Thredbo Golf Course Development
Flood Risk Management Assessment

Kosciuszko Thredbo Pty Ltd

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DOCUMENT TRACKING

Project Name	Thredbo Golf Course Development Flood Risk Management Assessment
Project Number	22SYD2528
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Status	**Draft**
Version Number	**v1**
Last saved on	**1 December 2025**

This report should be cited as 'Eco Logical Australia 2023. *Thredbo Golf Course Development Flood Risk Management Assessment*. Prepared for Kosciuszko Thredbo Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Kosciuszko Thredbo Pty Ltd.

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Abbreviations

Abbreviation	Description
2D	Two-dimensional
ADR	Australian Disaster Resilience
AEP	Annual Exceedance Probability
AIDR	Australian Institute for Disaster Resilience
ARI	Annual Recurrence Interval
ARF	Areal reduction factor
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
CL	Continuing loss
DA	Development Application
DEM	Digital Elevation Model
ELVIS	Elevation Information System
FFA	Flood frequency analysis
FRM	Flood risk management
GSAM	Generalised Southeast Australian Method
ICSM	Intergovernmental Committee on Surveying and Mapping
IFD	Intensity-Frequency Duration
IL	Initial loss
PMF	Probable maximum flood
PMP	Probable maximum precipitation
RCP	Representative Concentration Pathway
RFFE	Regional flood frequency estimation
SAP	Special Activation Precinct

Executive Summary

Eco Logical Australia Pty Ltd was engaged by Kosciuszko Thredbo Pty Ltd to prepare a Flood Risk Management (FRM) Assessment to support their Development Application relating to the subdivision and development of Thredbo Golf Course, located within Kosciuszko National Park (the 'site').

Hydrologic modelling was undertaken using the RORB software package to determine sub-catchment peak flows and verify peak flows from subsequent hydraulic modelling. Hydraulic modelling was conducted representing existing conditions using the HEC-RAS software package. HEC-RAS models were developed using a 2D rain-on-grid analysis to determine inundation extent, flood depth levels, flow velocities and flood hazard classification. The modelling methods were calibrated using best initial loss estimates based on previous similar modelling and flood frequency analysis for the region.

The modelled flood depths showed that, in general, the flows are concentrated to the waterways and defined overland flow paths within the site with sufficient terrain relief to limit the amount (depth and velocity) of sheet flow. The primary flood features comprise Thredbo River, which borders the site to the south, and minor tributaries that intersect the site and proposed development footprint. The model predicts that these features stay largely confined to their banks and defined flood plains and their most significant impact is likely to affect access tracks at the site.

Maximum modelled depth outside these channels across the site were generally shallow (< 0.4 m) under each AEP scenario. However, greater inundation, exceeding 0.5 m depth and 1.5 m/s velocity, is likely under intense storm conditions (>1% AEP or approximately 206 mm rainfall in 24--hours) resulting in a maximum flood hazard classification up to H5 (unsafe for vehicles and people, with buildings vulnerable to structural damage) in some isolated areas of site (see Figure ES- 1).

Although maximum flood hazard classification and associated risk based on assessment of potential consequences was medium to high under modelled events, the flood hazard across the majority of the site and proposed development footprint was much lower, with over 85% of the inundation areas classified as H1 (generally safe for vehicles, people and buildings) up to the 0.1% AEP event. Emergency response measures to manage flood risk include flood hazard awareness education, monitoring of flood warning systems, early communications and evacuation/shelter response implementation, as required, and post-flood recovery including asset inspection and repair.

Table ES- 1 Summary of qualitative relative flood risk

Scenario	Summary of potential flood impacts	Initial risk rating	Residual risk rating
10% AEP	Maximum flood hazard of H3 (unsafe for vehicles and people) in limited area north of carpark. Primarily safe for vehicles and people across site.	Medium	Low
1% AEP	Maximum flood hazard of H5 (unsafe for vehicles and people; buildings subject to failure) in limited area north of carpark. Emergency management procedures adequately limit the risk to low.	High	Low
0.1% AEP	Maximum flood hazard of H5 (unsafe for vehicles and people, buildings subject to failure) in limited area north of carpark. Emergency management procedures adequately limit the risk to low.	High	Low
PMF	Maximum flood hazard of H6 (unsafe for vehicles and people, buildings subject to failure). Emergency management procedures adequately limit the risk to low and this scenario is highly unlikely to occur within life of project.	High	Low

Based on results of the FRM assessment, it is considered that the proposed design meets design requirements specified in the Snowy SAP Masterplan from a flood risk perspective.

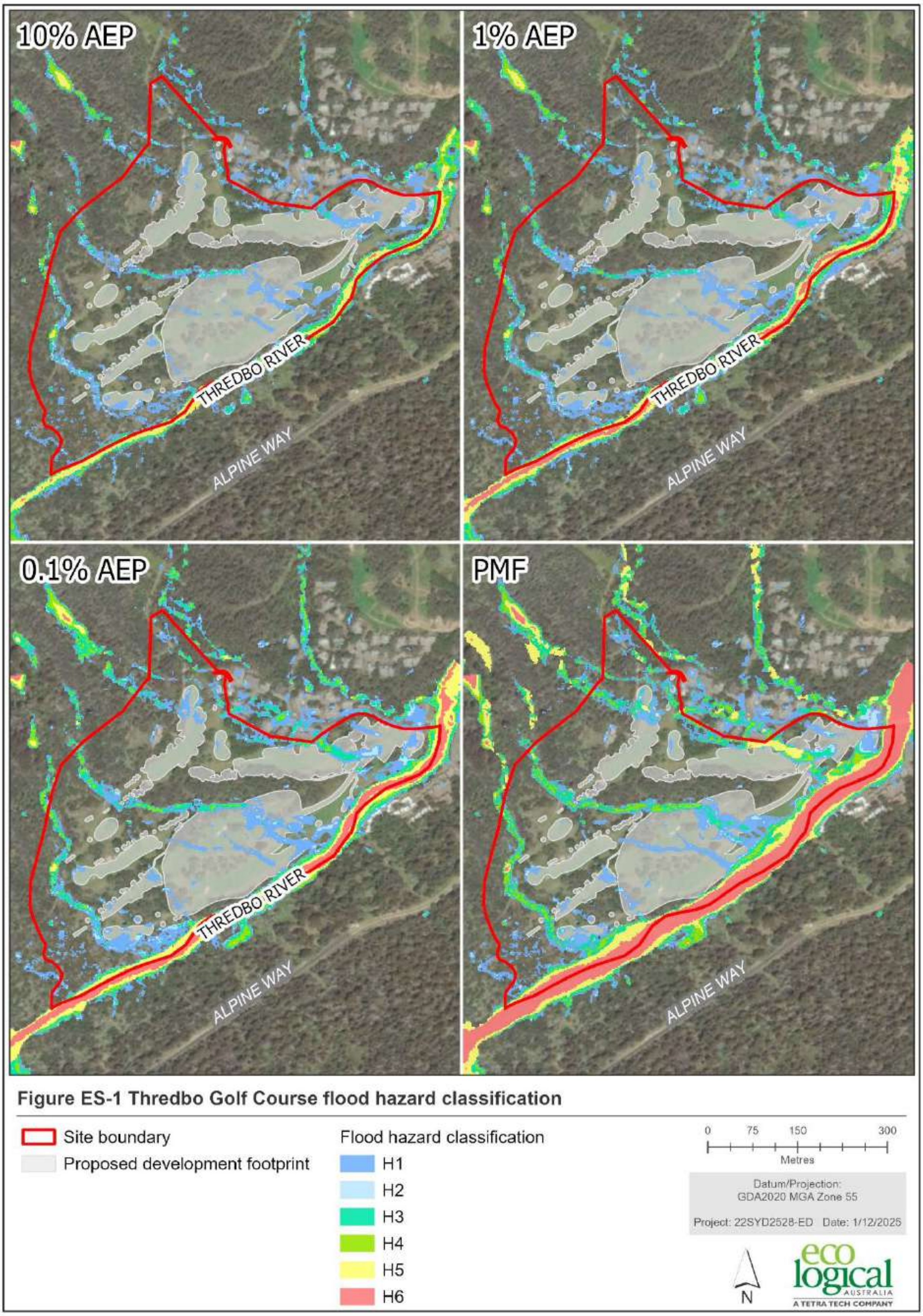

Figure ES- 1 Thredbo Golf Course flood hazard classification

1. Introduction

Eco Logical Australia Pty Ltd (ELA) was engaged by Kosciuszko Thredbo Pty Ltd (KT) to prepare a Flood Risk Management (FRM) Assessment to support their Development Application (DA) relating to the subdivision and development of Thredbo Golf Course (the 'Project'), located within Kosciuszko National Park (the 'site') (Figure 1-1).

This FRM Assessment includes:

- An assessment of potential flood impacts associated with hydrologic conditions under the 10%, 1% and 0.1% annual exceedance probability (AEP) and probable maximum flood (PMF) events, including medium-range (2050) intermediate (RCP 4.5) and high-emission (8.5) climate change scenarios.
- Details of the modelling approach utilised that underpins the FRM assessment.
- Characterisation of flood risk in accordance with the technical flood management guidelines H1-H6 classification system.
- Preliminary evacuation and emergency strategies based on the potential flood impact and risk assessment results.
- Recommendations for design considerations based on flood modelling results in accordance with Section 11.3 of the Snowy Special Activation Precinct (SAP) Masterplan.

1.1. Scope of work

The scope of work to undertake the FRM Assessment included:

- Review and collation of data sourced and applied as part of the assessment (Section 2).
- Hydrologic modelling to determine peak flows and verify hydraulic modelling (Section 3).
- Hydraulic modelling to determine maximum flood depths and velocities (Section 4).
- Review of hydrologic and hydraulic modelling results (Section 5).
- Assessment of flood impact results and associated risk in the context of the site (Section 6).
- Determination of appropriate evacuation and emergency management strategies based on flood risk (Section 7).

Representative Concentration Pathway (RCP) 4.5 and 8.5 climate model forcing was undertaken as part of this assessment in accordance with Australian Rainfall and Runoff (AR&R) (2019) guidance which includes climate change factors for predicted temperature and rainfall increases based on CSIRO's Climate Futures Tool.

Inclusion of the 0.1% AEP scenario modelling under medium-range (2050) RCP 8.5 climate change conditions is considered to represent a highly conservative assessment of flood risk at the site, exceeding realistic rainfall conditions that are likely to occur at the site in the mid-future, and satisfies requirements listed in the NSW Department of Environment and Climate Change (2007) *Floodplain Risk Management Guideline* and NSW DPE (2023) FRM guideline series. Note, climate change sensitivity analysis was not undertaken for the PMF scenario due to the extreme nature of the design event and considering assessment of climate change sensitivity for AEP event scenarios satisfies requirements specified in Section 11.3 of the Snowy SAP Masterplan.

