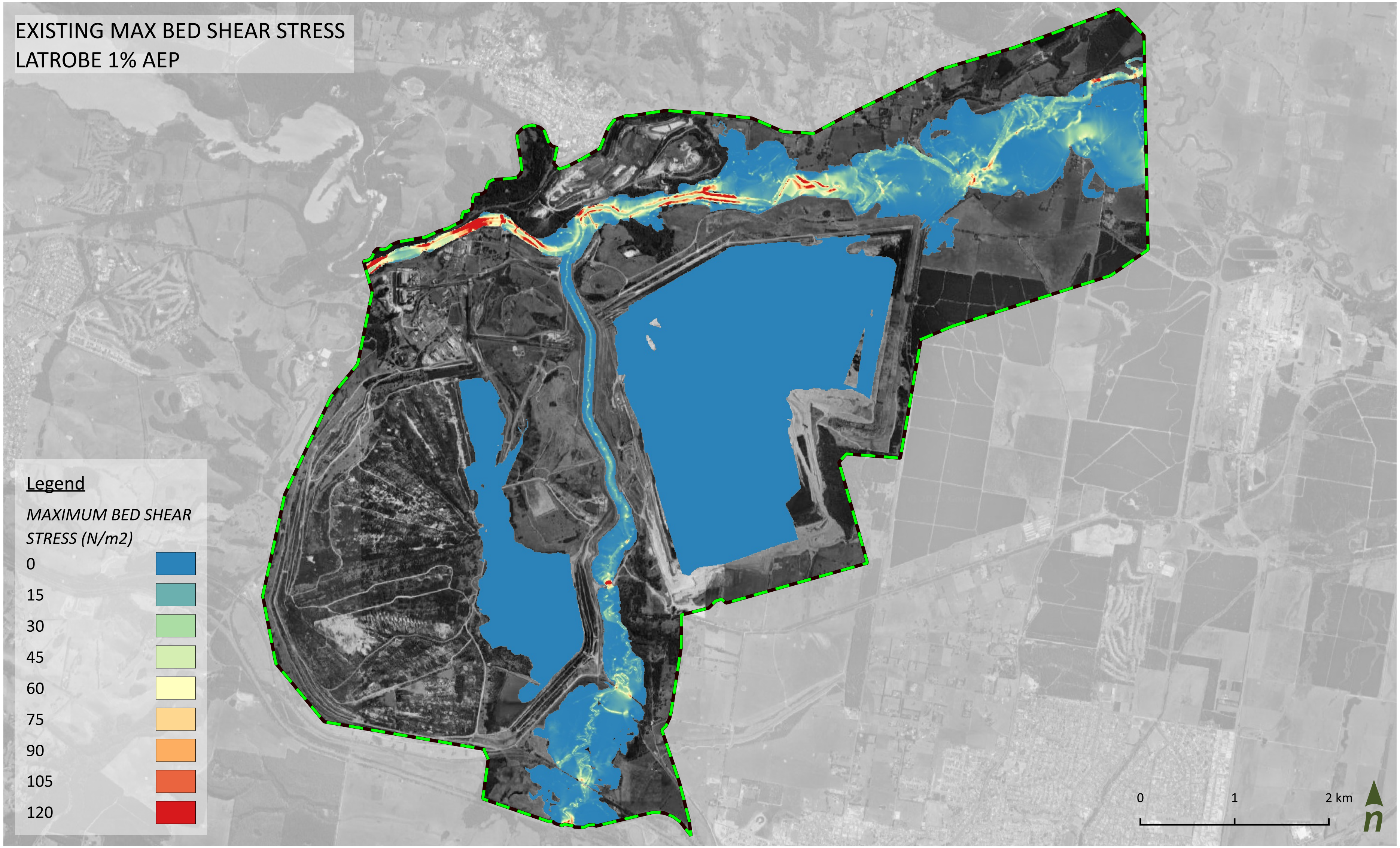


FIGURE A32. EXISTING MAX BED SHEAR STRESS LATROBE 1% AEP

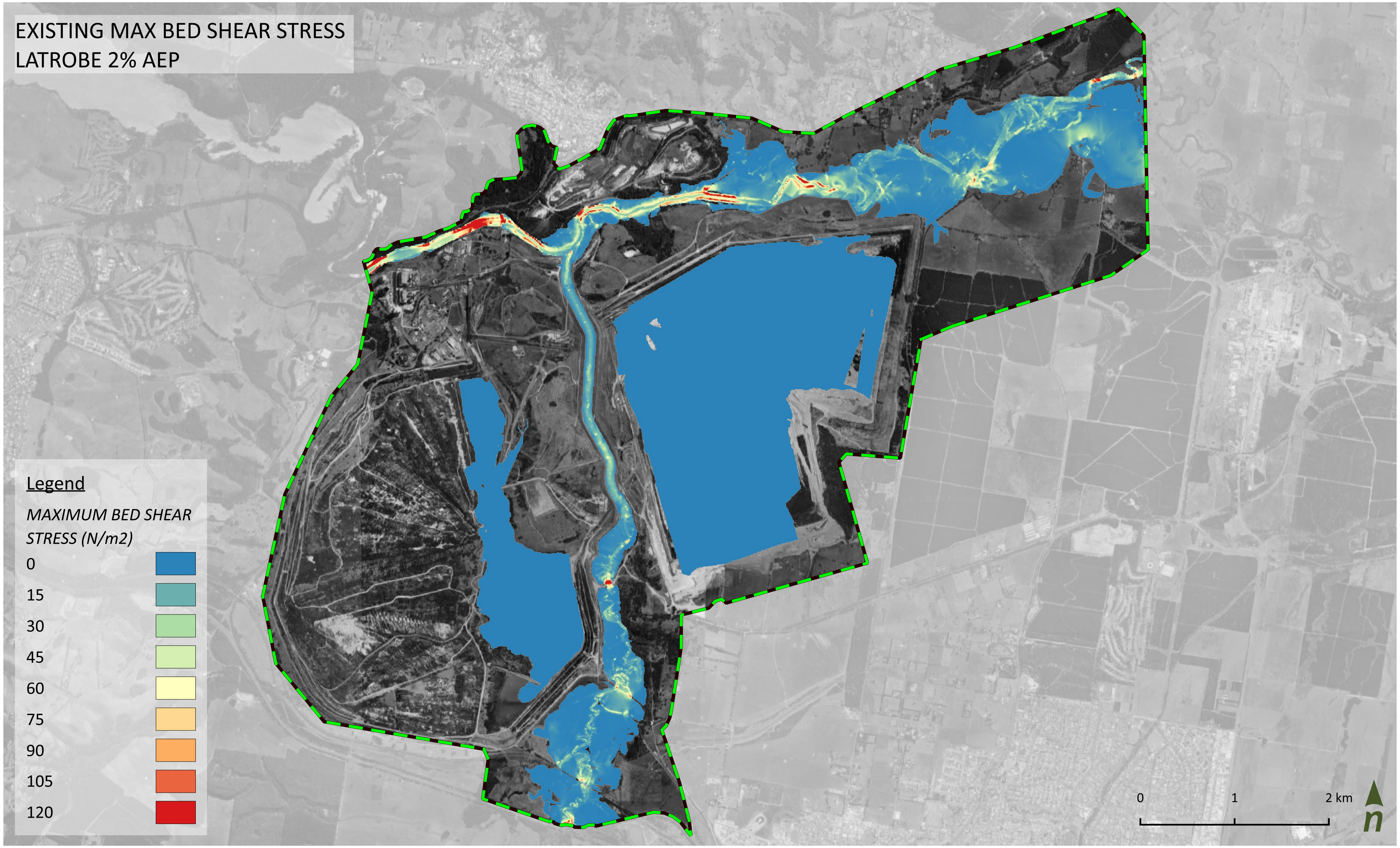


FIGURE A33. EXISTING MAX BED SHEAR STRESS LATROBE 2% AEP

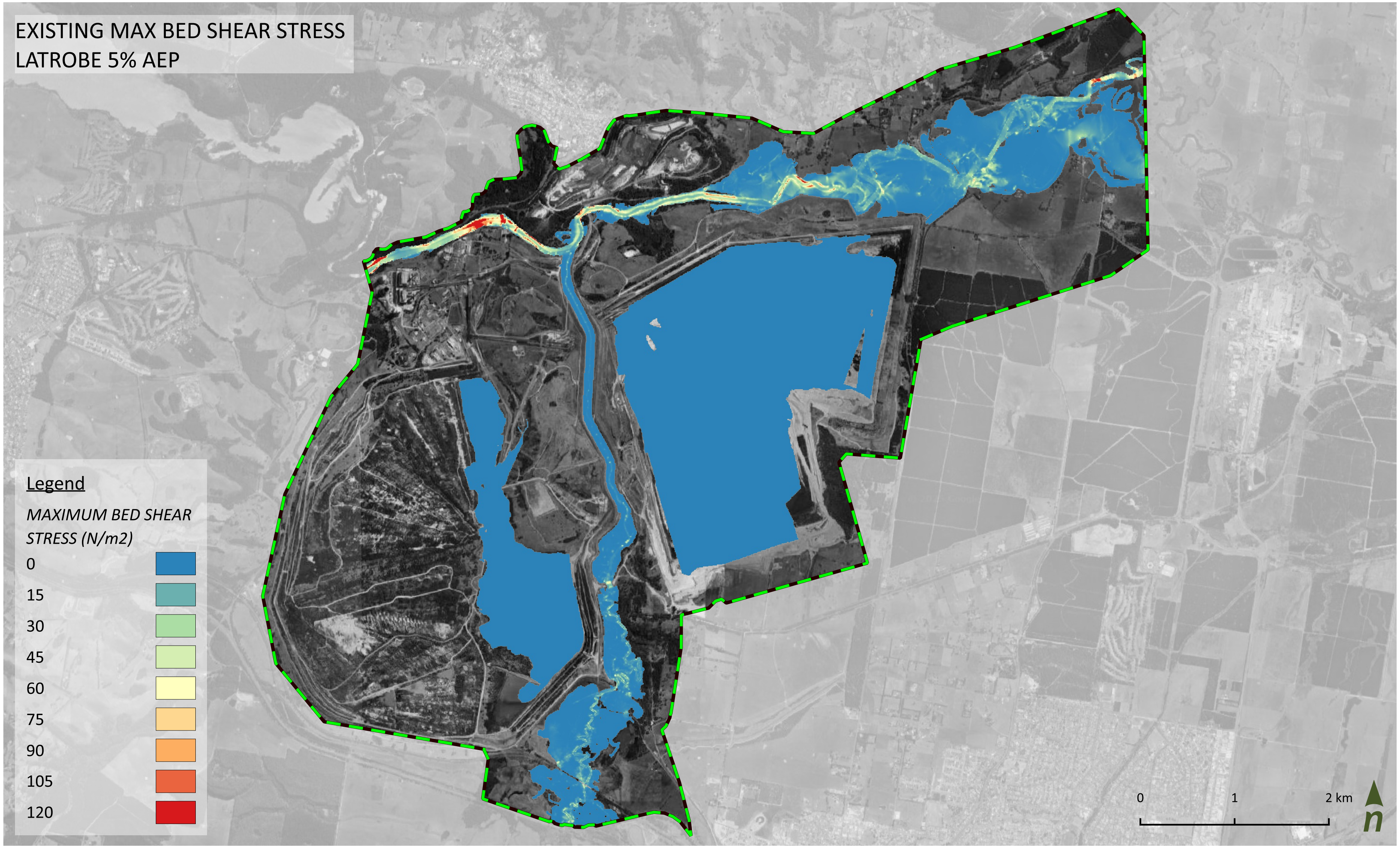


FIGURE A34. EXISTING MAX BED SHEAR STRESS LATROBE 5% AEP

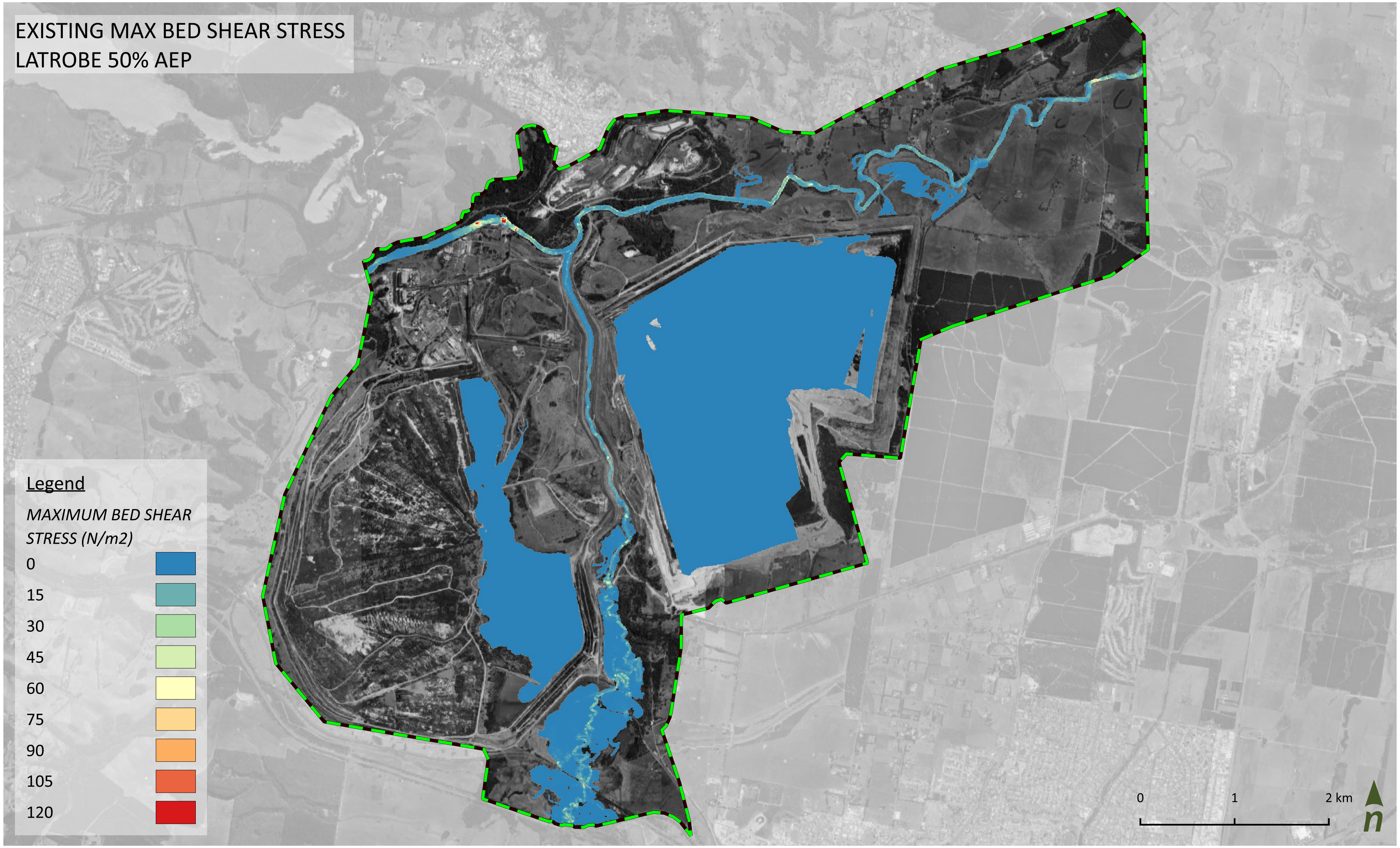


FIGURE A35. EXISTING MAX BED SHEAR STRESS LATROBE 50% AEP

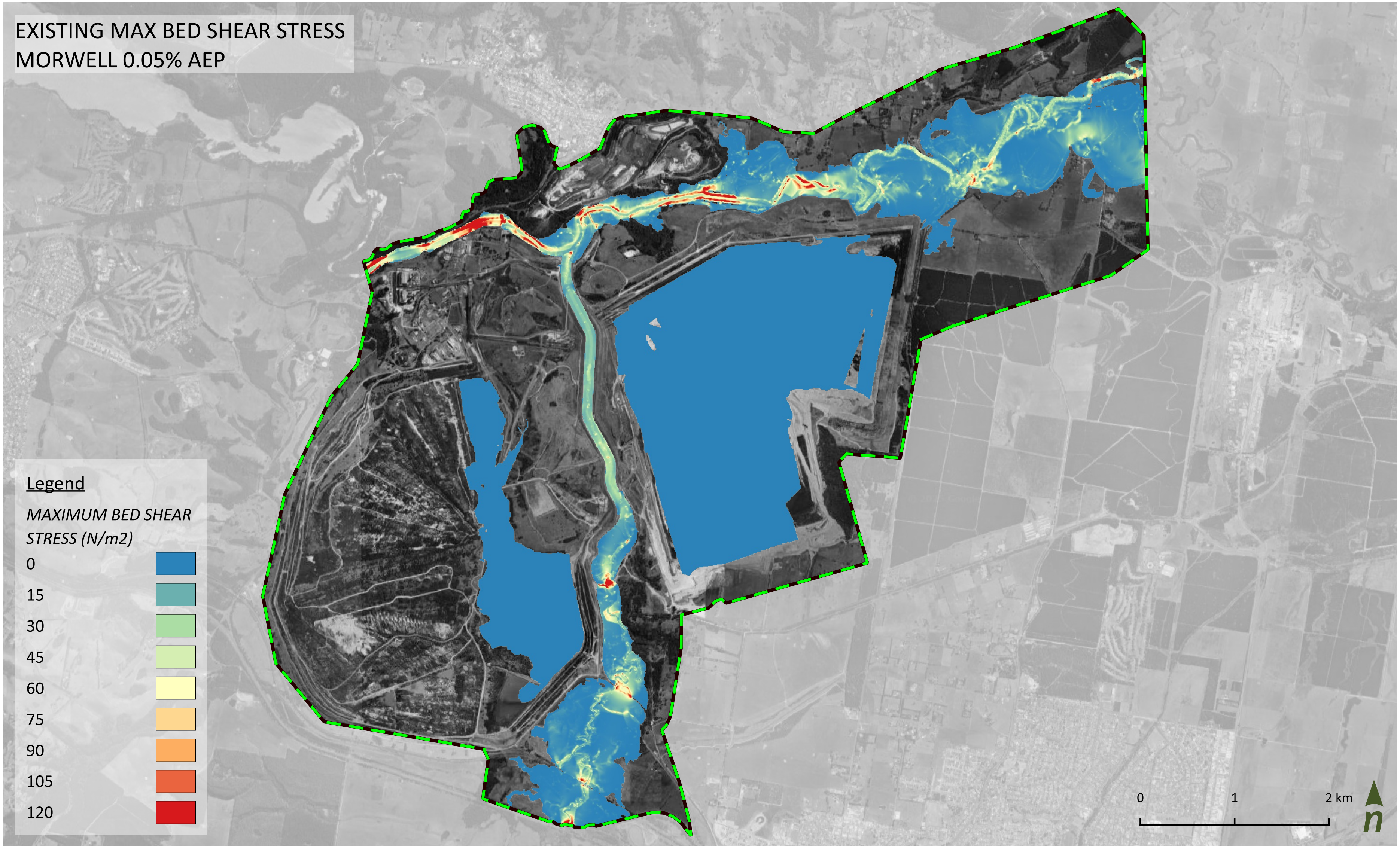


FIGURE A36. EXISTING MAX BED SHEAR STRESS MORWELL 0.05% AEP

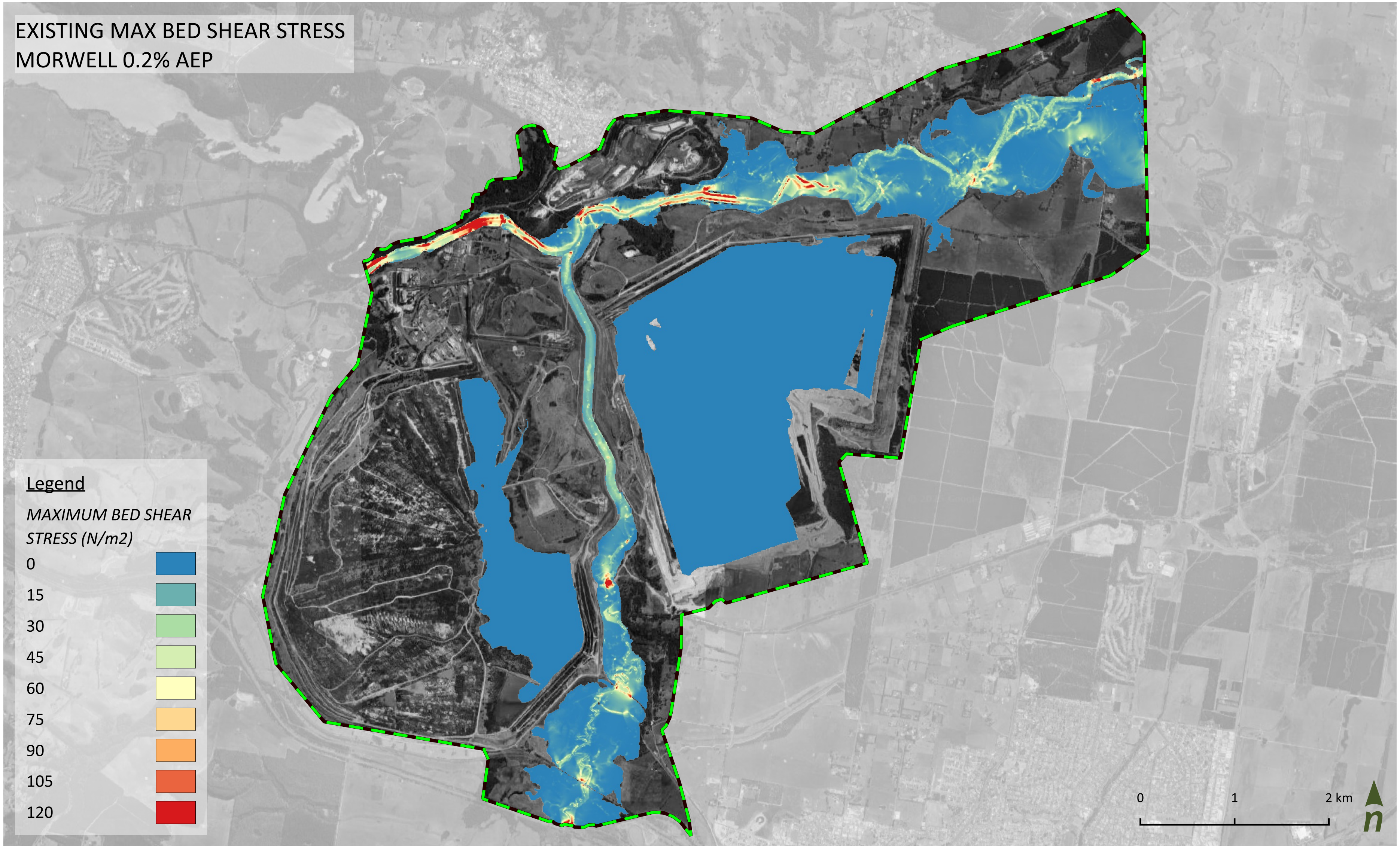


FIGURE A37. EXISTING MAX BED SHEAR STRESS MORWELL 0.2% AEP

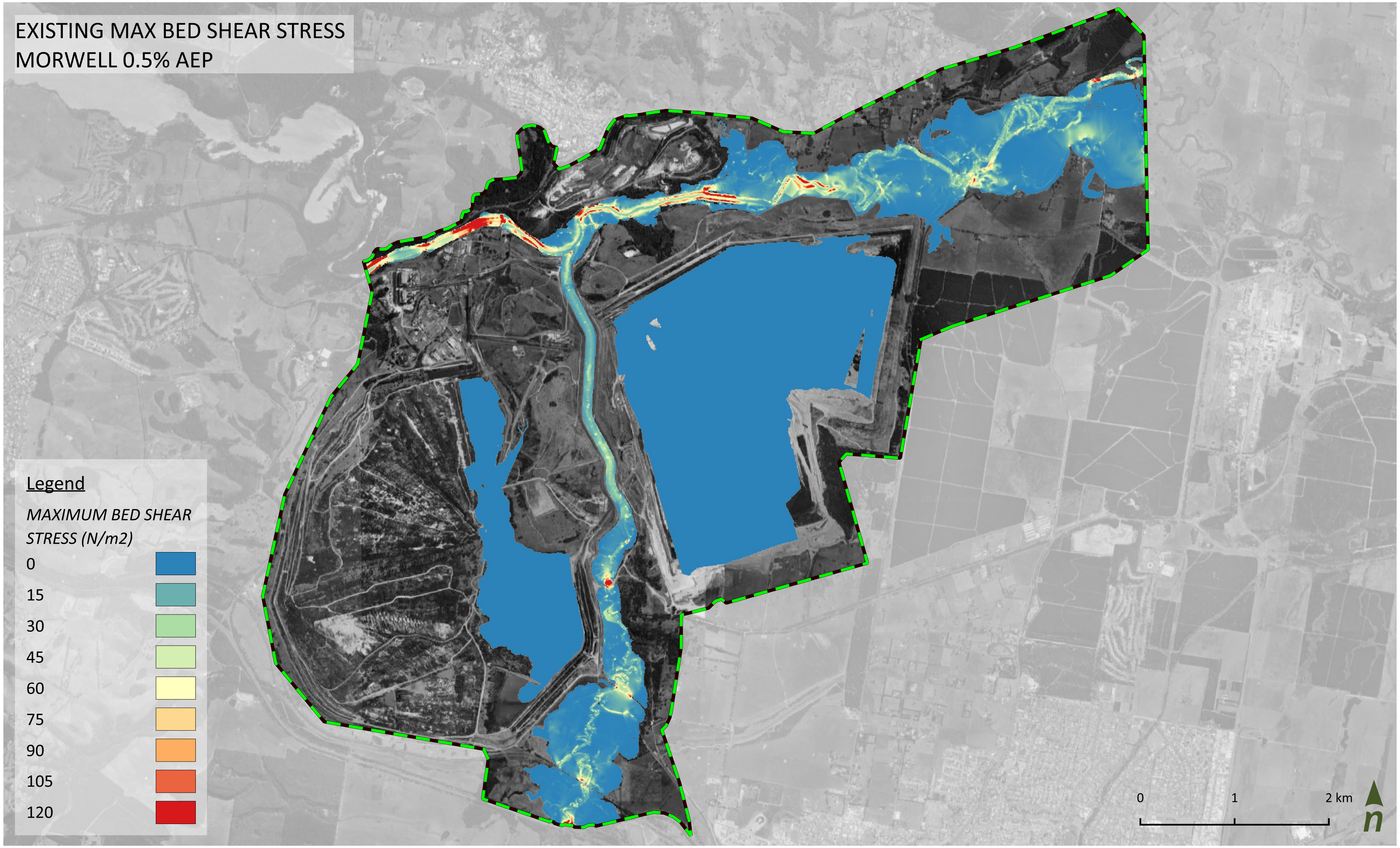


FIGURE A38. EXISTING MAX BED SHEAR STRESS MORWELL 0.5% AEP

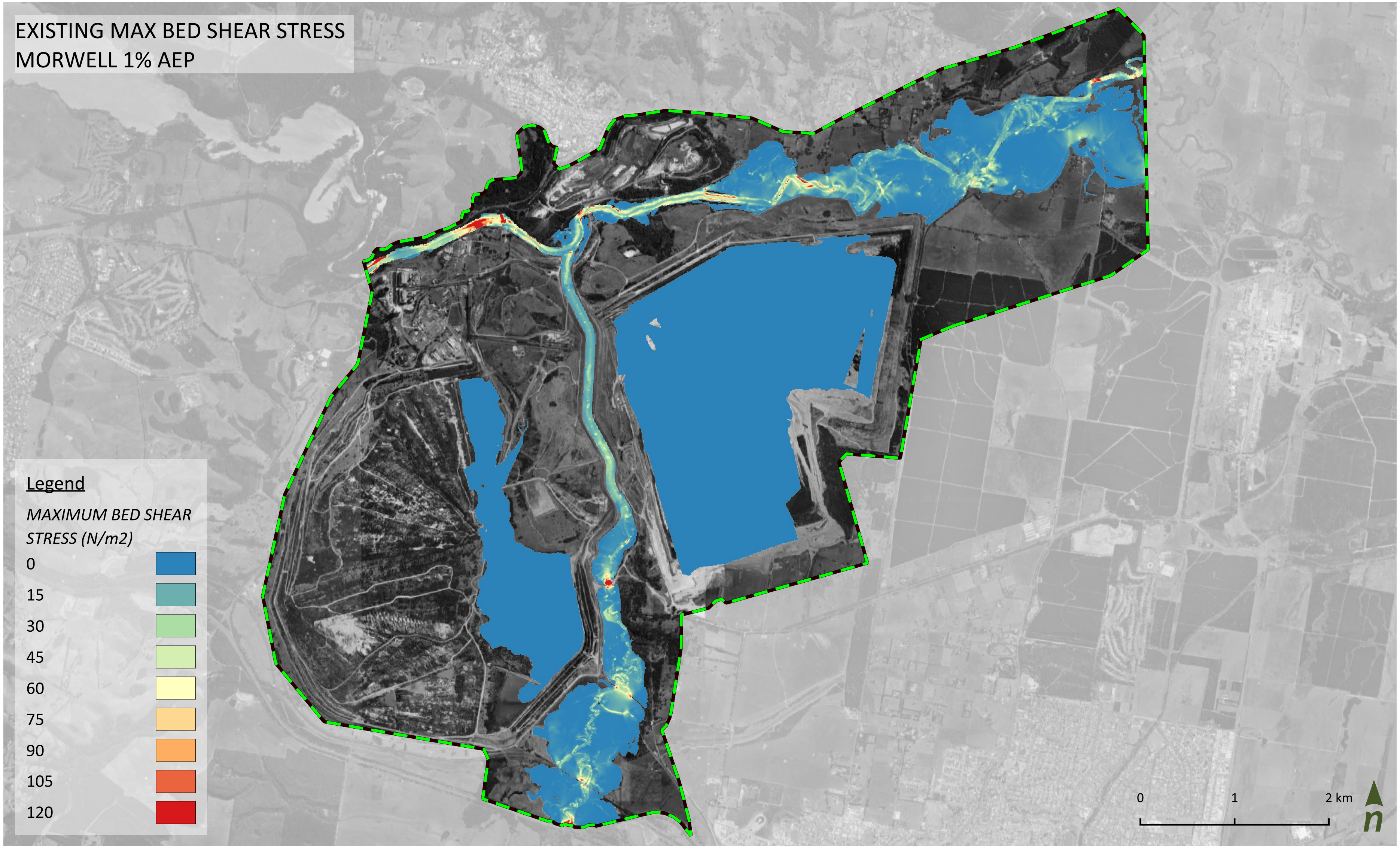


FIGURE A39. EXISTING MAX BED SHEAR STRESS MORWELL 1% AEP

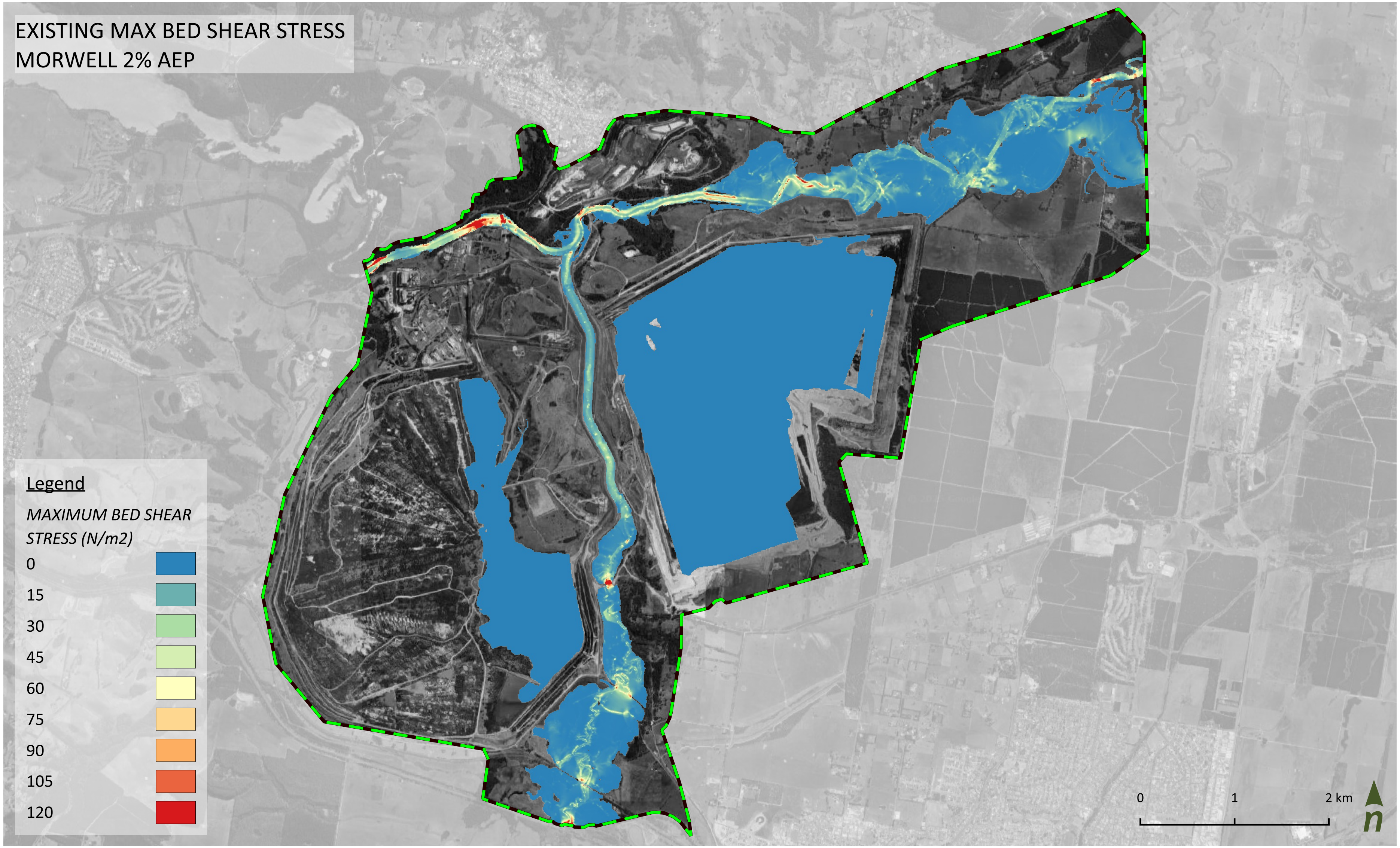


FIGURE A40. EXISTING MAX BED SHEAR STRESS MORWELL 2% AEP

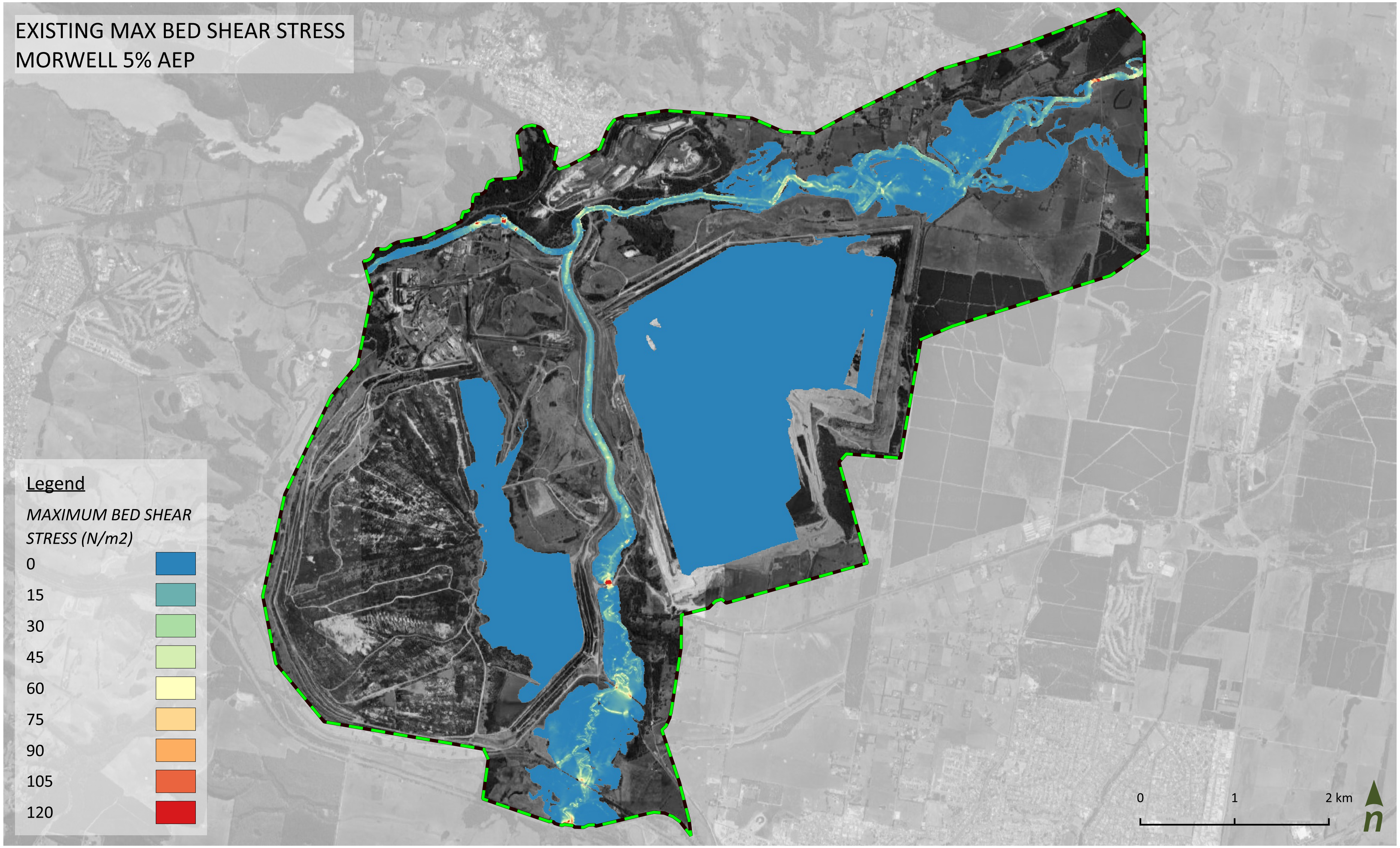


FIGURE A41. EXISTING MAX BED SHEAR STRESS MORWELL 5% AEP

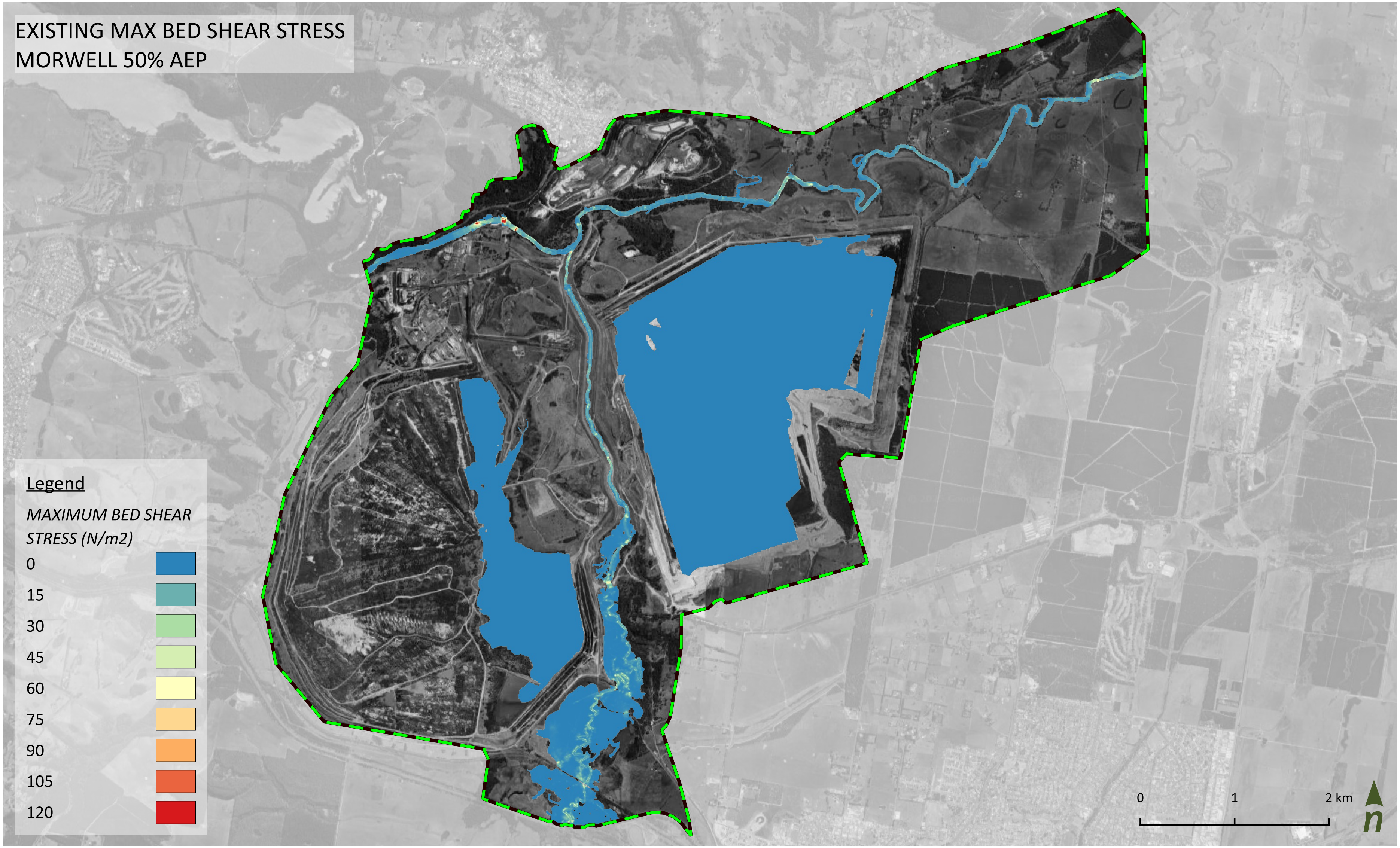


FIGURE A42. EXISTING MAX BED SHEAR STRESS MORWELL 50% AEP

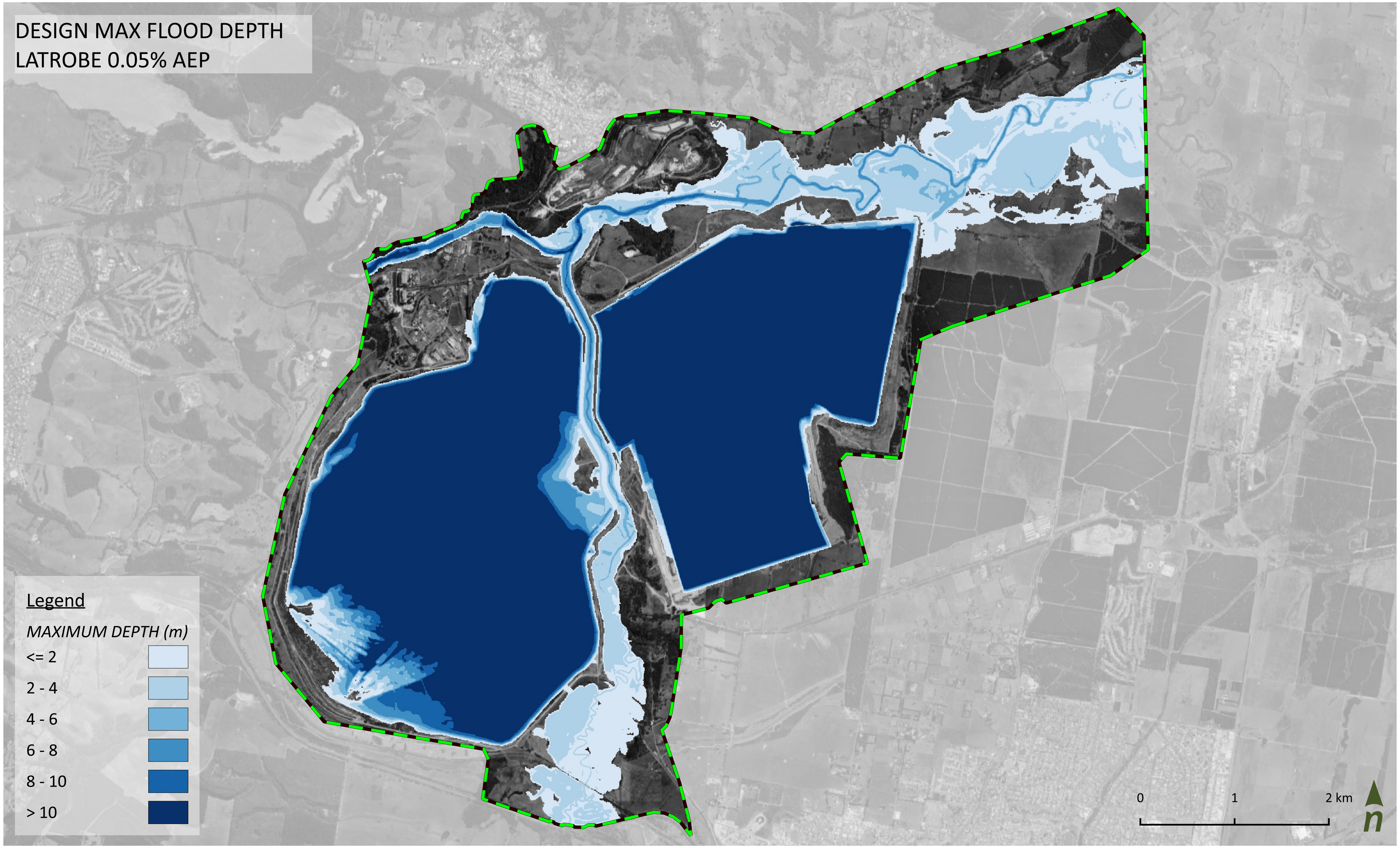


FIGURE A43. DESIGN MAX FLOOD DEPTH LATROBE 0.05% AEP

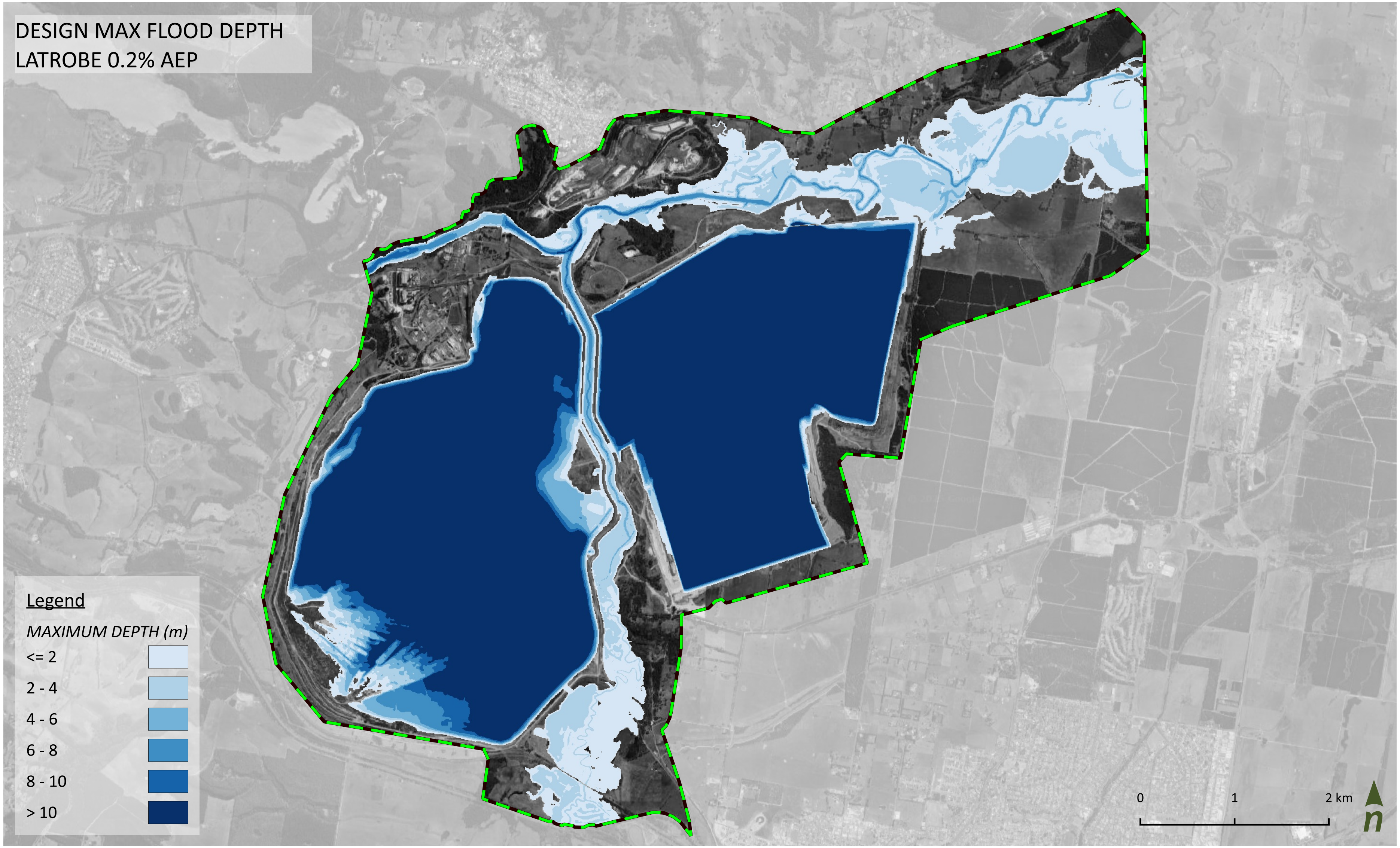


FIGURE A44. DESIGN MAX FLOOD DEPTH LATROBE 0.2% AEP

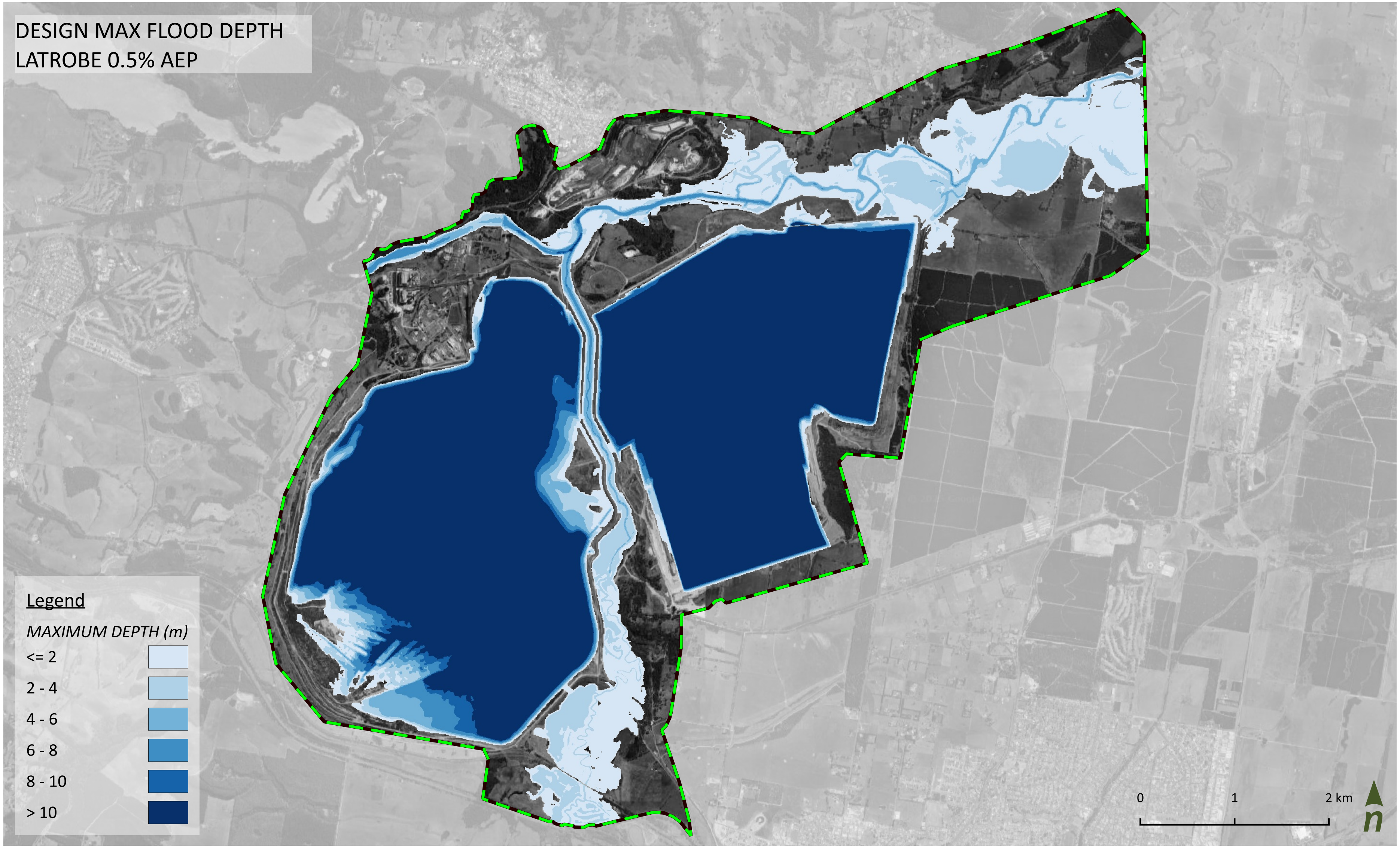


FIGURE A45. DESIGN MAX FLOOD DEPTH LATROBE 0.5% AEP

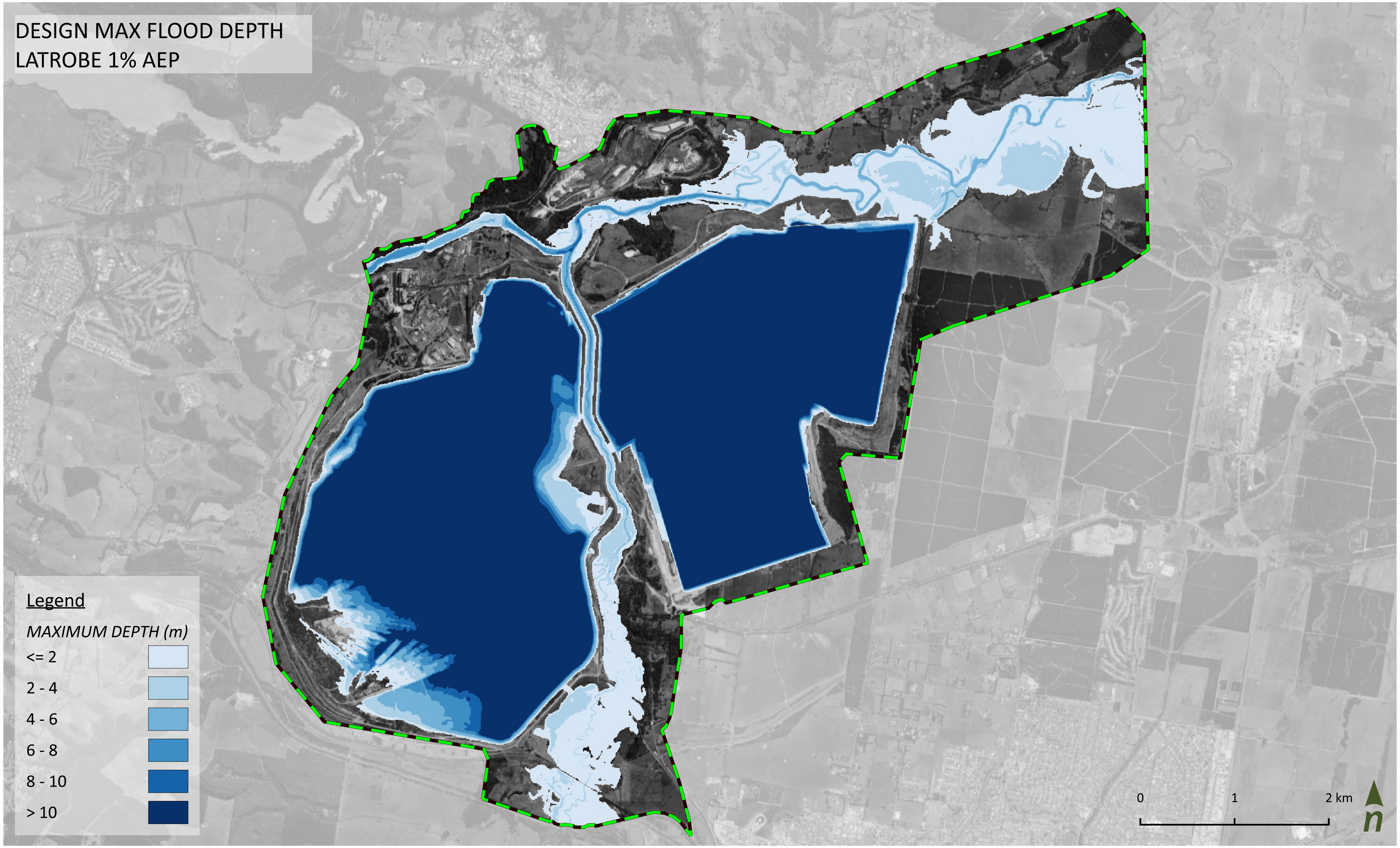


FIGURE A46. DESIGN MAX FLOOD DEPTH LATROBE 1% AEP

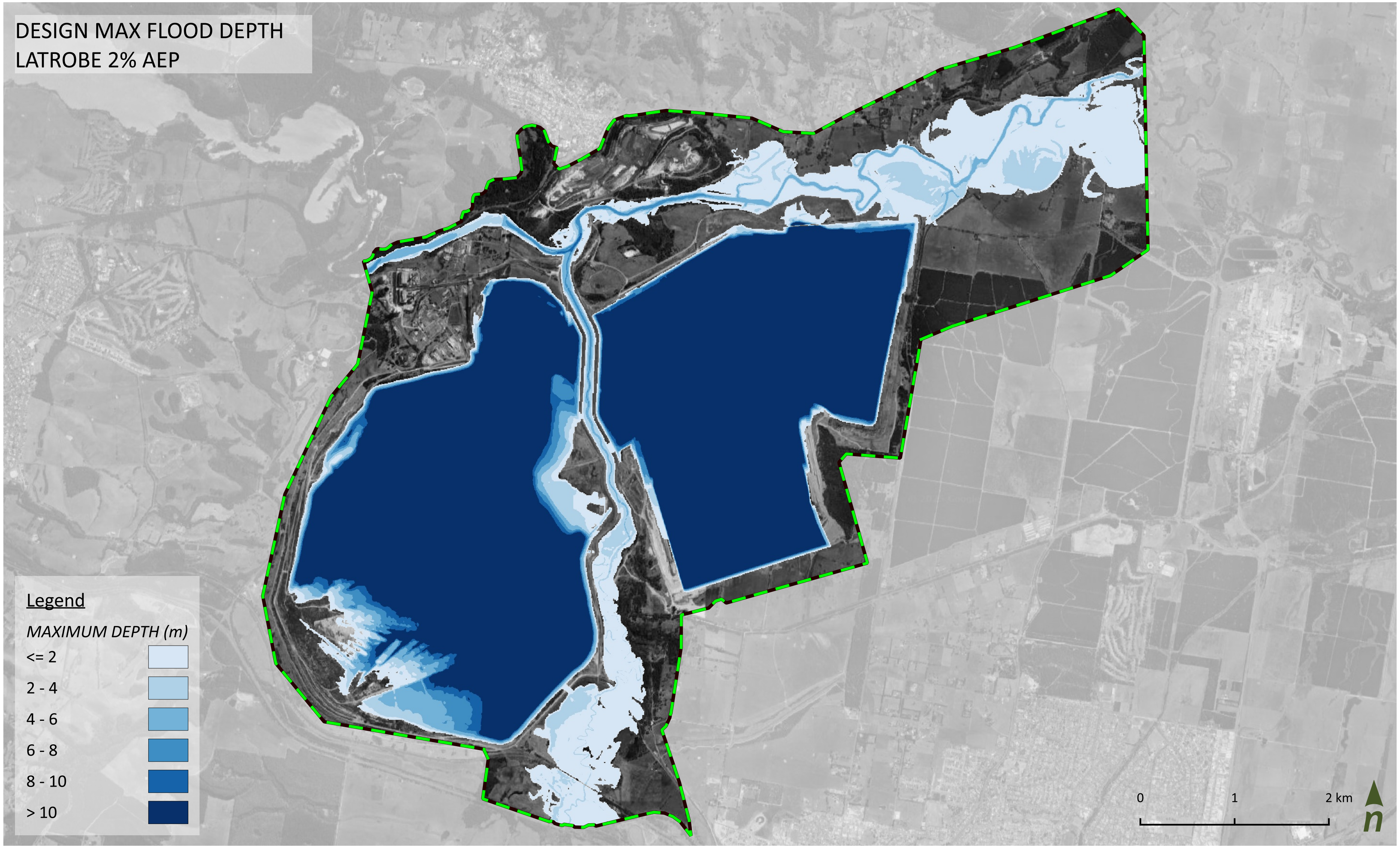


FIGURE A47. DESIGN MAX FLOOD DEPTH LATROBE 2% AEP

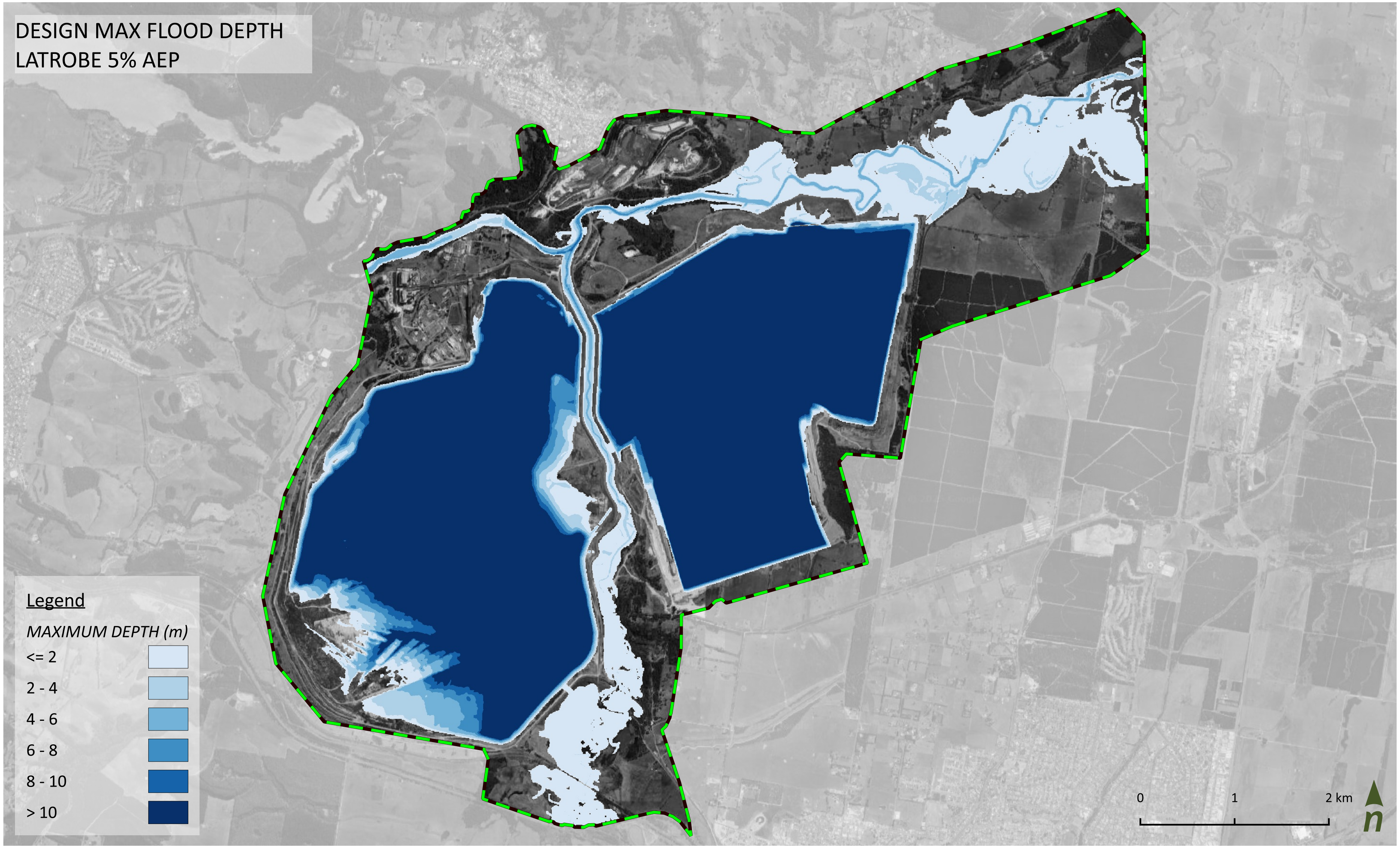


FIGURE A48. DESIGN MAX FLOOD DEPTH LATROBE 5% AEP

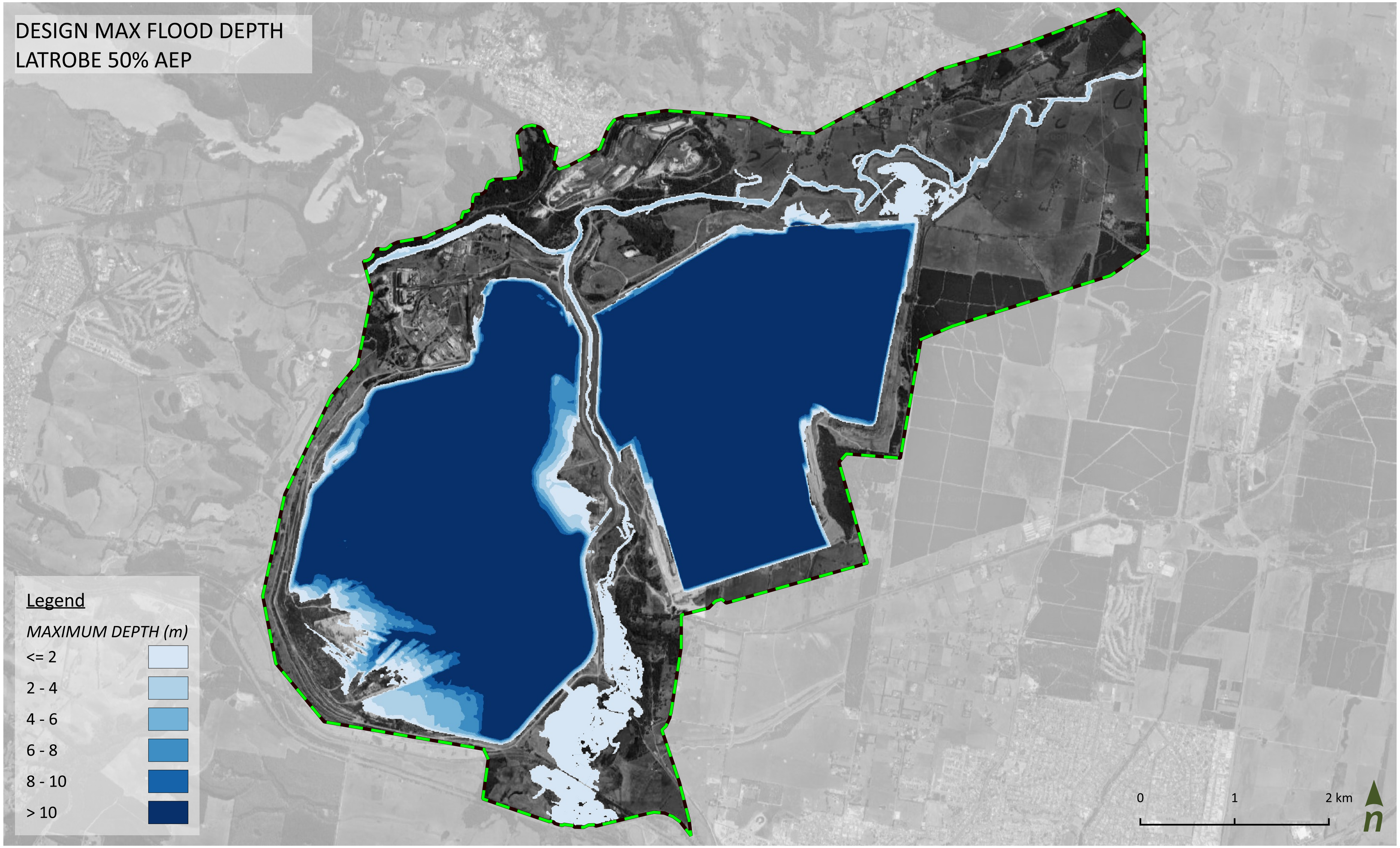


FIGURE A49. DESIGN MAX FLOOD DEPTH LATROBE 50% AEP

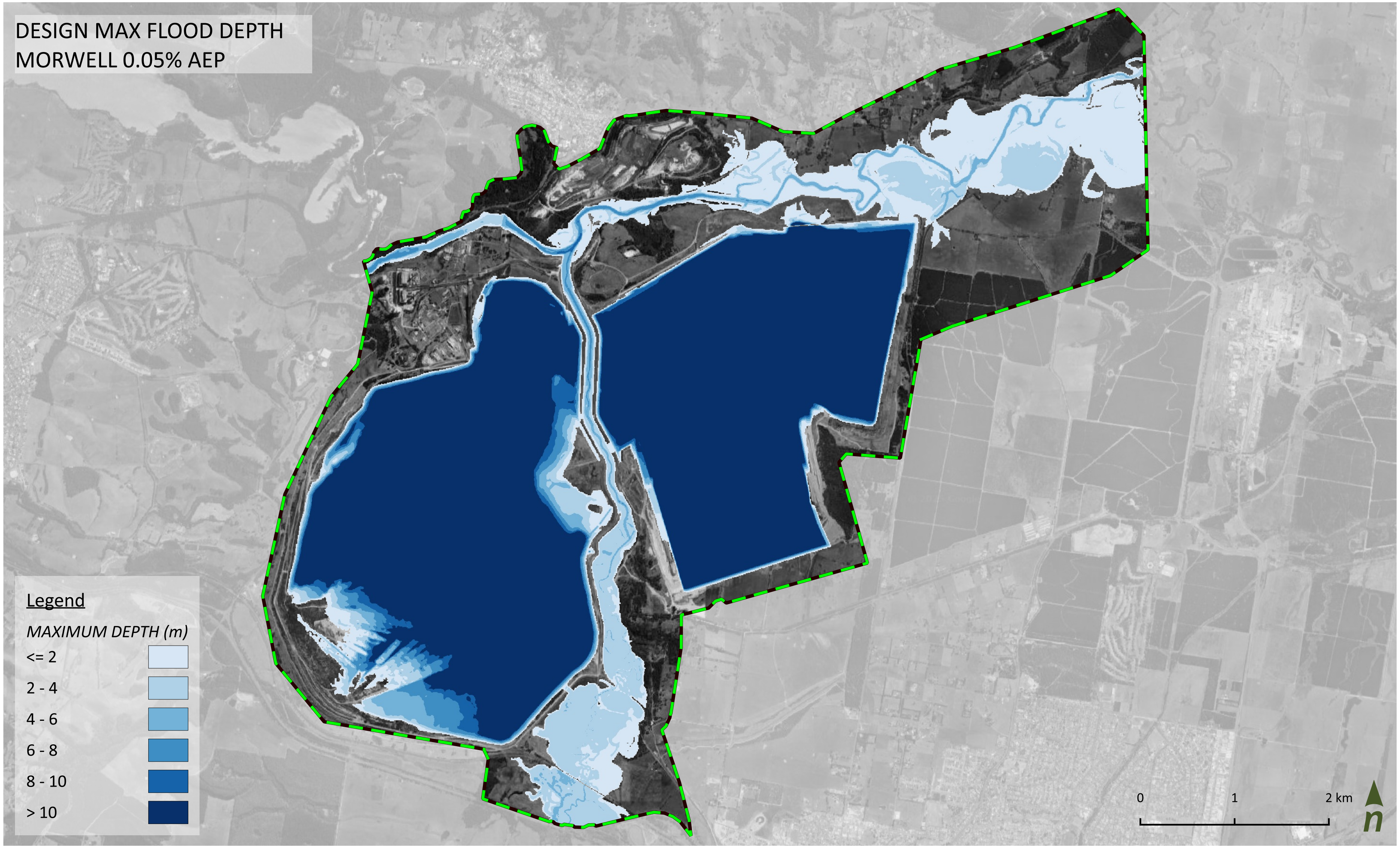


FIGURE A50. DESIGN MAX FLOOD DEPTH MORWELL 0.05% AEP

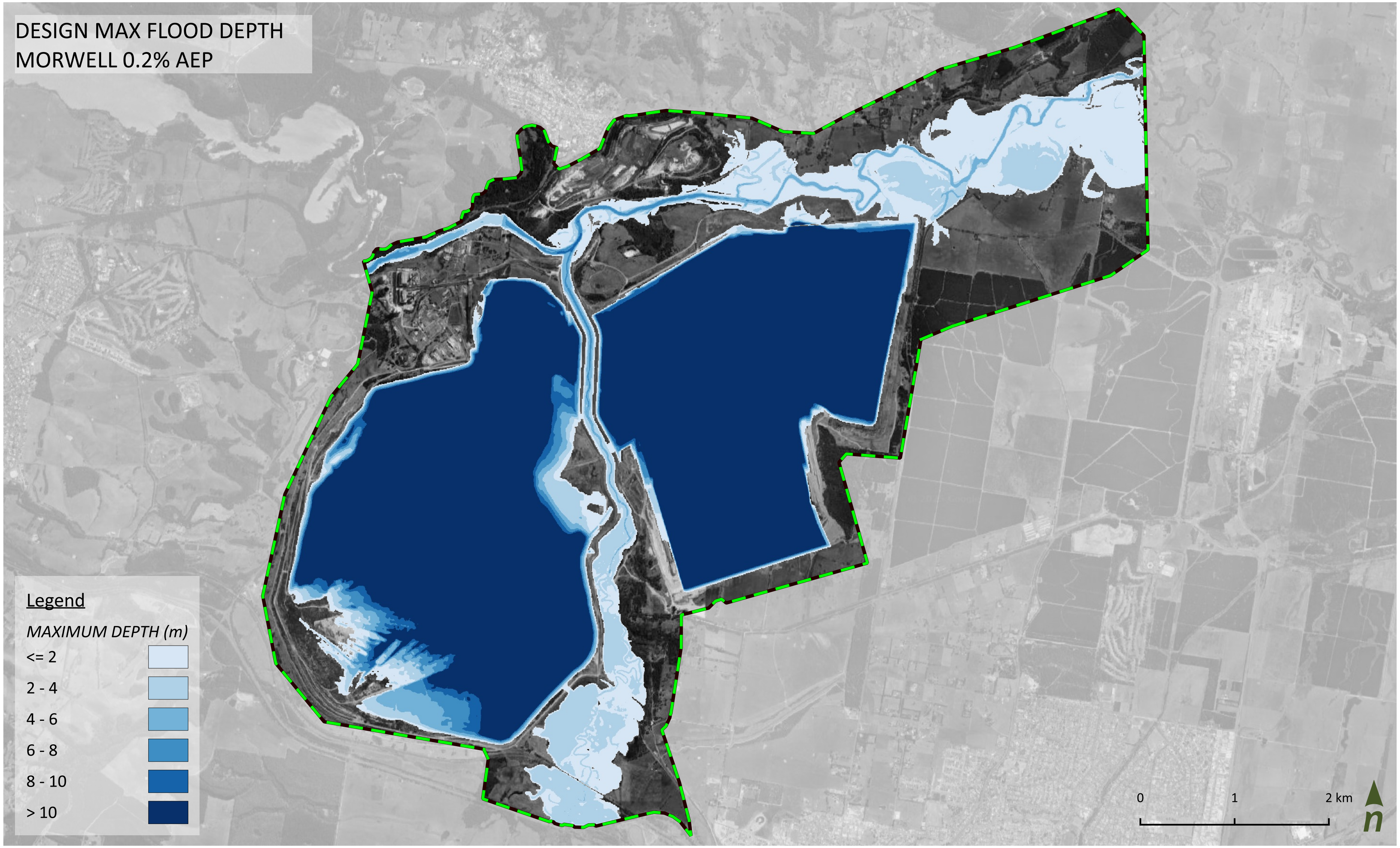


FIGURE A51. DESIGN MAX FLOOD DEPTH MORWELL 0.2% AEP

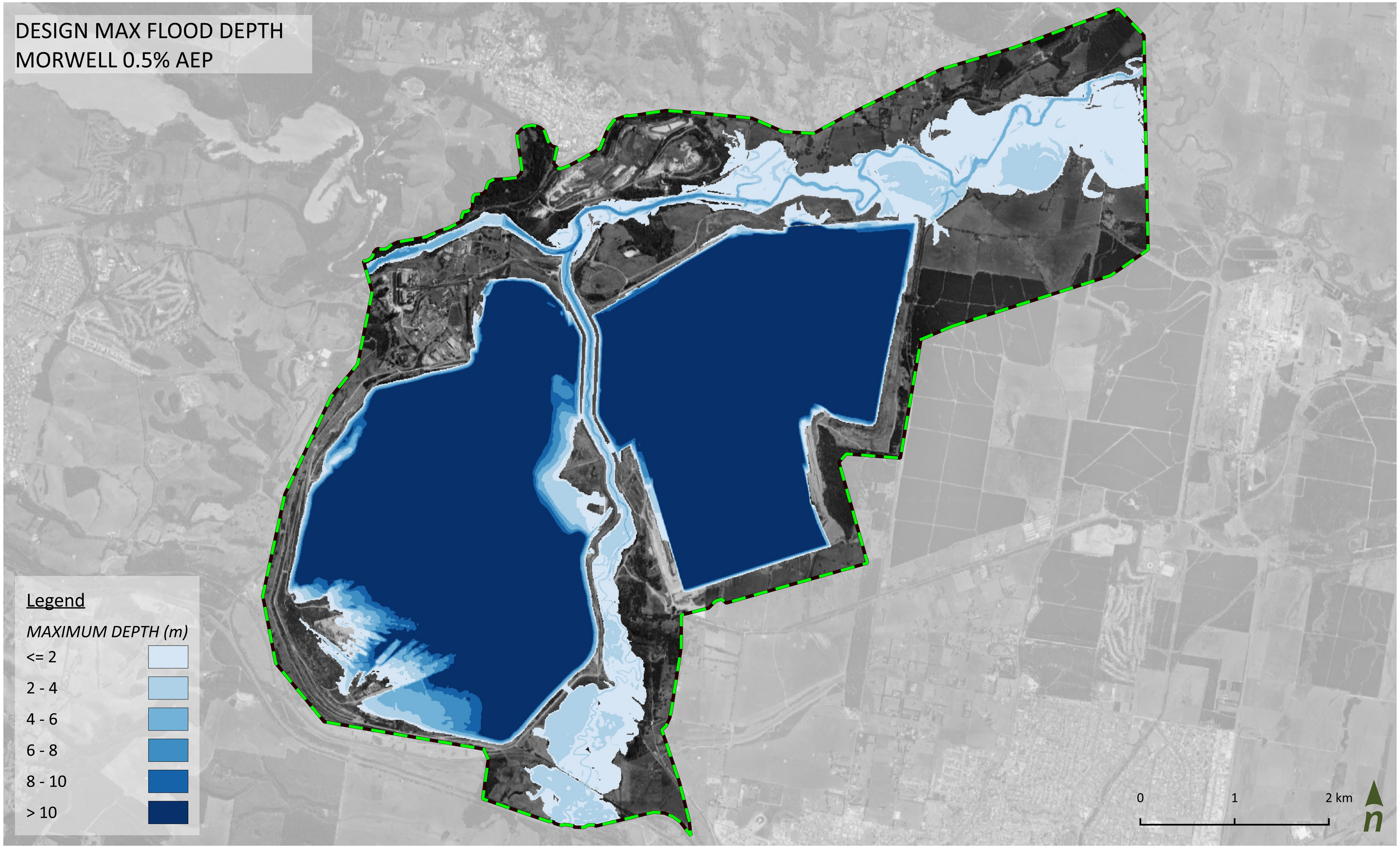


FIGURE A52. DESIGN MAX FLOOD DEPTH MORWELL 0.5% AEP

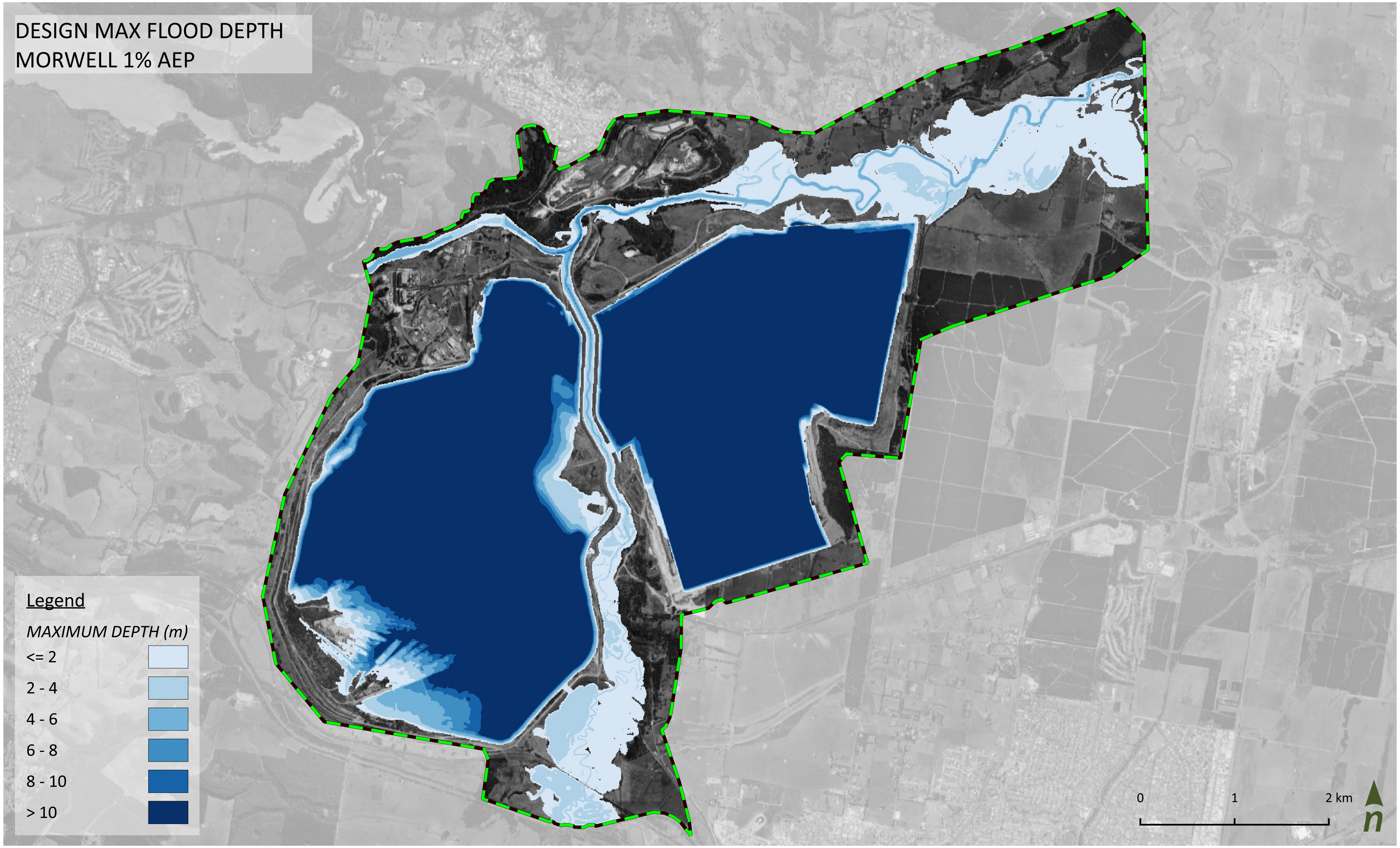


FIGURE A53. DESIGN MAX FLOOD DEPTH MORWELL 1% AEP

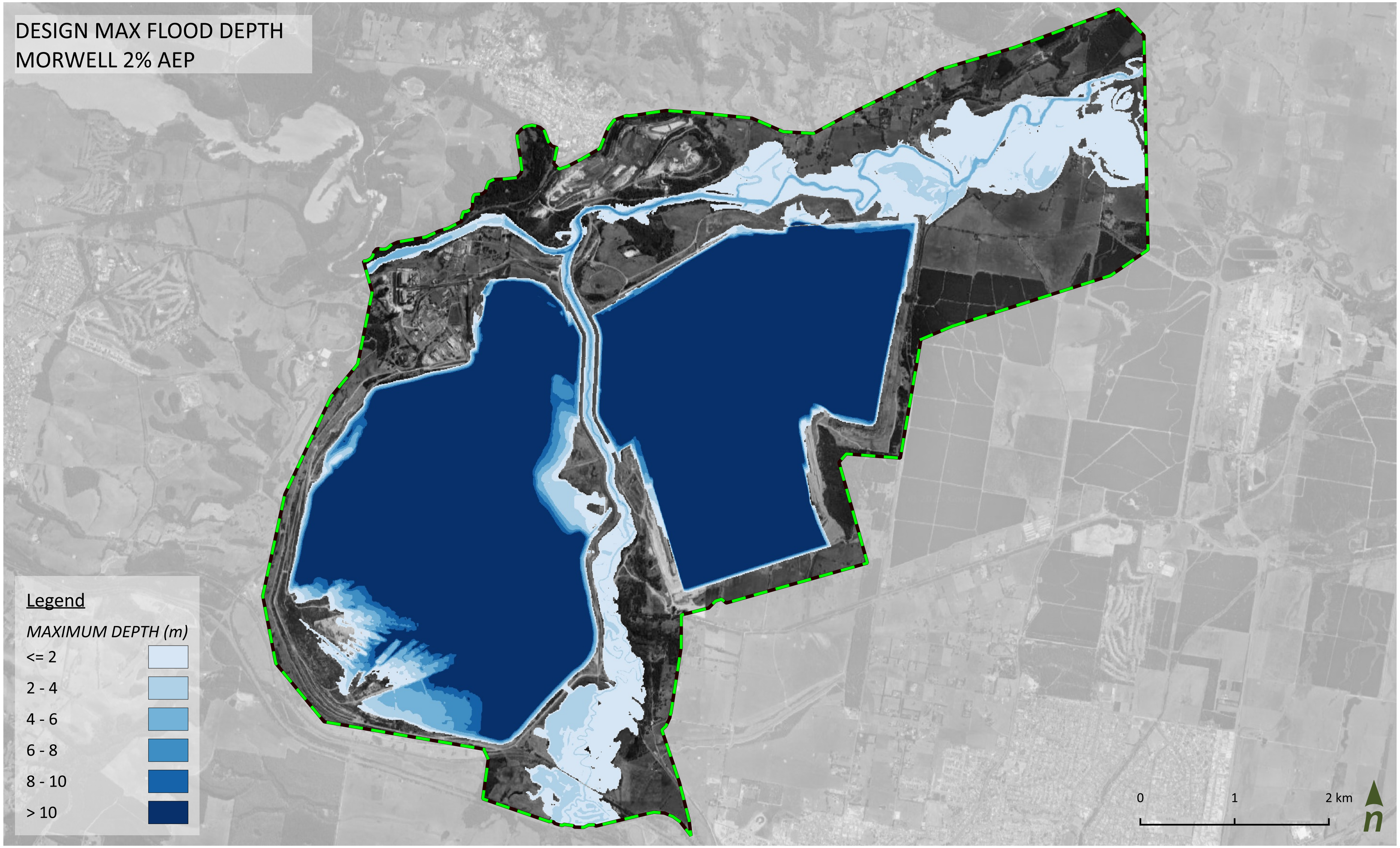


FIGURE A54. DESIGN MAX FLOOD DEPTH MORWELL 2% AEP

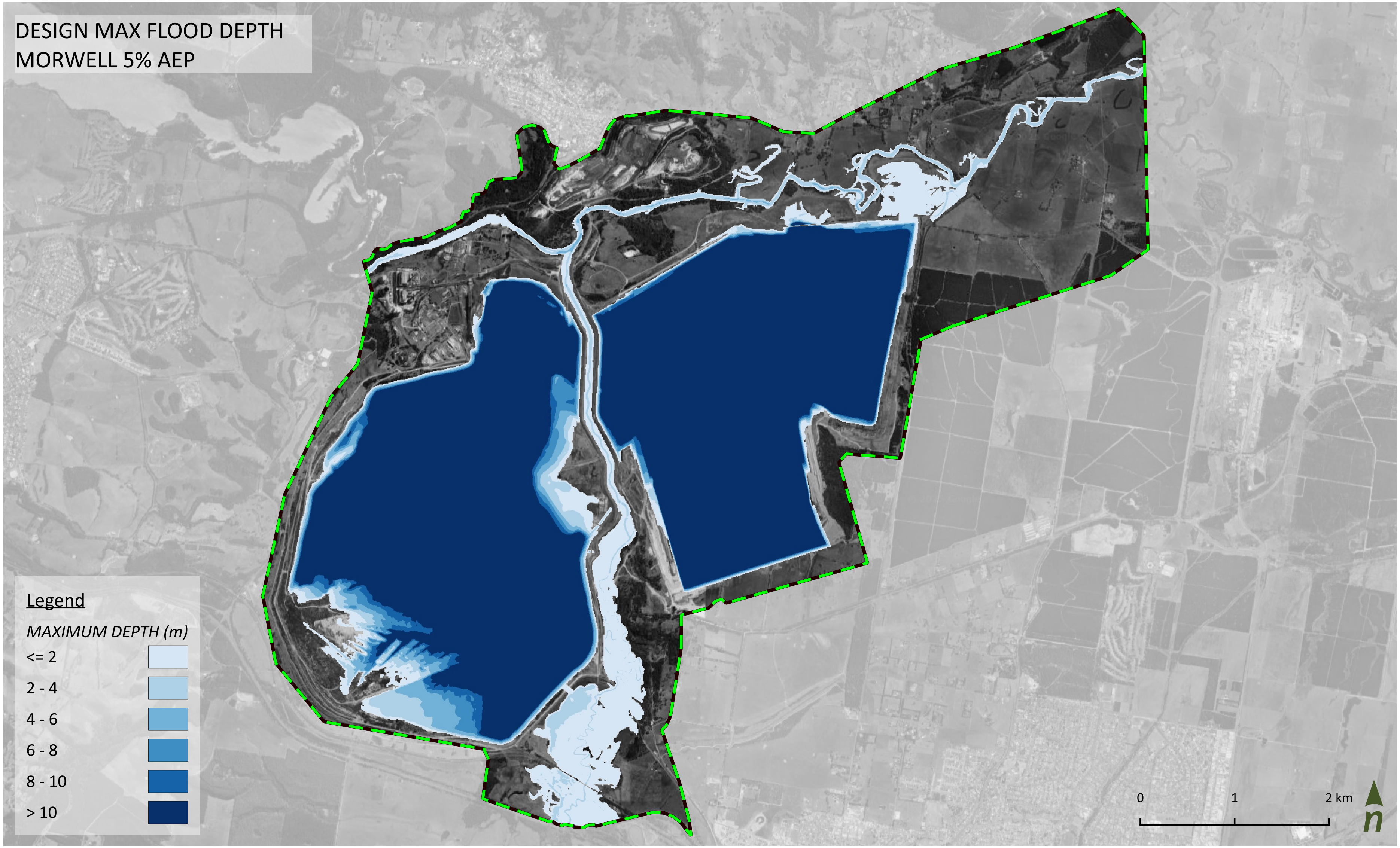


FIGURE A55. DESIGN MAX FLOOD DEPTH MORWELL 5% AEP

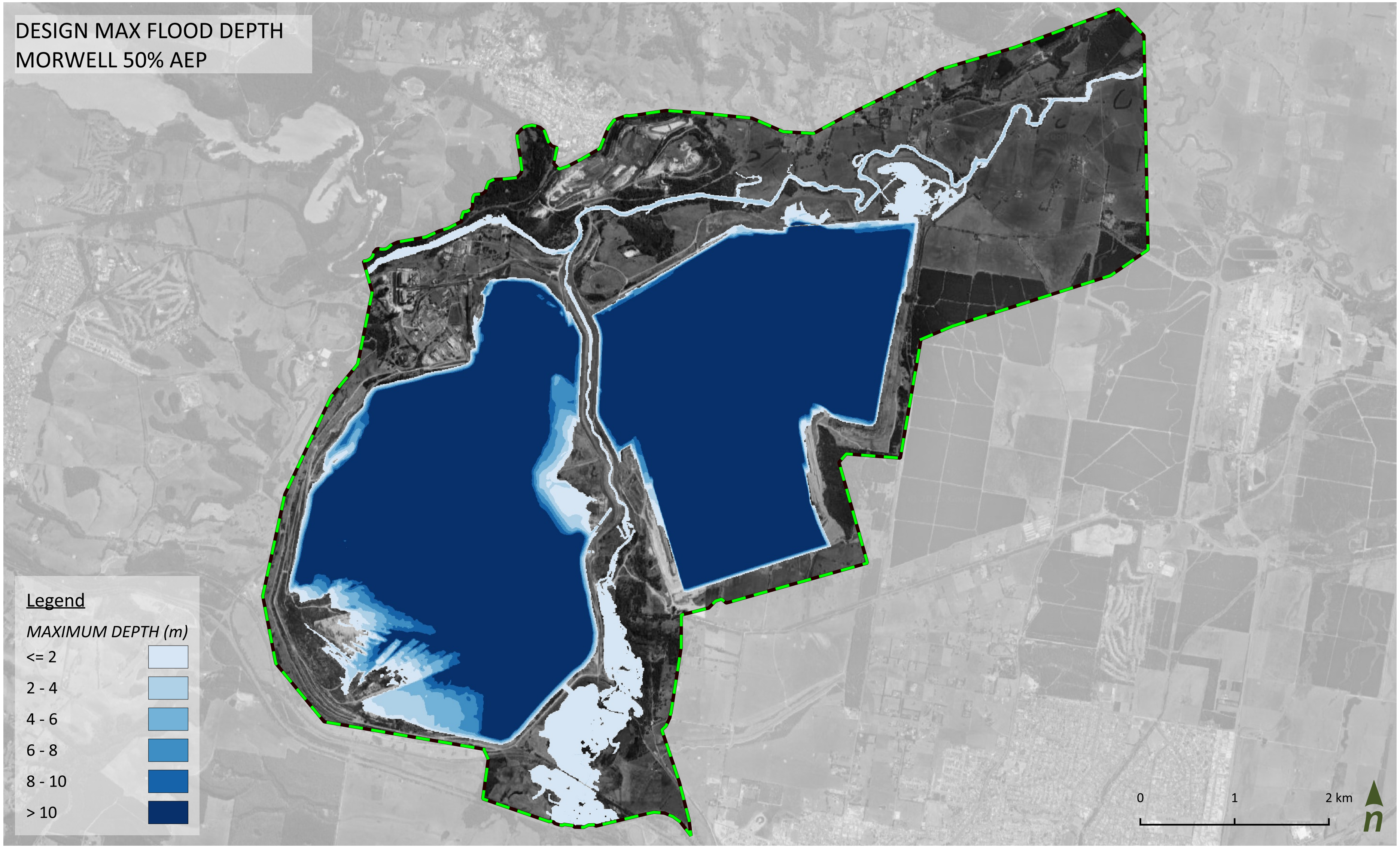


FIGURE A56. DESIGN MAX FLOOD DEPTH MORWELL 50% AEP

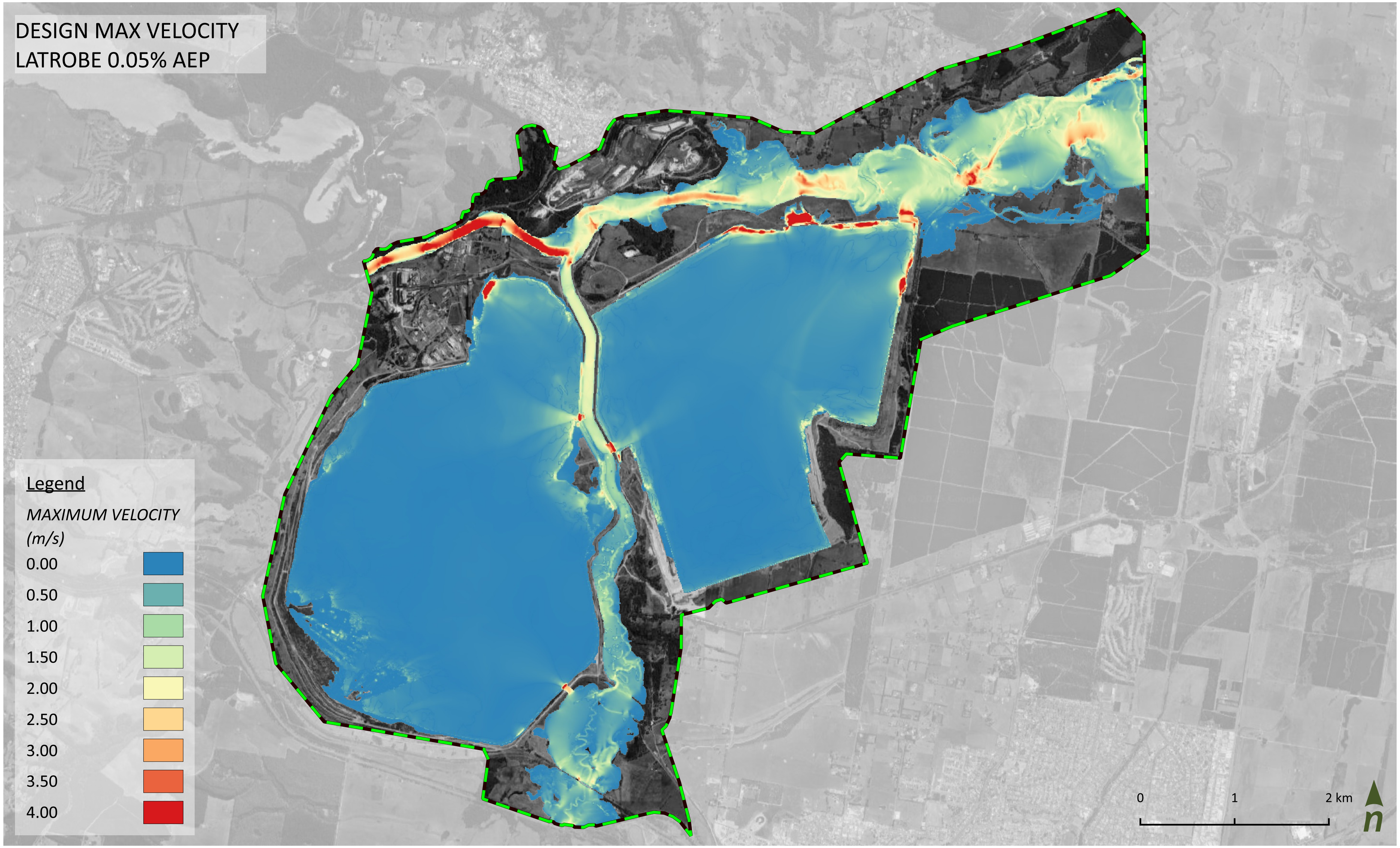


FIGURE A57. DESIGN MAX VELOCITY LATROBE 0.05% AEP

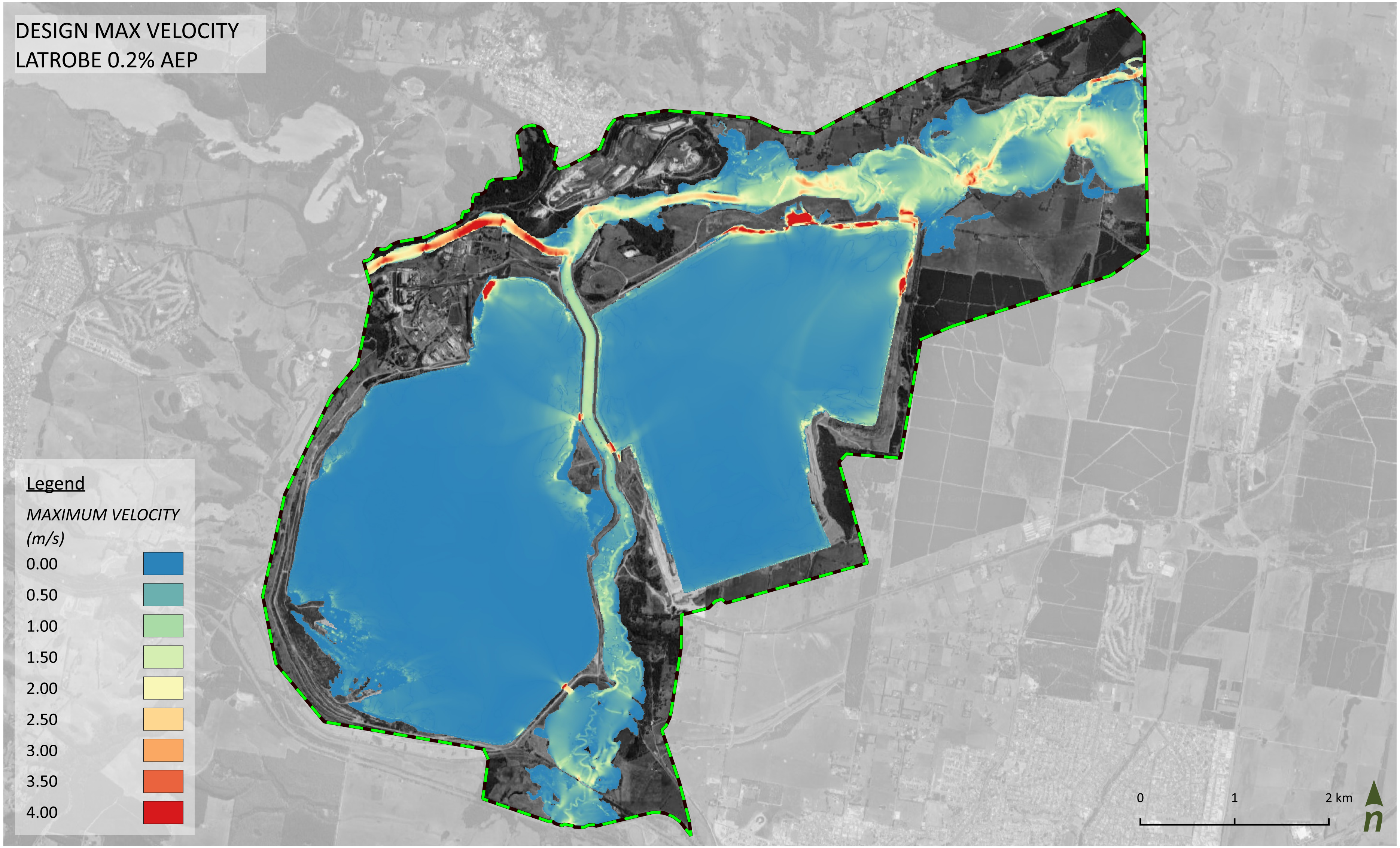


FIGURE A58. DESIGN MAX VELOCITY LATROBE 0.2% AEP

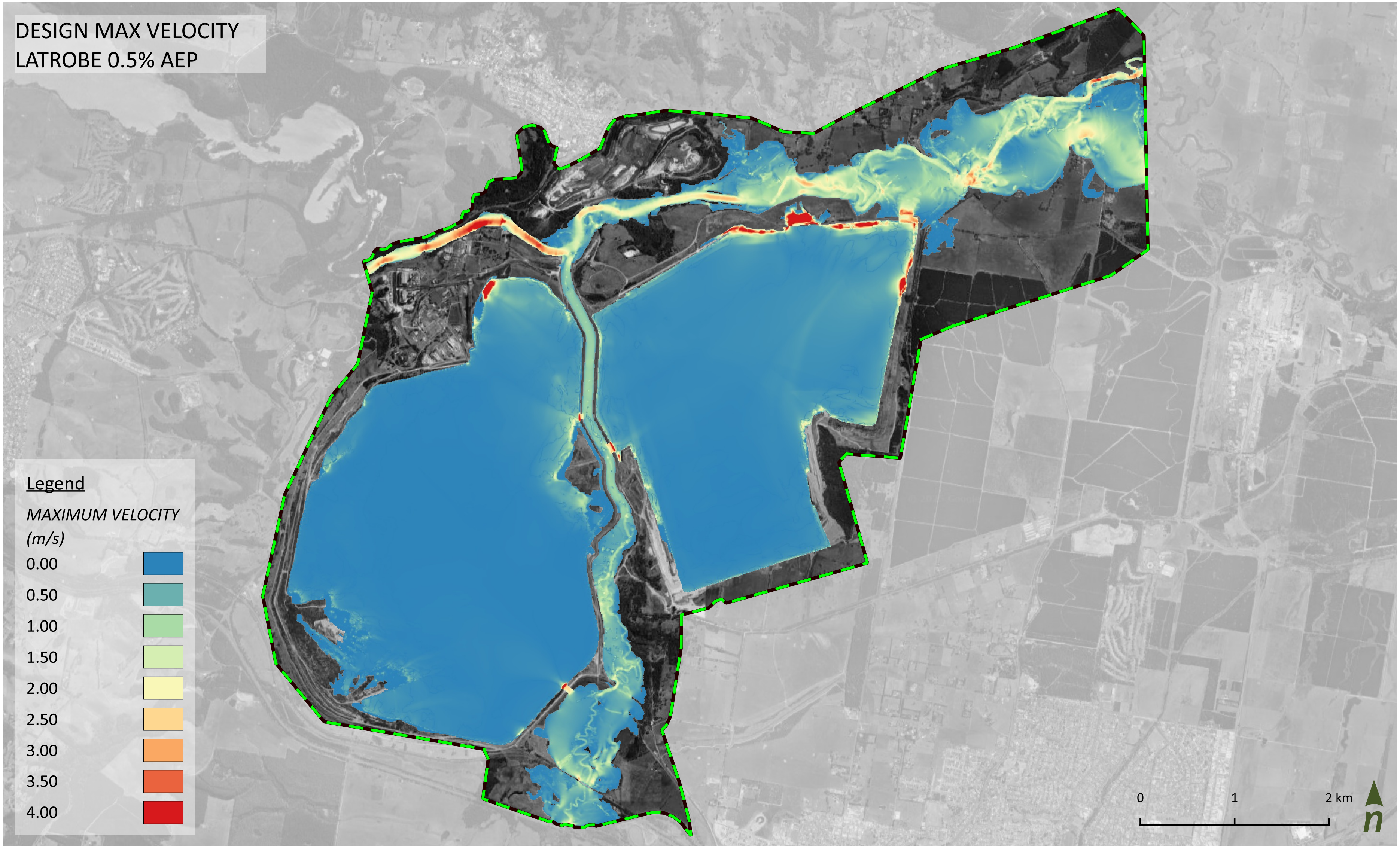


FIGURE A59. DESIGN MAX VELOCITY LATROBE 0.5% AEP

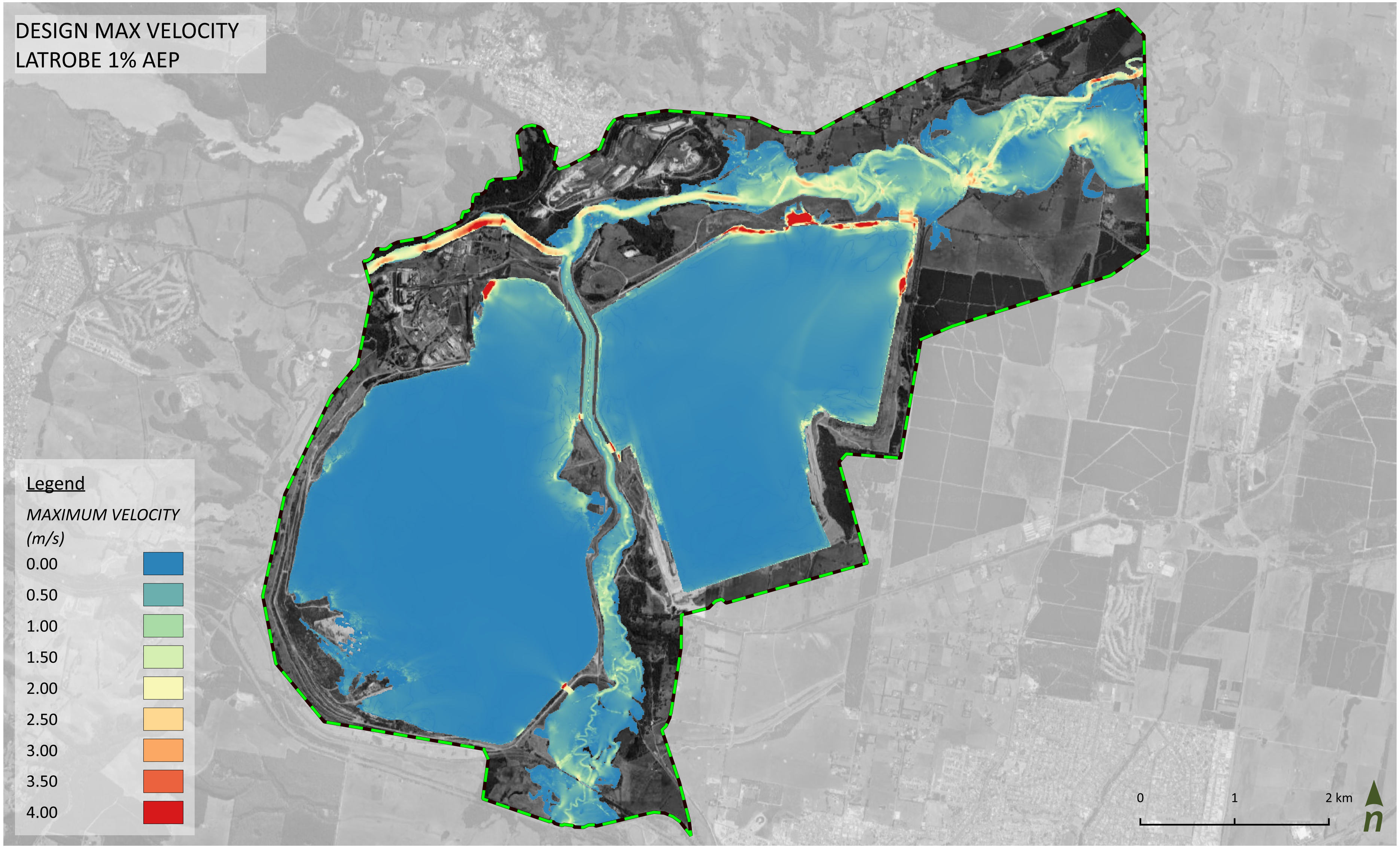


FIGURE A60. DESIGN MAX VELOCITY LATROBE 1% AEP

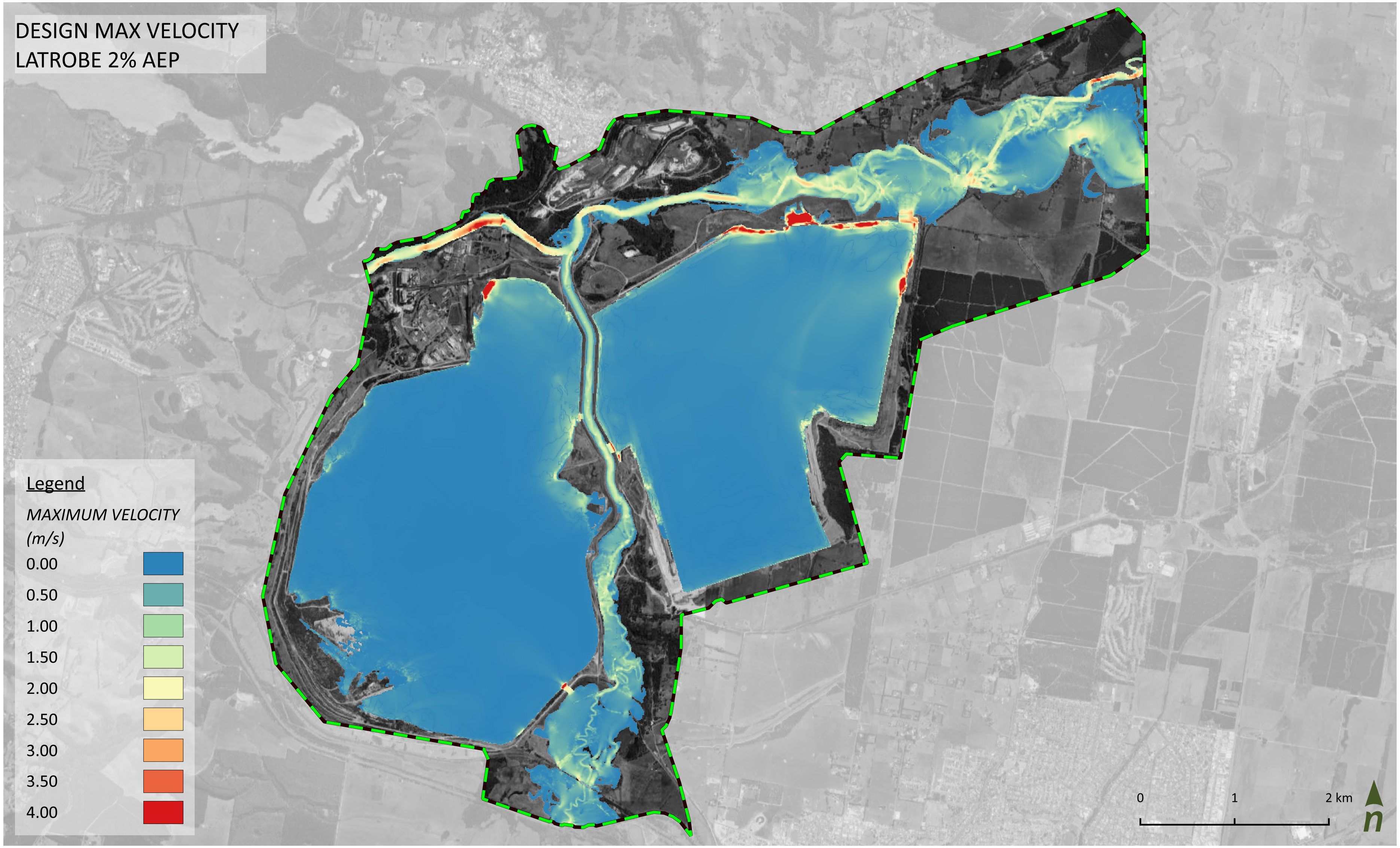


FIGURE A61. DESIGN MAX VELOCITY LATROBE 2% AEP

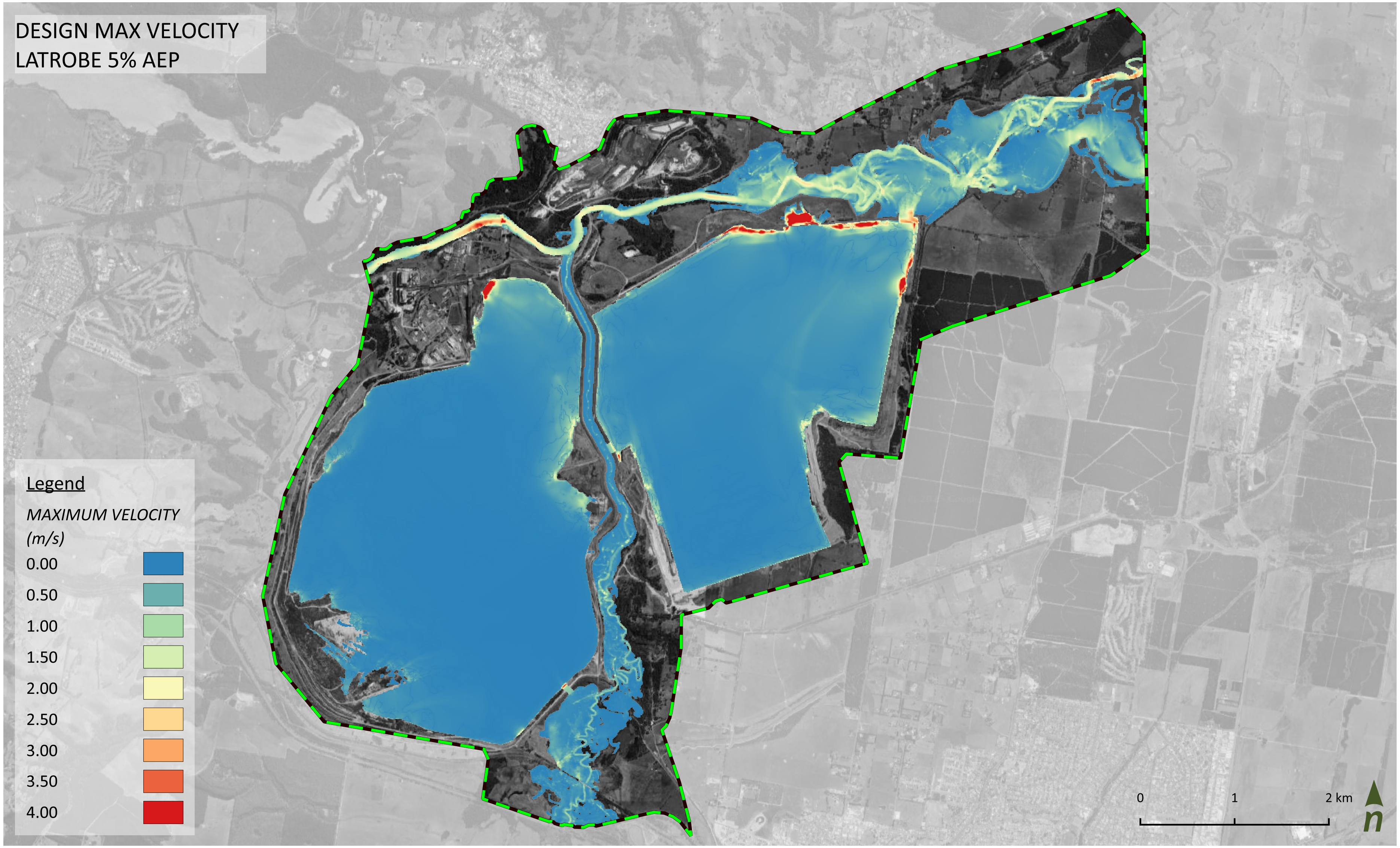


FIGURE A62. DESIGN MAX VELOCITY LATROBE 5% AEP

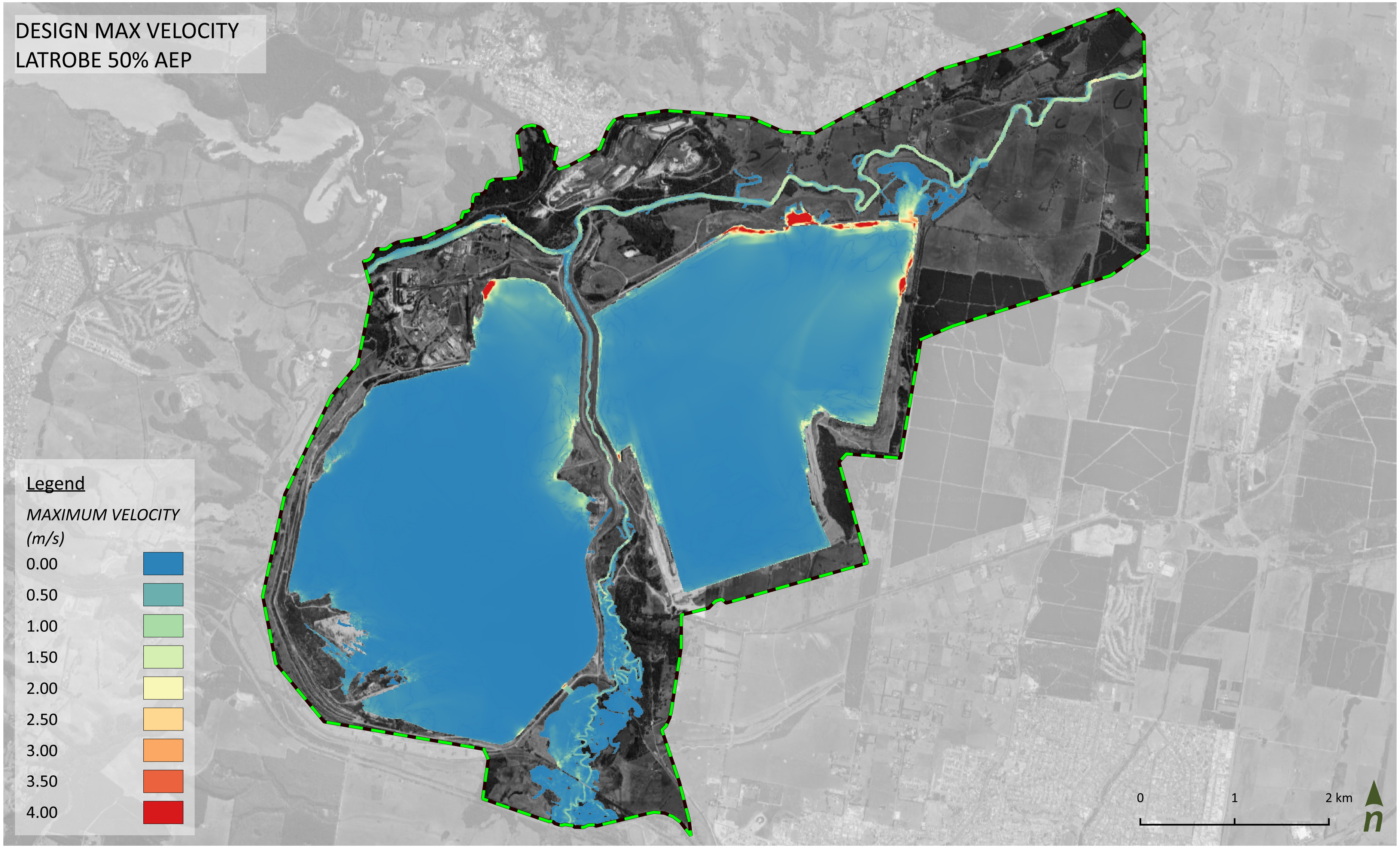


FIGURE A63. DESIGN MAX VELOCITY LATROBE 50% AEP

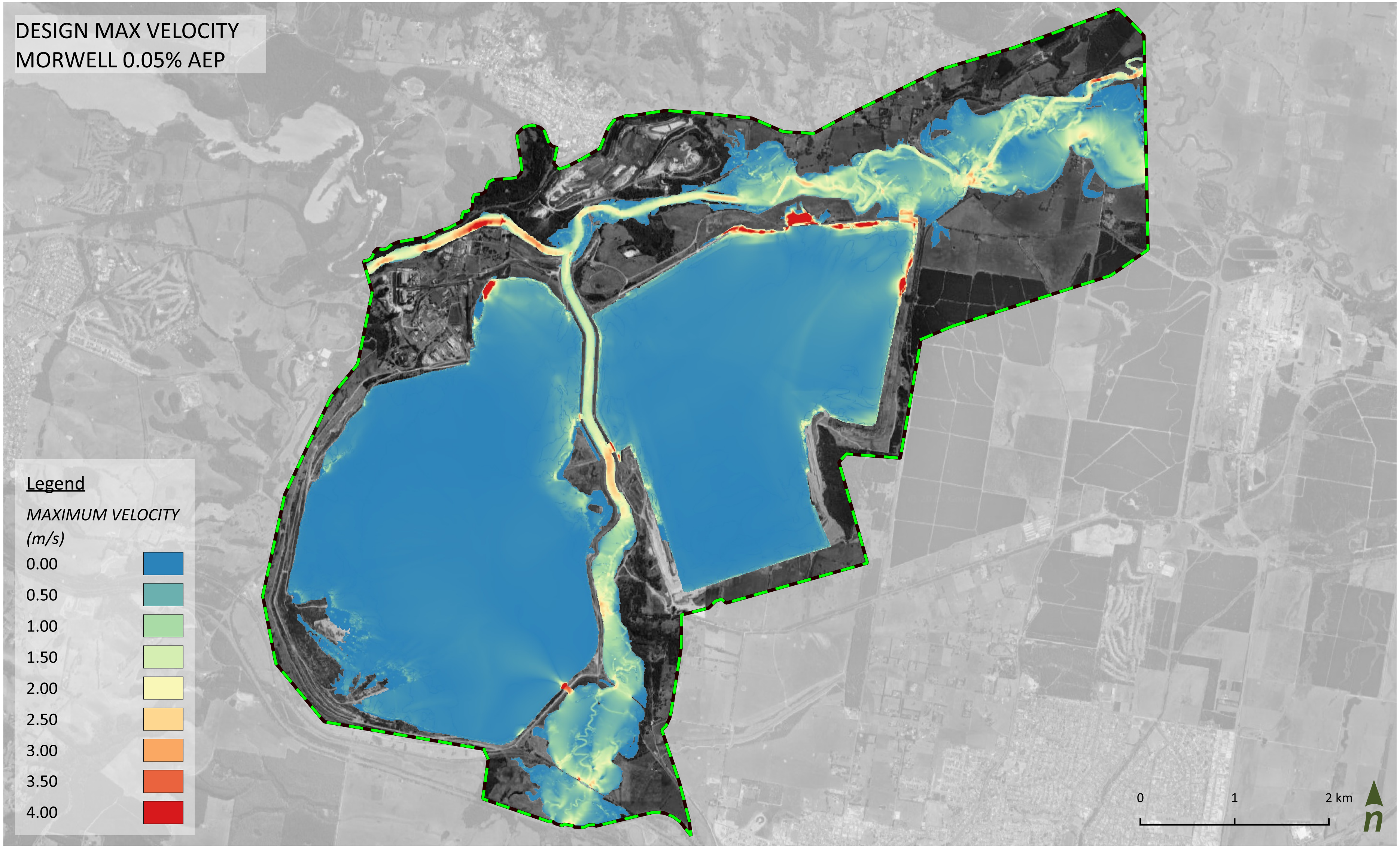


FIGURE A64. DESIGN MAX VELOCITY MORWELL 0.05% AEP

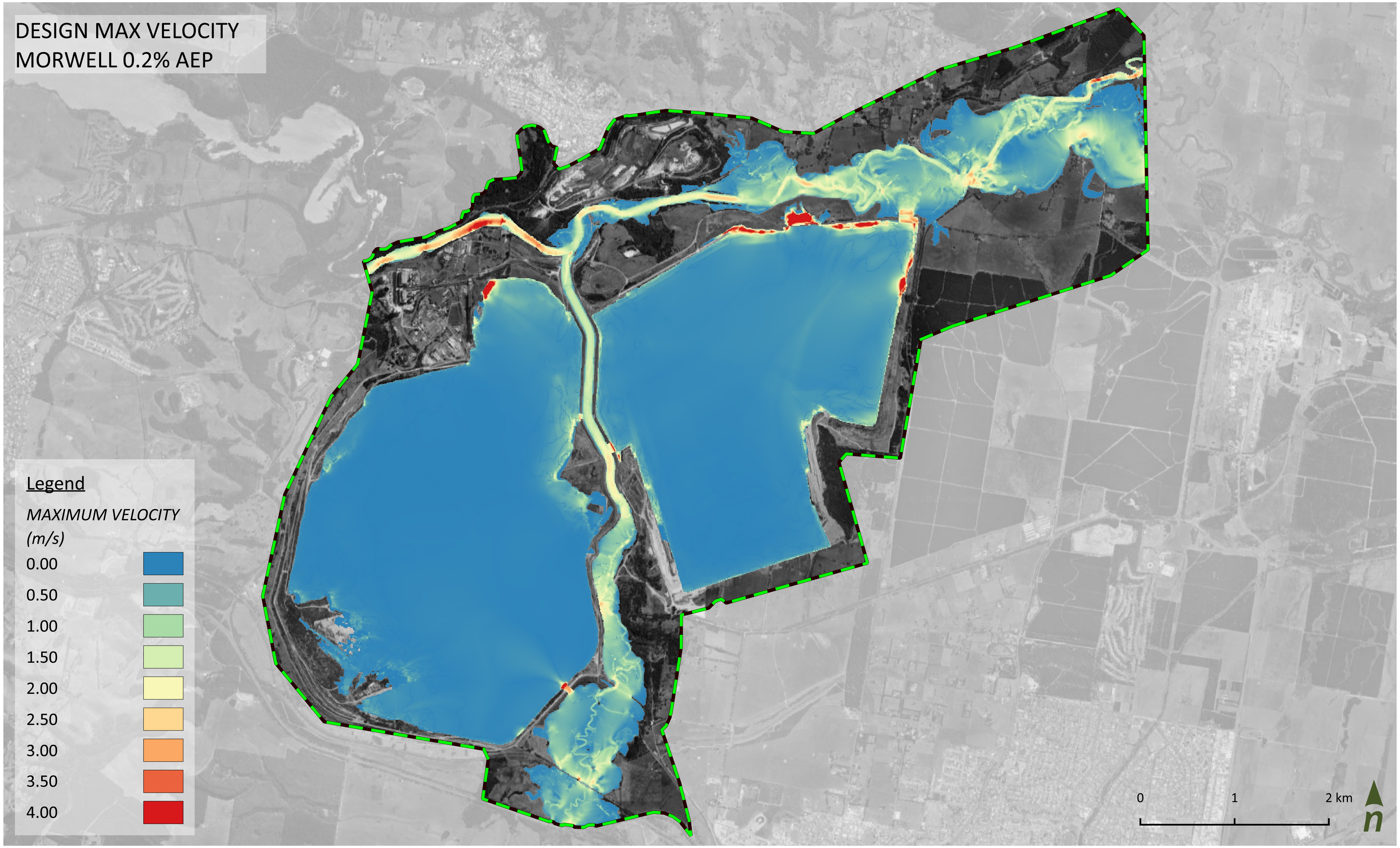


FIGURE A65. DESIGN MAX VELOCITY MORWELL 0.2% AEP

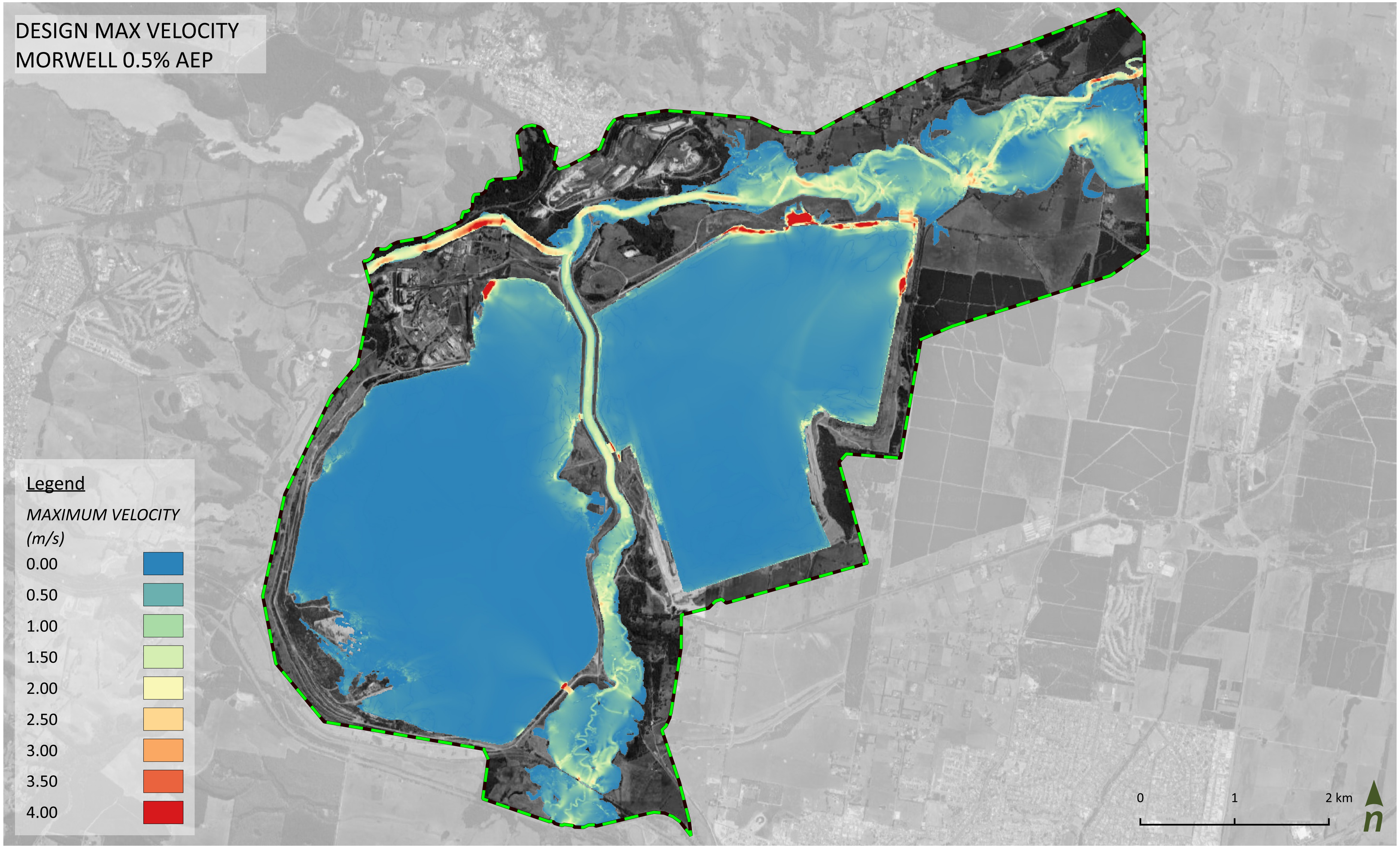


FIGURE A66. DESIGN MAX VELOCITY MORWELL 0.5% AEP

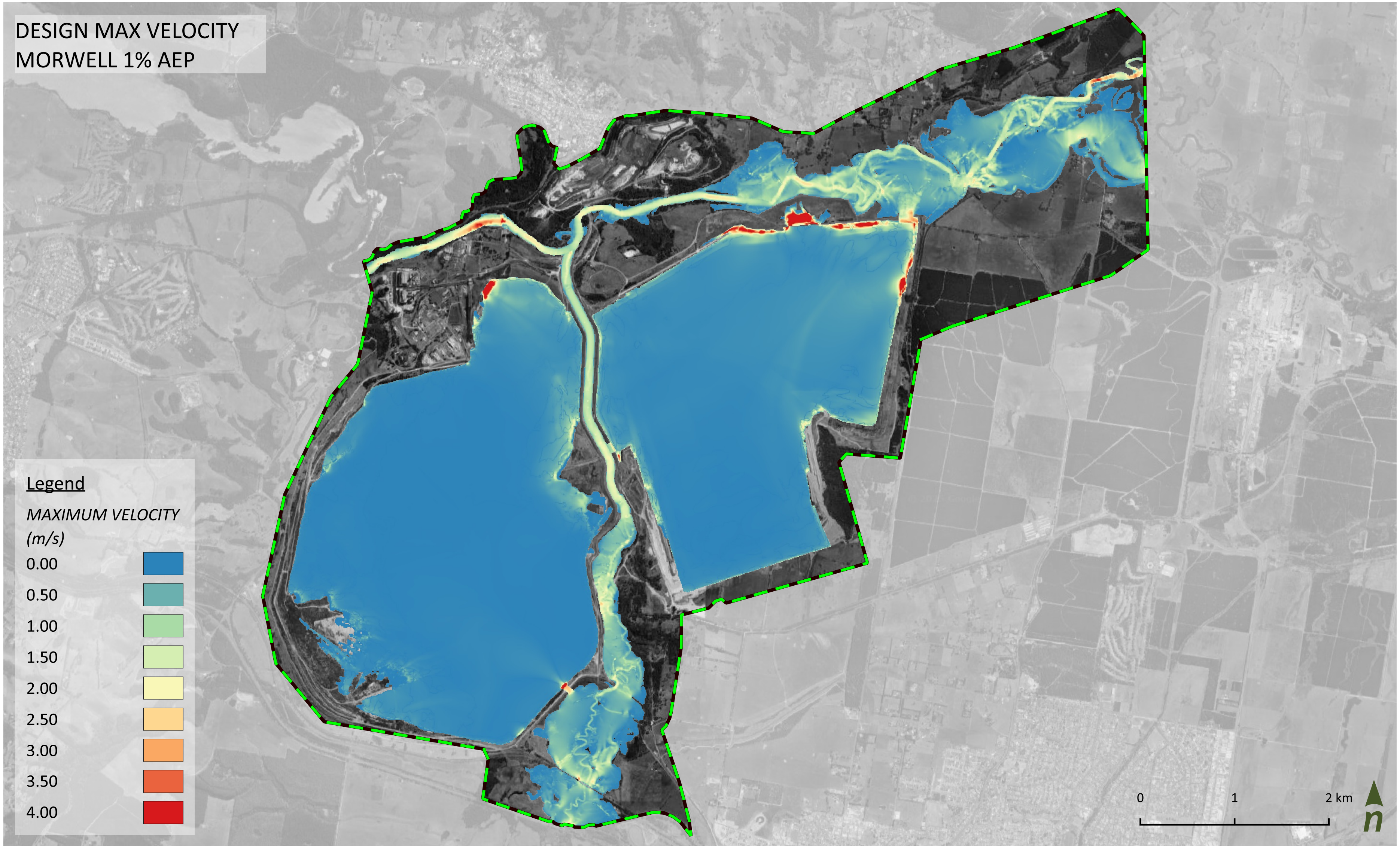


FIGURE A67. DESIGN MAX VELOCITY MORWELL 1% AEP

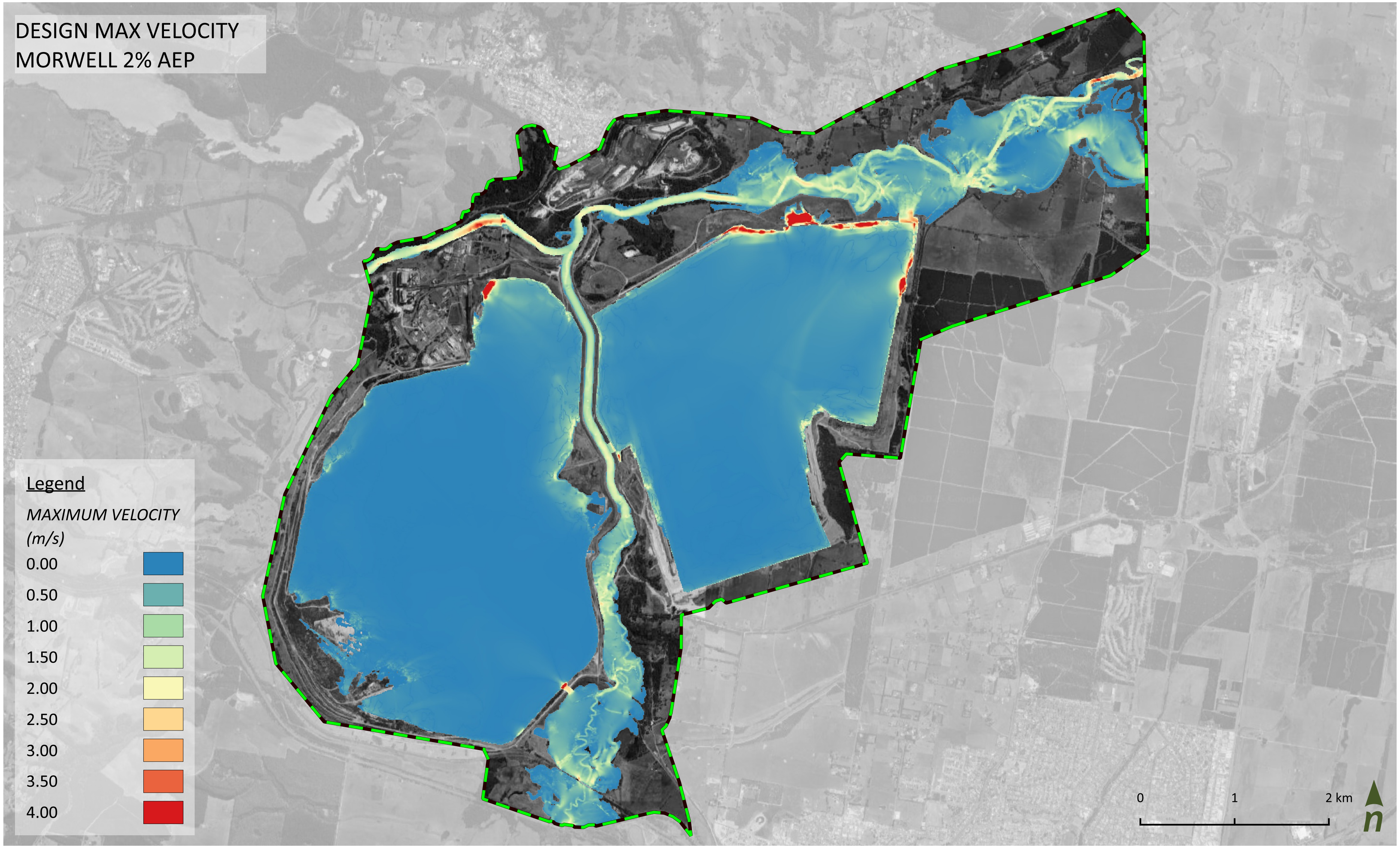


FIGURE A68. DESIGN MAX VELOCITY MORWELL 2% AEP

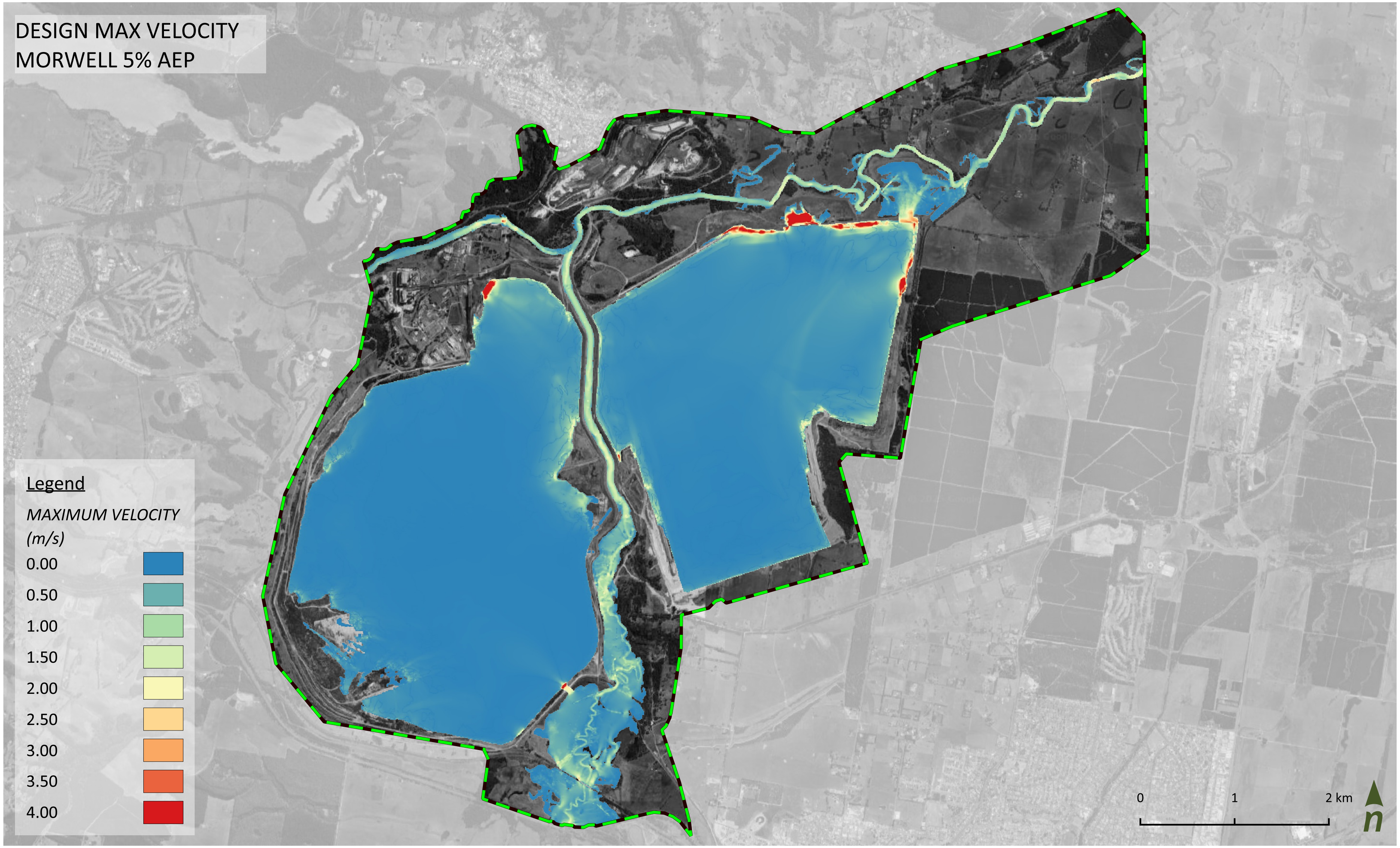


FIGURE A69. DESIGN MAX VELOCITY MORWELL 5% AEP

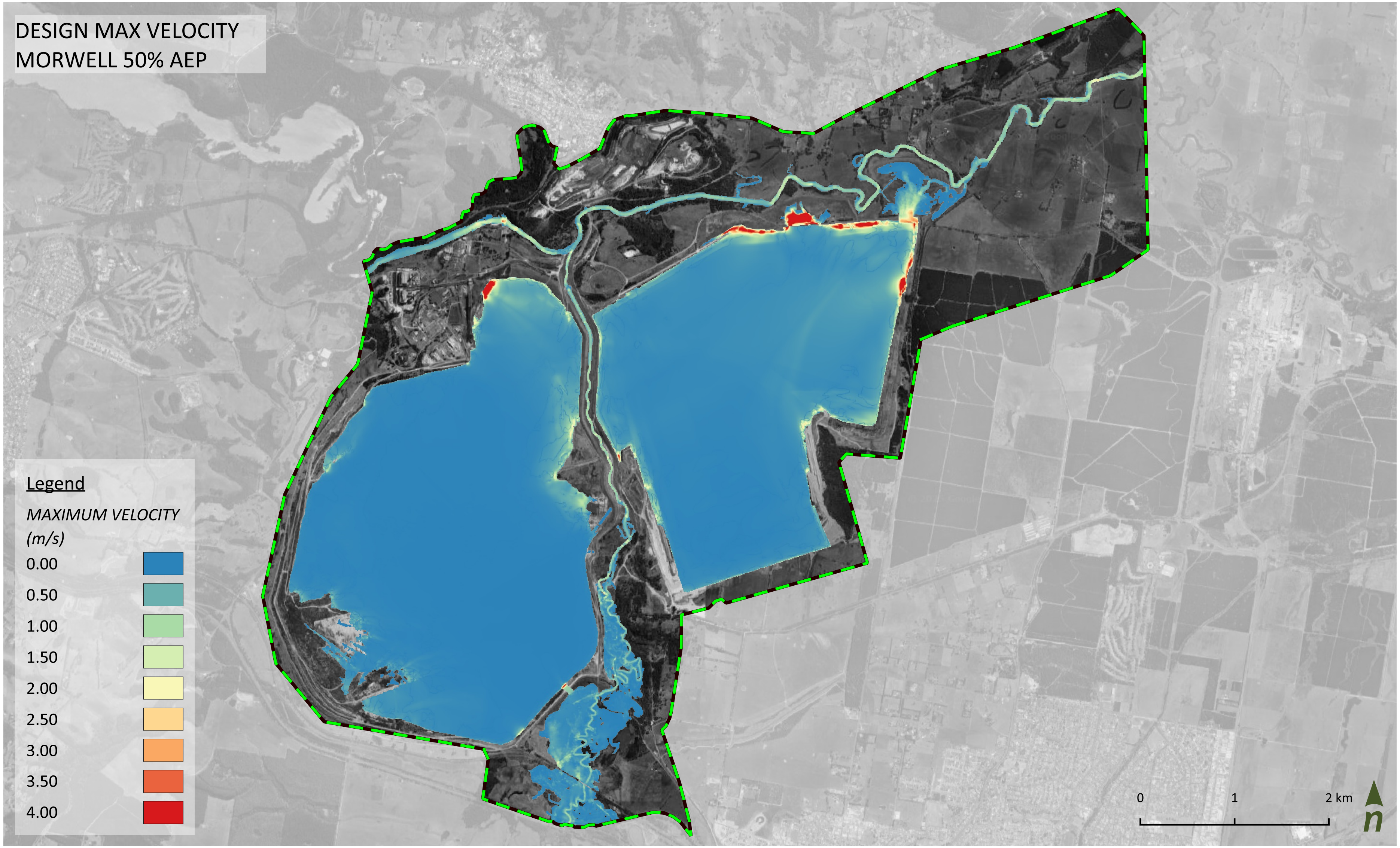


FIGURE A70. DESIGN MAX VELOCITY MORWELL 50% AEP

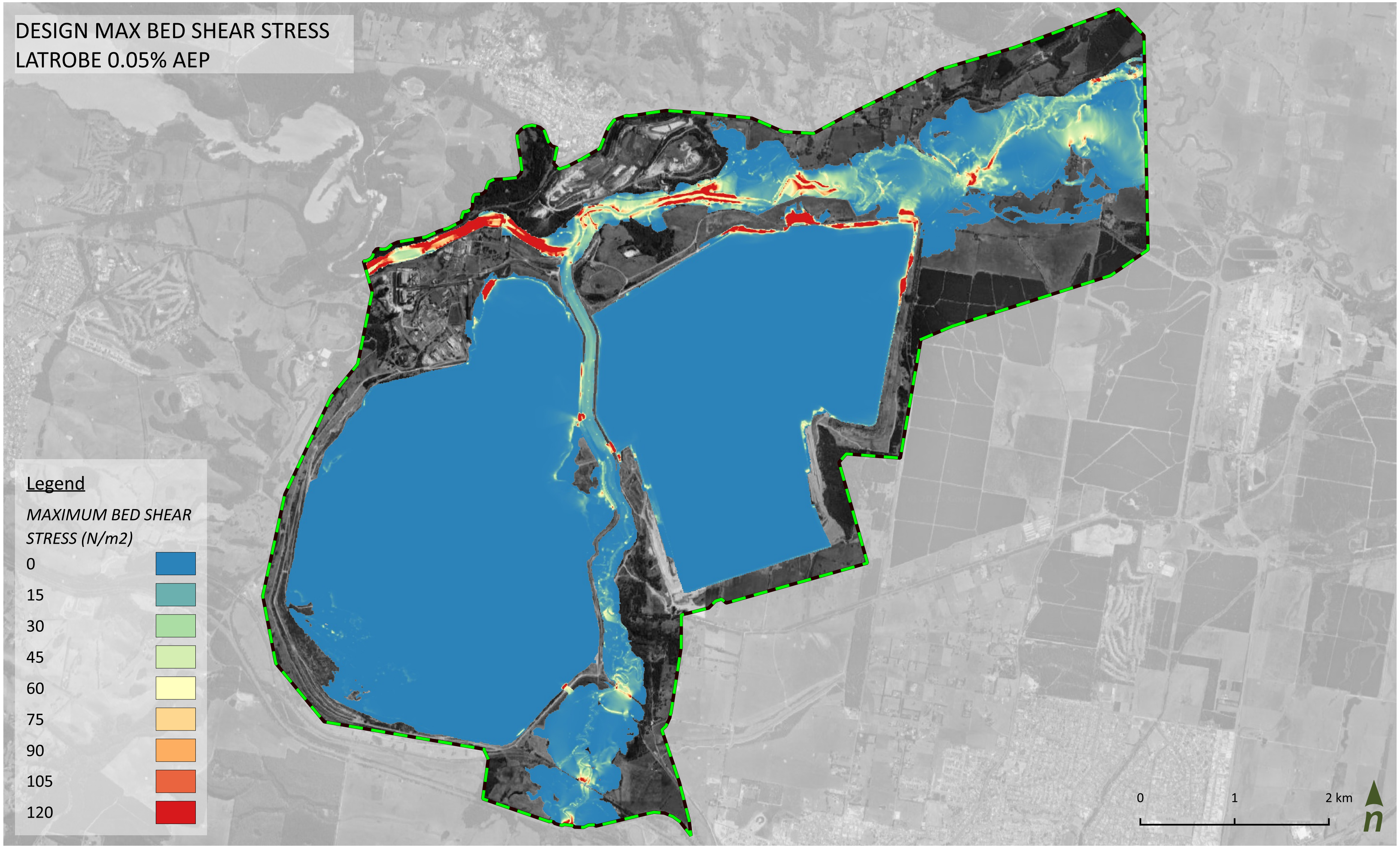


FIGURE A71. DESIGN MAX BED SHEAR STRESS LATROBE 0.05% AEP

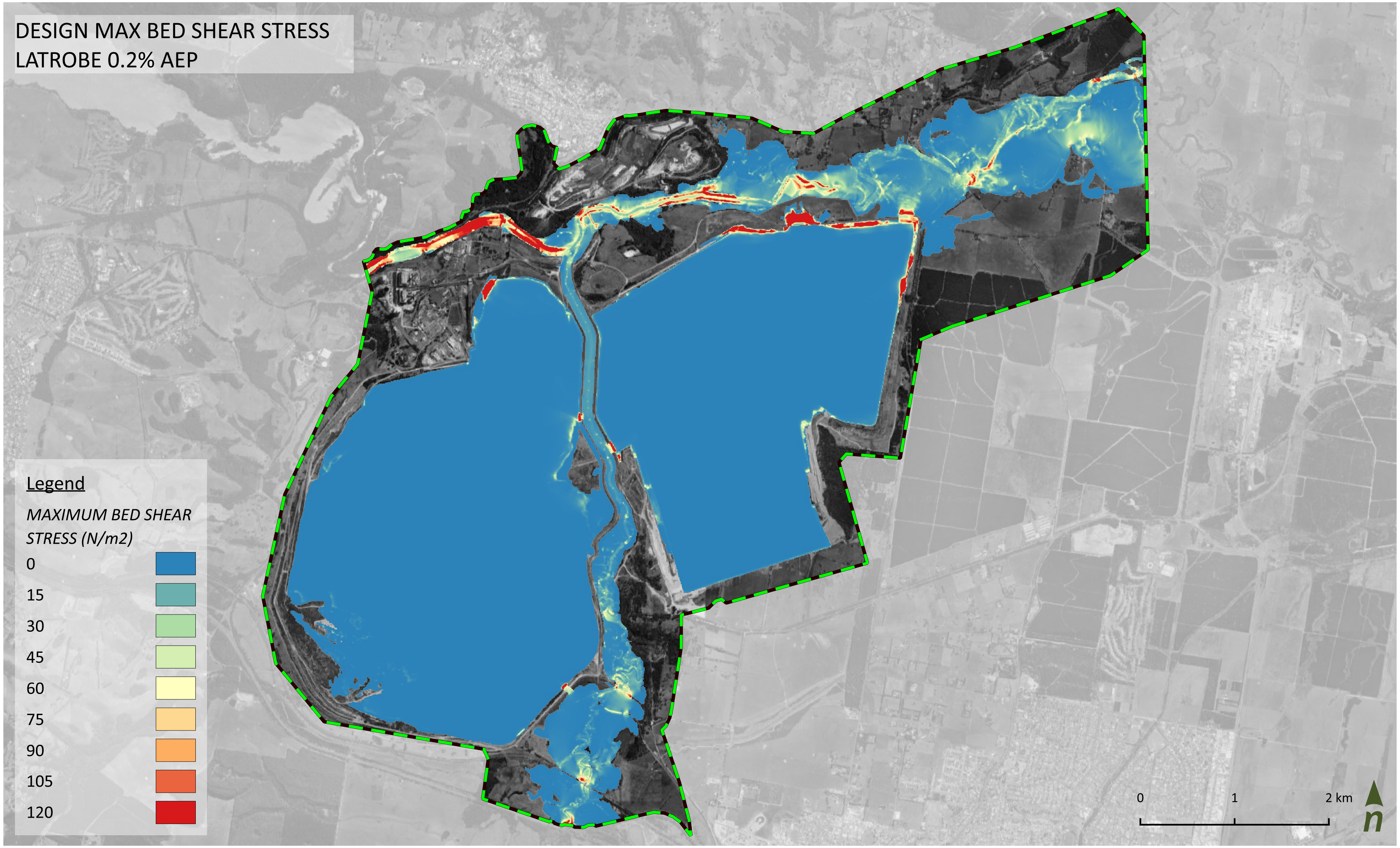


FIGURE A72. DESIGN MAX BED SHEAR STRESS LATROBE 0.2% AEP

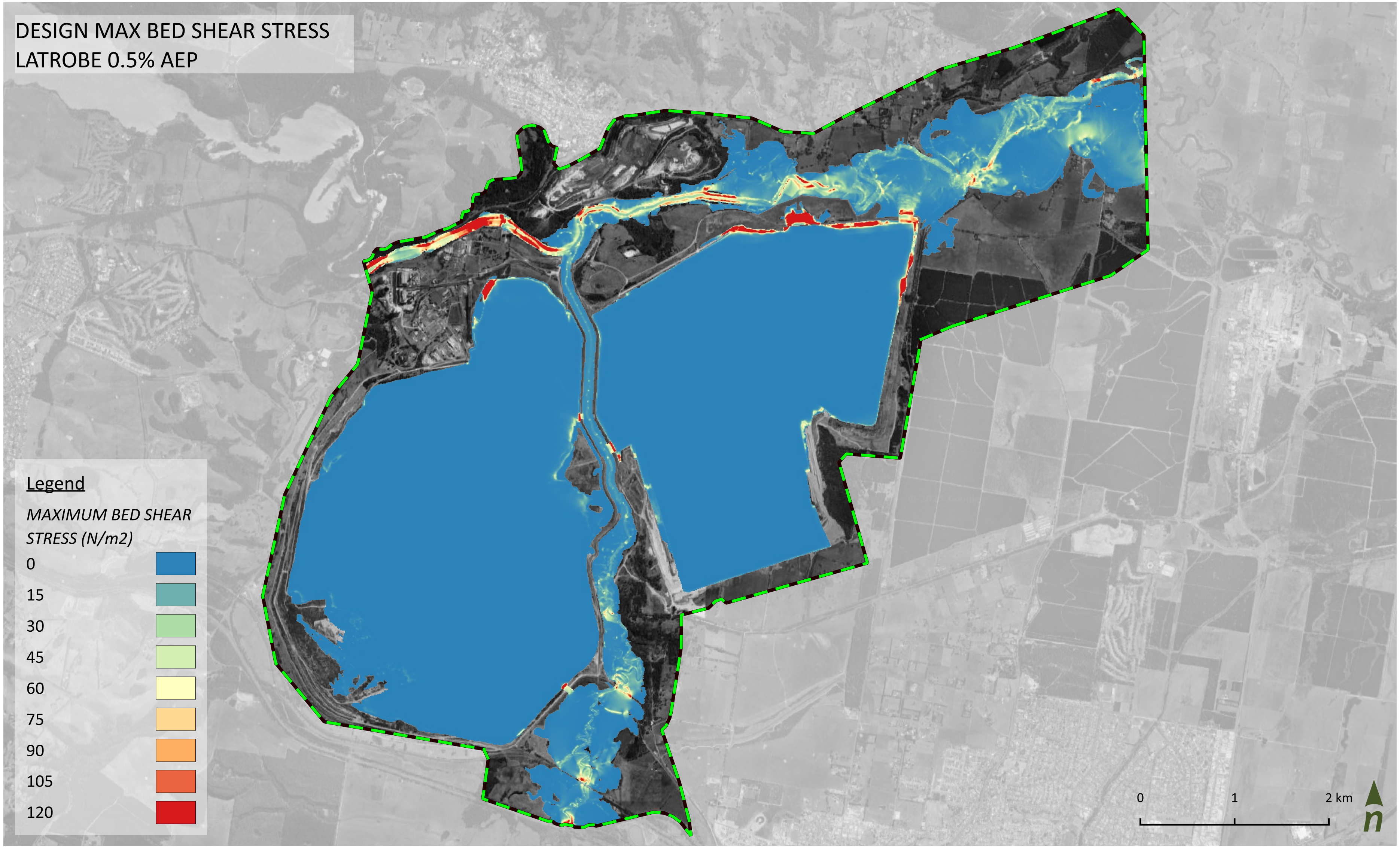


FIGURE A73. DESIGN MAX BED SHEAR STRESS LATROBE 0.5% AEP

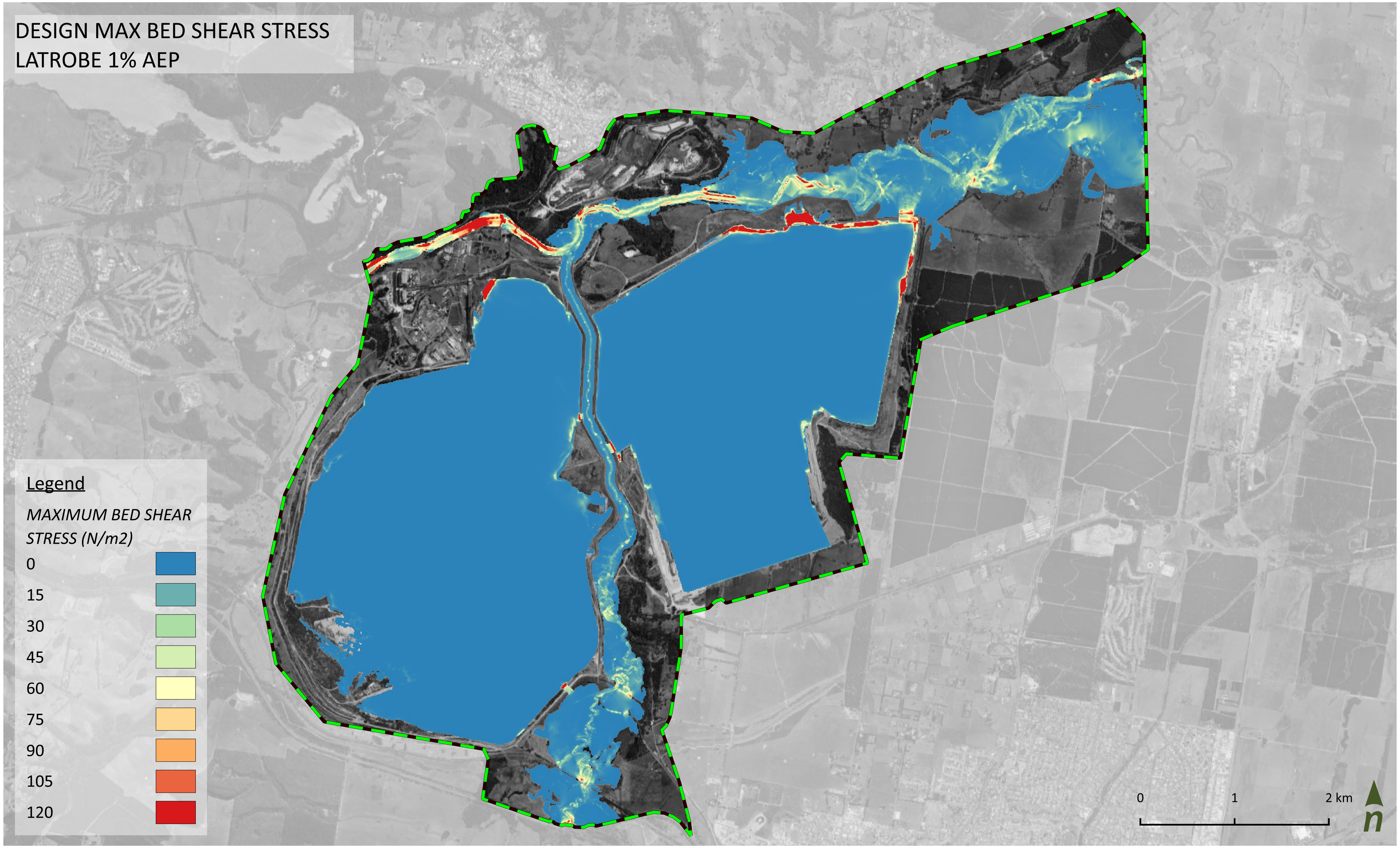


FIGURE A74. DESIGN MAX BED SHEAR STRESS LATROBE 1% AEP

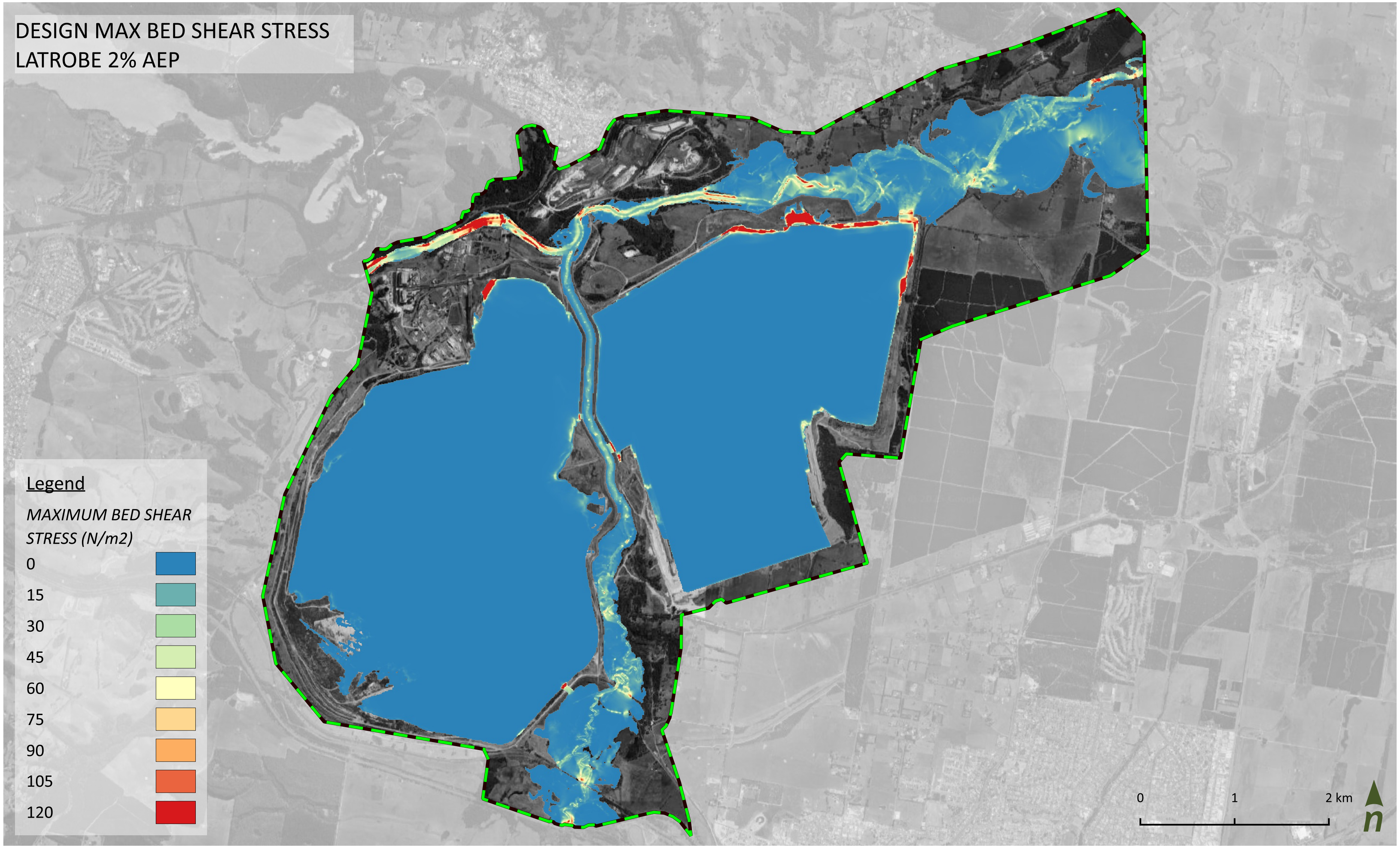


FIGURE A75. DESIGN MAX BED SHEAR STRESS LATROBE 2% AEP

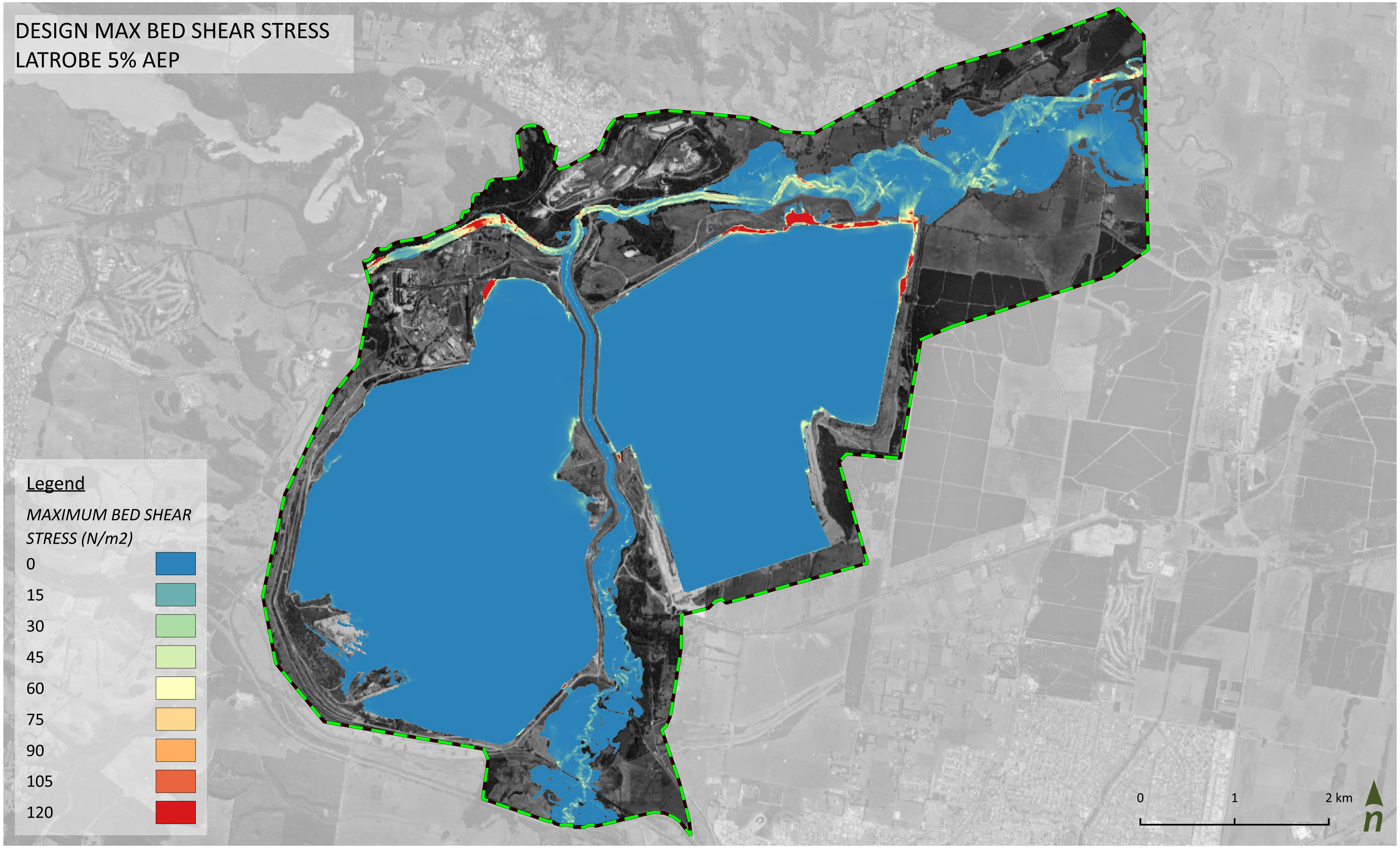


FIGURE A76. DESIGN MAX BED SHEAR STRESS LATROBE 5% AEP

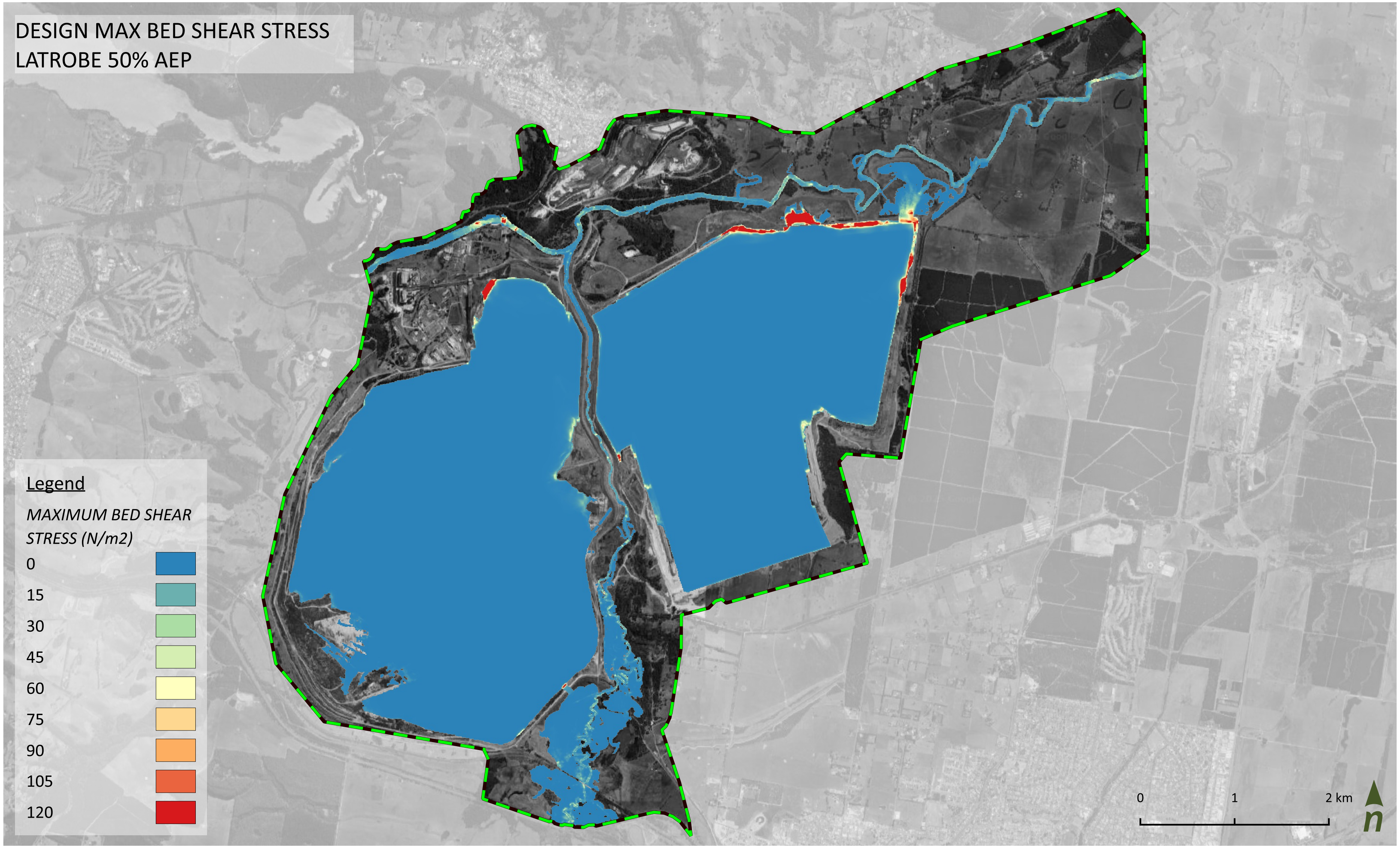


FIGURE A77. DESIGN MAX BED SHEAR STRESS LATROBE 50% AEP

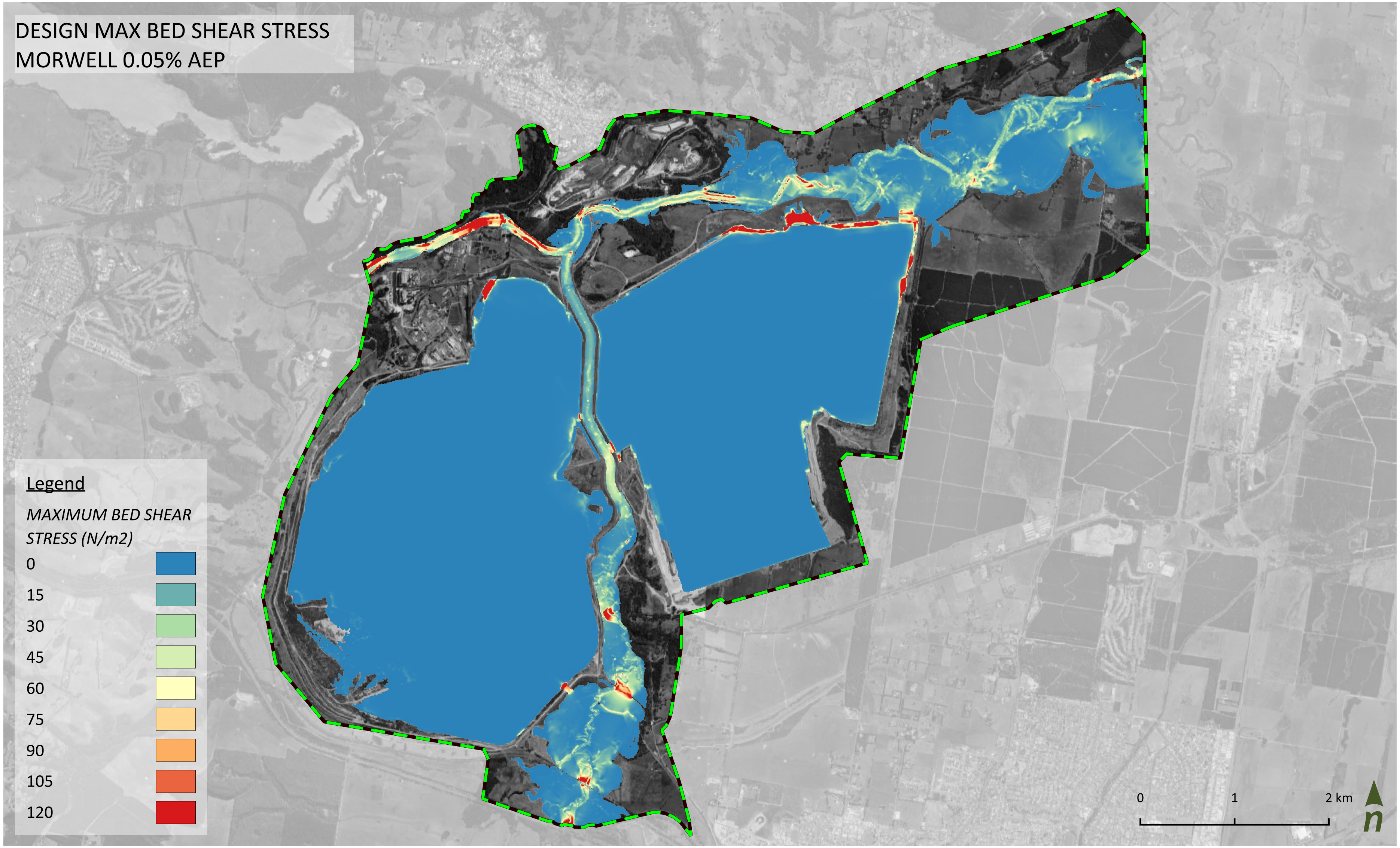


FIGURE A78. DESIGN MAX BED SHEAR STRESS MORWELL 0.05% AEP

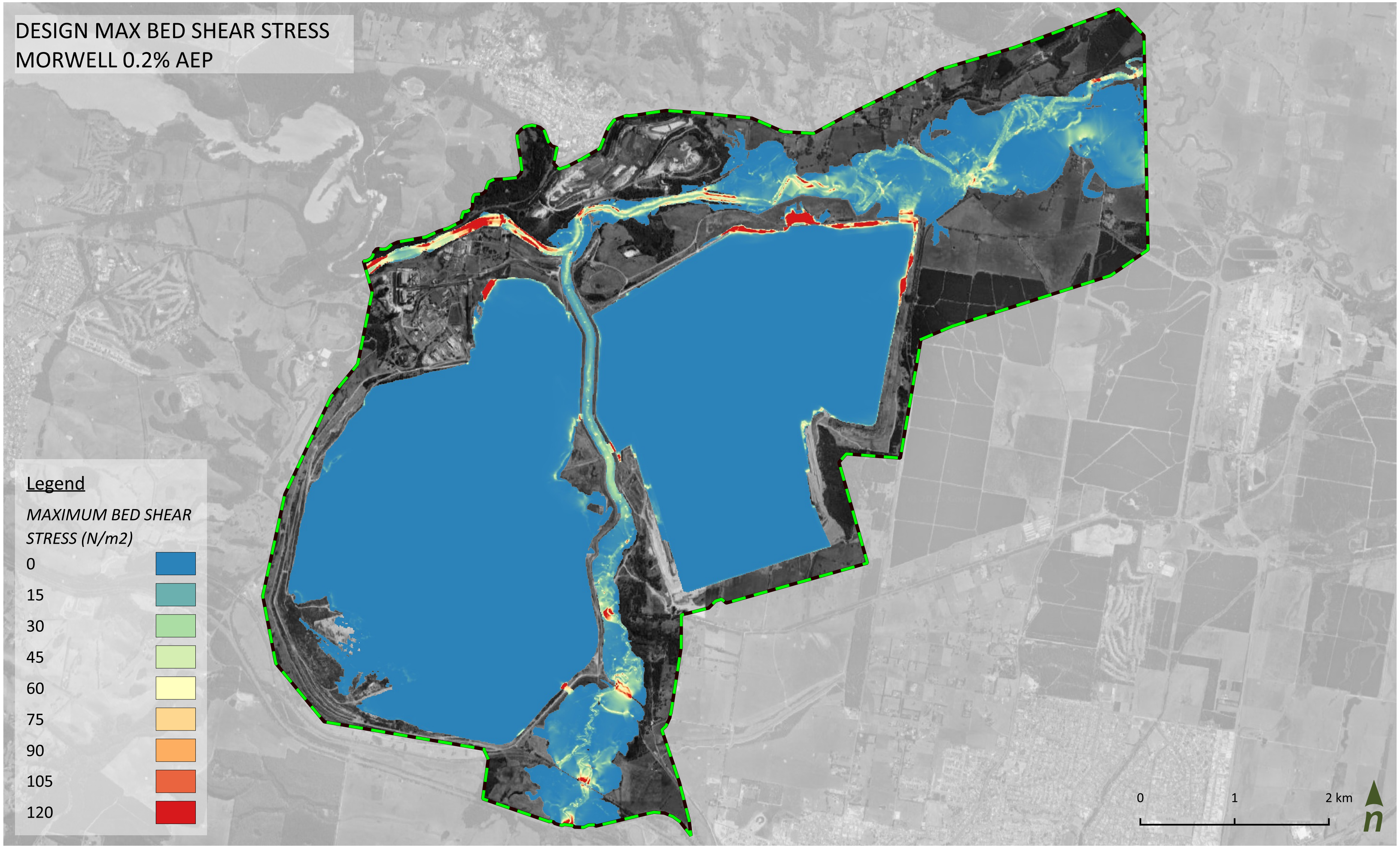


FIGURE A79. DESIGN MAX BED SHEAR STRESS MORWELL 0.2% AEP

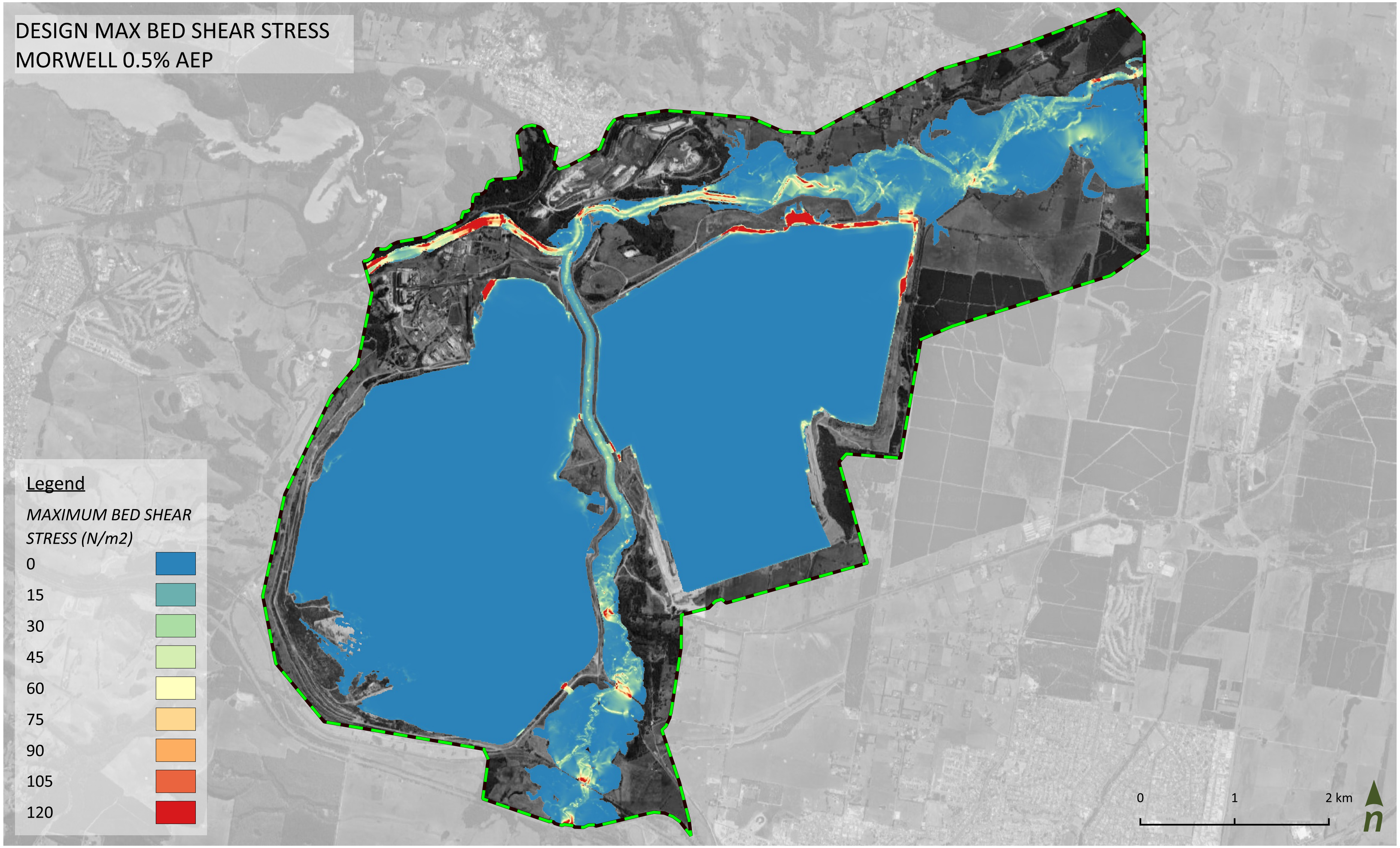


FIGURE A80. DESIGN MAX BED SHEAR STRESS MORWELL 0.5% AEP

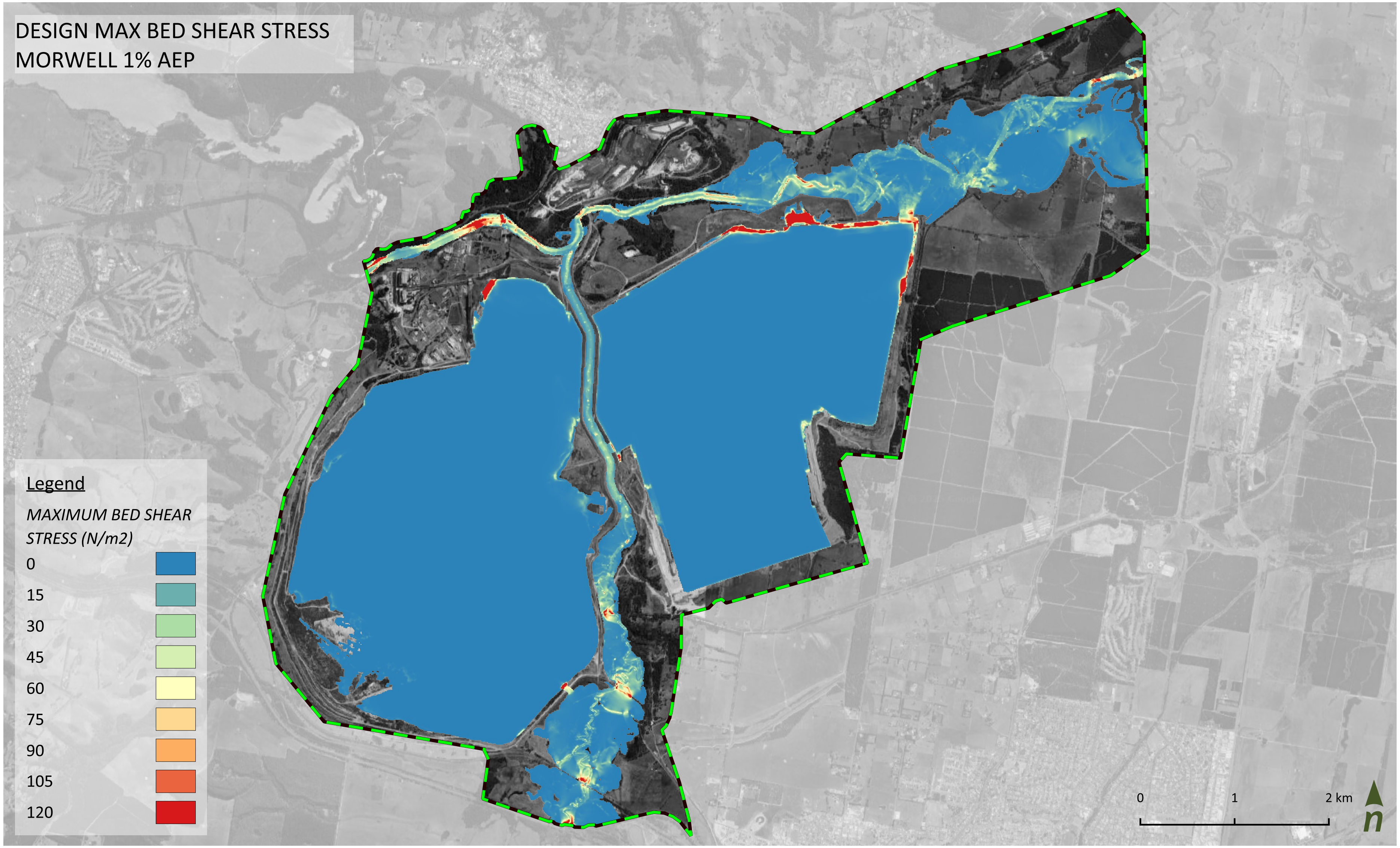


FIGURE A81. DESIGN MAX BED SHEAR STRESS MORWELL 1% AEP

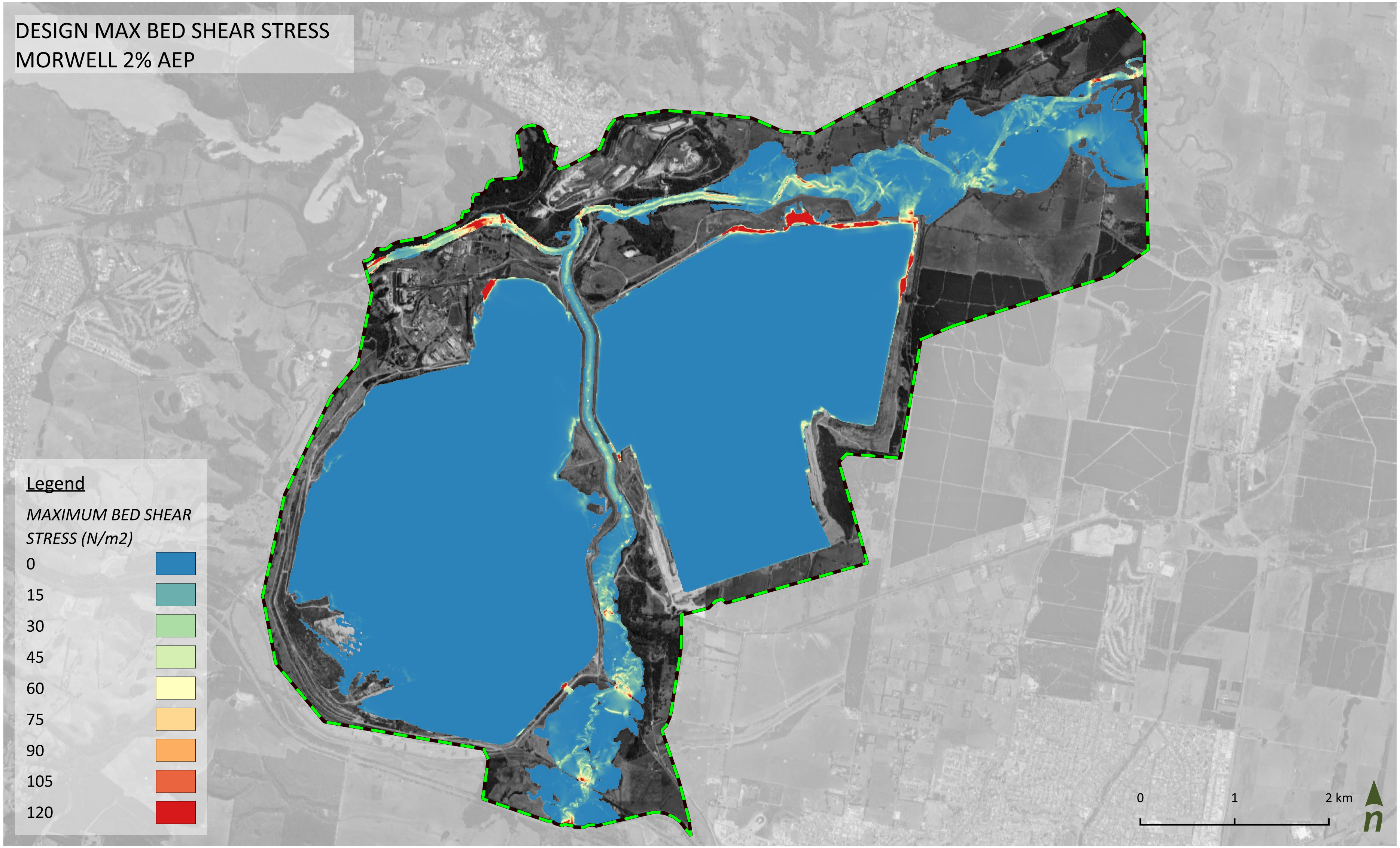


FIGURE A82. DESIGN MAX BED SHEAR STRESS MORWELL 2% AEP

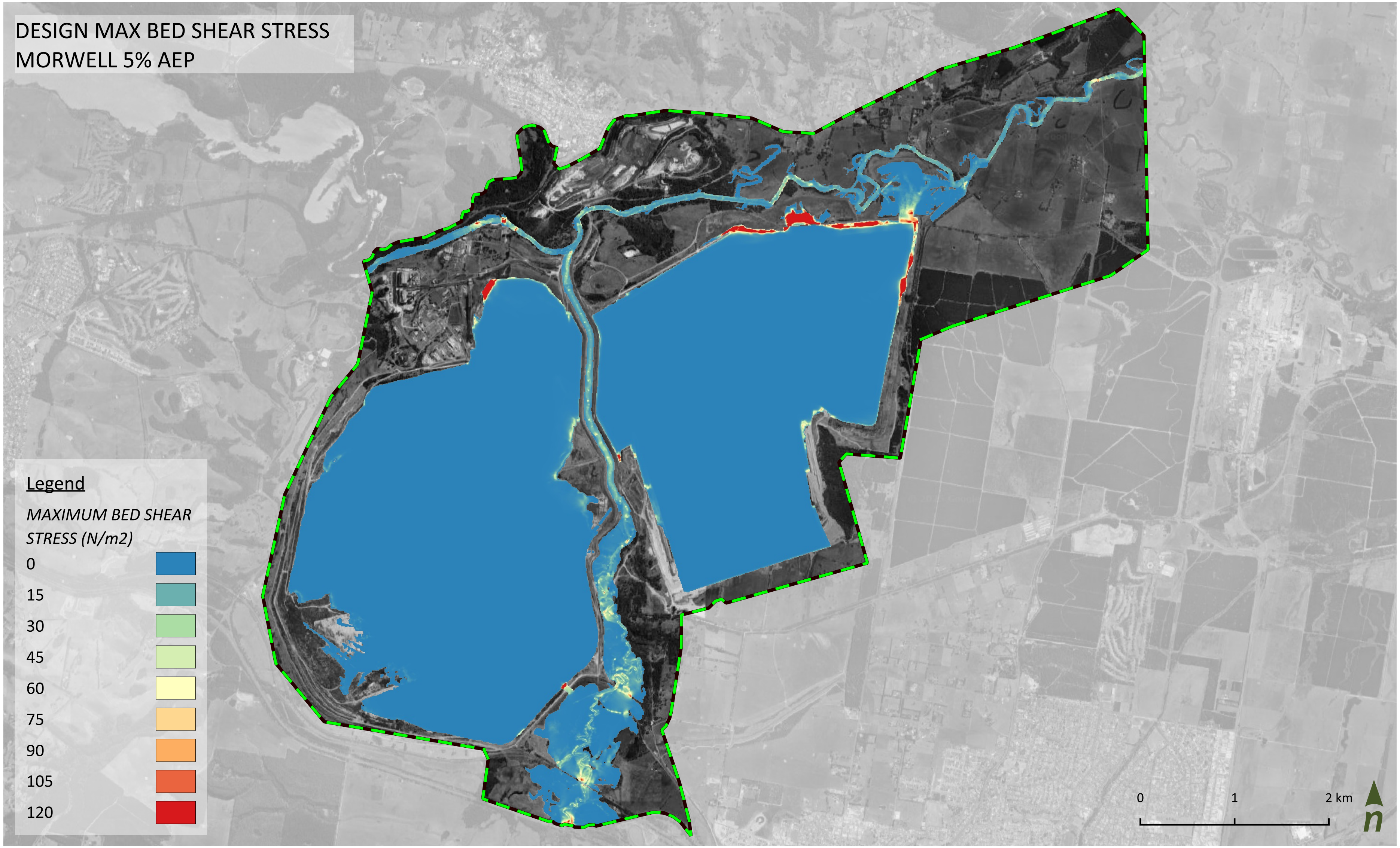


FIGURE A83. DESIGN MAX BED SHEAR STRESS MORWELL 5% AEP

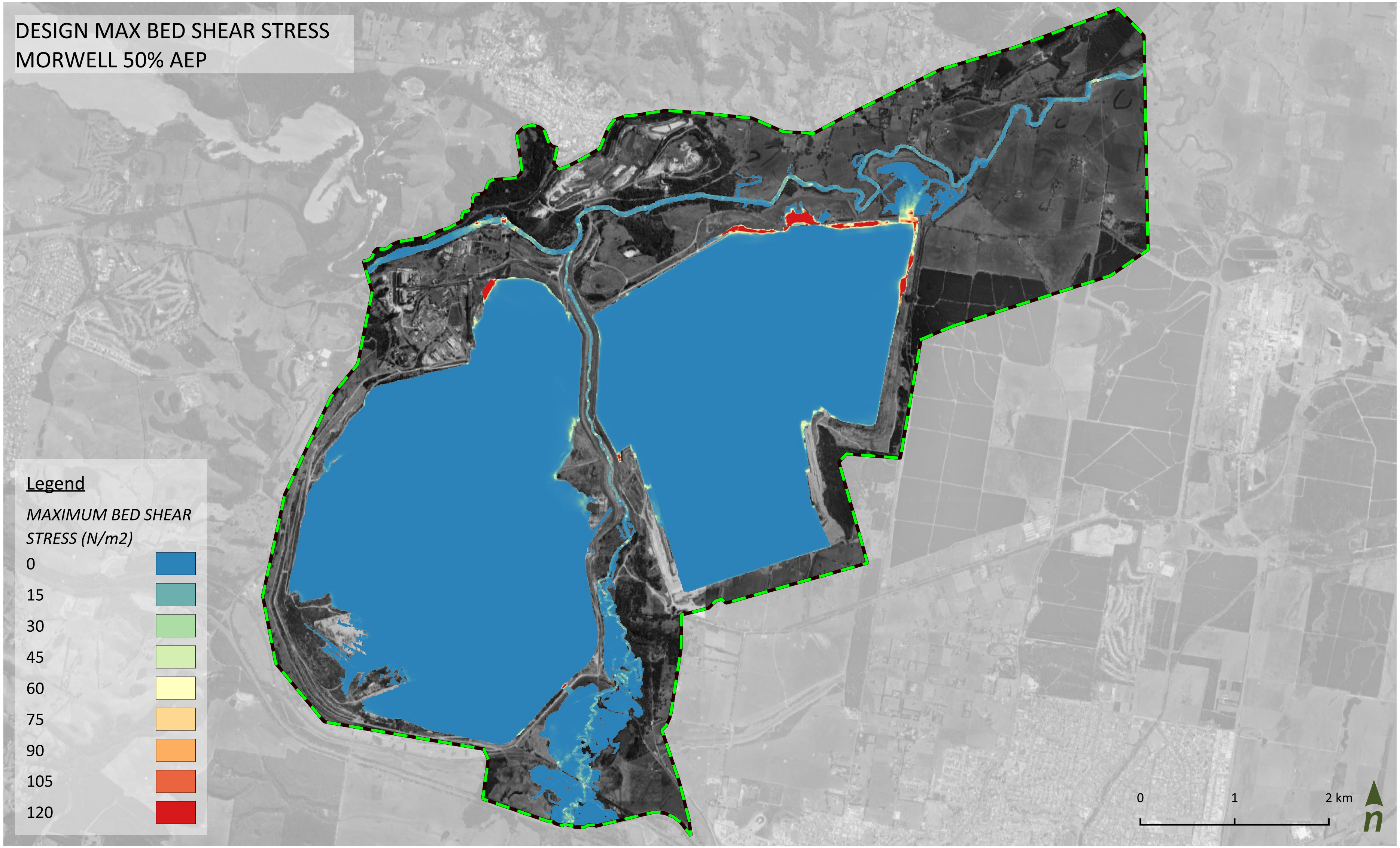
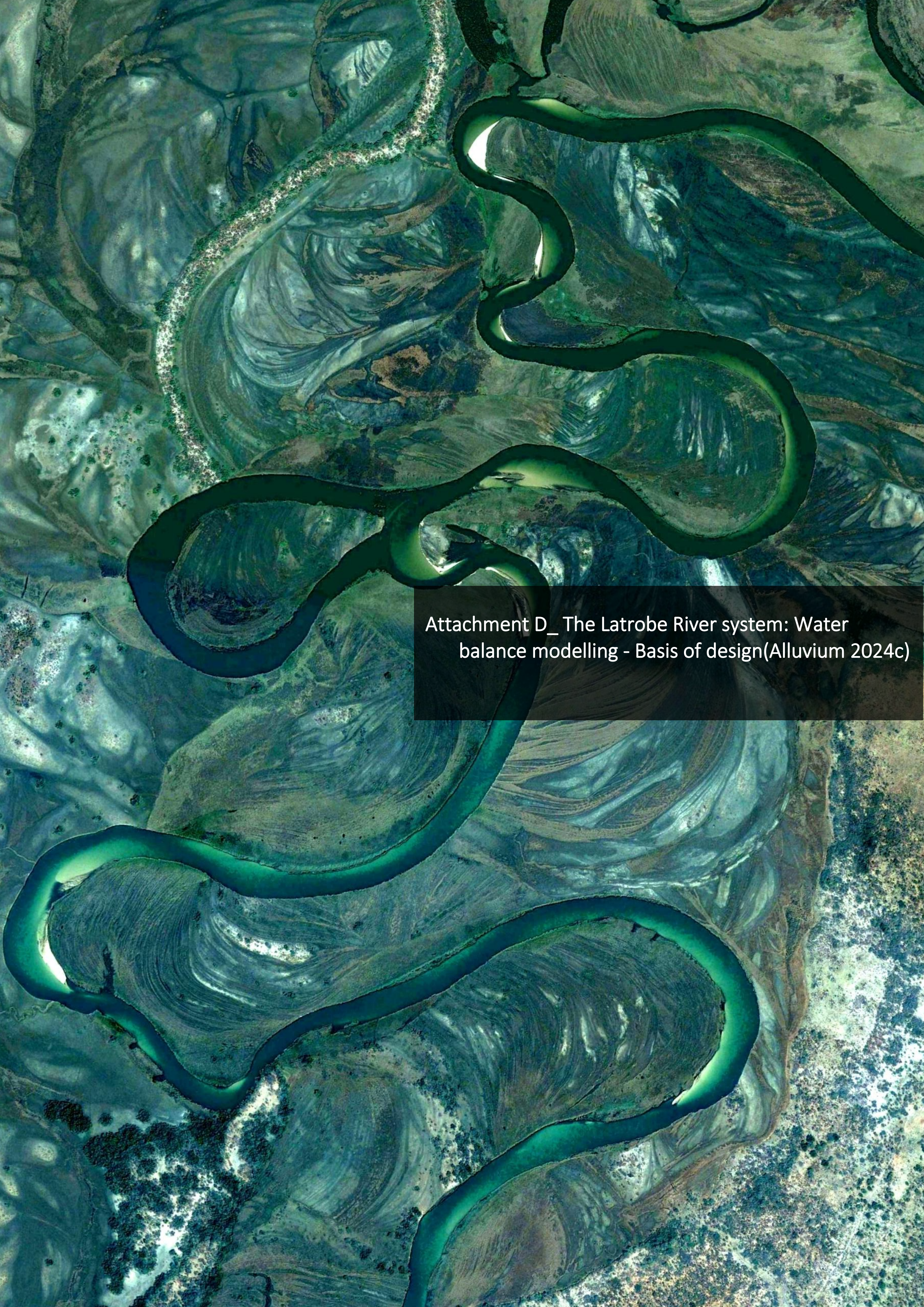


FIGURE A84. DESIGN MAX BED SHEAR STRESS MORWELL 50% AEP



Attachment D_ The Latrobe River system: Water balance modelling - Basis of design(Alluvium 2024c)

The Latrobe River system: Water balance modelling - Basis of design

June 2024

alluvium

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

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

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **EnergyAustralia Yallourn**