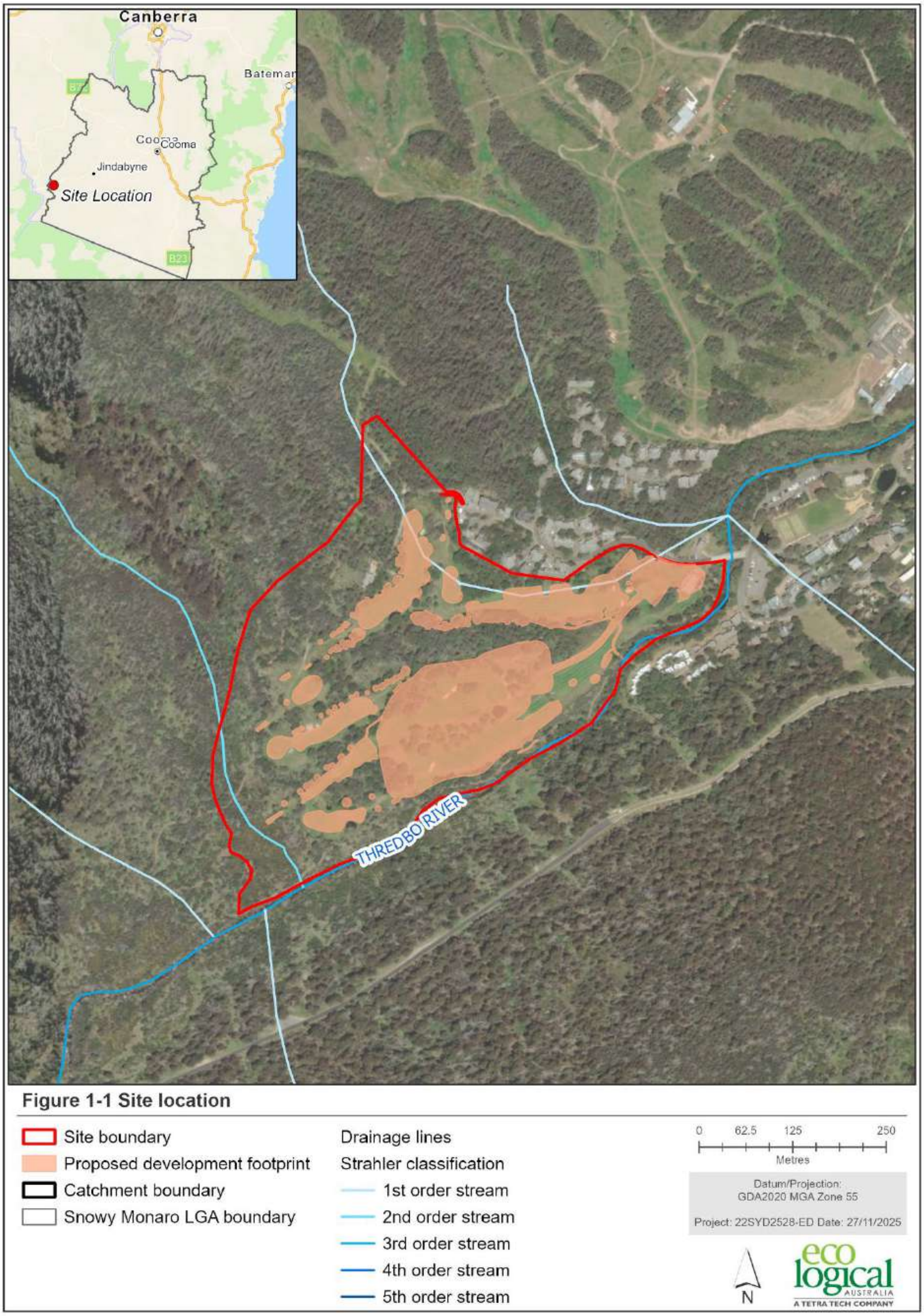

Figure 1-1 Site location

2. Data requirements

The following datasets were sourced for use in this assessment:

- Digital Elevation Model (DEM) to represent the watershed (catchment) that drains the site and any adjacent waterways.
- Site survey within the site boundary, as provided by KT.
- Development footprint for the site, as provided by KT.
- Gauged rainfall data representing the rainfall falling on the catchment at a sub-daily time step for use in calibration.
- Gauged flow data representing flows in the catchment for calibration of flow rates.
- Bureau of Meteorology (BoM) Intensity Frequency Duration (IFD) data representing the rainfall intensities for design rainfall events for the specified catchment.
- AR&R information for rainfall patterns and loss information for use in hydrologic modelling.
- Regional Flood Frequency Estimation (RFFE) modelling to validate model results for design storm events.

2.1. Digital Elevation Model (DEM)

A regional DEM was sourced to determine runoff catchments for waterways that drain to, through or immediately adjacent to the site, including Thredbo River which borders the site to the south.

Regional elevation information was sourced from the Australian Government's Intergovernmental Committee on Surveying and Mapping (ICSM) Elevation and Depth – Foundation Spatial Data (ELVIS) website. The most detailed DEM available that covered the regional catchment area relevant to the site was the NSW Government - Spatial Services 2 m by 2 m LiDAR dataset.

The regional DEM was supplemented by the site topographical survey data as provided by KT, which shows the elevation of the site ranges from approximately 1,367 AHD to 1,433 mAHD with a slope ranging from 4-20%.

The resulting surface elevation used for hydrologic modelling is illustrated in Figure 2-1.

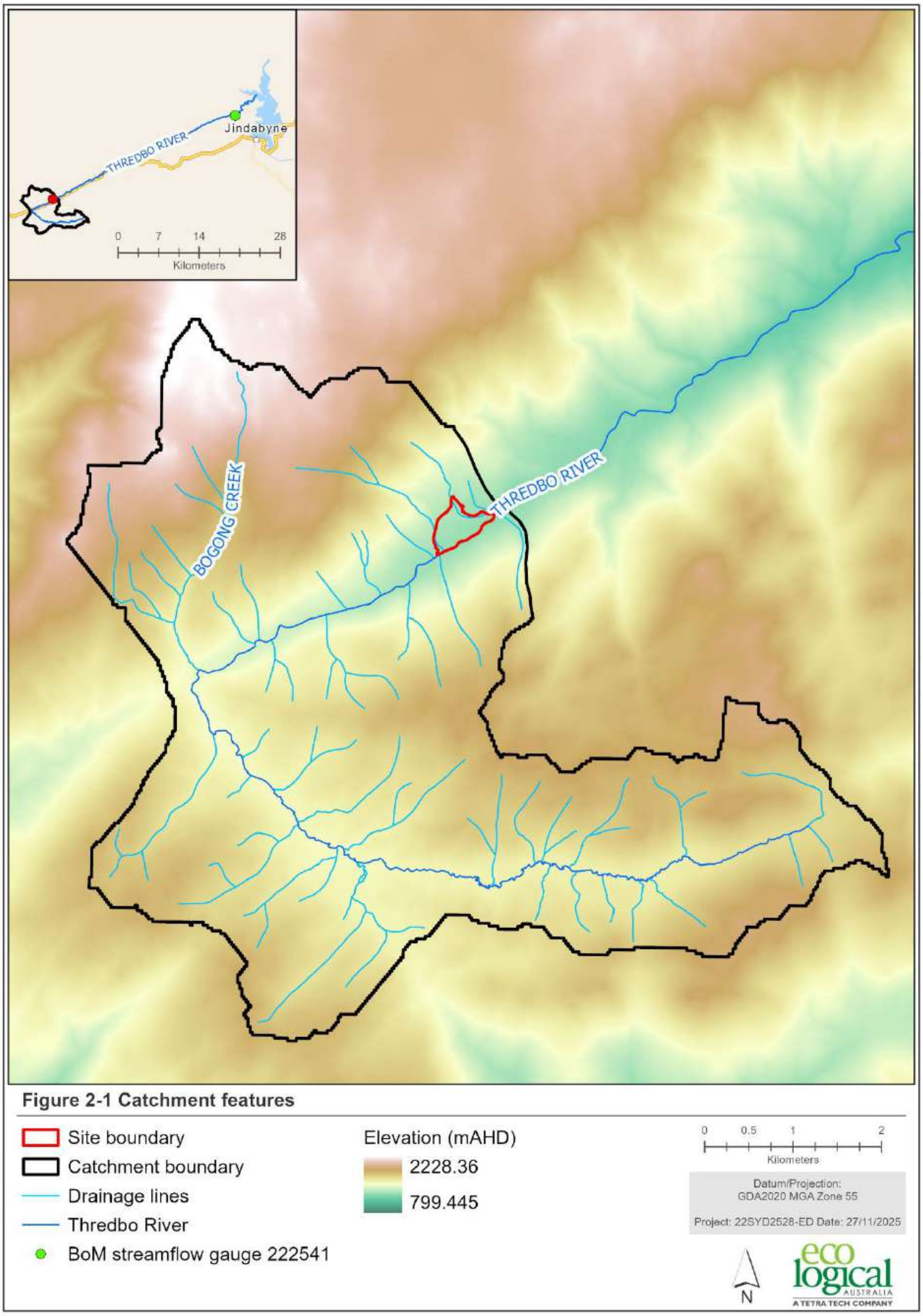

Figure 2-1 Catchment features

2.2. Observed streamflow

Observed streamflow information was available at the Thredbo River at Paddy's Corner (gauge number 222541), located approximately 30 km downstream of the site (-36.38˚ S, 148.58˚ E) as indicated in Figure 2-1. Data was sourced from the Bureau of Meteorology (BoM) from 1 September 1985 to 10 June 2025 as shown in Figure 2-2.

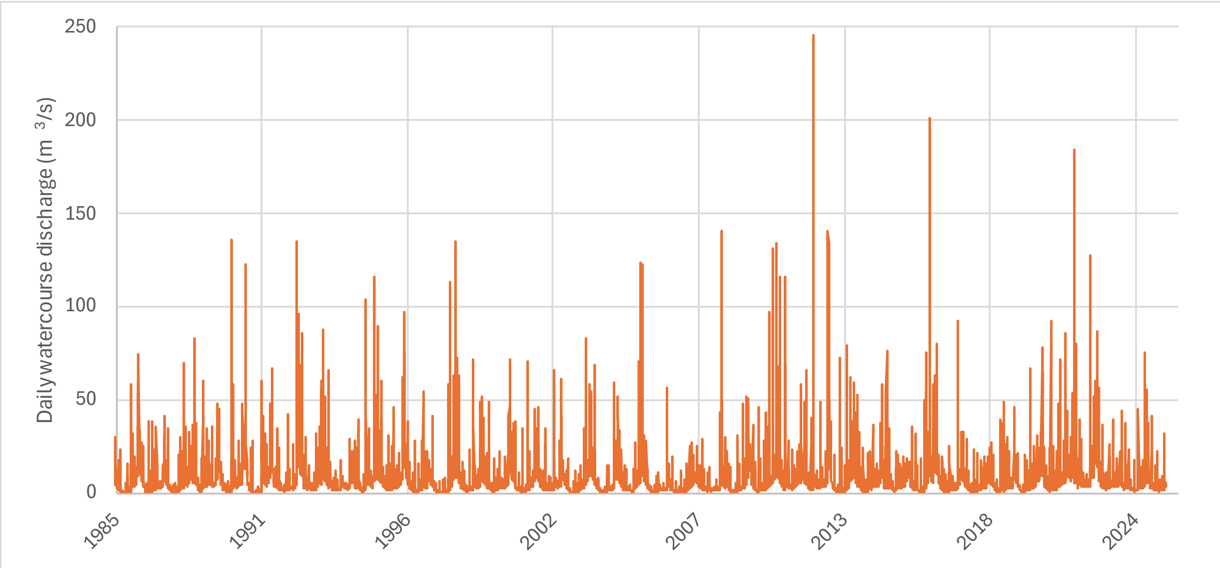

Figure 2-2 Thredbo River at Paddy's Corner gauge (222541) gauged streamflow

Based on the historical streamflow gauge data at Paddy's Corner, the maximum daily peak flow record stands at 245.8 m^3/s, with only 0.3% of records surpassing 57.1 m^3/s based on a normal distribution of streamflow records, as illustrated in Figure 2-3. Whilst the historical gauged streamflow data at Paddy's Corner is likely greater than flows which occur adjacent to the site due to a larger contributing catchment area (approximately 243 km^2 compared to approximately 36 km^2), it remains valuable to consider nearby measured discharge to provide context for expected peak flows adjacent to the site and calibrate the hydrologic (RORB) model. Specifically, comparing modelled peak discharge for Thredbo River at the site with historical rainfall and streamflow gauge records at Paddy's Corner provides indication of the conservativism of the resulting flood risk assessment (see Section 6).