Authors: **Ross Hardie, Bill Moulden**
Review: Stuart Cleven
Approved: Ross Hardie

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Citation: The Latrobe River system: Water balance modelling - Basis of design: Report prepared by Alluvium Consulting Australia for EnergyAustralia Yallourn

Cover image: abstract river image, Shutterstock

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Contents

Figures

Tables

1 Introduction

This report has been prepared for EnergyAustralia Yallourn to inform decisions regarding the closure and rehabilitation of the Yallourn Open Cut Mine. Closure planning for the site will require an assessment of the impacts of mine closure options for the proposed filling of the mine void with water. Water balance modelling for the Latrobe River system has been proposed to inform the investigation of such impacts.

This report has been prepared to define the proposed water balance modelling approach, assumptions and scenarios to be adopted for the Yallourn Mine Closure Plan. The report sets out the proposed 'base case', and 'project case' scenarios to be assessed and optional 'cumulative impacts' scenarios (if and as required). The report has been prepared to assist with the approval of proposed model runs prior to the commencement of modelling and subsequent analysis of results.

2 Background

The proposed Yallourn Mine Closure Plan will require an assessment of the impacts of the proposed project on waterways and wetlands of the Latrobe River catchment. It is proposed that the waterways and wetlands assessment be informed by hydrologic (water balance) modelling of the Latrobe River systems. The modelling and assessment will include alternate proposed water use arrangements associated with the proposed project. It is proposed that the hydrologic modelling be undertaken using the 'Source' hydrologic modelling package.

The reaches assessed will include those with potential to be impacted by the project and include the Morwell River, Latrobe River to Thomson River confluence, the Tanjil River and the Lower Latrobe River (downstream of the Thomson River confluence) to Lake Wellington.

It is proposed that the water balance modelling be used to inform a risk assessment on the potential impacts of using surface water resources to fill the mine void and maintain a pit lake. It is proposed that the risk assessment be based on an assessment of the likelihood and consequence of 'failures' to meet environmental water requirements in the Latrobe River system and more particularly the change in occurrence of such failures between a base case and adopted project cases. It is proposed that the water balance modelling be used to inform the likelihood of such impacts.

It is proposed that the approach for the wider assessment of project risks including the determination of the consequences of environmental water shortfalls be the subject of separate method statement.

3 LVRRS

As part of the Latrobe Valley Regional Rehabilitation Strategy (LVRRS), a series of future water use scenarios were modelled to understand the environmental flow compliance and potential risks that environmental values are facing due to mine rehabilitation. This study modelled the regional water balance under hypothetical future water access scenarios, including entitlement volume (for power generation), historic use, and seasonal restrictions.

This study will model two options (the combination of available licences and capture of overbank flood flows in the Morwell River) for the provision of water resources in the as built case as a validation of design. A base case will also be modelled for the purpose of quantifying incremental impact, and the risks that have been identified in the LVRRS will be built on to develop an Impact Assessment which explores the risks and impacts of the use of various water sources on environmental values in the project area.

4 Purpose

The purpose of the modelling described in this report is to do the following:

1. To inform the availability, timing and rate of mine pit lake filling from surface water sources; and,
2. To provide information to assess the impact of the long term proposed water use of surface water.

5 Modelling approach

The proposed approach to the hydrologic (water balance) modelling does not include, but requires integration with, lake water balance (in-pit) modelling undertaken by others. The proposed approach adopted for the Latrobe surface water balance modelling is based on:

Source model: It is proposed that the hydrologic (water balance) modelling will be undertaken using DEECA's Source daily timestep water balance model for the Latrobe River. This is the model that has been adopted for the assessment of the LVRRS and proposed for use in the development of the Hazelwood Environmental Effects Statement.

> DEECA approval will be required prior to the use of the DEECA source water balance model for this purpose.

Realisations (sequences) and scenarios: The hydrologic water balance modelling will include a single realisation (event sequence) and multiple climate scenarios.

Project options and alternatives: The assessment will include a single project option that reflects the proposed constructed components as agreed as part of the hydraulic design assessment. This assumes a high flow interconnection with the Morwell River through the designed offtake spillway. The model will adopt a single fast rate of fill for the incorporation of inflows from the flood harvesting point at the offtake spillway.

Project assessment cases: Alternate project assessment cases with potential supply options will be examined for the purpose of comparative analysis of the proposed project. These include (Table 1):

- a base case, and
- 2 alternate project cases

These project assessment cases will each be run twice, based on the projected harvesting options at Hazelwood. In one instance (run A), as assumption has been made that there will be flood harvesting of the Morwell River at Hazelwood. If this were the case, Hazelwood harvesting of overbank flows would reduce the water availability from this source at Yallourn. Under the other instance (run B) the model runs will assume no harvesting from Hazelwood.

Under all model runs, the water use at Loy Yang is assumed to run as current (operational) until 2035, and then historic use for ongoing pit filling.

Each project case models a different combination of proposed water sources. A single time series output from each case (total inflow volume to the mine pit lake) will be extracted from each case for input into the Water Balance and Groundwater Goldsim modelling component to be completed by RGS.

Table 1 - **Water Balance modelling water sources supply options**

	Water source	**Base Case**		**Project Case Supply Scenario 1**		**Project Case Supply Scenario 2**	
		A	**B**	**1A**	**1B**	**2A**	**2B**
1	Overbank flows from the Morwell River (flood harvesting)			✓		✓	
2	Local sources currently reporting to Morwell River			✓		✓	

3	Groundwater sources	A water source that will not be represented in the Source model but will be reflected in the Goldsim model.					
4	Gippsland Water Bulk Entitlement in Blue Rock Reservoir					✓	
5	Current Bulk Entitlement (in line with historic use) and local catchment sources currently reporting to pit	✓		✓		✓	
Assumptions for other sites							
6	Hazelwood Project without flood harvesting for pit filling and top-up	✓		✓		✓	
	Hazelwood project with flood harvesting for pit filling and top up		✓		✓		✓
7	Loy Yang based on 2035 closure and historic take for pit filling	✓		✓		✓	

In addition, a cumulative impact case can be undertaken if and as required

The 'Source' water balance model package is typically used to model static water use arrangements/ demand rules over a long period of time. The Latrobe Source water model operates over the period 1957 to 2020. The static arrangements are modelled via a set of water rules that are defined within the water balance model. However, in the Latrobe Valley and for the purpose of the Yallourn Mine closure planning, the water use arrangements will be changing through time in response to changing water demands associated with the project (fill and lake operation phases) and in response to anticipated changes in water demand by the other power generators.

It would be possible to model and assess a worst-case water demand i.e. peak water demand by all water users over the entire duration of the project. However, such a simplification may be overly conservative and overstate the risks associated with the more variable demand on water through time.

A more nuanced assessment of the risks arising from the project and the changing water demand through time will necessitate a more complex analysis approach to that typically employed for the review of water balance model results. An analysis approach is proposed for the assessment based on each phase of project implementation using water demand profiles for each phase of operation.

The hydrologic modelling approach and phase analysis can be used to inform a risk-based assessment that can aid the identification of changes in risk to ecological values, arising from the proposed project. In this respect the proposed hydrologic modelling approach and post processing analysis can identify the likelihood of shortfalls in the delivery of environmental water to reaches of the Latrobe River and the ecological values within these reaches for each project phase.

The modelling approach requires the identification and analysis of water use 'demand profiles' for each phase of mine void filling and operations. A description and examples of such water demand profiles is set out below.

5.1 Water use 'demand profiles'

A water use 'demand profile' is defined as a set of water use arrangements that may exist for a time increment for the base case and any project options assessed.

A water demand profile would represent the water use demands across all sites and power generators at any point in time. Any one water demand profile may be applicable to one or several years. An illustrative set of water demand profiles for a 'Base case' is provided below. Note: The example Base case water use rates and demand profiles are illustrative only and do not represent the water demand profiles that will be developed and adopted for the purpose of the hydrologic modelling.

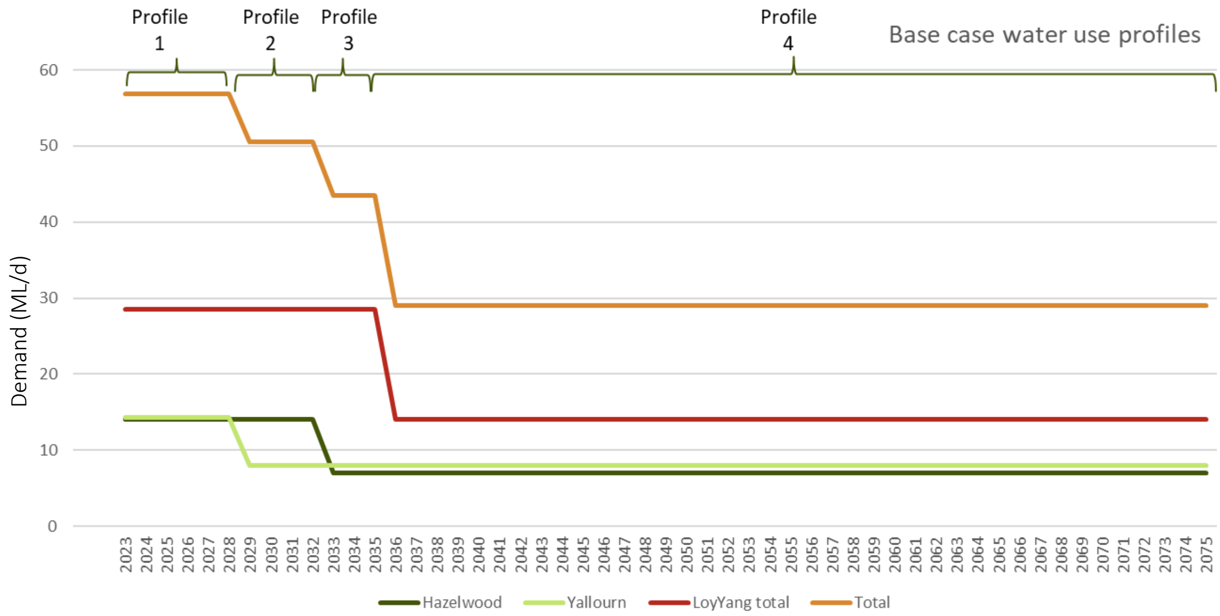

Figure 1 Example base case water use demand profiles

An example set of 'cumulative project' water use demand profiles is also provided for illustrative purposes. Again, the water use rates and profiles are illustrative only and do not represent the water use rates and profiles that would be developed and adopted for the water balance modelling.

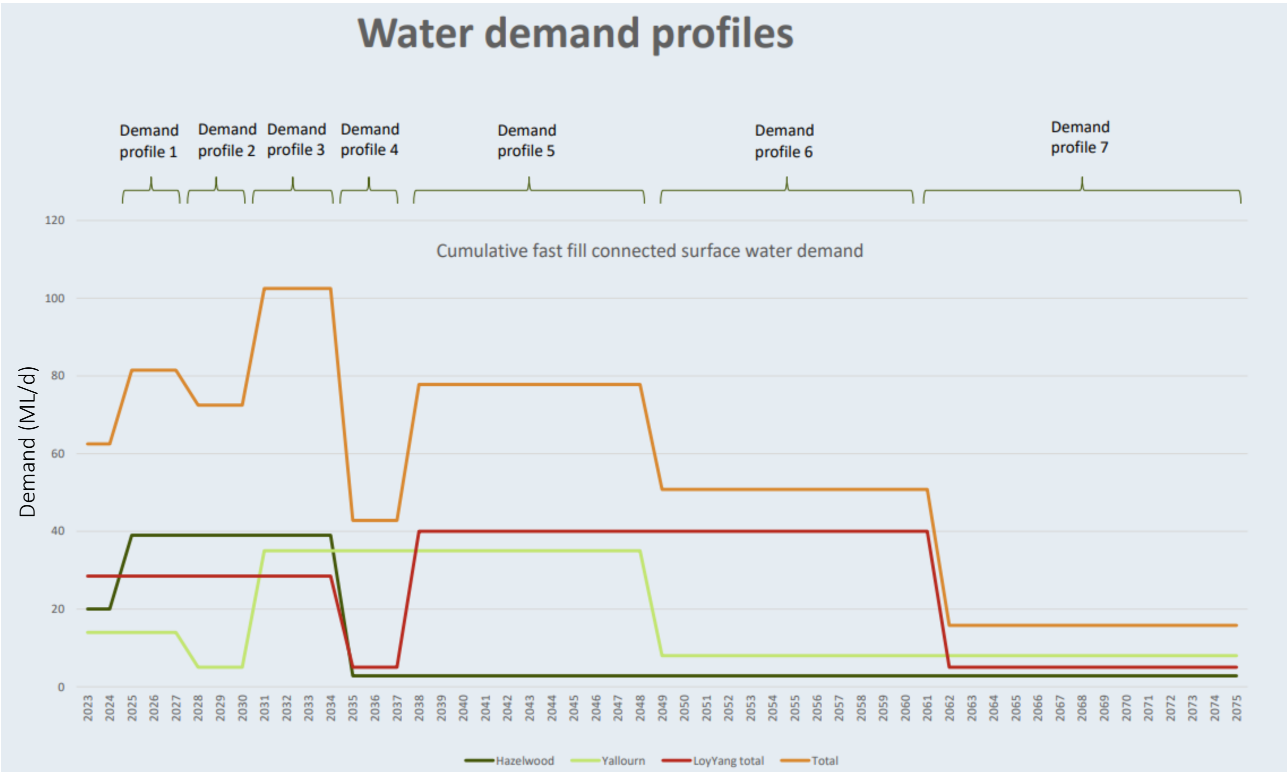

Figure 2 Example water use demand profiles for a cumulative impact assessment

5.2 Project phases

The Yallourn demand profiles can be divided into two project phases, a fill phase and an operation phase. For the purpose of a cumulative impact assessment, the operation phase could be divided into sub phases.