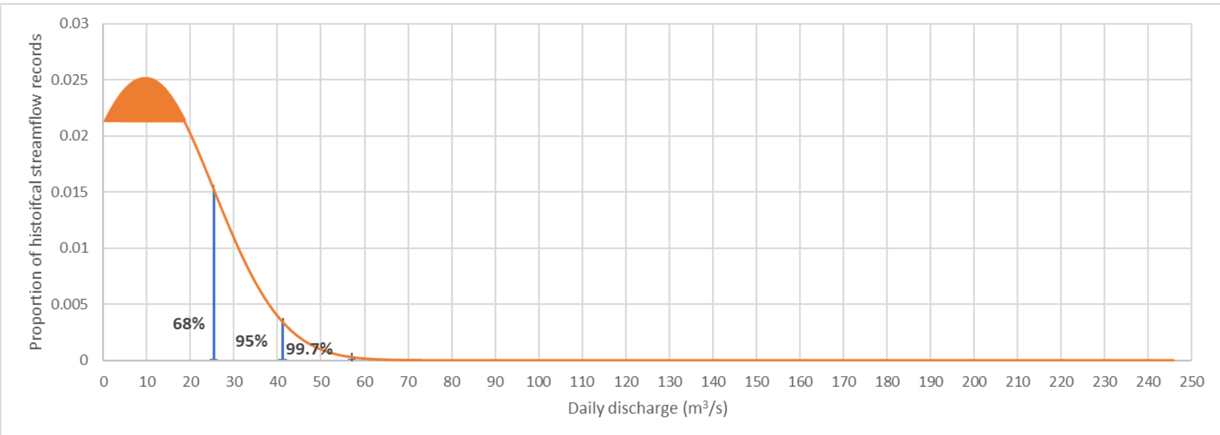

Figure 2-3 Thredbo River at Paddy's Corner gauge (222541) gauged streamflow record distribution

In addition to streamflow data, gauged water level data from the Paddy's Corner gauge was available for review. Water level records indicate a maximum of 4.38 m. As Thredbo River at the site has similar hydrologic characteristics relative to the location of available gauge data, water levels in Thredbo River at the site are likely relatively consistent with the plot of water level data (Bureau of Meteorology, 2025) presented in Figure 2-4, providing further context for hydraulic (HEC-RAS) model calibration and expected maximum depth results.

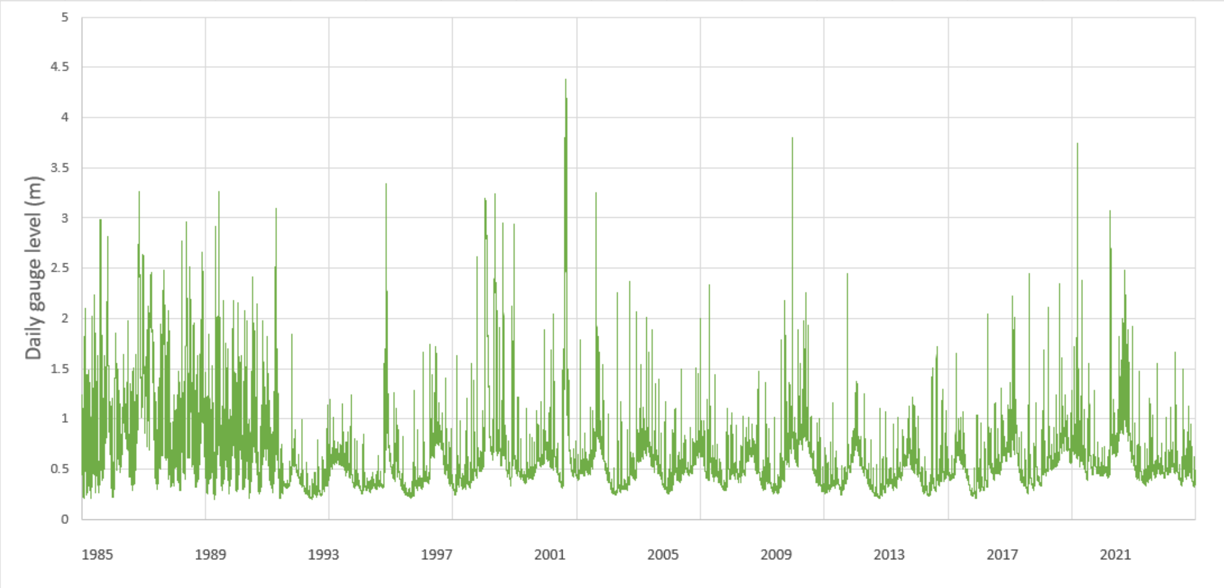

Figure 2-4 Thredbo River at Paddy's Corner (222541) gauged water levels

The relevant RFFE data was utilised to supplement historical flow and water level gauge data and ensure appropriate flood model calibration (Section 3.4).

2.3. Observed rainfall

Observed rainfall information was available at the Thredbo Village weather station (gauge number 071041). Data was sourced from the BoM from 1 January 1971 to 10 November 2025 as shown in Figure 2-5. Based on data retrieved, the average rainfall is 1,795 mm/year, with an average of 132 rain days per year. Typically, the wettest month (mean rainfall) is September and the driest is February as shown in Figure 2-6 (Bureau of Meteorology, 2025).

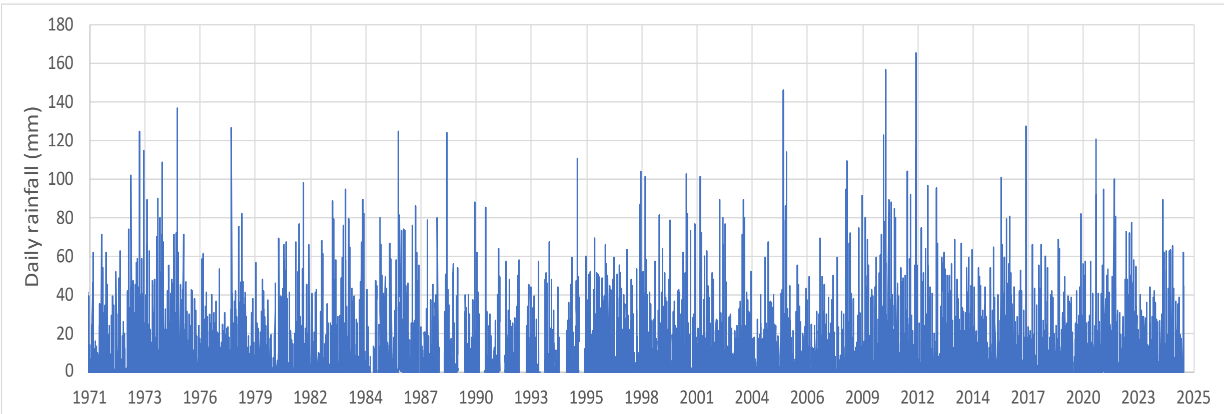

Figure 2-5 Thredbo Village station (071041) observed daily rainfall

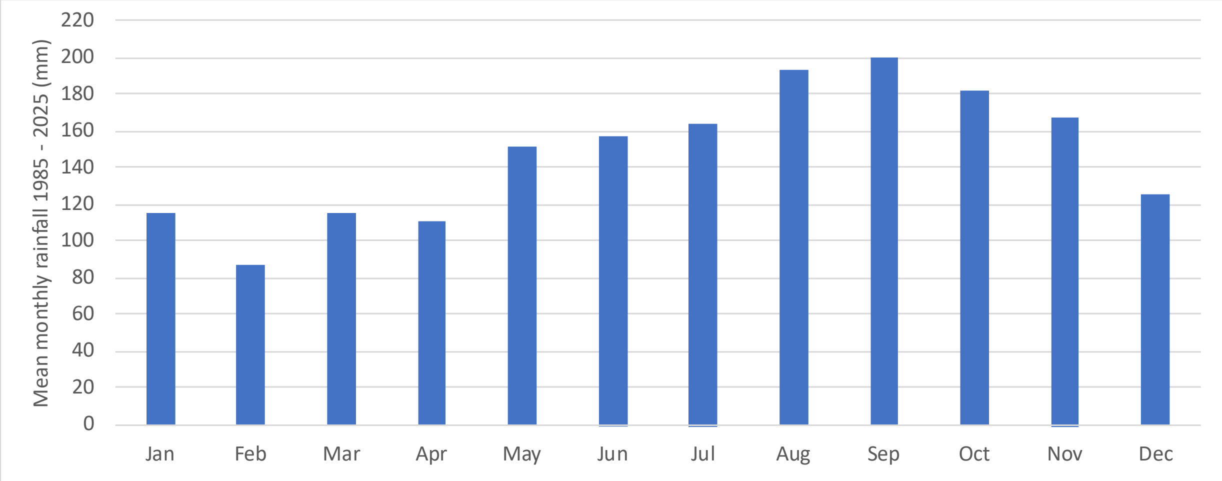

Figure 2-6 Thredbo Village station (071041) mean monthly rainfall

A review of the historical rainfall data at Thredbo Village Station (071041) against BoM IFD curves identified eight rainfall events after 1985 equal to or greater than the 10% AEP 18-hour critical duration storm event (>122 mm). Rainfall records do not indicate occurrence of a 1% AEP 18- or 24-hour critical duration storm event (>178 mm), with a daily maximum of 165.5 mm recorded in March 2012. The corresponding peak discharge results at the Paddy's Corner streamflow gauge for each identified historical storm event were reviewed, as shown in Figure 2-7, to provide further context in consideration of hydrologic modelling results (see Section 5.1.1).

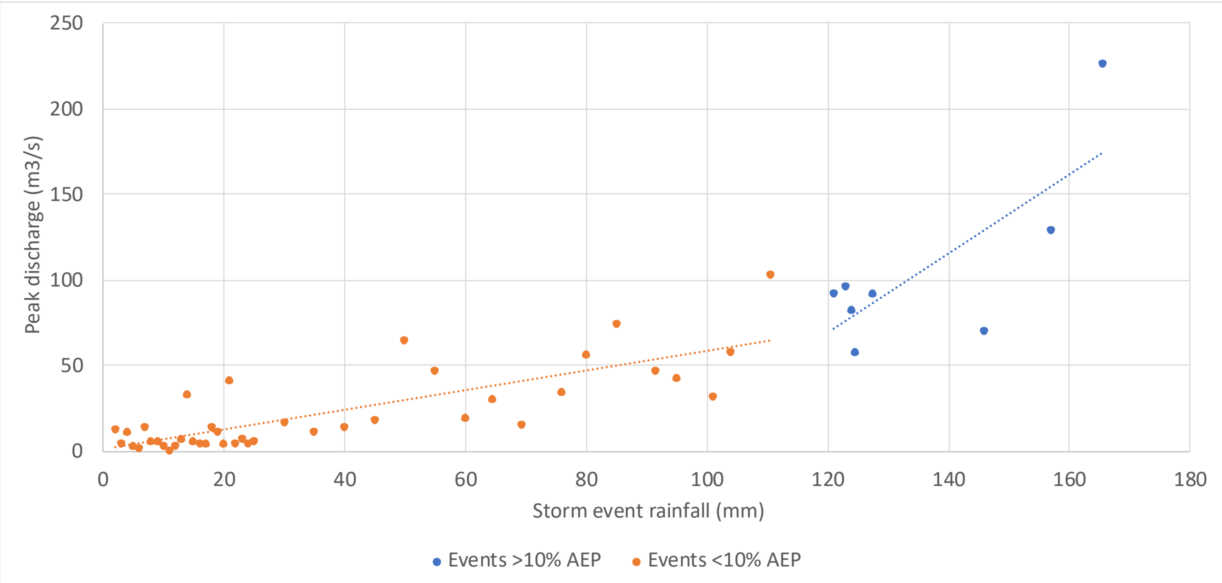

Figure 2-7 Historical rainfall at Thredbo Village station (071041) and corresponding peak flow at Paddy's Corner (222541)

2.4. Intensity-Frequency-Duration (IFD) information

The IFD information was sourced from the BoM IFD curves (retrieved 12 June 2025) using the centroid coordinates for the relevant contributing catchment (-36.5118°S, 148.2854°E) (Figure 2-1). IFD information is required to produce design (e.g. 1% AEP) flow and flood events from the modelling suite. The IFD data is presented in Appendix A1.