1. Fill phase:
    - While Hazelwood continues to fill
    - Following the completion of Hazelwood fill phase and Loy Yang continues to use water for power production and or pit filling
2. Operation phase
    - while Loy Yang continues to operate and or fill its mine void
    - beyond the Loy Yang operations and filling:

5.3 Representative water demand profiles

A representative water demand profile will need to be identified for each project option and each phase assessed. The demand profile or profiles adopted for each phase could be based on the expected water demands over the phase, of interest.

5.4 Water balance modelling and probabilistic analysis process

It is proposed that the hydrologic modelling and probabilistic analysis comprise the following steps:

1. Identify a representative water demand profile for each water use option for each phase.
2. For each phase and the base case and each water use option for that phase,
    - run the Source model over the duration of the historic sequence for the adopted representative water use 'demand profile' applicable to that option.
    - Determine compliance with environmental flow recommendations (or environmental shortfall) for each demand profile.
    - Employ stochastic modelling to assess probability by:
        - Randomly sampling years from each of the relevant demand profiles to create many assessment sequences (effectively multiple climate realisations) of compliance with environmental flow recommendations.
        - Determining the probability that a sequence will not meet flow recommendations and that there will be an environmental shortfall.
3. Calculate the change in probability in short fall (for each flow component and reach) over the agreed assessment period for each option by comparing the probability of environmental water shortfalls in the base case against the probability of shortfalls for the options assessed.

Note:

1. There is potential for an overwhelming number of risks to be identified arising from the multiple flow reaches, flow components, project phases, climate scenarios and consequence categories. A two-stage process may be required that comprises:
    a. Stage 1: A scoping exercise that identifies reaches, flow components, phases, climate change scenarios and consequences of concern.
    b. Stage 2: A detailed assessment of key risks identified in Stage 1
2. Flow components are the elements of a flow regime and aid the investigation and development of environmental water recommendations and the provision of environmental flows. Flow components and associated flow rates, timing, duration and occurrence have been identified for the Latrobe River

system and reaches of interest to this Environmental Effects Statement through the Latrobe River Environmental Water Study 2021. These flow components include:

- Summer/ autumn base flows
- Summer autumn freshes
- Winter spring base flows
- Winter spring freshes
- Bankfull events
- Overbank events

5.5 Risk assessment

A risk assessment is proposed to inform the Yallourn Mine Closure Plan process, whereby the assessment comprises a review of the change in risk associated with the proposed project.

The categorisation of risk and of likelihood and consequence would be based on that adopted by EnergyAustralia Yallourn for other risk assessments accompanying the development of the mine rehabilitation plan.

The probabilistic hydrologic analysis will be used to identify the 'likelihood' of impact arising from the proposed project. The 'consequence' of impact will be based on a review of the values within the reaches impacted by the changes in the hydrologic regime. These values will be based on that identified in the environmental flow assessment for the Latrobe River and updated as appropriate by the project team specialists.

Mitigation measures will be explored to reduce and/ or offset impacts identified through the risk assessment.

6 Model options, cases and realisations

6.1 Project options

A single project option will be modelled for the assessment.

- **Project Option: Partially connected**: This project option comprises a high-level (overbank flow) connection between the Morwell River and the Yallourn pit (and lake) capable of receiving water in high flow events. An offtake arrangement will need to be developed that sets the offtake level for the harvesting of a proportion of overbank flood water at an agreed Morwell River flow rate.

  Notes on Project Option: Partially connected

  1. A flow rate at which flows commence to spill toward the pit will need to be identified and documented
  2. A functional design for and hydraulic modelling of the Morwell River offtake should be undertaken to a level suitable to inform the assessment. The final elevation of any offtake and refinement of the design arrangements should be undertaken following the outcome of the assessment process..
  3. A lower threshold flow rate of approximately 3000ML/d (approx.) could be adopted as a basis for the exploration of design options including the tradeoff between harvestable volumes and the impacts on Lower Latrobe saline wedge.
  4. Only a proportion of water in excess of the adopted commence to spill (toward the pit) event is expected to be harvested (directed to the pit lake). The hydraulic modelling should include provision of a rating table that identifies the split in flow between that retained in the Morwell River and that diverted to the pit lake. Following the completion of filling, and subject to pit top up arrangements, a majority of any flood water diverted to the pit would be returned to the Morwell River via a constructed return channel from the pit lake to the Latrobe River.

5. Morwell River flood flow supply will be limited for the period of any overlap of pit filling for Hazelwood and Yallourn if Hazelwood is successful in its request to use such supply for pit filling. Once full it is assumed that the Hazelwood pit water level would be maintained via an ongoing supply contract with Gippsland Water. Once full it would be assumed that any and all water harvested by a Hazelwood flood offtake would be returned to the Morwell River and be available for harvesting by EnergyAustralia Yallourn

6.2 Pit fill rates and schedule

A single fill rate will be explored based on historic gross take plus the additional inflow from a flood spillway from the Morwell River.

Table 2 Yallourn Project pit lake water sources and fill rates

Potential water sources	Fill rate (rate of fill GL/yr)
Groundwater	1.5
Blue Rock Reservoir via Latrobe River	Gross historic take
Flood flow from Morwell River (TBC)	5-9 (TBC) Based on Source Model, any flows above trigger nominated. Need to close design gap first.
Return flows	0 (reduced from current TBC)
Additional surface water	24
Gippsland Water BE held in Blue Rock Reservoir	TBC

Note: Morwell River flood flow supply will be constrained for the period of any overlap of pit filling for Hazelwood and Yallourn if Hazelwood is successful in its proposal to use such supply for pit filling.

The following pit lake fill and operation schedule is proposed for Yallourn, Hazelwood, and Loy Yang.

Table 3 Notified and potential dates for changes in water demands in the Latrobe Valley (from ERM 2023)

Site	Expected change in water use for Base case	Start	End	Source
Hazelwood (ENGIE)	Current water use to meet stability and fire suppression requirements and resultant filling to RL -7.0m AHD	N.A	2026	Based on current rates of fill
	Fill of pit	2026	2035	Assumed completion date TBC
	Lake operations	2035	2128	
Yallourn (EnergyAustralia)	Power production	N.A.	2028	Proposed for investigation
	Pit filling	2029	Scenario dependant	Assumed dates for completion of pit filling to be confirmed by pit lake water balance modelling
	Lake operations	TBC	2128	Assume 100 year analysis period
Loy Yang A (AGL)	Cessation of power production as currently notified		2035	Proposed for investigation
Loy Yang B (Alinta)	Cessation of power production in 2035 to align with the Loy Yang A closure		2035	Proposed for investigation

	Alternate Base case: Cessation of power production as currently notified (TBC)		2047	Not included in investigation
Loy Yang A&B	Pit filling	2035	2055	Assume 20 year to fill pit
	Lake operations	2055	2148	Assume 100 year period of analysis

6.3 Timing of fill

It is proposed that pit filling (via Bulk Water Entitlement) be limited to the July to November period as per Scenario 5 in Alluvium 2023 *Types of conditions that could apply to water access for Latrobe Valley mine rehabilitation and associated risks and benefits. Report for DEECA September 2023.*

6.4 Cases

Project cases can comprise a base case (baseline) against which alternate cases will be assessed. Project cases should include a project only case and the potential for a cumulative impact case. The base case enables comparative analyses, identifying the impact of the proposed project and/ or the cumulative impact of multiple Latrobe Valley rehabilitation projects against the base case.

Baseline/ base case:
The project will be assessed against a baseline/ base case.

Further work is required to define the Basecase arrangements for EnergyAustralia Yallourn and for Hazelwood and Loy Yang. This will be undertaken with EnergyAustralia Yallourn in collaboration with stakeholders.

Project cases assessed:
Two alternate project cases can be assessed

1. **Project impact case 1: Yallourn project only impact assessment 1**
   This case would be used to identify the impact of the Yallourn Mine closure plan in isolation to any other proposed mine void rehabilitation projects. For this Yallourn only impact assessment, the Baseline assumptions will be retained for the Hazelwood and Loy Yang (A and B) water use. This case would include use of water from the following sources (TBC):

   - Current Blue Rock Bulk entitlement
   - Local sources of water currently reporting to the Morwell River
   - Morwell River flood harvesting
   - Cessation of return flows

2. **Project impact case 2: Yallourn project only impact assessment 2**
   This case would be used to identify the impact of the Yallourn Mine closure plan in isolation to any other proposed mine void rehabilitation projects. For this Yallourn only impact assessment, the Baseline assumptions will be retained for the Hazelwood and Loy Yang (A and B) water use. This case would include use of water from the following sources (TBC):

   - Blue Rock Bulk entitlement
   - Local sources of water currently reporting to the Morwell River
   - Morwell River flood harvesting
   - Cessation of return flows, and
   - Additional inputs from Gippsland Water via its Blue Rock entitlements

Optional inclusion: Cumulative impact case: Cumulative project impact assessment

An optional inclusion would be a cumulative impact assessment. This case would be used to identify the potential cumulative impact associated with rehabilitation of all three mine voids with freshwater from Gippsland Water (Hazelwood) and modified Bulk Entitlements (Yallourn and Loy Yang).

6.5 Climate realisations and climate scenarios