2.5. Australian Rainfall and Runoff (AR&R) Data Hub information

Information required for parameterising the models was sourced from the AR&R data hub[1] (retrieved 12 June 2025) at the catchment centroid coordinate location specified in Section 2.4. Relevant parameters were sourced from the South-East Coast (Victoria) Division, Snowy River sub-region. Retrieved parameters included:

- Initial loss of 29.0 mm and continuing loss of 5.4 mm/hr.
- Point and areal temporal patterns. Available durations of the point and areal temporal patterns, compared with the IFD durations, are shown in Appendix A2.
- Areal reduction factor (ARF) parameters from the South-East Coast (Victoria) Division Southern Temperate zone:
    - a = 0.158
    - b = 0.276
    - c = 0.372
    - d = 0.315
    - e = 0.000141
    - f = 0.41
    - g = 0.15
    - h = 0.01
    - I = -0.0027.
- 2050 RCP 4.5 and 8.5 climate change factors including rainfall and loss adjustment factors.

AR&R data hub information imported into the flow modelling software is provided in Appendix A3.

2.6. Regional Flood Frequency Estimation (RFFE) Modelling

The RFFE model[2] was run on 12 June 2025 and used to provide design flow comparison for the RORB model (Section 3.4) for the full catchment domain (Figure 2-1). This model uses information from nearby similar catchments to provide an estimation of the peak flow rates. The details required for this are:

- Catchment outlet: 148.3015° (E) and -36.5052° (S).
- Catchment centroid: 148.2887° (E) and -36.5266° (S).
- Catchment area: 36.2 km^2.

The expected RFFE peak flows and upper and lower confidence limits are presented in Figure 2-8. RFFE analysis is provided in Appendix A4.

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[1] http://data.arr-software.org

[2] http://rffe.arr-software.org

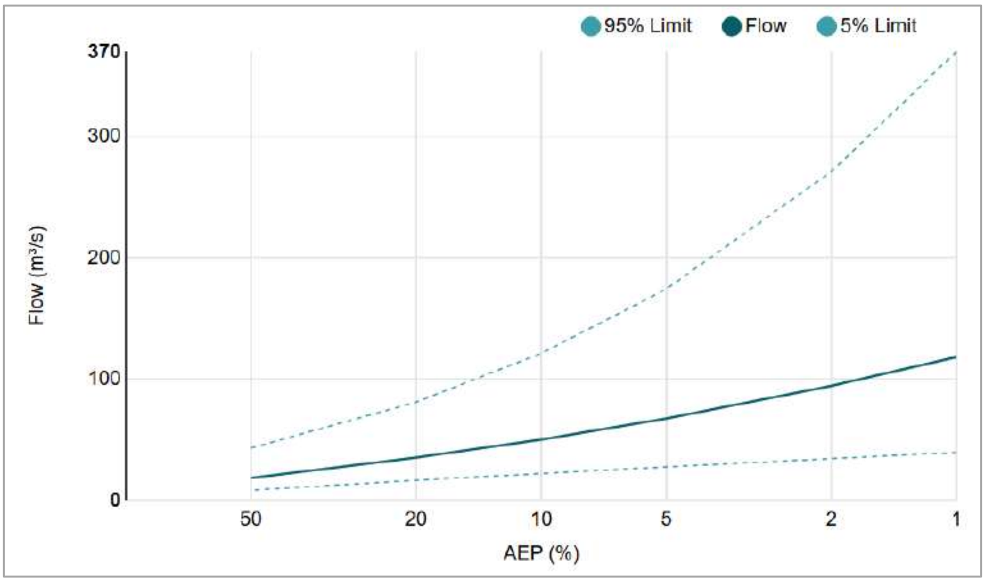

Figure 2-8 RFFE flow estimates including 5% and 95% confidence intervals

2.7. Probable maximum precipitation (PMP)

In order to model the PMF, the probable maximum precipitation (PMP) rainfall depth is required. Based on the location of the site and critical storm duration determined from hydrologic design storm analysis, the PMP was determined using the Generalised Southeast Australian Method (GSAM) (see Figure 2-9).

The GSAM Guidebook (BoM, 2006), rainfall depth data and temporal distributions were obtained from the BoM GSAM PMP estimates data package.

Details of the method used to determine the PMP for the site and application to PMF modelling to inform the FRM assessment is provided in Section 4.1.

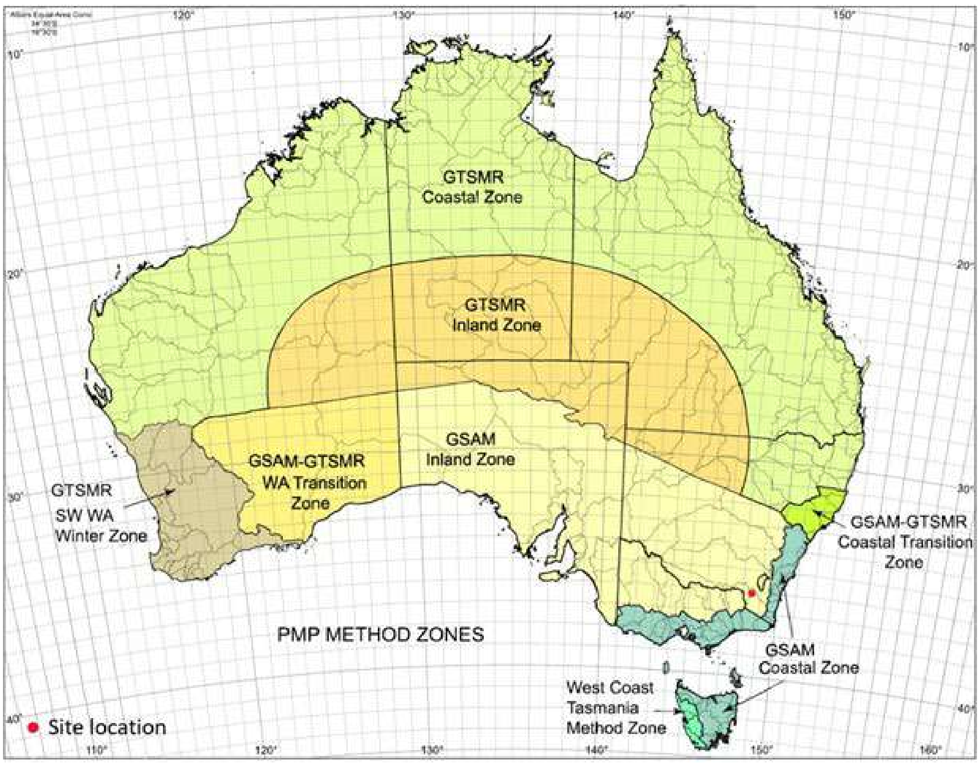

Figure 2-9 PMP method zones

3. Hydrologic modelling methodology

This section outlines the hydrologic model approach for determining rainfall-runoff relationships at the Project Site. The flow rate modelling was undertaken using the RORB (version 6.49) software package[3] to determine sub-catchment flows for the relevant regional catchment shown in Figure 2-1.

The RORB runoff and routing modelling software package simulates rainfall-runoff processes using the unit hydrograph method to predict the temporal distribution of runoff and associated hydrological response of a catchment resulting from a given rainfall event.

The in-built routing equations allow for adjustment of the following parameters to calibrate the hydrologic model to observed streamflow or RFFE in accordance with AR&R guidelines:

- Rainfall-runoff transformation (m) – the response time between rainfall input and resulting runoff within the specified catchment area. A higher 'm' value indicates a relatively faster response and shorter duration, while a lower 'm' value results in a broader peaked unit hydrograph with a more prolonged runoff response.
- Channel routing coefficient (kc) – the rate at which runoff travels through the defined catchment channels or reaches. A higher 'kc' value indicates faster routing through the channel network, while a lower 'kc' value represents slower routing.
- Initial loss (IL) – the amount of rainfall that is removed from the input hydrograph, due to immediate infiltration, transpiration and/or evaporation of water which does not contribute to surface runoff within the specified catchment area.
- Continuing loss (CL) – the amount of rainfall that is lost during a storm event after runoff has started due to infiltration, storage and/or evaporation.

The resulting peak flows were used as inputs to the subsequent hydraulic (depth and velocity) modelling for each design AEP (10%, 1%, 0.1%) and PMF scenario. The RORB runoff routing software was used to calculate flood hydrographs from rainfall for input to the HEC-RAS hydraulic modelling package (see section 3.4).

3.1. Catchment and drainage

The DEM presented in Figure 2-1 was used to create the overall catchment boundary, sub-catchment boundaries and drainages for use in the RORB modelling process. The ArcHydro add-in to ArcGIS was applied to generate the catchment, sub-catchments and drainage line features.

[3] Monash University and Hydrology and Risk Consulting https://www.harc.com.au/software/rorb/, version 6.49

3.2. Catchment input file

The RORB model requires a catchment file to specify how rainfall is applied to the area of interest and how water is routed through the catchment to the outlet. An add-in to ArcGIS, ArcRORB[4], was used to develop shapefiles that were converted into the catchment input file for RORB (Figure 3-1).

The modelled catchment relevant to the site is assumed to be in a natural condition (i.e. no artificially formed waterways/channels/drains) and all reach types within the catchment file were set to 'Natural'. The 'fraction impervious' for the model domain was set to zero. The fraction impervious in this context refers to impervious areas directly connected to waterways. Any impervious regions of the model (e.g. roads) were considered unlikely to be directly connected to the streamlines and any areas that are connected would be such a small proportion (<0.1%) of the overall catchment that they would not affect the modelled outcome.

The catchment file was configurated to print excess hydrograph results for the specified model node located along the main channel of Thredbo River for input into the hydraulic model (see Section 4).

Reach and sub-catchment details along with the catchment file layout are outlined in Appendix B.

[4] https://www.harc.com.au/software/arcrorb/

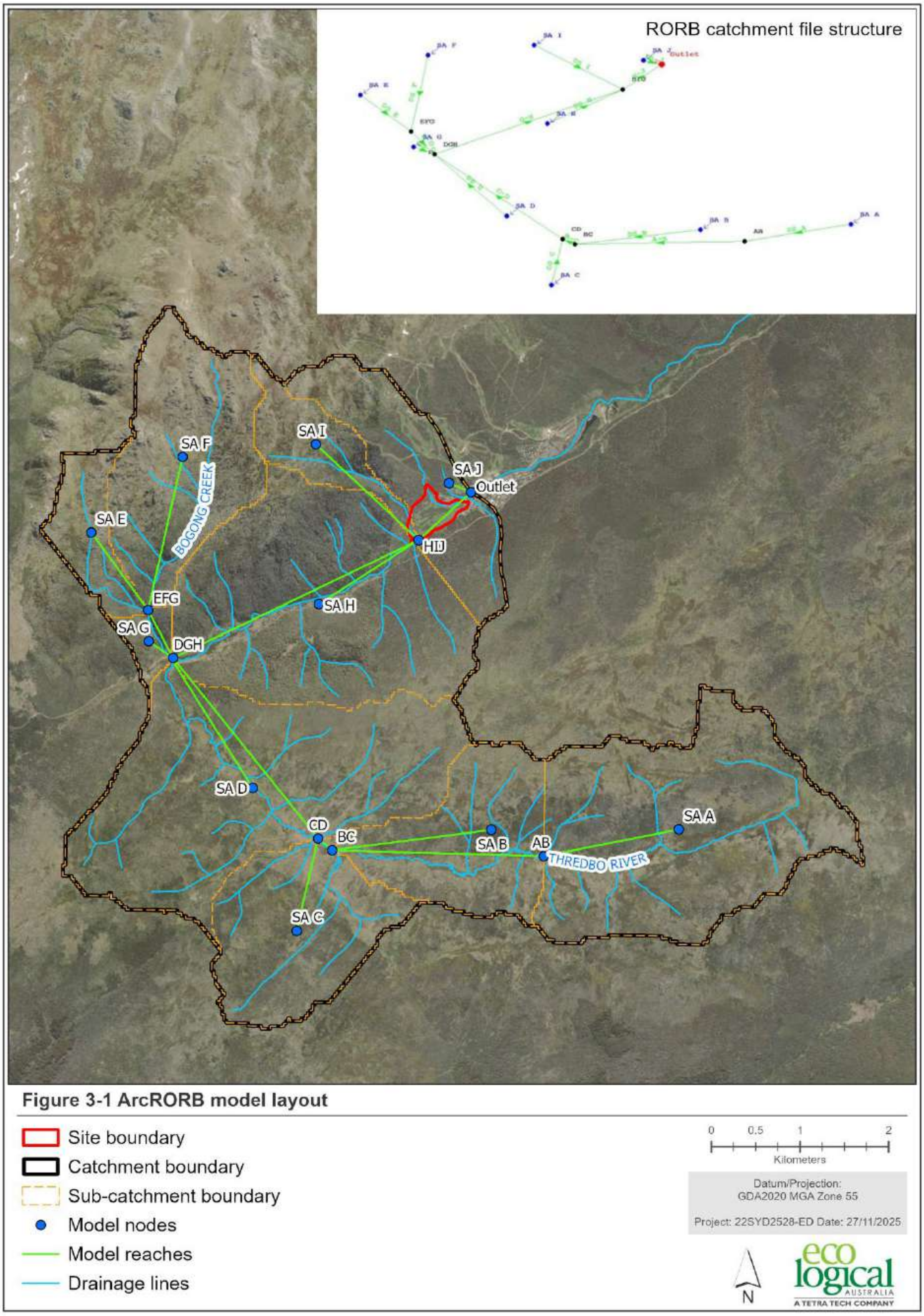

Figure 3-1 ArcRORB model layout

3.3. Design storm parameter file

Parameter files were created for the RORB model for design storm simulations. The following setup parameterisation was used:

- Separate catchment and generated design storm
- RORB catchment file (Figure 3-1
- Storm file corresponding to the event being modelled
- Single set of routing parameters
- Initial loss / continuing loss model
- DESIGN run
- Parameters of m, kc, IL and CL calibrated to RFFE (Section 3.4):
  - m = 0.8
  - Kc = 17.08
  - IL = 19 mm
  - CL = 2.4 mm/hr
- Print at node DGH (14) and Outlet (17) (approximately 115m hydraulically downgradient of the site to the north-east).

The setup for the design storm simulations run in RORB is shown in

Table 3-1. The Monte Carlo framework was used to examine the impact of different temporal patterns upon the design flow rate results and subsequently select the appropriate design storm for generation of input hydrographs for the hydraulic model (see Section 4).

Table 3-1 RORB parameter file specification for design storms

Parameter file section	Detail
Data Hub Files	• Data hub file as discussed in Section 2.5. • Temporal patterns as discussed in Section 2.5. • Use regional losses is unchecked. • Use ARFs from file is checked.
Design Rainfall Specification	• A user defined IFD as discussed in Section 2.4. • Monte Carlo simulation from 10 minute to 168-hour durations. • Default time increments of 200. • Uniform areal pattern. • No pre burst. • Constant losses.
Parameter Specification	• Adjusted k_c of 17.03 • Default m of 0.8. • Adjusted IL of 19 mm. • Adjusted CL of 2.4 mm/hr.
Monte Carlo Specification	• Number of rainfall divisions: 50 (default). • Number of samples per division: 20 (default). • Temporal patterns as described above. • Monte-Carlo sample initial loss.

3.4. Calibration

Although observed flows relevant to the Thredbo River catchment downgradient of the site were available for contextual review of peak flow results within the model boundaries, the hydrologic model was calibrated to the RFFE analysis to fit the expected peak flow curve within the confidence limits specified.

A review of the trendline in RFFE nearby gauged catchment results indicated the expected peak discharge for the target flood events is likely lower than RFFE values for the upper Thredbo River catchment relevant to the site (see Appendix A4). Therefore, the RORB model was appropriately calibrated to RFFE with a probability natural adjustment to better match expected peak flows for nearby gauged catchments. Figure 3-2 shows the RORB model results calculated relative to the specified catchment size (36.2 km^2) compared to weighted design event results for nearby gauged catchments. The results show that the RORB model fits within the middle of the nearby gauged catchment results for the target storm events (10%, 1% and 0.1% AEP). The storm design events are therefore considered applicable for use in providing target peak flow rates for the hydraulic modelling results in Section 5.2.

The resulting calibration parameters are shown in Table 3-2 with routing parameter and loss sensitivity analysis presented in Figure 3-3. Comparing the IL and CL values with those from AR&R (29 mm and 5.4 mm/hr, respectively) showed that a reduced IL and CL were required to calibrate the model to expected RFFE results for the catchment.

Table 3-2 Resulting RORB calibration parameters

Event	m	k_c	IL (mm)	CL (mm/hour)
Default	0.8	7.75	29	5.4
Adopted for design events	0.8	17.03	19	2.4

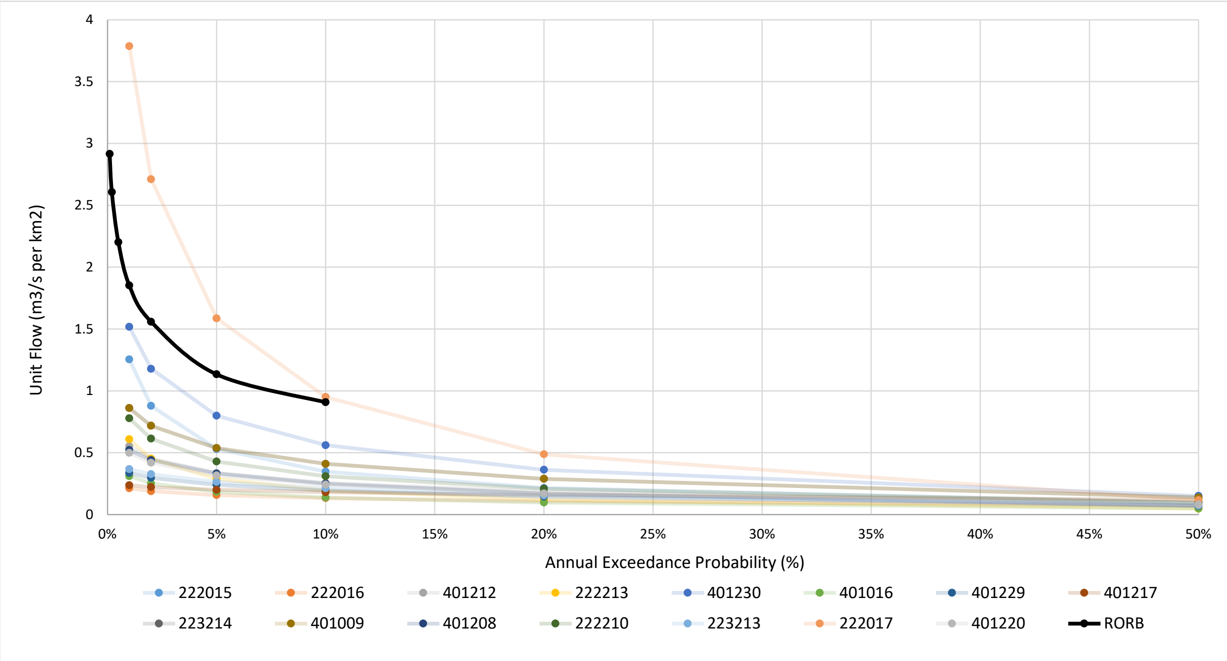

Figure 3-2 RFFE area weighted nearby catchments comparison

Note, six digit IDs in Figure 3-2 correspond to nearby gauged catchments.

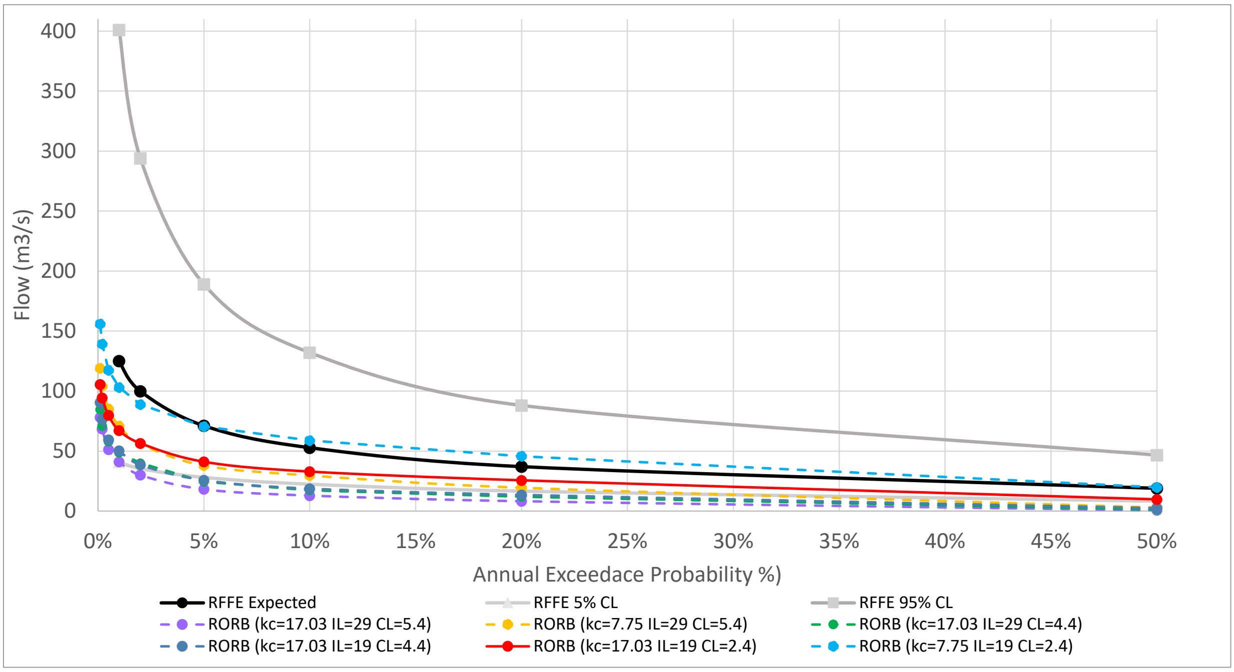

Figure 3-3 RORB routing parameter and loss sensitivity analysis

3.5. Climate change factors

The following medium-range (2050) RCP climate change factors were applied to the calibrated hydrologic model:

- RCP 4.5, representative of intermediate climate change conditions with moderate emission reduction.
- RCP 8.5, representative of a high-emission scenario with little to no mitigation.

These climate change scenarios were selected for modelling to represent reasonable 'middle-of-the-road' and conservative conditions, respectively, to aid in assessment of potential future flood risk at the site, inform development of appropriate flood risk management measures and meet requirements of AR&R guidance as well as NSW Department of Environment and Climate Change (2007) *Floodplain Risk Management Guideline* and NSW DPE (2023) FRM guideline series.

Rather than individually calculating adjusted rainfall depths and losses for climate change scenarios, the AR&R Data Hub provides climate change factors based on rate of change and global temperature projections that can be directly applied, as summarised in Table 3-3. Detailed methodology for determination of these factors and resulting adjusted rainfall depth and losses is available in AR&R *Book 1* (Commonwealth of Australia (Geoscience Australia), 2019). Results were used to determine inflow hydrographs at model node DGH (14) for inputs to the hydraulic model (see Section 4). Climate change sensitivity results are presented in Section 5.

Table 3-3 Adopted climate change factors

Climate change scenario	Rainfall factors										Loss adjustment factors	
	<1 hour	1.5 hours	2 hours	3 hours	4.5 hours	6 hours	9 hours	12 hours	18 hours	>24 hours	Initial loss	Continuing loss
2050 RCP 4.5	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14	1.07	1.15
2050 RCP 8.5	1.34	1.31	1.29	1.26	1.24	1.23	1.21	1.2	1.18	1.18	1.08	1.18

4. Hydraulic modelling methodology

This section outlines the hydraulic modelling approach for determining flow characterisation across the Thredbo Golf Course site. Hydraulic modelling was conducted using the U.S. Army Corps of Engineers' HEC-RAS[5] (version 6.5) software package. HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis for the target AEP scenarios (10%, 1% and 0.1%) and PMF conditions. The sections below outline the process undertaken to set up the HEC-RAS model.

4.1. Precipitation

The precipitation inputs for the modelled AEP design scenarios were derived from the IFD tables sourced from the BoM (BOM, 2016) on the 11 June 2025. The PMP rainfall depth input was determined using the GSAM method based on BoM (BOM, 2006) guidance and data package.