The Source hydrologic (water balance) model will be run on a daily timestep for a single realisation comprising the historic sequence of events. Four climate scenarios could be considered for the assessment.

- Wet: 1975 onwards (post 1975 low climate change)
- Dry: 1975 onwards (post 1975 high climate change)
- Median: 1975 onwards (post 1975 moderate climate change), and
- Drought: 1997 onwards (steep change post 1997 current)

Note: For the purpose of the surface water modelling the DELWP climate factors are used to scale the entire time series of flow (or temperature and rainfall) to represent AVERAGE conditions at a point in time (2040 or 2065).

> The base case and project options can be assessed for one, some or all these climate scenarios.
>
> It may be appropriate to assess the project for 'median conditions' and explore sensitivity of results for dry or drought conditions

6.6 Number of assessments

It is intended that the hydrologic model be run multiple times (i.e. for each water demand profile) under each model configuration (i.e. each option). The different model runs for each configuration will reflect different levels of water use through time (demand profiles) under each configuration. Approximately 6 x demand profiles are anticipated to be required and run for each model configuration.

Each model configuration will be assessed for each of 5 reaches of river, with potential to be impacted by the proposed water use. These reaches are consistent with that included in the Latrobe Environmental Flow Study (Alluvium 2022) comprising:

- Morwell River
- 2 x Latrobe River Reaches
- Tanjil River
- Lower Latrobe River

Each reach will be assessed to identify impacts on 6 flow components

- Dry season (Summer and Autumn)
    - base flow
    - fresh
- Wet season (Winter and Spring)
    - base flow
    - fresh

- Bankfull events
- Overbank events

Therefore, each model configuration will require analysis of each adopted phase demand profile (up to 3) x 5 river reaches x 6 flow components i.e. up to 180 flow components.

7 Hydrologic (water balance) modelling assumptions

Assumptions have been proposed (in this memo) to inform the water balance modelling. These assumptions include general assumptions that impact all model configurations and more specific assumptions that impact on the baseline and project options assessed.

7.1 General assumptions

- The recommendations contained in the Central and Gippsland Sustainable Water Strategy will be implemented by government.
- Other than the changes proposed in the Central and Gippsland Sustainable Water Strategy, the existing bulk entitlements and current / historic water use will be consistent with that set out in the Latrobe Valley Regional Rehabilitation Strategy (refer attachment No. 2).
- Other than the changes proposed in the Central and Southern Sustainable water Strategy, the existing water supply priorities and rules in the Latrobe River system and included in the existing Source model will remain in place.

Other assumptions include the volume of water required to fill pits and the status of water held in Hazelwood at the commencement of proposed filling. These assumptions are set out below.

Table 4 Major mine void volumes in the Latrobe Valley (from Basis of Design ERM 2023)

	Hazelwood	Yallourn	Loy Yang Total
Pit volume	637	666	1340
Pit volume at start of fill	170	20	0
Volume to fill	467	646	1340

It is assumed that:

- Yallourn
    - The Yallourn pit holds 20 GL of operational water storage at the start of filling
    - Filling the pits at Yallourn Commences in July 2029
- Hazelwood
    - The Hazelwood pit will be at or near RL -7.0 m AHD in 2025.
    - The Hazelwood project fill options commence on 1 Jan 2026.
- Loy Yang (TBC)
    - The Loy Yang pit will be at near empty at the commencement of fill

7.2 Central and Gippsland Sustainable Water Strategy

A review of the Central and Gippsland Sustainable Water Strategy (CGSWS) was undertaken to inform the Source water balance modelling proposed to inform the assessment.

Four specific policy initiatives were identified that impact on the Source Latrobe Water Balance Model:

Action 4-8: **Reallocation of the Latrobe 3 – 4 Bench bulk entitlement (25 GL) by 2024**

- The Victorian Government proposes to use water from the Latrobe 3 – 4 Bench bulk entitlement to support the region's socio-economic transition and build resilience to climate change using two-thirds (16 GL) of the entitlement
- The entitlement is currently unused
- The Victorian Government would retain the remaining one-third (9 GL) of the entitlement to provide flexibility to respond to emerging needs

Implications for Yallourn Mine Rehabilitation surface water modelling: 16 GL of formerly unused entitlement now being allocated to existing water users (refer Policies 8-12 and 8-13). For the purpose of this assessment, we will only reallocate the environmental water from the bulk entitlement in the model; we won't include agricultural or traditional owner water demands.

Policy 8-12: **Return water to the Durt-Yowan (Latrobe River) in the short term by 2027**

- Return up to 7.3 GL of water for the environment to improve waterway health by maintaining water quality in pools and increasing habitat
- Achieved by reallocating a share of water from the Latrobe 3 – 4 Bench bulk entitlement

Implications for Yallourn Mine Rehabilitation surface water modelling: Modification of the Latrobe Source Model to include 7.3 GL of additional environmental water entitlement for all model configurations, sourced from the 3-4 Bench bulk entitlement.

Policy 8-13: Return water to the Durt-Yowan (Latrobe River) by 2029

- Return an additional 7.7 GL of water for the environment to improve waterway health
- Achieved by reallocating water from the Latrobe 3 – 4 Bench bulk entitlement, increasing the use of stormwater, recycled water, or efficiency measures to reduce water extraction from rivers for cities and towns, and opportunities through the development of a vision and plan for the water future of the Latrobe Valley

Implications for Yallourn Mine Rehabilitation surface water modelling: Modification of the Latrobe Source Model to include 7.7 GL of additional environmental water entitlement for all model configurations. Water is assumed to be sourced from the 3 - 4 Bench bulk entitlement (i.e. 0.4GL over that returned under policy 8-12).

Policy 8-15: **Return water to the Tyers River by 2032**

- The Victorian Government will return up to 13 GL of water for the environment to improve waterway health.
- Achieved by developing a vision for the reconfiguration of the Latrobe Valley water supply system and increasing the use of stormwater, recycled water, or efficiency measures to reduce water extraction from rivers for cities and towns

Implications for Yallourn Mine Rehabilitation surface water modelling: For the purpose of this assessment, it is assumed that the return of 13 GL of water to the environment (Tyers River) as set out in the CGSWS will occur via a reallocation of 13 GL from Gippsland Water's bulk entitlement to a new environmental entitlement once the Hazelwood mine lake has been filled. Although this is likely to be later than 2032 it is consistent with the proposed mechanism for delivering the water.

Attachment No. 1: Extract from Latrobe Valley Regional Rehabilitation Strategy – Latrobe System Water Availability Technical Report May 2020

Table 9 Average annual surface water use by consumptive water users (source: Victorian Water Accounts, e.g. DELWP, 2018)

<table>
<tr><th rowspan="2">Entitlement(1)</th><th rowspan="2">Maximum Annual Entitlement Volume (ML)</th><th colspan="3">Average annual volume (ML/yr) 2006/07 to 2018/19</th><th colspan="3">Drought Year (2006/07) volume (ML/yr)</th></tr>
<tr><th>Diversions</th><th>Return Flows</th><th>Net Diversions</th><th>Diversions</th><th>Return Flows</th><th>Net Diversions</th></tr>
<tr><td>Gippsland Water –Blue Rock(2)</td><td>20,000 (averaged over 3 years)(5)</td><td rowspan="2">51,396</td><td rowspan="2">24,246</td><td rowspan="2">27,150</td><td rowspan="2">50,450</td><td rowspan="2">21,405</td><td rowspan="2">29,045</td></tr>
<tr><td>Gippsland Water – Moondarra Reservoir(2)</td><td>62,000 (averaged over 2 years)</td></tr>
<tr><td>Gippsland Water – Narracan Creek (Moe)</td><td>3,884</td><td>1,901</td><td>0</td><td>1,901</td><td>2,695</td><td>0</td><td>2,695</td></tr>
<tr><td>Yallourn</td><td>36,500</td><td>27,447</td><td>13,142</td><td>14,305</td><td>30,580</td><td>12,293</td><td>18,287</td></tr>
<tr><td>Loy Yang A</td><td>40,000</td><td>21,790</td><td rowspan="2">4,576</td><td rowspan="2">32,020</td><td>24,942</td><td rowspan="2">4,040</td><td rowspan="2">39,554</td></tr>
<tr><td>Loy Yang B</td><td>20,000</td><td>14,806</td><td>18,652</td></tr>
<tr><td>Loy Yang 3/4 Bench</td><td>25,000</td><td>0</td><td>0</td><td>0</td><td>0(4)</td><td>0(4)</td><td>0(4)</td></tr>
<tr><td>Latrobe – Southern Rural</td><td>13,400 (averaged over 2 years)</td><td>6,646</td><td>0</td><td>6,646(3)</td><td>7,399</td><td>0</td><td>7,399(3)</td></tr>
<tr><td>Private diversion licences from unregulated rivers</td><td>18,891</td><td>7,734</td><td>0</td><td>7,734</td><td>14,000</td><td>0</td><td>14,000</td></tr>
<tr><td>Total</td><td>239,675</td><td>131,720</td><td>41,964</td><td>83,110</td><td>148,718</td><td>37,738</td><td>103,581</td></tr>
</table>

Notes to table

1. Excludes unused bulk entitlements for Boolarra, Thorpdale and Noojee, as well as minor volumes available under bulk entitlements for Erica-Rawson and Mirboo North. Excludes diversions from stock and domestic farm dams, which do not require a licence.
2. Water from these Bulk Entitlements includes water that has historically provided for power generation at the Hazelwood Power Station, but also includes supply to other major industrial water users
3. Includes diversions from the return flows from power generators and industry
4. Usage from the Loy Yang 3/4 Bench entitlement that was made available in 2006/07 to other entitlement holders is accounted for in the water use of those other entitlement holders.
5. In 2014, Gippsland Water was allocated a 3.87% inflow and storage share of the previously unallocated share of Blue Rock Reservoir. To correspond with this, its max take was increased from 15,150 ML/year to 20,000 ML/year over 3-year consecutive period.

Flow rate (ML/d)	Days	(2) McArdles Gap	(3) Upper Thomson Midway	(5) Swing Bridge	(6) Flooding Creek	(7) Central Heart Morass Structures	(8) Middle Estuary	(9) Dowd Morass/Eastern Heart Morass Inflows	(10) Parks Victoria Boat Ramp	(11) River Mouth
<250	60	NF	NF	NF	NF	NF	NF	NF	NF	NF
250[1]	3	UF (1m)	NF	NF	NF	NF	NF	NF	NF	NF
250[1]	4	FF	NF	NF	NF	NF	NF	NF	NF	NF
340	30 - 60	FF	NF	NF	NF	NF	NF	NF	NF	NF
430[1]	5	FF	UF (2m)	NF	NF	NF	NF	NF	NF	NF
600	30	FF		NF	NF	NF	NF	NF	NF	NF
930[1]	2	FF	FF	NF	NF	NF	NF	NF	NF	NF
1100	5 -20	FF	FF	UF (2.5m)	UF (2.5m)	NF	NF	NF	NF	NF
1100	30	FF	FF			NF	NF	NF	NF	NF
1500	4	FF	FF	FF		NF	NF	NF	NF	NF
1500	5 - 10	FF	FF	FF	FF	NF	NF	NF	NF	NF
2200	4	FF	FF	FF	FF	UF (2.5m)	NF	NF	NF	NF
2200	5	FF	FF	FF	FF		UF (2.5m)	NF	NF	NF
2900	3	FF	FF	FF	FF	FF	FF	NF	NF	NF
2900	5	FF	FF	FF	FF	FF	FF	UF (2.5m)	NF	NF
3200	4	FF	FF	FF	FF	FF	FF	FF	NF	NF
3900	5	FF	FF	FF	FF	FF	FF	FF	UF (2.5m)	NF
4100	5	FF	FF	FF	FF	FF	FF	FF	FF	NF
4100	6	FF	FF	FF	FF	FF	FF	FF	FF	UF (2m) /FF

Flushing behaviour as reported in Water Technology (2013). NF = Not Flushed; UF = Upper Flushed; FF = Fully Flushed

[1] Flows in Thomson River only. All other flow rates refer to combined flow from Thomson and Latrobe Rivers at Swing Bridge (Water Technology 2013)

Attachment E_Water Balance Modelling and Environmental Flow Compliance report (Alluvium 2025b)

The Latrobe River system: Water balance modelling and Environmental Flow Compliance Report

September 2025

alluvium

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

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for **EnergyAustralia Yallourn** under the contract titled 'Surface water modelling assessment'.

Authors: Ross Hardie, Bill Moulden, Tom Stewart, Ella Guthrie
Review: Stuart Cleven, Bill Moulden
Approved: Ross Hardie

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Cover image: abstract river image, Shutterstock

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Contents

Figures

Tables

1 Introduction

This report has been prepared for EnergyAustralia Yallourn to document the modelling process and results of the water balance modelling and environmental flow compliance assessment undertaken to identify the potential impacts arising from the use of water to fill the Yallourn open cut pit / mine void. The assessment has been based on a proposed design arrangement for the closure and rehabilitation of the Yallourn Open Cut Coal Mine set out in Declared Mine Rehabilitation Plan (EnergyAustralia Yallourn Pty Ltd, June 2025).

The report has been prepared as part of the suite of investigations required to support the preparation of the updated Yallourn Declared Mine Rehabilitation Plan (DMRP).

This report sets out the water balance modelling approach, assumptions and scenarios assessed. The report sets out the 'base case', and 'project case' scenarios, the approach to the assessments and the outcome of those assessments.

2 Background

The Yallourn DMRP requires an assessment of the impacts of the proposed project on waterways and wetlands of the Latrobe River catchment. The waterways and wetlands assessment has been informed by hydrologic (water balance) modelling of the Latrobe River system. The hydrologic modelling has been undertaken using the Latrobe Source model (version ***Latrobe_S5.16.0_M2.7.3_MineRehab***) managed by DEECA.

The modelling and assessment has comprised a single proposed water use arrangement for the site. However, the scale of impact of mine rehabilitation in the Latrobe Valley is also dependent on the timing and form of rehabilitation proposed for the other major mine sites, at Hazelwood (Engie) and Loy Yang (AGL). The assessment has also contemplated the rehabilitation of these sites based on available information.

The investigations for this DMRP has focussed on the fill phase of the proposed rehabilitation planning. It is this phase that has the greatest potential to impact on water resources and dependent values. Further investigations will be required for the post fill phase where other issues such as potential water quality impacts will need to be assessed.

The project proposes the use of water for pit filling from three primary sources:

1. Groundwater: The impact of the proposed project on groundwater has been assessed by others and is not included in this assessment
2. Regulated surface water resources from the Latrobe system (in in particular, Blue Rock Reservoir): Refer Text box 1
3. Flood spills from the Morwell and potentially Latrobe Rivers. It is noted that such use is lies outside the current water allocation framework.

Text box 1: The use of Blue Rock Bulk Water Entitlements (BE's) for mine rehabilitation and implications for this DMRP assessment:

EnergyAustralia Yallourn has a current BE held in Blue Rock Reservoir for power production. No approval has been given to the use of this BE for mine rehabilitation. However, the use of water resources from the Latrobe system has been contemplated in the Latrobe Valley Regional Rehabilitation Strategy (LVRRS) Amendment (2023). The LVRRS Amendment (2023) investigated and documented the conditions on water access that might be applied to avoid negative impacts from the use of water for mine rehabilitation.

This regional water balance and environmental flow compliance assessment undertaken to inform the Yallourn DMRP has not sought to reprosecute the investigations undertaken for and included into the LVRRS Amendment (2023). The modelling included in this DMRP assessment has included the proposed conditions on water access contemplated and assessed in the LVRRS Amendment (2023).

The assessment has focussed on the reaches with potential to be impacted by the project and in particular the spill of water from the Morwell and Latrobe Rivers into the mine void to fill the proposed pit lake. Reaches assessed include the Latrobe River to the Thomson River confluence (including Thoms Bridge and Rosedale monitoring / compliance sites), and the Lower Latrobe River (downstream of the Thomson River confluence) to Lake Wellington.

The water balance modelling has been undertaken for an adopted project base case and project scenarios for alternate climate change projections consistent with Victorian Government guidelines for the assessment of surface water resources.

The assessment has used the results of the water balance modelling for the base case and project scenarios as inputs to an analysis of compliance against environmental flow requirements. The assessment has comprised a review of environmental flow compliance for the base case and alternate project fill scenarios, for the impacted reaches and the alternate climate change projections assessed.

A qualitative assessment of the implications of the change in environmental flow compliance has also been undertaken and set out in this report. In this respect the water balance modelling and environmental flow compliance assessment informs the likelihood of impact. The qualitative impact assessment has been informed by the consequence of any change in environmental flow compliance.

A wider assessment of ecological risk (consequences and likelihood of non-compliance with flow recommendations) should be explored as the project description is further developed.

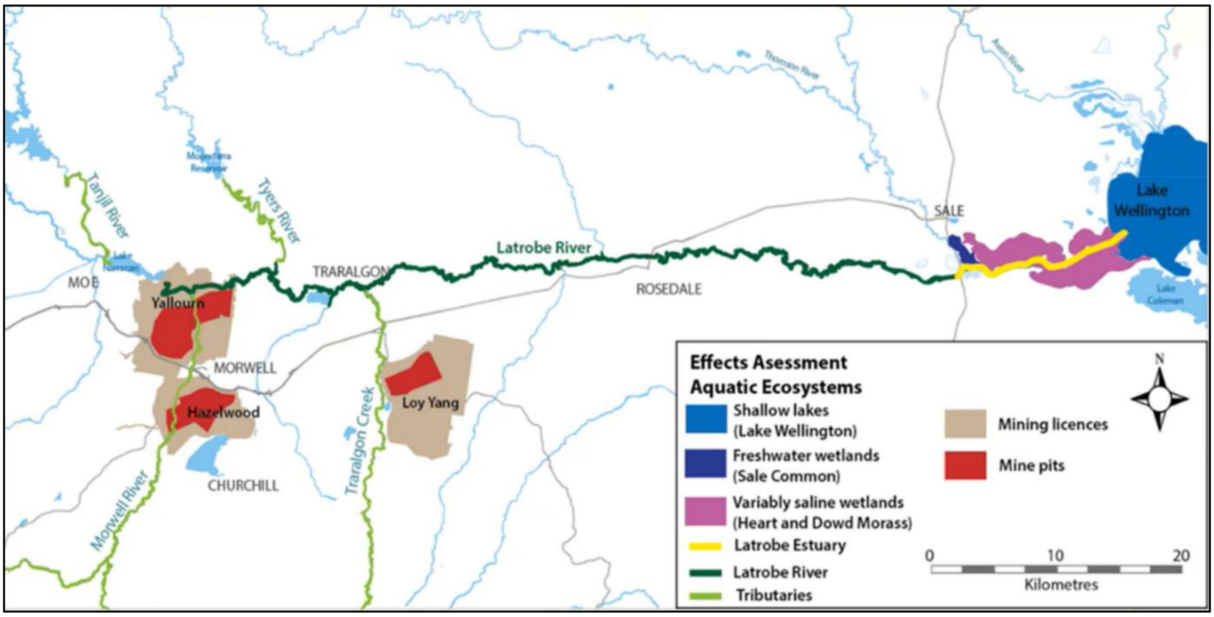

Figure 1. *The Latrobe Valley showing location of rivers and mine sites*

2.1 Latrobe Valley Regional Rehabilitation Strategy (LVRRS) Amendment (2023)

As part of the investigations undertaken for the Latrobe Valley Regional Rehabilitation Strategy (LVRRS) Amendment (2023), a series of future water use scenarios were modelled to understand the environmental flow compliance and potential impacts arising from the use of water for mine rehabilitation. This LVRRS Amendment (2023) modelled the regional water balance under hypothetical future water access scenarios, including bulk entitlement configuration and volume (for power generation), historic use, and seasonal restrictions.

As previously set out in Text box 1, the LVRRS Amendment (2023) contemplated conditions that could be imposed on access to water held in Blue Rock Reservoir for mine rehabilitation. These conditions have been included into the water balance modelling undertaken to inform this assessment for the Yallourn DMRP. The assessment for this DMRP has also included assumptions on water use at Hazelwood for mine site rehabilitation and at the Loy Yang site for ongoing power production and subsequent rehabilitation.

3 Water Balance Modelling

The DEECA managed, Latrobe Source model version ***Latrobe_S5.16.0_M2.7.3_MineRehab*** was adopted for assessing the impact of the mine rehabilitation arrangements on the water resources and environmental flow compliance within the Latrobe Valley region. This model was contemporary at the time of acquisition in July 2024.

Several changes were made to the working model to incorporate future configurations of the water supply systems, offtake infrastructure and use of bulk entitlement volumes under the rehabilitated design scenario. These model updates are described in this section.

The updated model was run for the adopted scenarios to determine the impact of the rehabilitation design on regional water resources. Scenarios were designed and adopted to test project options and alternatives, under different supply scenarios, in line with that set out in the proposed in the Basis of Design report and the conditions described in the LVRRS Amendment (2023). The purpose of the modelling described in this report is to provide information to assess the hydrological impact of the project's use of surface water on the downstream ecosystems of the Latrobe River.

3.1 Model approach

The representation of mine pit lakes in the Source model during the fill phase requires an understanding of pit lake inflows, to both determine time to fill under each supply scenario (to support the broader assessment) and to determine the mine outflows once the pit lake is full and hydrologically connected to the Morwell and Latrobe River systems.

The Source model is a deterministic model, with historic daily timestep inputs running from 1/1/1957 to 30/6/2020 (63 years). Each project scenario is run as a single realisation, where model runs differ between supply configuration, assumptions of demands at other mine sites (Hazelwood and Loy Yang) and climate change scenarios. The assessment approach is set out in Figure 2.

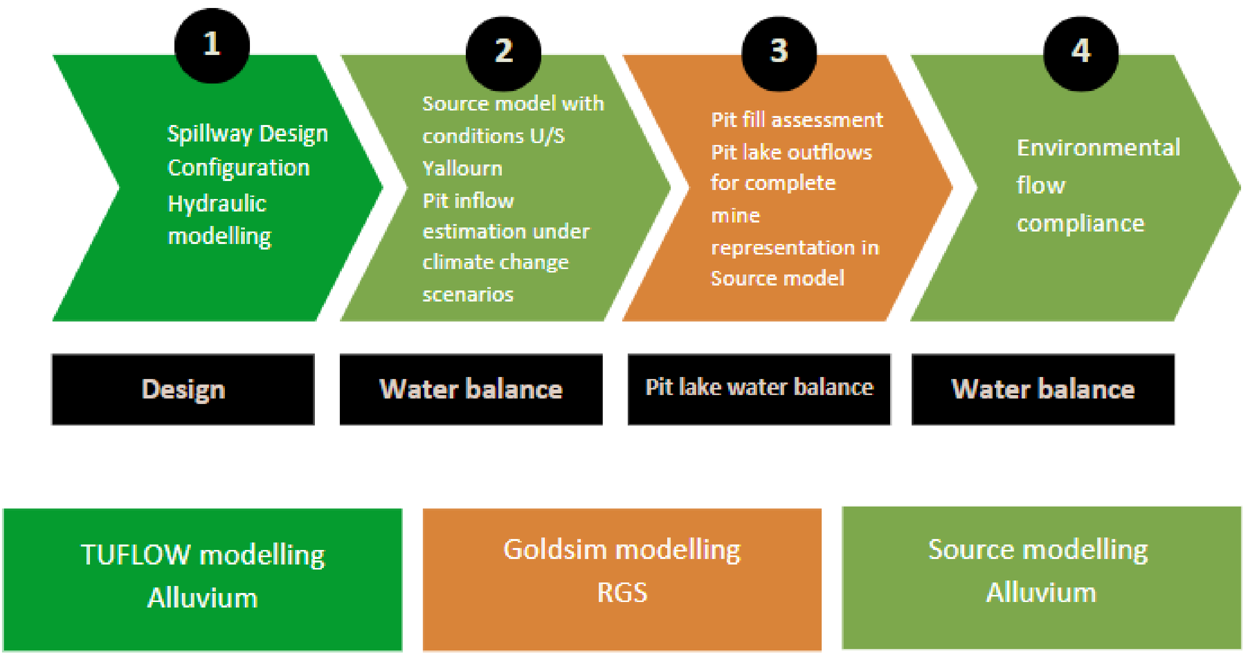

Figure 2. *Modelling approach for the water balance assessment and environmental flow compliance assessment (note: For this assessment of the fill phase, step 4 did not require outputs from the pit lake water balance modelling)*

Model changes were made to represent the final design configuration of the rehabilitated site into the Source model. This approach is shown in Figure 2. These changes include incorporating offtakes (represented as demand nodes) at the mine site to reflect the spillways that divert flood overflows from the Morwell River, and outflow from the pit lake to the Latrobe River at the downstream end to reflect mine pit lake overflows that engage once the mine pit lake is at capacity. The offtakes from the Morwell River are designed to divert overbank flows into the mine pit, and were designed in a first phase of hydraulic modelling using TUFLOW. Flows over the spillways were translated into inflows into the mine pit through a calculated weir equation. These outflows were used as inputs to a Goldsim model as inputs to a GoldSIM pit lake water balance model developed by RGS (RGS, 2025). The GoldSIM model has been used to estimate time to fill the pit, outflows once the pit lake is filled and reaches steady state and water quality outcomes in the pit lake. The pit lake outflows developed through the pit lake water balance modelling have not been used in the assessment of impacts in the fill phase.

As set out above, for the fill phase assessment undertaken for the Yallourn DMRP, it is assumed that there is no outflow from the pit lake. The Source model was modified to only reflect the loss of water from the Morwell and Latrobe Rivers to the pit lake.

For the post fill phase, it is intended that the model be modified to reflect the discharge of water to the pit lake via the proposed Morwell River Diversion spillways and the return of water to the Latrobe River from the pit lake via the lake outlet spillway. This has not been included in the work for this DMRP assessment.

3.2 Project scenarios assessed

A basis of design report was prepared to define the proposed water balance modelling approach, assumptions and scenarios to be adopted for the Yallourn Mine Closure Plan. The report was prepared to assist with the approval of proposed model runs prior to the commencement of modelling and subsequent analysis of results.

The report sets out the proposed 'base case', and 'project case' scenarios to be assessed and optional 'cumulative impacts' scenarios (if and as required). Refer to *The Latrobe River system: Water balance modelling - Basis of design (Alluvium 2024b)*.

The hydrologic model runs are set out in Table 1. The model configurations include alternate arrangements for the Hazelwood site. These alternate arrangements represent alternate potential arrangements for the Hazelwood Rehabilitation Project that are the subject of an Environmental Effects Statement (EES) process. That EES process has not been concluded and as a result two alternate Hazelwood Mine Rehabilitation arrangements have been assessed for this EnergyAustralia Yallourn project.

Further information on the configuration for each model run is shown in Table 2.

3.3 Climate scenarios

Three climate change projections have been modelled and assessed, which have been previously derived as part of the LVRRS and the reference document *Climate Change Projections, Latrobe Valley Regional Rehabilitation Strategy, Method report and user guidance* (Brown, R. 2017):

- Baseline_2065 High CC (Dry condition)
- Baseline_2065 Med CC (Medium condition)
- Baseline_2065 Low CC (Wet condition)

Table 1. Summary of supply scenario conceptualisation under each model run for the water balance assessment

Baseline/ Project	Demand profiles assessed for the fill phase	Yallourn assumptions	Hazelwood assumptions	Purpose of model configuration
Baseline	Baseline filling	Pit lake not connected Water supplied from Blue Rock under LVRRS amendment conditions, No return flows	Pit lake not connected 20 GL / annum supplied from Moondarra Reservoir No return flow	Base case for comparative analysis
Project	Project filling 1	Pit lake connected (flood inflow) Water supplied from Blue Rock under LVRRS amendment conditions No return flows	Pit lake not connected 20 GL / annum supplied from Moondarra Reservoir No return flow	To assess implications of Yallourn project under recent average use at Hazelwood and reflecting a potential Hazelwood mine void fill arrangement
	Project filling 2	Pit lake connected (flood inflow) Water supplied from Blue Rock under LVRRS amendment conditions No return flows	Pit lake Connected 30 GL / annum supplied from Moondarra Reservoir No return flow	To assess the cumulative implications of pit filling at Yallourn at the same time as a fast fill and connected pit lake arrangement at Hazelwood

Table 2. Project case configuration of demand values to run demand profile scenarios

					Assumed annual surface water demand (GL/yr)								
						Yallourn				Loy Yang			
Model Scenario name	Model Run	Model scenario prefix	Morwell Flood Harvesting - Hazelwood Connection		Hazelwood	Base Case	Dry	Med	Wet	Base Case	Dry	Med	Wet
baseline filling	**Unconnected**, water supplied from Blue Rock under LVRRS conditions No return flows	Dry/Med/Wet	Unconnected		20	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)
Project filling 1	**Connected**, water supplied from Blue Rock under LVRRS conditions no return flows	Dry/Med/Wet	Unconnected		20	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)
project filling 2	**Connected**, water supplied from Blue Rock under LVRRS conditions no return flows	Dry/Med/Wet	Connected		30	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	25 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)	35 (LVRRS)

4 Source model overview and modification

For the purposes of this assessment, the Latrobe Source Model (DEECA, 2024) was adopted, and changes were made to reflect the rehabilitation design. The sections below describe the changes that were made to reflect the Latrobe Valley Regional Rehabilitation Strategy conditions, the Central Gippsland Sustainable Water Strategy conditions and mine site node representation in the model. Updates include details of the supply sources and Bulk Entitlement details that were applied to run the final model scenarios described in Section 4.5.

As described in Section 2.1, the determined surface water conditions in the LVRRS were applied to this assessment to determine the resulting impacts of the Mine Rehabilitation scenarios under the specified rules and limits. The assessment has assumed the LVRRS conditions are upheld for the purposes of hydrologic modelling, and results of environmental flow compliance relate to the way in which these conditions were interpreted in the Source modelling. The conditions stipulate annual or seasonal demand limits, and assumptions have been made as to how they are disaggregated to a daily timestep. It is possible that the resulting flow conditions are sensitive to the sub-annual or sub-seasonal release patterns, and this will require further investigation in the next phase of modelling. The way the conditions have been implemented into the modelling in this assessment is described below.

4.1 Latrobe Valley Regional Rehabilitation Strategy (LVRRS) Amendment (2023)

The LVRRS Amendment (2023) outlines the following surface water access conditions as guidance for Latrobe Valley mine rehabilitation planning:

a) a maximum period of surface water access of up to 30 years from the initial supply date at each mine or until 2065, whichever is earlier. This gives the community and stakeholders more certainty about the timing of when rehabilitation may be complete and when water could be returned to support other uses and values in the Latrobe River system.

b) limiting access to water in the Latrobe River system to winter and spring only (June to November), to avoid competition for water when irrigator and commercial water demand is typically high and when the river environment is most flow stressed.

c) a flow threshold to prevent winter-spring baseflow in the Latrobe River below 447 megalitres per day from being diverted for mine rehabilitation. These baseflows are important for flushing sediment out of pools which in-turn supports habitat for aquatic mammals and fish species. These flows also limit the encroachment of terrestrial vegetation, support emergent macrophyte vegetation and maintain dissolved oxygen levels in pools.

d) an annual release limit of 44 gigalitres per year from mine licensees shares of Blue Rock Reservoir to retain more water in storage in dry times, limiting the likelihood of using that water for mine rehabilitation during a series of dry years.

These conditions have a number of implications for the Source modelling, as they relate to changes in system supply configurations from current conditions. The source model has been modified to reflect these changes. These modifications are set out below:

Item a) A maximum period of surface water access of up to 30 years from the initial supply date at each mine or until 2065, whichever is earlier.

This requirement is satisfied in the defined scenarios for filling, as the Yallourn filling phase is expected take 20 years approx. and is scheduled for completion before 2065. No change to the model configuration was made.

Item b) limiting access to water in the Latrobe River system to winter and spring only (June to November).

This guideline has been applied to Yallourn and Loy Yang during both their filling phases. To do this, water uptake from the Latrobe River for Yallourn and Loy Yang has been restricted to only permit access during the winter and spring months only.

Item c) a flow threshold to prevent winter - spring baseflow in the Latrobe River below 447 megalitres per day from being diverted for mine rehabilitation (this is measured at a new compliance point at Willow Grove on the Latrobe River).

To meet this guideline, an 'if-clause' is applied to check the water level downstream of the "Latrobe R @ Willow Grove" gauge. If the water flow exceeds 447 ML/d, then water uptake for Yallourn and Loy Yang can proceed.

Item d) an annual release limit of 44 gigalitres per year from mine licensees shares of Blue Rock Reservoir to retain more water in storage in dry times, limiting the likelihood of using that water for mine rehabilitation during a series of dry years.

To achieve this, a 'Maximum Order Constraint node' was added between the Blue Rock Lake node and the water supply points for Loy Yang A & B, and Yallourn offtakes. This allowed the cumulative order of the Loy Yang and Yallourn to be restricted to an annual limit of 44 GL/year for applicable scenarios using the LVRRS Constraint Node (Figure 3).

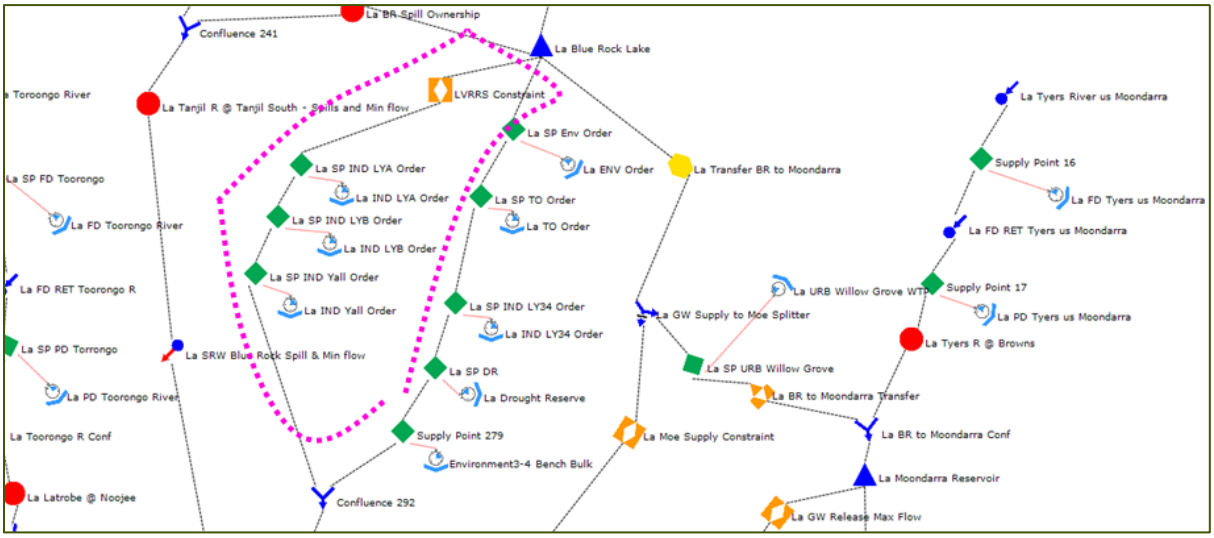

Figure 3. *Addition of the LVRRS Constraint upstream of Loy Yang A & B, and Yallourn supply point offtakes.*

4.2 Central and Gippsland Sustainable Water Strategy

Four specific policy initiatives were identified from a review of the Central and Gippsland Sustainable Water Strategy that have an impact on the Source Latrobe Water Balance Model. The policies and their implications for Yallourn Mine rehabilitation surface water modelling are Action 4-8, Policy 8-12 and Policy 8-13. Listed below are the actions and policies, and implications for the Source modelling.

Action 4-8: Reallocation of the Latrobe 3 – 4 Bench bulk entitlement (25 GL) by 2024

16 GL of formerly unused entitlement is to be allocated to existing water users (refer Policies 8-12 and 8-13).

Policy 8-12: Return water to the Durt-Yowan (Latrobe River) in the short term by 2027

Modification of the Latrobe Source Model to include 7.3 GL of additional environmental water entitlement for all model configurations, sourced from the 3-4 Bench bulk entitlement.

Policy 8-13: Return water to the Durt-Yowan (Latrobe River) by 2029

Modification of the Latrobe Source Model to include 7.7 GL of additional environmental water entitlement for all model configurations. Water is assumed to be sourced from the 3 - 4 Bench bulk entitlement (i.e. 0.4GL over that returned under policy 8-12).

To incorporate these policies into the Latrobe Source model, a new water user node, named "Environment 3-4 Bench Bulk", was added downstream of the 'Blue Rock Lake' storage, as shown in Figure 4 below. The demand model for this water user is set at 41.1 ML/day, which equates to 15 GL/year. This is based on the combination of Policy 8-12 and Policy 8-13 (7.3 GL of additional environmental water for Policy 8-12 and 7.7 GL for Policy 8-13).

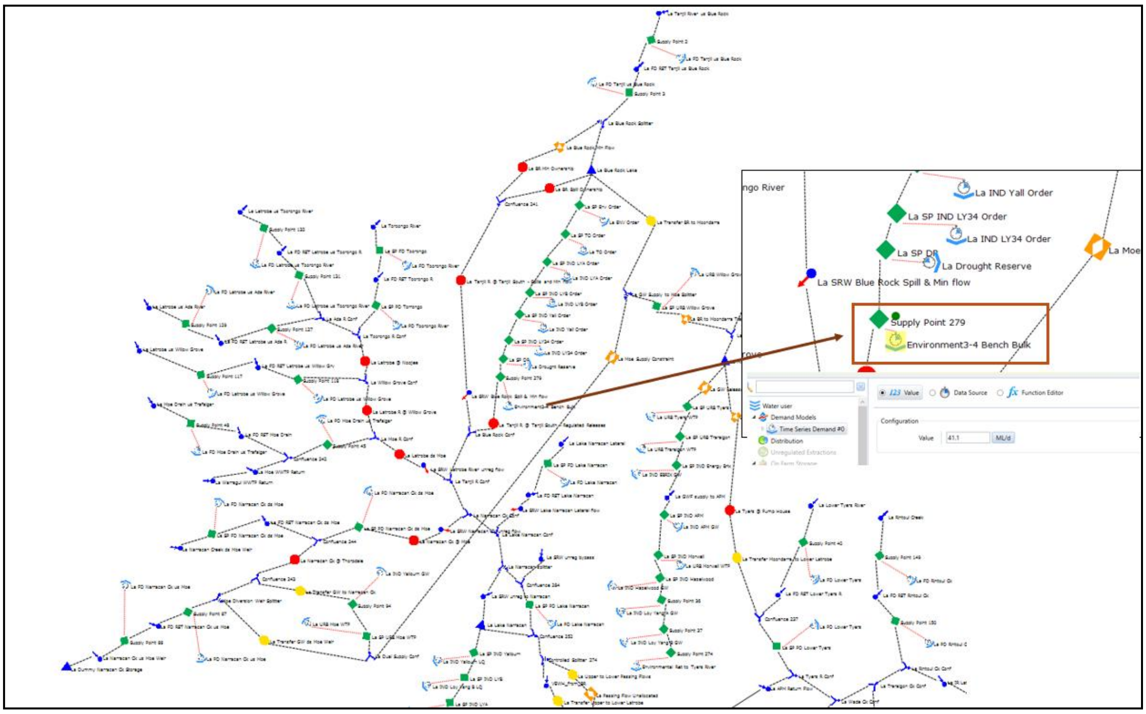

Figure 4. *New water user node, named "Environment 3-4 Bench Bulk".*

Policy 8-15: Return water to the Tyers River by 2032

For the purpose of this assessment, it is assumed that the return of 13 GL of water to the environment (Tyers River) as set out in the CGSWS will occur via a reallocation of 13 GL from Gippsland Water's bulk entitlement to a new environmental entitlement once the Hazelwood mine lake has been filled. Although this is likely to be later than 2032 it is consistent with the proposed mechanism for delivering the water.

To implement this policy in the Latrobe Source model, a new water user node, named "Environmental Ret to Tyers River", was added downstream of the 'Moondarra Reservoir' storage, as shown in Figure 5 below. The demand model for this water user is set at 35.62 ML/day, which equates to 13 GL/year, in accordance with Policy 8-15.

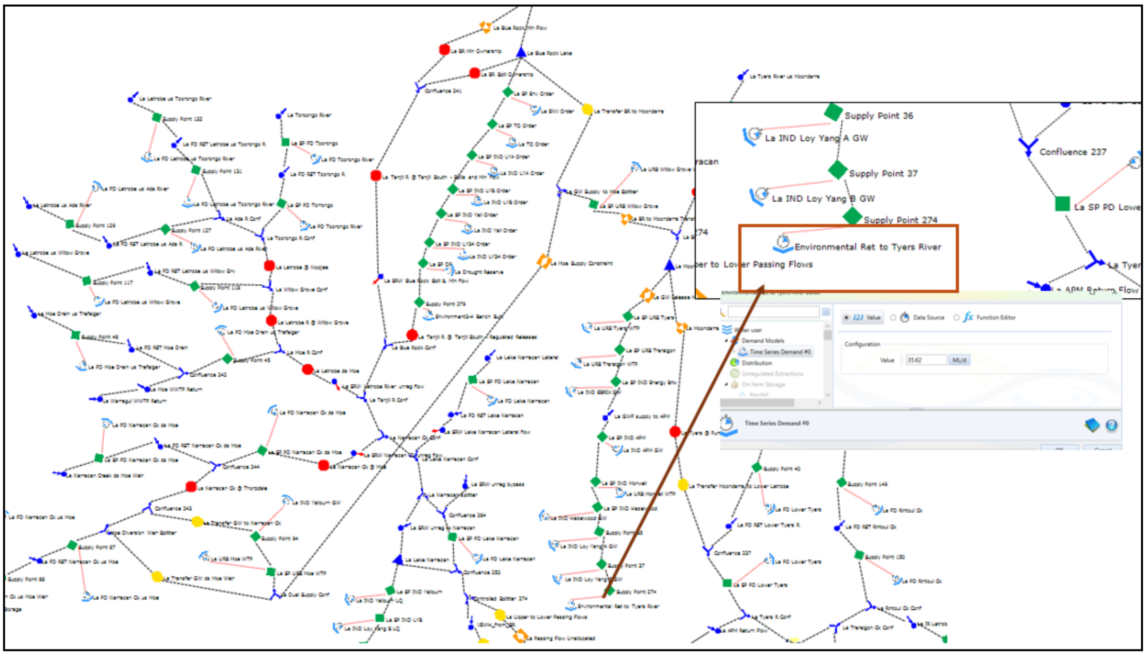

Figure 5. *Supply point and water user nodes on the Moondarra Reservoir.*

To represent annual full demand volume from the Gippsland Water Bulk Entitlement from the Moondarra reservoir, additional supply and demand nodes (Supply Point: Full_Demand, Water User: Moondarra Full Demand) were added (Figure 6). These nodes were activated for the full demand scenarios, where the demand on the bulk entitlement was set to either an annual maximum demand of 49 GL or 62 GL annually, to correspond with the maximum Bulk Entitlement volume in the Gippsland Water Bulk Entitlement stored in Moondara for each scenario. The full demand volumes (i.e. 49 or 62 GL annual demand) were distributed in a scaled monthly pattern from water users extracting from the Moondarra Reservoir.