To define the critical rainfall duration, i.e. the duration which yields the highest flow and depth, the time of concentration for the catchment was calculated using two different methods. The first method used the Friend's formula (Australian Rainfall & Runoff, 2014), which considers the land cover, the length of the main drainage path and the average slope in determining the time of concentration:

$$Time\ of\ Concentration = 107\ \times \frac{n\ \times L^{0.333}}{S^{0.2}}$$

Equation 1: Friend's time of concentration formula

Where *n* is the Horton's roughness value for the surface, *L* is the flow path length in metres, *S* is the slope of the surface in percentage, and *Time of Concentration* is in minutes.

The second method used the following formula from Pilgrim (1989), which returns the time of concentration in hours and uses only the drainage area in square kilometres as input:

$$Time\ of\ Concentration = 0.76\ \times A^{0.38}$$

Equation 2: Pilgrim & McDermott's time of concentration formula

The Pilgrim and McDermott method usually results in smaller values than those produced by the Friend method. Therefore, the Friend method was used as a reference for the smallest duration tested whilst the Pilgrim and McDermott was used as a reference for the longest duration, in order to find the critical rainfall duration for the catchment. However, durations higher and lower than the values determined by the Pilgrim and McDermott, and Friends methods, respectively, were also tested to extend confidence in the interpretation of results.

The model results for the rainfall durations for each selected AEP event were compared to evaluate which duration would yield the highest flows and depths. For this assessment, the rainfall was distributed across the temporal patterns downloaded from the AR&R Data Hub and the time series produced were used as an unsteady flow boundary condition (inflow hydrograph) for the model.

[5] U.S. Army Corps of Engineers' HEC-RAS Version 6.5 (USACE 2024)

When the critical duration was found for each target AEP scenario for the catchment, the temporal patterns for that duration were compared to choose the pattern that yielded the next highest peak flow from the median for each AEP event. For the PMF scenario, the temporal pattern was selected based on the critical duration determined for the 0.1% AEP, as the most conservative estimate, and the BoM (2006) temporal patterns for the region where the site is located. The determined temporal patterns were then applied to represent the rainfall distribution for the design scenarios modelled (10%, 1% and 0.1% AEP and PMF).

The patterns applied are shown in Figure 4-1 with a summary provided in Table 4-1 Event and temporal pattern summary. Note 1% AEP, 0.1% AEP and PMF events are 24 hours in duration, and the 10% AEP event is 18 hours in duration, as determined from the RORB results. As the temporal patterns were selected based on each AEP event they vary in their form.

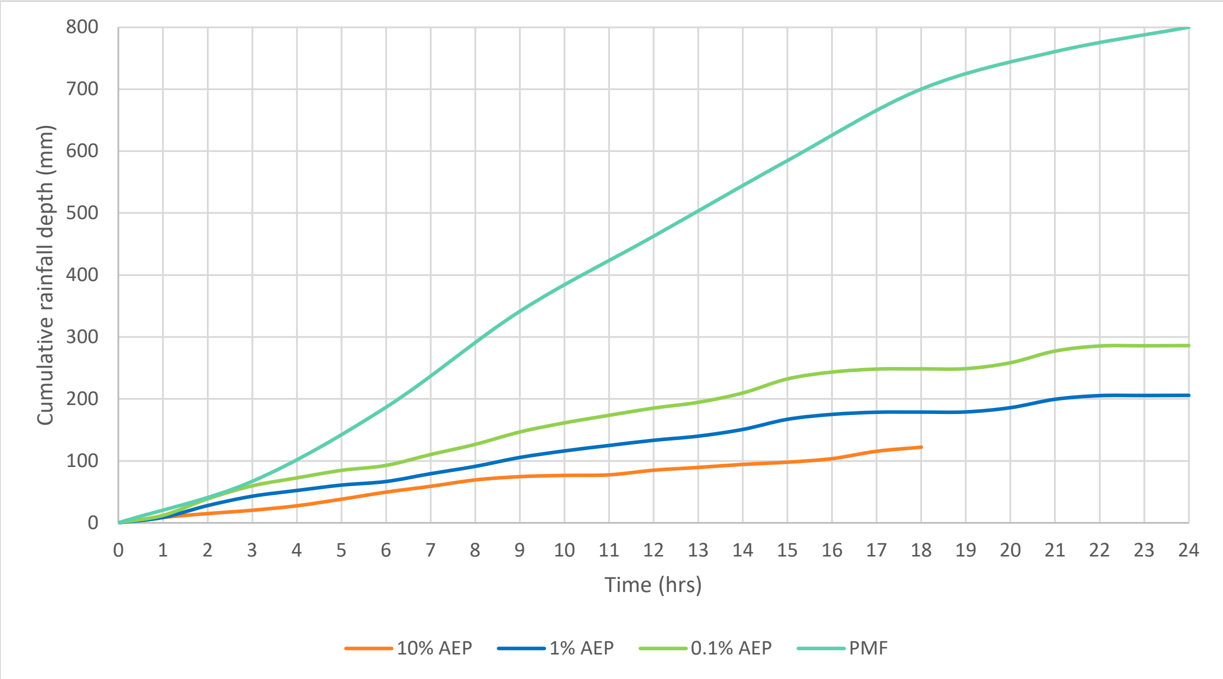

Figure 4-1 Rainfall depths applied to 2D flow area for the 10%, 1% and 0.1% AEP and PMF design events

Table 4-1 Event and temporal pattern summary

Event	Rain depth (mm)	Temporal pattern (event ID)	Critical duration (h)
10% AEP	122	TP14 (6221)	18
1% AEP	206	TP22 (6053)	24
0.1% AEP	286	TP22 (6053)	24
PMF	800[(1)]	GSAM inland 100km^2	24

[(1)] PMP depth as determined using GSAM method

The climate change rainfall factors were applied for each modelled AEP event under the selected climate change scenarios as summarised in Table 4-2, noting the same temporal pattern and critical durations as listed above were applied to provide direct comparison for climate change sensitivity analysis. Noting, however, climate change factors were not applied to the PMF scenario due to the already extreme nature of the design event and considering assessment of climate change sensitivity for AEP event scenarios satisfies requirements of specified in Section 11.3 of the Snowy SAP Masterplan.

Table 4-2 Climate change scenario rainfall depths

Event	No climate change factor	2050 RCP 4.5		2050 RCP 8.5	
	Rain depth (mm)	Factor	Rain depth (mm)	Factor	Rain depth (mm)
10% AEP	122	1.15	140	1.18	144
1% AEP	206	1.14	235	1.18	243
0.1% AEP	286	1.14	326	1.18	338
PMF	800	-	-	-	-

4.2. Losses

A rainfall excess time series (the amount of rain that runs off after the losses) was directly applied to the model through manual removal of initial and continuing losses. An example of this is outlined in Figure 4-2 for the 1% AEP event using the adjusted initial and continuing losses (19 mm and 2.4 mm/hr, respectively) determined through calibration of the RORB model to RFFE expected peak and nearby observed flows. For the PMF scenario, initial and continuing losses were set to 0 mm and 1 mm/hr, respectively, in accordance with AR&R guidance for estimation of extreme flood events (Ball et al, 2019).

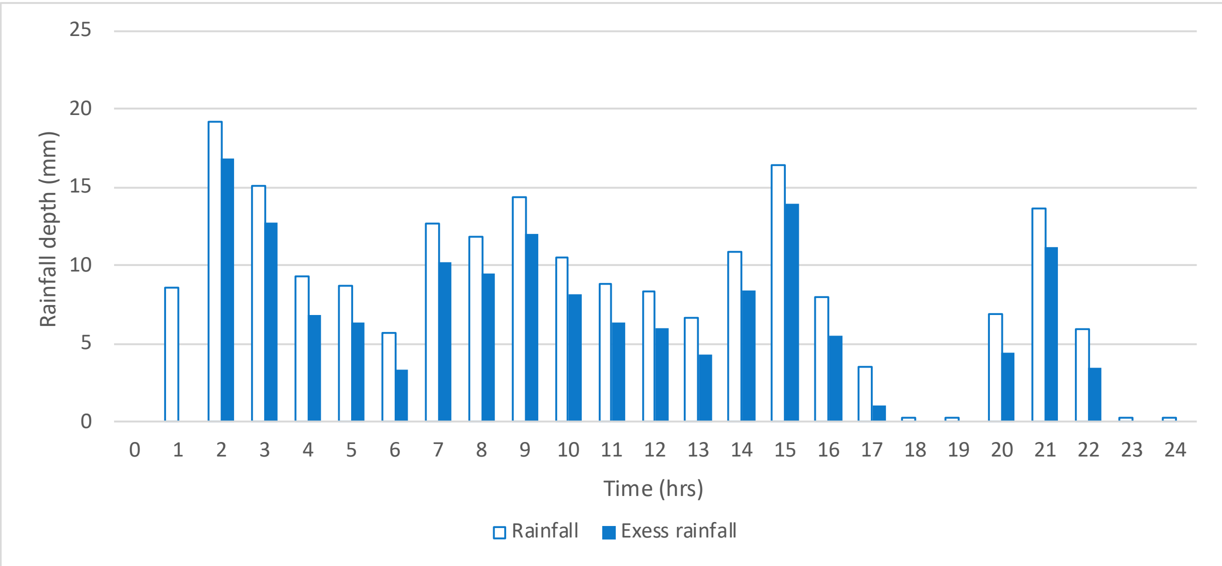

Figure 4-2 1% AEP design event rainfall pattern applied to HEC-RAS after losses are removed

Loss adjustment factors were applied for each modelled AEP event under the selected climate change scenarios as summarised in Table 4-3.

Table 4-3 Climate change scenario loss adjustments

Event	No climate change factor	2050 RCP 4.5		2050 RCP 8.5	
	Value	Factor	Value	Factor	Value
IL (mm)	19	1.07	20.3	1.08	20.5
CL (mm/hour)	2.4	1.15	2.76	1.18	2.83

A comparison of 1% AEP excess rainfall for each climate change scenario is shown in Figure 4-3.

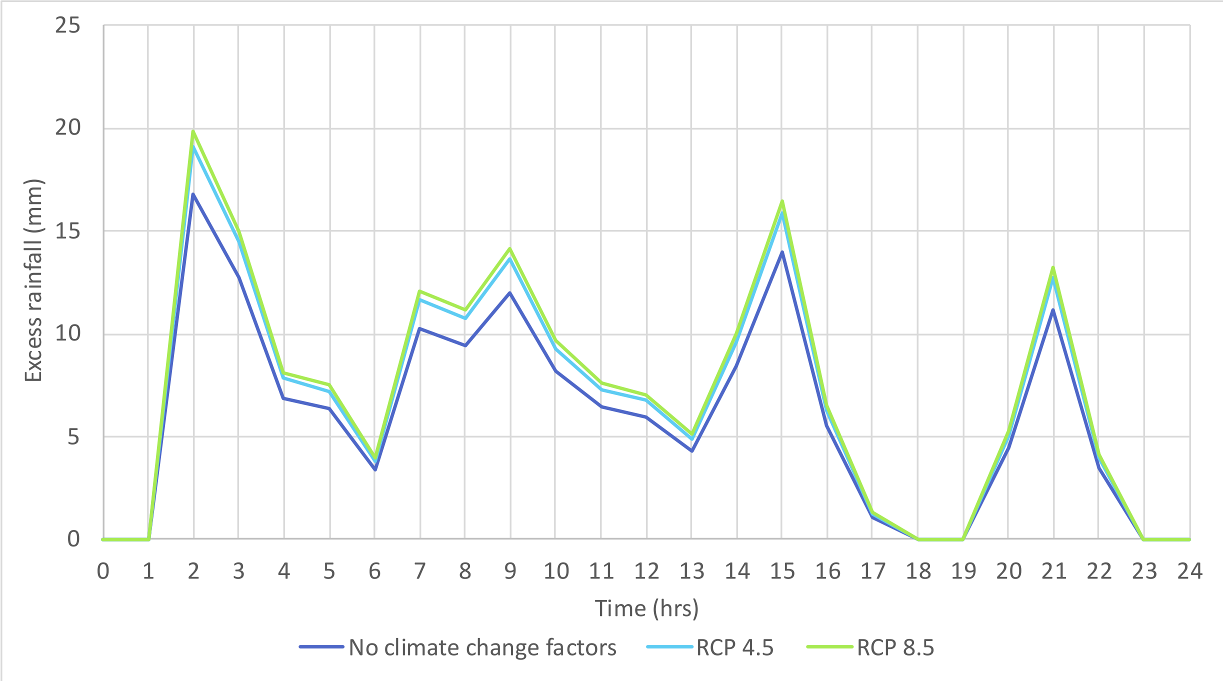

Figure 4-3 1% AEP design event excess rainfall pattern climate change scenario comparison

4.3. Inflow hydrographs

Excess hydrographs were generated from RORB at model node DGH (14), located along the main channel of Thredbo River approximately 3 km upgradient of the site. For each target AEP and PMF scenario, the determined temporal pattern was input as a single storm with resulting hydrographs used as an input boundary condition to the hydraulic model. The energy slope applied at the inflow boundary was 0.03.

The peak flow and total inflow for each scenario are summarised in Table 4-4, with hydrographs presented in Figure 4-4. Note, climate change factors were not applied to the PMF scenario due to the already extreme nature of the design event and considering assessment of climate change sensitivity for AEP event scenarios satisfies requirements of specified in Section 11.3 of the Snowy SAP Masterplan.

Table 4-4 Inflow hydrographs determined from RORB

Scenario	Baseline		RCP 4.5		RCP 8.5	
	Hydrograph peak flow (m^3/s)	Total inflow (m^3)	Hydrograph peak flow (m^3/s)	Total inflow (m^3)	Hydrograph peak flow (m^3/s)	Total inflow (m^3)
10% AEP	25	459	33	577	34	594
1% AEP	51	927	64	1,224	67	1,269
0.1% AEP	81	1,497	108	2,030	112	2,106
PMF	281	5,356	-	-	-	-

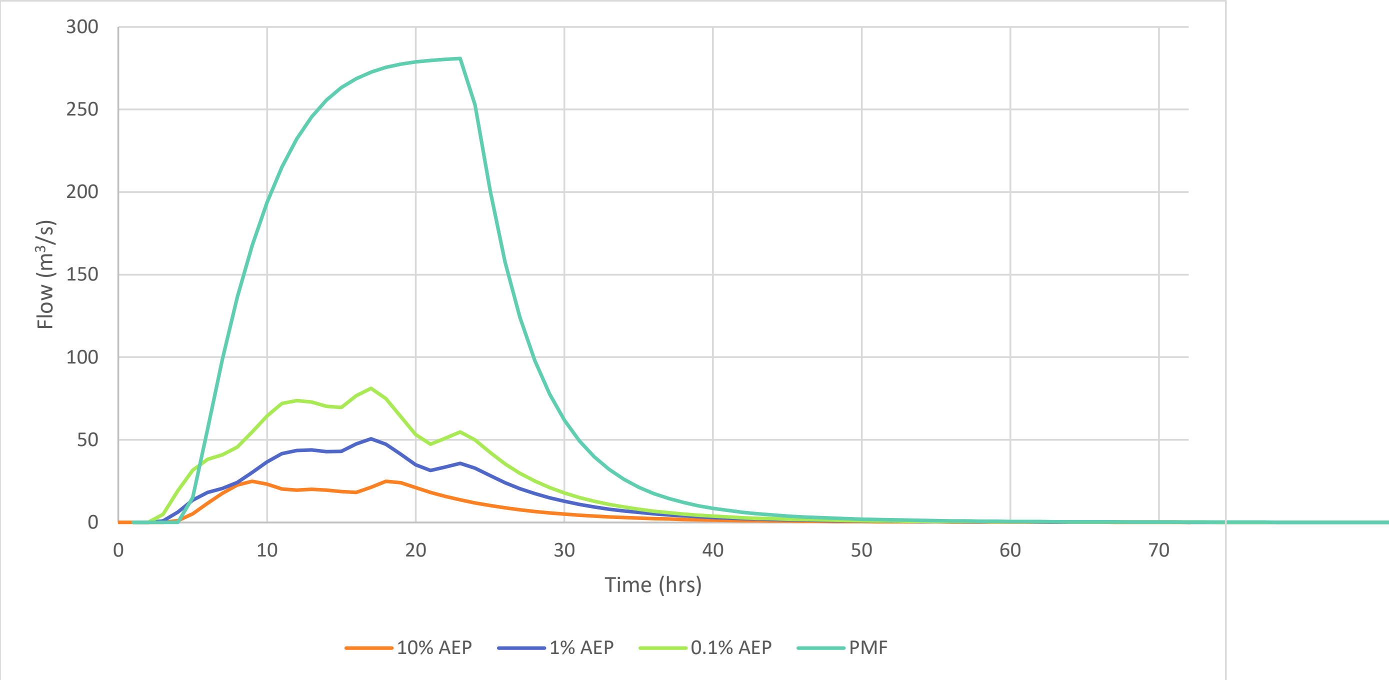

Figure 4-4 Hydraulic model inflow boundary condition hydrographs

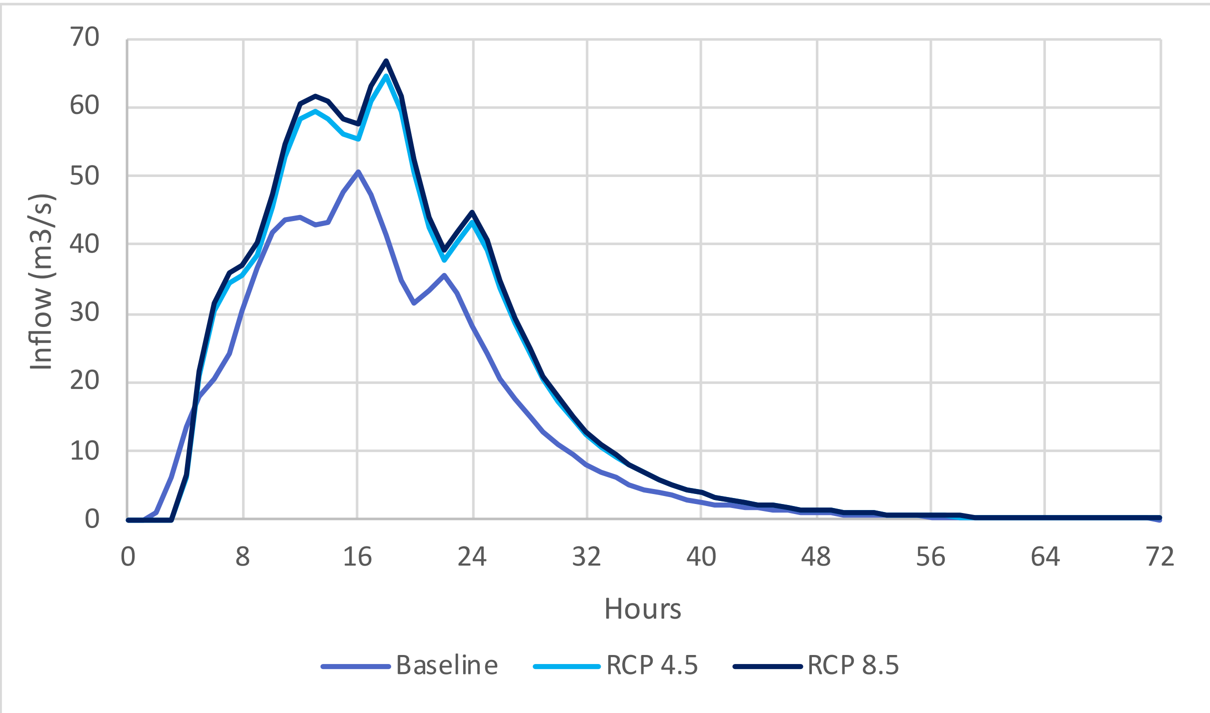

Figure 4-5 Comparison of 1% AEP inflow boundary condition hydrographs for climate change factors

4.4. Outflow

Locations where water exits the model domain (outflows) require boundary conditions to be specified. The concentrated flow path that exits the model domain was set to a normal depth boundary condition, using the uniform bed slope of that flow path as the estimated energy slope, as measured from the available terrain data. The normal depth boundary condition applied to the outlet was 0.01.

4.5. Computational mesh

A 2D flow area was delineated in HEC-RAS to coincide with the catchment boundary. A computational mesh spacing of 100 m by 100 m was applied across the regional catchment, as shown in Figure 4-6. HEC-RAS recognises the sub-grid terrain resolution within individual computational cells and the flow transfer calculations between individual grid cells account for the geometry of the underlying surface at the terrain resolution. This computational mesh was applied except as noted surrounding breaklines and the refinement regions.

Breaklines were used to alter the direction of grid cells to align with features within the catchment. Breaklines were implemented in the model for drainage lines as per Figure 2-1.

Refinement regions were used to denote areas where the computation mesh resolution required a finer scale than the overall mesh. The following refinement regions were specified:

- drainage line breaklines with a computational mesh of 50 m by 50 m
- approximately 100 m beyond the extent of the Project Site and immediately adjacent waterways with a computational mesh spacing of 10 m by 10 m.

Figure 4-6 outlines an example region of the computation mesh applied to the existing terrain, showing the mesh spacing, break lines and refinement regions applied.

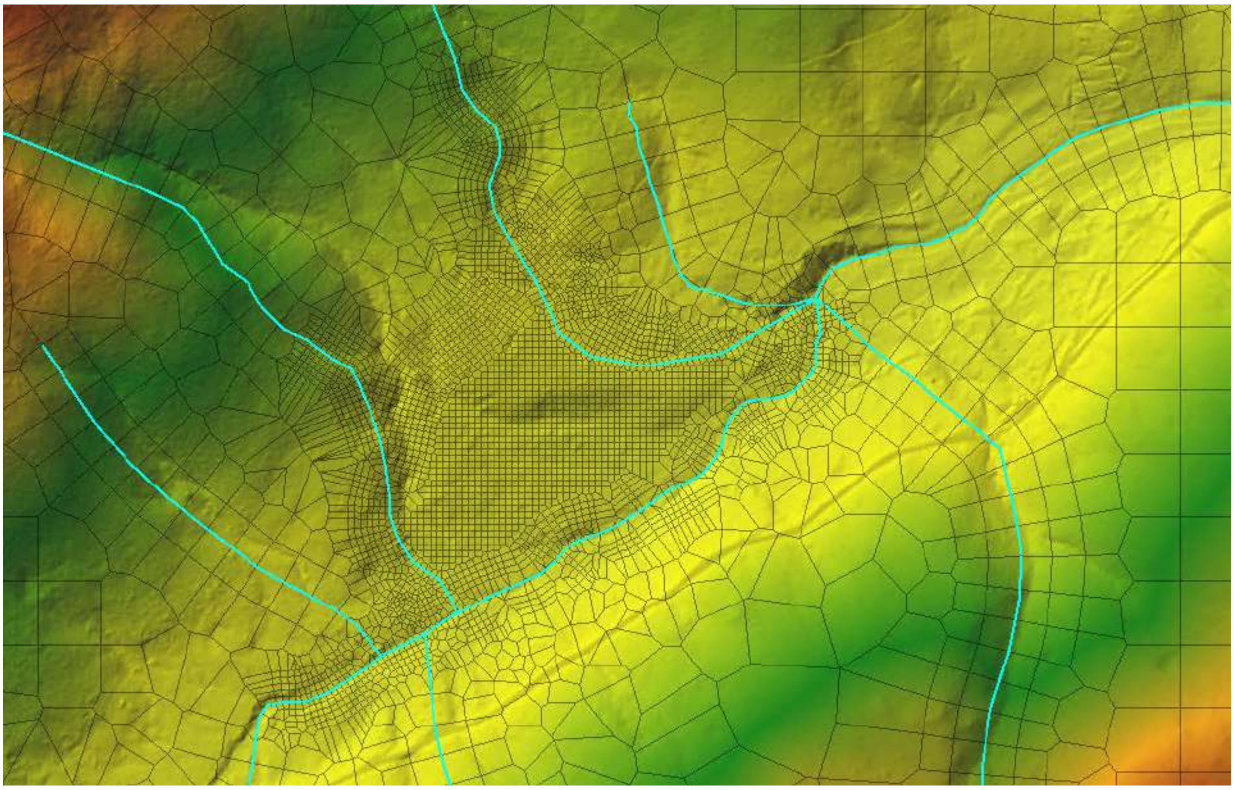

Figure 4-6 Example configuration of HEC-RAS computational mesh (black lines) and breaklines (blue lines)

4.6. Roughness

Roughness coefficients are used to define how quickly water moves across the terrain and controls the shape of flow hydrographs resulting from the rainfall and upstream flow. Typical roughness values are defined for the range of flow path extents, i.e. from concrete channels to floodplains. Modelling the full

2D catchment area which extends outside of normal channels and their corresponding slopes requires much larger roughness values than are typically applied to models that just model streamflow.