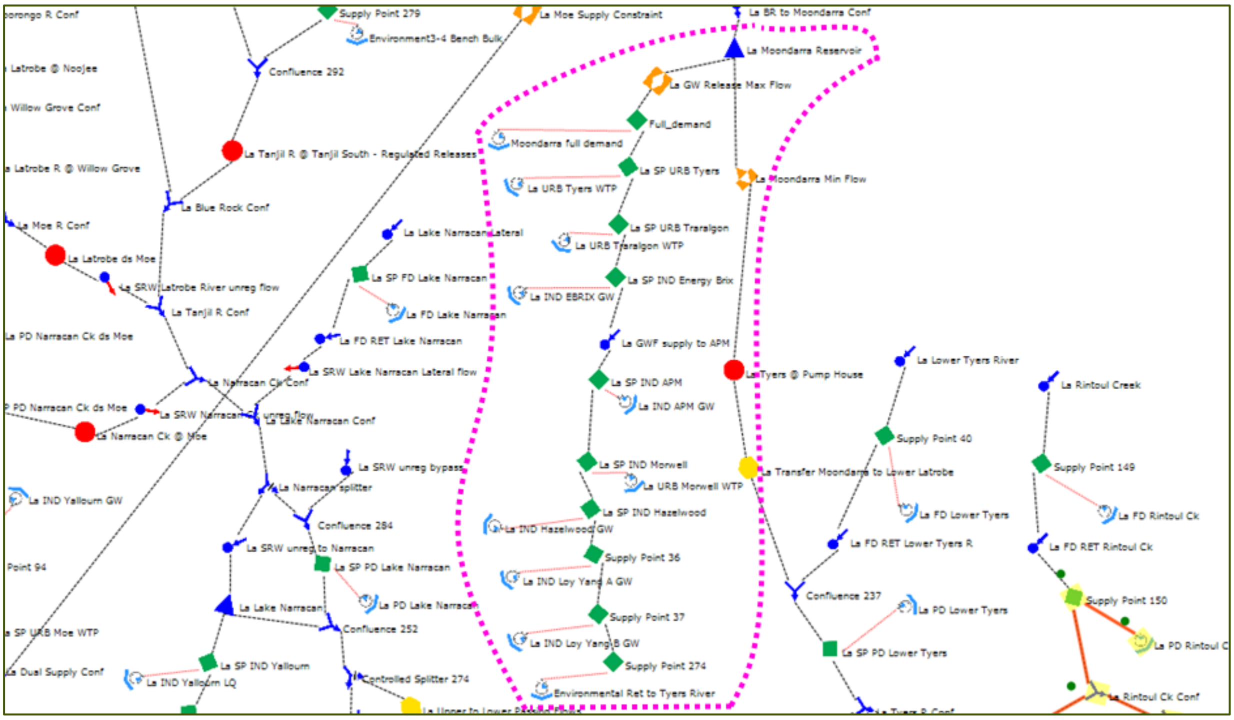

Figure 6. *Additional supply and demand nodes (Supply Point: Full_Demand, Water User: Moondarra Full Demand) were added.*

4.3 Mine node representation in the model

Hazelwood and Yallourn mines are located on the lower reach of the Morwell River, which snakes around the western section of the Hazelwood site before channelling between east and west pits of the Yallourn site and terminating at the confluence of the Latrobe River at the northern edge of the Yallourn mine site. The Latrobe River receives inflows from the Tanjil River, Morwell River, Tyres River and Traralgon Creek. Loy Yang mine is located against the eastern bank of the lower Traralgon Creek (Figure 7).

This Source model contains contemporary details of the entire Latrobe Valley water supply system with mine sites as operational. The model includes details such as mining demands for full scale energy production, Bulk Entitlements, ownership, regulation rules, minimum flow requirements and storage releases and transfers. Updates have been made to the model to represent the mine site configuration at closure, including the supply requirements and usage of Bulk Entitlements and LVRRS conditions.

In order to represent the future conditions for mine site rehabilitation in the Source model, relevant nodes associated with the three mine sites have been identified, as well as any new nodes that need to be added to prepare the model for project runs. Figure 7. *Map of the Latrobe Valley mine sites with showing representative Source model nodes*

below highlights all relevant nodes related to the three mines in the Source model.

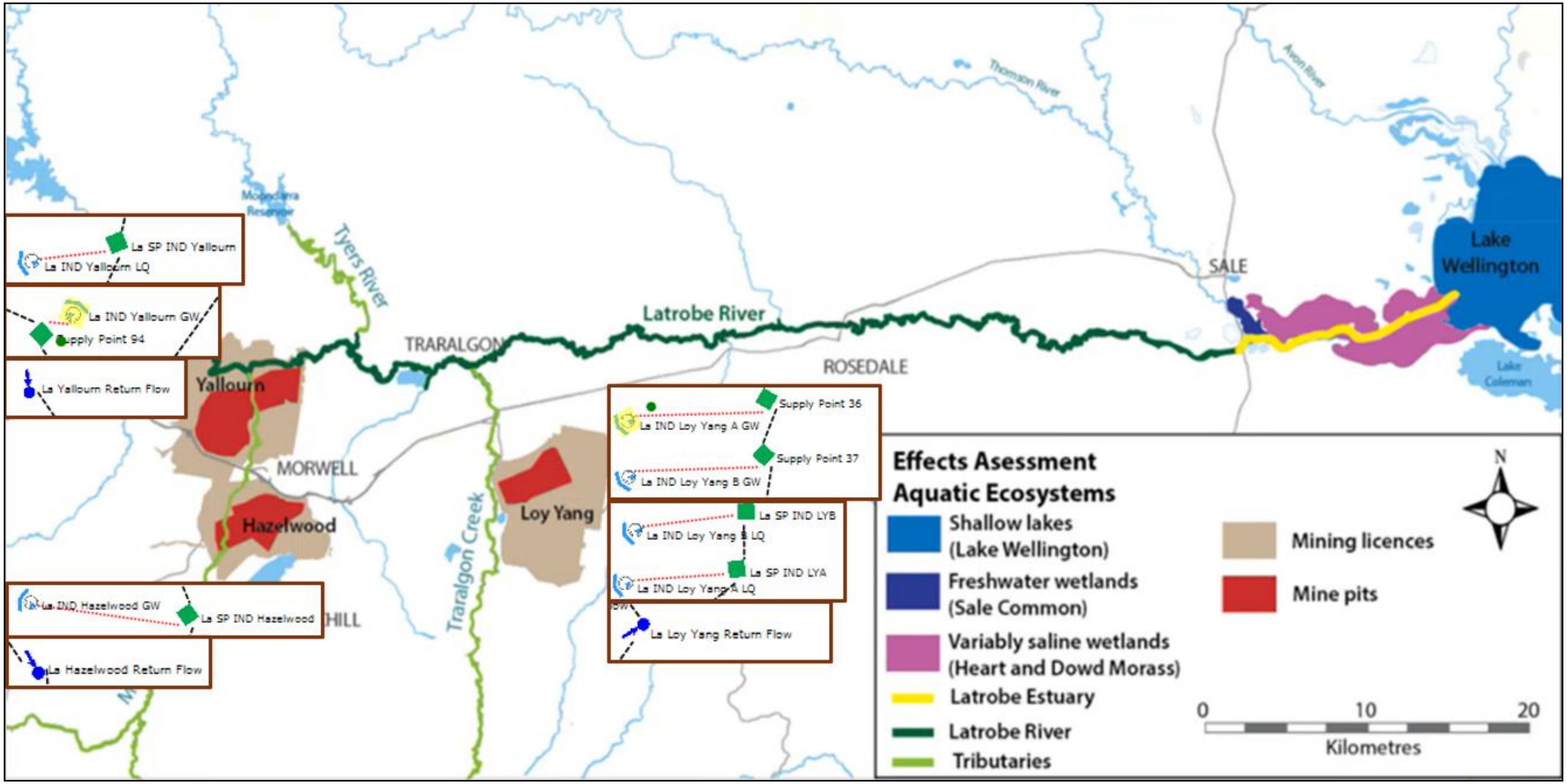

Figure 7. *Map of the Latrobe Valley mine sites with showing representative Source model nodes*

The mines are represented in the model as demands and inflows, where flow into the pit is drawn from the model through supply point demands, and the return flows from the pit back into the system are represented as inflow nodes. Table 3 describes the existing mine site representation in the Source model, including the additional nodes that were added to represent flow over the spillways to capture overbank flows from the Morwell River.

Table 3. Source model mine site node representation and details

Node Name	Node type in Source model	Description
LA IND Hazelwood GW	Water User	High quality raw water supply to Hazelwood power station from Gippsland Water's Moondarra Reservoir
LA Hazelwood Return Flow	Inflow	Gippsland Water Bulk Entitlement Return flow
LA IND Yallourn GW	Water User	(Treated) supply to the Yallourn power station from Gippsland Water's Moe WTP
LA IND Yallourn LQ	Water User	Supply to the Yallourn power station from the Latrobe River at Yallourn Weir
LA Yallourn Return Flow	Inflow	Gippsland Water Bulk Entitlement Return flow
LA IND Loy Yang A GW	Water User	(High quality) supply to the Loy Yang A power station from Gippsland Water's Moondarra Reservoir
LA IND Loy Yang B GW	Water User	(High quality) supply to the Loy Yang B power station from Gippsland Water's Moondarra Reservoir
LA IND Loy Yang A LQ	Water User	Supply to the Loy Yang A power station from the Latrobe River at Yallourn Weir
LA IND Loy Yang B LQ	Water User	Supply to the Loy Yang B power station from the Latrobe River at Yallourn Weir
LA Loy Yang Return Flow	Inflow	Gippsland Water Bulk Entitlement Return flow
Nodes that have been added to represent the rehabilitated mine site configuration		
Yallourn Spill1	Water User	Supply of overbank flow spills into the mine pit lake from the Morwell River over spillway 1
Yallourn Spill2and3	Water User	Supply of overbank flow spills into the mine pit lake from the Morwell River over spillway 2 and 3 (combined). Note, these spillways designed to divert backwater from the Latrobe during peak events, so for the purposes of Source modelling, have been added to the Latrobe branch upstream of the spillway 4 inflow
Yallourn Spill4	Inflow	Yallourn pit lake outflows (as modelled in Goldsim) to represent flows out of the pit lake into the Latrobe River once the pit is filled

4.4 Mine site closure configuration

To represent the final site configuration of the rehabilitated mines, the Source model was modified to represent both inflows to and outflows from the pit lake. Under existing conditions, water is delivered to the mine site under the current Bulk Entitlement through the demand nodes described in Table 3.

However, in the rehabilitated site design, inflows are also delivered to the proposed Yallourn pit lake through a series of spillways, designed to divert overbank peak flows from the Morwell River. The site design consists of 3 spillways along the Morwell River upstream of the Latrobe River confluence. These spillways have been designed to divert flow from the Morwell River to the pit lake when flows in the Morwell River exceed the following Morwell River rates:

- Spillway 1: Commence to flow at 6,048 ML/d
- Spillway 2: Commence to flow at 11,664 ML/d
- Spillway 3: Commence to flow at 19,008 ML/d

These spillway elevations have been set at an elevation high enough to limit impacts to environmental water requirements, but low enough to reduce flood event water level in the Morwell River Diversion (MRD) to assist the structural integrity of the MRD.

There is a fourth spillway out falling from Eastfield Pit to the Latrobe River, which is designed to return pit lake outflows to the system. The three inlet spillways are represented as additional demand nodes, which are configured with calculated spillway flows that are computed using weir equations that take dimensions of spillways that have been conceived with the aid of the hydraulic modelling.

These calculations have considered the potential for flow from both the Morwell River and the Latrobe River to the pit lakes via spillways 2 and 3 (no Latrobe input through spillway 1). In order to capture this flow sequence in the Source model, the spillways 2 and 3 have been configured downstream of the confluence of the Morwell and Latrobe Rivers (Figure 8). The three inflow spillways are represented in the Source model through two demand nodes, the first representing spillway 1, located on the Morwell River directly upstream of the Latrobe River confluence. The second and third spillways are represented by a single demand node downstream of the Latrobe River confluence (to account for any flows over these spillways from the Latrobe River). The nodes that represent the three inflow spillways are recorded during model runs for the purpose of conducting the pit lake water balance (completed by RGS).

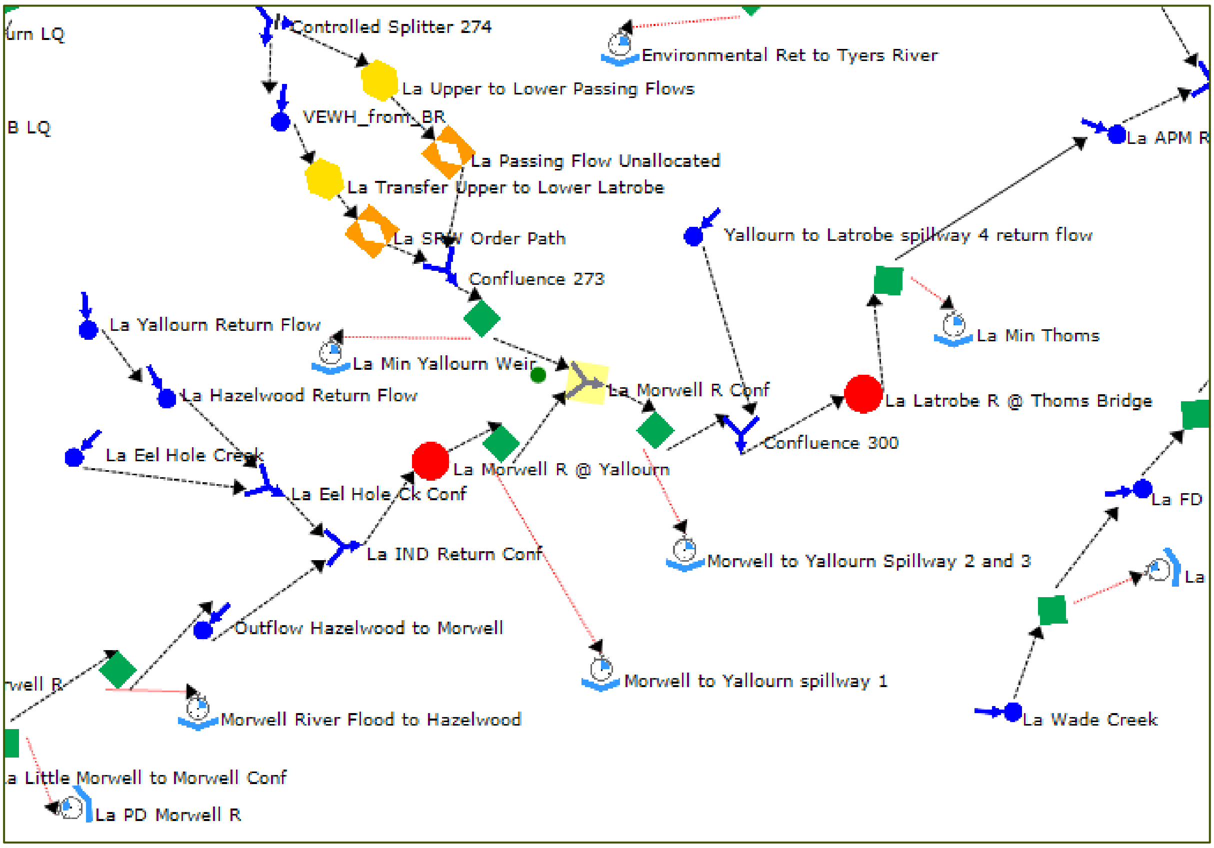

Figure 8. *Source model configuration to represent the spillway configuration to and from the mine pits*

RGS have assessed pit lake water balance using a Goldsim model, which takes the spillway pit inflows (over spillways 1, 2 and 3) as an input. These provided the Source modelled pit lake inflows (from these nodes) for input into their Goldsim lake water balance model. Outflows from the lake water balance can be taken from the Goldsim modelling for different climate scenarios and can be configured (imported) into the Source model to represent flow over spillway 4 out of the Eastfield pit lake into Latrobe River. The fourth spillway has been included into the model and is represented as an inflow node connecting calculated flows into the Latrobe River above the gauge La Latrobe R @ Thoms Bridge. This node has not been used for the modelling undertaken for the Yallourn DMRP.

4.5 Scenario input sets

Scenario Input Sets were configured to run the Source model under each scenario. Changes between scenarios were made through the scenario input sets to adjust the configuration of each demand and for each of the following climate changes scenarios:

- Baseline_2065 High CC (Dry condition)
- Baseline_2065 Med CC (Medium condition)
- Baseline_2065 Low CC (Wet condition)

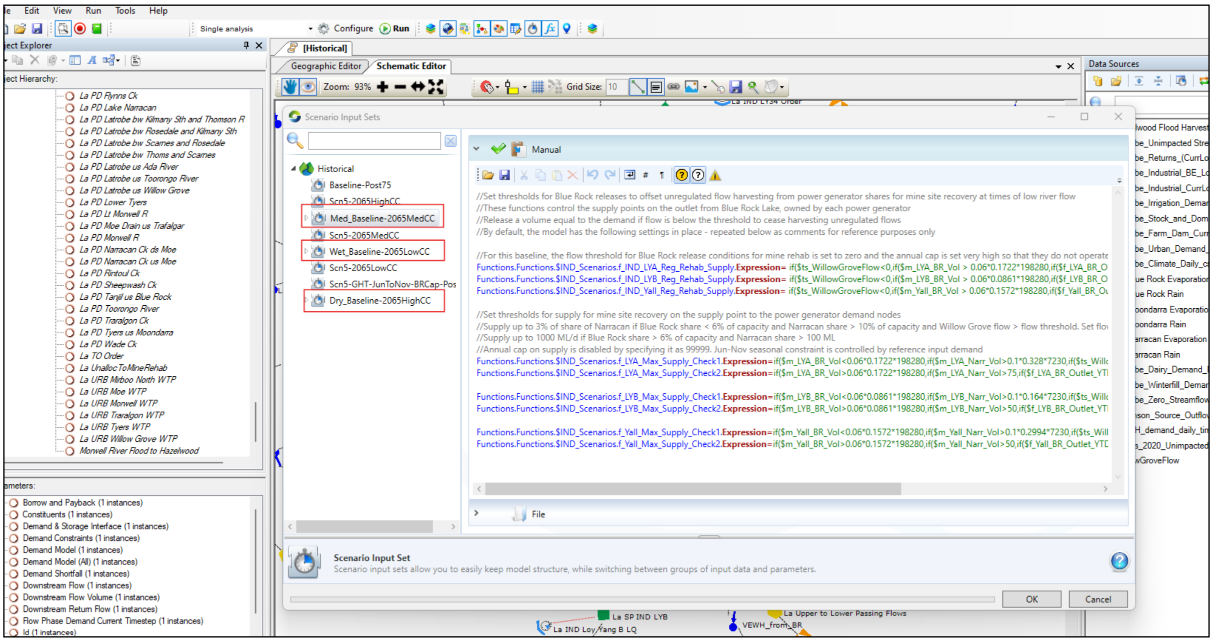

Figure 9. *Screen capture of the Source model showing Scenario Input sets*

4.6 Output locations

A number of environmental flow compliance points are measured in the Latrobe to determine the impact of the modelled scenarios on the environmental flow conditions in the Latrobe River system. The streamflow data required for this project are the flow measurements immediately downstream of the following gauges/ compliance points:

- La Tyers R @ Browns
- La Latrobe R @ Willow Grove
- La Narracan Ck @ Thorpdale
- La Narracan Ck @ Moe
- La Latrobe R @ Thoms Bridge
- La Traralgon Ck @ Traralgon
- La Little Morwell R @ Boolara

- La Morwell R @ Yallourn
- La Latrobe R @ Scarnes Bridge
- La Latrobe R @ Swing Bridge
- La Latrobe R @ Rosedale
- La Latrobe R @ Kilmany South
- La Tyers @ Pump House

For the hydraulic modelling of the Yallourn pit related to flood harvesting from the Morwell River, the flow upstream of Yallourn was also extracted. This flow indicates the amount of water in the Morwell River downstream of the Hazelwood pit (after flood harvesting for Hazelwood) and directly upstream of Yallourn.

5 Hydrologic modelling results

The updates that were made to the Source model to represent the Yallourn, Hazelwood and Loy Yang mines under closure and rehabilitation conditions resulted in the determination of hydrologic impact of each scenario.

Flow statistics were derived from modelled daily flows for each climate case and scenario at four reference locations. As expected, the climate cases produced distinct outcomes, with the Dry case yielding lower daily flow volumes compared to the Medium and Wet cases. Assessment of scenario differences showed limited variation in the modelled median and minimum daily flows. However, notable differences were observed for the maximum and average flows under the Project Fill 2 scenario across all climate cases, Table 4. This difference between scenarios (Project Fill 1 and Project Fill 2) could be a result of the change in Hazelwood demand assumptions (30 GL/day demand from the Moondarra supply) and pit lake connectivity. The changes in Hazelwood operations shows that there is an impact on the higher flows beyond that of the impact of Yallourn.

A comparison of the project fill scenarios against the baseline for each climate case (as shown in Figure 10) shows that proposed project has been identified to have no impact on base flows or freshes in the Latrobe River system.

Table 4. Statistics for average, median, maximum, and minimum daily flows at four reference locations.

	Morwell River at Yallourn				Latrobe River at Thoms Bridge				Latrobe River at Rosedale				Latrobe River at Swing Bridge			
Flows ML/day	Avg	Med	Max	Min	Avg	Med	Max	Min	Avg	Med	Max	Min	Avg	Med	Max	Min
Dry_Baseline	336	102	14259	0.3	990	511	22395	122	1284	699	23999	171	2466	1077	69383	248
Dry_Project_Fill_1	336	102	14259	0.3	943	512	17570	122	1285	700	23999	171	2467	1077	69416	248
Dry_Project_Fill_2	295	102	9894	0.3	943	508	17462	119	1261	673	23854	170	2442	1051	69204	249
Med_Baseline	493	156	20387	3.7	1521	755	37959	222	1913	1030	36338	255	3586	1552	99191	365
Med_Project_Fill_1	493	156	20387	3.7	1409	755	26553	222	1891	1030	33921	255	3588	1552	99191	365
Med_Project_Fill_2	448	156	15220	3.7	1421	753	27469	224	1865	998	33653	254	3561	1520	98760	365
Wet_Baseline	595	191	24375	9.1	1851	926	45399	271	2328	1251	43415	315	4326	1877	118257	455
Wet_Project_Fill_1	595	191	24375	9.1	1727	926	32427	271	2303	1251	40458	315	4330	1877	118257	455
Wet_Project_Fill_2	538	191	17873	9.1	1740	925	33196	271	2277	1221	40106	315	4303	1845	117985	455

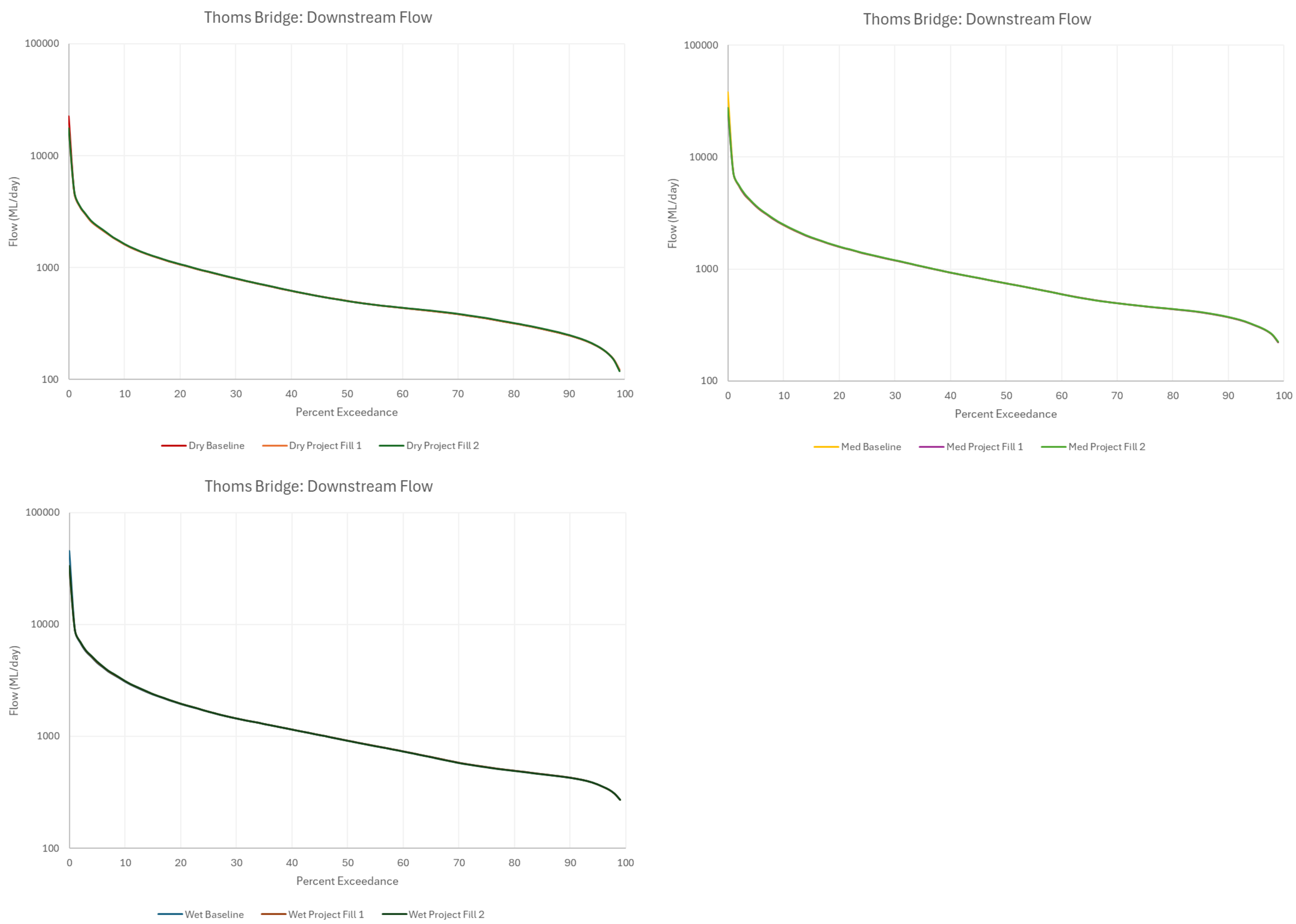

Figure 10. *Comparison of the project fill scenarios against the baseline for each climate case*

6 Environmental flow compliance assessment

6.1 Approach

An environmental flow compliance assessment has been undertaken using outputs from the Source modelling. The compliance assessment has comprised a review of the hydrologic model results against environmental flow recommendations for the river reaches downstream of the project site. The timeseries of daily flow generated by the Source model have been run through eFlow predictor software (eWater 2017), using the flow recommendations from the 2020 FLOWS study for the Latrobe River system (Alluvium 2020). Compliance with flow recommendations were calculated for reaches of interest for each project scenario. The reaches of interest are:

- Tanjil River
- Morwell River at Yallourn
- Middle Latrobe River between the Morwell and Tyers Rivers confluences (Thoms Bridge)
- Lower Latrobe River downstream of the Tyers River confluence (Rosedale)
- Latrobe River estuary (Swing Bridge)

Results for the Latrobe River reaches under the medium climate change projection are set out in Table 5, Table 6, and Table 7. The result for all reaches and all climate projections assessed have been included as an attachment to this report.

The environmental flow recommendations for the subject reaches are set out in the tables. The metrics adopted for the compliance assessment comprise:

- Baseflow: Percent (%) of days that the flow target is exceeded per season, results are averaged over the period of modelling.
- Freshes: Percent (%) achievement of the target number of events occurring per season. Annual results are averaged across the period of modelling.
- Annual events: Percent (%) of years that (bankfull and overbank) events occur.

The compliance with flow recommendations have been assessed over the entire 63-year modelled period.

Note: The percentage compliance with flow recommendations is almost always less than 100%, even in unimpacted catchments with no dams or water extraction because:

- Some recommendations, such as overbank flows are not required every year for the ecosystem to be healthy
- There will naturally be dry years where flow is less, and ecological values are impacted.

The implications of the Project case 2 (Hazelwood fast fill and connected pit lake) have been discussed where these have a cumulative effect over any changes identified under the Project case 1. Impacts associated with Project Case 2 in the absence of an impact under Project Case 1 are not related to the Yallourn rehabilitation project and have not been described, assessed and discussed.

6.2 Reach Results

Tanjil River: The impact of the project scenarios on environmental flow compliance in the Tanjil River is insignificant as the project cases are identical to the base case in terms of flow regimes in the Tanjil River. No further discussion is provided on the implications for the Tanjil River.

Morwell River: The impact on environmental flow compliance in the Morwell River is insignificant as the Hazelwood offtake (u/s of the compliance point) is set at flow rate above the environmental flow recommendations for the Morwell River. The Yallourn spillways are located downstream of the compliance point on the Morwell River (Morwell River at Yallourn) and above the recommended environmental flow rates. No further discussion is provided on the implications of compliance assessment for the Morwell River.

Latrobe River at Thoms Bridge (refer Table 5): The hydrologic impact of the project is greatest in the middle Latrobe River, measured at Thoms Bridge. This compliance point is immediately downstream of the confluence with the Morwell River and is located upstream of other tributary inputs such as the Tyers River.

At Thoms Bridge, the impact of the project scenario on compliance with baseflow and fresh recommendations is minimal (Table 5). This is not surprising as the spill of water to the Yallourn pit lake occurs at flow rates above the base flow and fresh recommendations for the Latrobe River at Thoms Bridge.

However, the impact of diverting flood spills to the Yallourn pit lake, on bankfull and overbank flows may be material. The project can be expected to reduce the occurrence of bankfull events at Thoms Bridge from 27% of years to 25% of years. The cumulative impacts of flood spills into the Yallourn and Hazelwood pits reduces the occurrence of overbank events to 22% of years over the approx. 6 to 12 years where the fill phase of the Hazelwood pit lake might overlap with a fill phase for Yallourn. Rather than receiving approximately 5.4 events over a 20 year Yallourn fill period, the modelling reveals 4.7 events over the fill phase. The implication of this reduction in occurrence of bankfull events is discussed in section 7 of this report.

The impact on overbank flows is also material with the project reducing the occurrence of overbank events from 13% of years to 11% of years. Again the connection of the Morwell River at Hazelwood has a cumulative impact reducing the occurrence of overbank events at Thoms Bridge to 9% of years. Rather than receiving 2.6 overbank events in the fill phase, the Thoms Bridge site could be expected to receive 2 overbank events in a 20 year fill period. The implication of this reduction in overbank events is discussed in section 7 of this report.

Latrobe River at Rosedale (refer Table 6): The impact of spilling high flow events into the mine void diminishes downstream at Rosedale as a result of flood inputs from tributary streams (Table 6). The project is not expected to have a material impact on the Latrobe River at Rosedale under a medium climate change projection.

Latrobe River at Swing Bridge (refer Table 7): This reach of river comprises the lower Latrobe Estuary. The modelling has revealed the project to not have any material impact on baseflows, freshes or bankfull events i.e. the events needed to flush salt from the adjoining Sale Common, Heart Morass and Dowd Morass wetland regulating structures. As such the project is not expected to have an impact on the watering of the adjoining wetlands. However, the project has the potential to reduce the occurrence of overbank events from 50% of years to 48% of years. The implication of this change is discussed in Section 6.3. The Hazelwood rehabilitation project does not create a cumulative impact on these overbank events.

Table 5. Environmental flow compliance (%) for the Latrobe River at Thoms Bridge during the filling phase (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 440 ML/d baseflow	65	65	65
summer & autumn 980 ML/d fresh	82	82	81*
winter & spring 1500 ML/d baseflow	37	37	37
winter & spring 6000 ML/d fresh	42	42	43*
annual 10000 ML/d bankfull	27	25	22
annual 15000 ML/d overbank	13	11	9

*Note: As noted in Section 4.4 flows of at least 6058 ML/d are bypassed through the MRD with no diversion, thus results for Project Case 2 are expected to be an impact associated with Hazelwood works. We acknowledge the inconsistency in results, possibly a rounding issue, which is to be further explored. This is not expected too fundamentally change the outcomes of this assessment for Yallourn.

Table 6. Environmental flow compliance (%) for the Latrobe River at Rosedale during the filling phase (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 380 ML/d baseflow	89	89	89
summer & autumn 1400 ML/d fresh	55	55	52
winter & spring 1800 ML/d baseflow	45	45	44
winter & spring 3000 ML/d fresh	83	83	81
annual 8000 ML/d bankfull	56	56	56
annual 10000 ML/d overbank	36	36	36*

*Note: We acknowledge the inconsistency in results between Latrobe River at Thoms Bridge and Latrobe River at the Rosedale, which is to be rectified as part of future scenario testing. This is not expected too fundamentally change the outcomes of this assessment.

Table 7. Environmental flow compliance (%) for the Latrobe River at the Swing Bridge (medium CC)

Flow recommendation	Baseline	Project case 1	Project case 2
summer & autumn 1100 ML/d baseflow	41	41	39
summer & autumn 2200 ML/d fresh	24	24	23
summer & autumn 3200 ML/d fresh	27	27	27
winter & spring 1100 ML/d baseflow	90	90	89
winter & spring 3200 ML/d fresh	47	47	46
winter & spring 4500 ML/d fresh	35	35	35
annual 9500 ML/d bankfull	51	51	50*
annual 14000 ML/d overbank	50	48	48

*Note: We acknowledge the inconsistency in results between Latrobe River at Rosedale and Latrobe River at the Swing Bridge, which is to be rectified as part of future scenario testing. This is not expected too fundamentally change the outcomes of this assessment.

6.3 Alternate climate change scenarios assessed

The proposed project arrangements have also been assessed for alternate climate change projections.

Dry climate projection: The dry climate change project resulted in

- Thoms bridge: A reduction in the occurrence of bankfull events from 6% of years to 5% of years. Under a dry climate change scenario there are no changes to the occurrence of overbank events, base flows or freshes.
- Rosedale: Reduced occurrence of overbank events at Rosedale. The occurrence of overbank events reduces from 12.5% of years to 11% of years. The project has no impact on other environmental flow requirements at Rosedale
- Swing Bridge: The project has no impact on the environmental flow requirements at the Swing Bridge

Wet climate projection: The wet climate change project resulted in:

- Thoms bridge: A reduction in the occurrence of bankfull events from 47% of years to 45% of years and a reduction in the occurrence of overbank events from 23% of years to 19% of years.
- Rosedale: The project has no impact on environmental compliance in wet years at Rosedale
- Swing Bridge: The project has no impact on the environmental flow compliance in wet years at the Swing Bridge

7 Implications of changes to environmental flow compliance

The proposed project has been identified to have no impact on base flows or freshes in the Latrobe River system. These events are required for essential instream habitat, the maintenance of water quality and the provision of triggers for fish movement. This outcome is not surprising as the flow rates at which the proposed spillways at the Yallourn mine site, were set are above that required for these environmental flow requirements.

Similarly, the modelling has revealed the project to not have an impact on the base flow and freshes required for the Latrobe estuary. These flow rates are required not only for the Latrobe River estuary but to remove salt water from the estuary in the vicinity of the regulating structures used to water the Ramsar listed fringing wetlands, Sale Common, Heart Morass and Dowd Morass. As such the project is not expected to have an impact on the watering of the subject wetlands.

However, the project has been identified as having the potential to impact on the occurrence of bankfull and overbank events. These events are required for the watering of floodplain vegetation, to maintain channel form and to limit terrestrial vegetation encroachment into the channel. The project is expected to reduce the occurrence of these events. These changes are most notable at Thoms Bridge where reductions in the occurrence of events were identified for bankfull in all climate change projections assessed and overbank events for the medium and wet climate projections. Impacts on overbank events were also identified for Rosedale under a dry climate projection and the Swing Bridge for the medium climate change projection. While reductions in the occurrence of bankfull and overbanks have been identified to occur, the investigation has revealed that the project will result in only a small change to the occurrence of events over the 20 year (approx.) duration of the fill phase. As an example, the expected reduction in the occurrence of overbank events at Thoms Bridge from approximately 5.4 events to 4.7 events over the duration of the fill phase is not expected to have a material impact on the vegetation community or channel form over this period. Further testing of this implication will be required.

8 Conclusions

A preliminary spillway design arrangement has been developed and assessed for the site based on the Partially Connected Morwell option and its potential to meet key hydrologic, geomorphic and ecological criteria outlined in *The Latrobe River system: A context statement for EnergyAustralia Yallourn to inform the rehabilitation of the Yallourn Open Cut mine (Alluvium 2024)*.

Regional water balance modelling was undertaken using the Latrobe Source model to identify the flow regimes under the proposed arrangements for the fill phase at Yallourn and with consideration for arrangements at both Hazelwood and Loy Yang. The implications of the proposed arrangements on environmental flow and waterways and wetlands have been investigated via a review of compliance with environmental water recommendations for the Latrobe River system.

The investigations for this DMRP have focussed on the fill phase where there is the greatest potential for impact on water resources and environmental water requirements

8.1 Findings

The proposed arrangements do not impact on the environmental flow requirements of the Tanjil River or Morwell River. Further, the proposed arrangements do not impact the:

1. Base flow or fresh requirements of the freshwater reaches of the Latrobe River system or
2. The occurrence of events required to displace the salt wedge from the Latrobe River estuary and hence the capacity to provide freshwater to the lower Latrobe fringing wetlands (Heart Morass and Dowd Morass).

These outcomes are not surprising as the proposed spillways do not intercept flows below that to meet these environmental water requirements. However, the proposed arrangements have the potential to reduce the occurrence of some bankfull and overbank events through the Latrobe River, under alternate climate projections. Reductions in the occurrence of bankfull events were found in the mid Latrobe River (at Thoms Bridge) during the fill phase for all climate projections, and for overbank events at Thoms Bridge (medium and wet climate projections), Rosedale (dry climate projection only) and at the Swing Bridge (medium climate projection only). The consequence of the reduction to bankfull (Thoms Bridge) and overbank events has not been fully assessed. A preliminary review suggests that the changes to the occurrence of bankfull and overbank events is not likely to be material over the duration of the fill phase. However further investigations are required to confirm (or otherwise) these findings.

While there is some impact on bankfull and overbank events during the fill phase at Thoms Bridge, such adverse impacts are not anticipated in the post fill phase. In the post fill phase, spillway inflows to the pit lakes are expected to pass through the pit lake (subject to top up arrangements) and contribute to downstream bankfull and overbank events. Modelling and flow compliance analysis will be required to confirm this outcome. The investigations should explore the implications of a connected pit lake arrangement at Yallourn on regional water resources, environmental flow compliance and water quality for the waterways and wetlands including Lake Wellington.

Further the investigation has not sought to identify the impact of the proposed arrangements on other related matters including sediment transport in the lower Morwell River and fish passage. These matters will require investigation and assessment.

8.2 Next steps

Further investigations will be required to support the assessment and design of the proposed rehabilitation arrangements at the Yallourn open cut mine site. Investigations that will rely on the water balance modelling will include but may not be limited to:

- Water use strategy: Further work is required to develop a water use strategy that maximises delivery of water to fill the mine lake and to represent that strategy in the Source model. This will require iterative manipulation of the Source model. This is required for an accurate estimation of the filling period and likelihood of a major shortfall in environmental flow compliance.

- Environmental compliance in the pit fill phase: The environmental risk associated with reductions in compliance with bankfull and overbank flow recommendations at Thoms Bridge and elsewhere should be assessed. This will require an assessment of the ecological consequence of not complying with recommendations for nominated intervals and the likelihood of those intervals occurring during the filling phase.
- Environmental compliance and related waterway and wetland assessments for the post fill phase: Water balance and environmental flow compliance assessments are required to assess the implications of the project in the post fill phase. These assessments will need to be informed by the expected pit outflows to the Latrobe River as determined by pit lake water balance modelling.
- Water quality assessments: The post fill phase assessment should also include water quality assessments. This regional water quality assessments should be informed by the output of pit lake water balance and water quality modelling, regional water balance modelling and regional water quality data.
- Morwell River sediment transport assessment: The results of the water balance modelling will also be important to identify the implications of the proposed arrangements on bed load sediment transport through the Morwell River in the vicinity of and downstream of the proposed pit lake inlet spillways.

9 References

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