An initial roughness coefficient of 0.08, representing a natural channel condition, was applied to the whole model. This roughness was used in combination with a 10% AEP rainfall event to define waterway channel extents.

HEC-RAS has the ability to apply different roughness coefficients spatially across the model domain. This is achieved through applying a shapefile of "land cover" regions to the model and assigning a roughness coefficient to those regions independently. To improve accuracy of the hydraulics assessment, a roughness of 0.06 was applied to the land cover representing the channels that run through and adjacent to the Project Site as shown in Figure 4-7 (Chow, 1959).

Figure 4-7 Manning's n roughness coefficient specification (green is 0.08, blue is 0.06)

4.7. Computational settings

An adaptive computational time-step was applied based on a maximum Courant Number of 2.0. This results in a minimum adopted time-step of approximately 2 seconds. The Full Momentum equation set was adopted in the model to account for the varying flow directions. Mass balance errors and water surface elevation convergence errors were checked for model stability and to confirm that imbalances remained below reasonable thresholds for model stability. A 72-hour simulation window was applied to capture critical-duration peak discharges and allow the flood peaks to propagate through the model.

Default threshold depths were decreased by one order of magnitude to capture the flow transfer effects of direct precipitation sheet flow across the catchment. Except where otherwise noted, other program defaults have been applied to all remaining coefficients, options, tolerances and model settings.

4.8. Model set-up summary

Table 4-5 below summarises the model parameters used for the catchment in this project.

Table 4-5 HEC-RAS parameters

Model Parameter	Value
Precipitation	10%, 1% and 0.1% AEP and PMF frequency storm excess precipitation hyetographs Existing conditions and RCP 4.5 and RCP 8.5 climate change scenarios for AEP events
Losses	IL = 19 mm CL = 2.4 mm Climate change factors applied for RCP 4.5 and RCP 8.5 scenarios for AEP events
Inflow	10%, 1% and 0.1% AEP and PMF frequency storm excess hydrographs Existing conditions and RCP 4.5 and RCP 8.5 climate change scenarios for AEP events Energy slope of 3%
Outflow	Normal depth slope of 1%
Simulation window	72 hours
Computational time step	Controlled by Courant number
Computational mesh grid	100 m by 100 m to 10 m by 10 m
Roughness	0.06 for channels adjacent to site, 0.08 for remaining catchment area including land cover and overland flow
Equation Set	Full Momentum
DEM grid resolution	2 m by 2 m supplemented by site survey information

5. Flood modelling results

5.1. Hydrologic results

5.1.1. Peak flows

The RORB model was run to provide verification flows for the water level modelling. The HEC-RAS model was subsequently calibrated to the RORB results. A summary of the peak flows for each modelled AEP and PMF scenario at the catchment outlet from the two modelling methods against expected peak flows based on historical rainfall and gauge records is provided in Table 5-1. Visual comparison of results to RFFE for the site is presented in Figure 5-1.

Table 5-1 Summary of design event peak flow rates at specified Thredbo River catchment outlet

Scenario	Expected range[1]	RORB peak flow (m^3/s)	HEC-RAS peak flow (m^3/s)
10% AEP	30 – 50	33	43
1% AEP	50 – 90	67	82
0.1% AEP	100 – 180	106	133
PMF	>360	392	382

[1] Determined by comparison of BoM IFD design curve to historical rainfall and corresponding peak discharge measured at Paddy's Corner (gauge 222541), linear regression for rainfall events >10% AEP and 60%-80% estimated reduction considering relatively decreased contributing catchment size at the site.

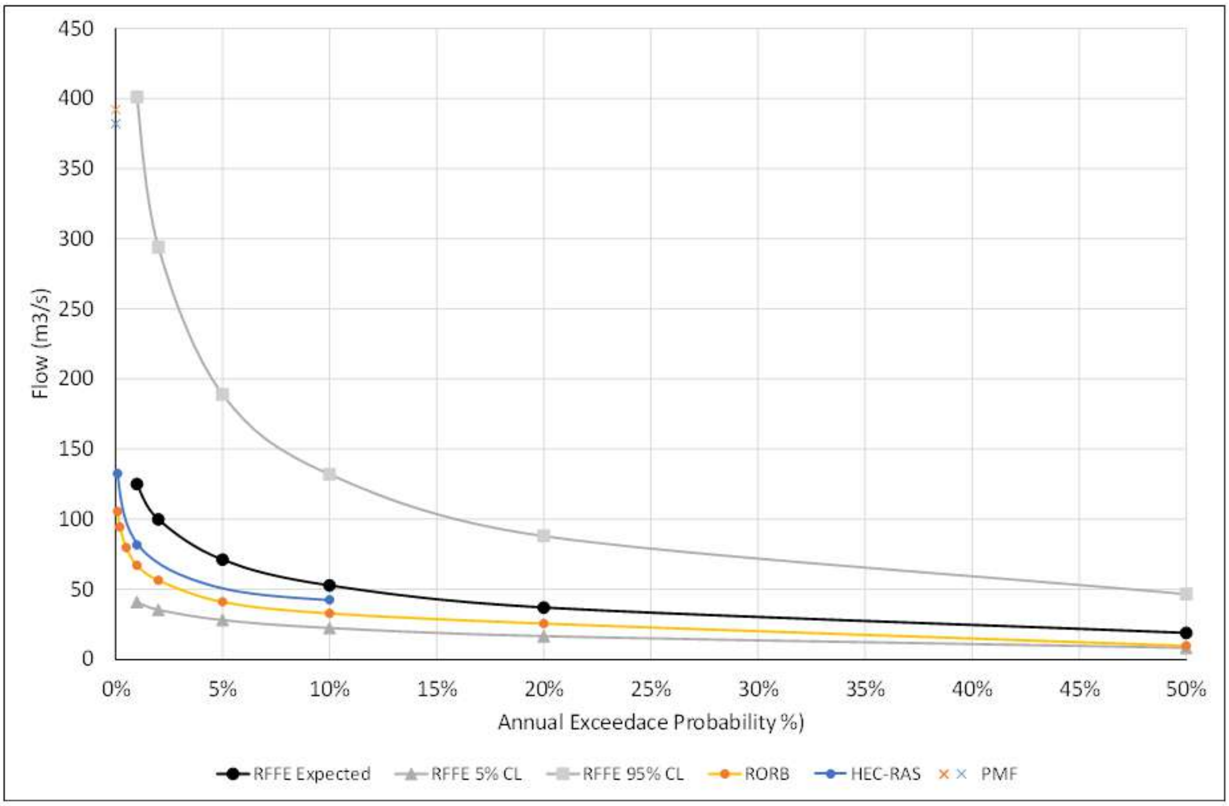

Figure 5-1 RORB and HEC-RAS peak discharge results at Thredbo River approximately 115 m downgradient of site

The comparison between modelled peak flows, RFFE, and the expected range based on nearby historical records validates the accuracy of the RORB and HEC-RAS peak flow results for this assessment. Moreover, given that the actual contributing catchment size at the site is only 14.8% of the catchment at the Paddy's Corner gauge, the determination of expected flow range, calibrated peak flows from RORB and HEC-RAS, and subsequent hydraulic modelling results presented in Section 5.2 are deemed representative of a conservative assessment of potential flood risk at the site.

5.2. Hydraulic results

For each AEP event, site and regional depth and velocity were extracted across the model domain and are discussed below. Maximum flood depths and velocities are presented in Appendix C1 and Appendix C2, respectively.

5.2.1. Depth and inundation extent

The flood depths for existing conditions at the Project site (Appendix C1) show that, in general, the flows are concentrated to the waterways and defined overland flow paths through and adjacent to the Project site with sufficient terrain relief to limit the amount of sheet flow.

The primary flood feature is Thredbo River, which flows to the north-east along the southern site boundary. During all flood events modelled the flow remained constrained to the channel and well-defined floodplain approximately 10-40m wide (see Appendix C1). As the proposed development generally allows a minimum 40m buffer corridor along the Thredbo River, risk of inundation to the proposed development area is low. However, larger flood events such as the 1% AEP scenario indicate inundation of the Thredbo River floodplain corridor outside the primary channel banks is likely to occur, particularly in the central southern and eastern portions of the site.

Secondary flood features include three unnamed drainage line tributaries to Thredbo River which flow through the site from the north-west to south-east. The three unnamed tributaries are located in the western, central and eastern portions of the site, respectively. Modelling indicates that both the central and eastern drainage lines intersect the proposed development footprint under each modelled scenario. However, predicted inundation depths remain relatively low (<0.5 m) and flood impacts should drain quickly following cessation of a storm event due to the gradient of the site. The deepest areas of induction, excluding the Thredbo River, are isolated areas on the western side of the site that may exceed 2 m depth under the 0.1% AEP event but do not intersect with the development footprint. Although minor potential impacts were identified, the flood model is considered a conservative assessment of potential impacts and major inundation is considered unlikely. Nevertheless, the proposed development design should consider stormwater management measures to sufficiently convey flows downgradient and limit ponding at the site.

Table 5-2 shows the maximum depth and flow velocity for the Project site and the proposed development footprint. The maximum modelled depth and velocity for the Project site in each scenario is within Thredbo River. Maximum depth results are within expected ranges based on comparison to historical water level gauge records for Thredbo River at Paddy's Corner (222541) (see Section 2.2). The remaining inundation across the Project site is generally shallow (<0.5 m), with isolated pockets of deeper water. Maximum depths for each modelled design storm AEP scenario are presented in Appendix C1.

Table 5-2 Max modelled depths and flow velocities for each AEP event

	Site[1]		Proposed development footprint	
Scenario	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
10% AEP	3.44	4.05	0.59	1.43
1% AEP	3.83	4.46	0.86	1.64
0.1% AEP	4.18	4.58	1.15	2.07
PMF[2]	5.14	6.06	2.27	3.83

[1] Project site borders Thredbo River; the maximum depth and velocities can be attributed to the river.

[2] PMF results are presented for comparative purposes only. The PMF event is defined as the limiting value of a flood that could reasonably be expected to occur based on the PMP design storm scenario. In this case, the PMF event is highly unlikely to occur within the life of the Project, with a calculated AEP of <0.0001% (10,000-year annual recurrence interval).

5.2.2. Peak velocities

Outside the channels discussed above, modelled velocities across the Project site typically range between 0.5 m/s and 1.5 m/s. The maximum modelled velocity in the development footprint under the 0.1% AEP event was 2.07 m/s, just above the 2 m/s threshold for rock armouring, and is shown in Appendix C2.

Mitigation strategies should be implemented should erosion form within these flow paths that intersect the proposed development. It is noted the proposed internal roads and emergency access track within the site are likely to remain passable under the 10% AEP flood conditions, with caution advised under any larger storm events.

5.2.3. Flood mapping

The maximum flood depths and velocities relevant to the Project site under modelled 1% AEP scenario are presented in Figure 5-2 and Figure 5-3, respectively.

A comparison of inundation extent and depth under each modelled AEP (10%, 1%, 0.1%) and PMF scenario is shown in Figure 5-4.

Depth and velocity mapping for each modelled AEP scenario are presented in Appendix C1 and Appendix C2, respectively.

Flood hazard classification mapping is included in Appendix D, and discussed in Section 5.3.

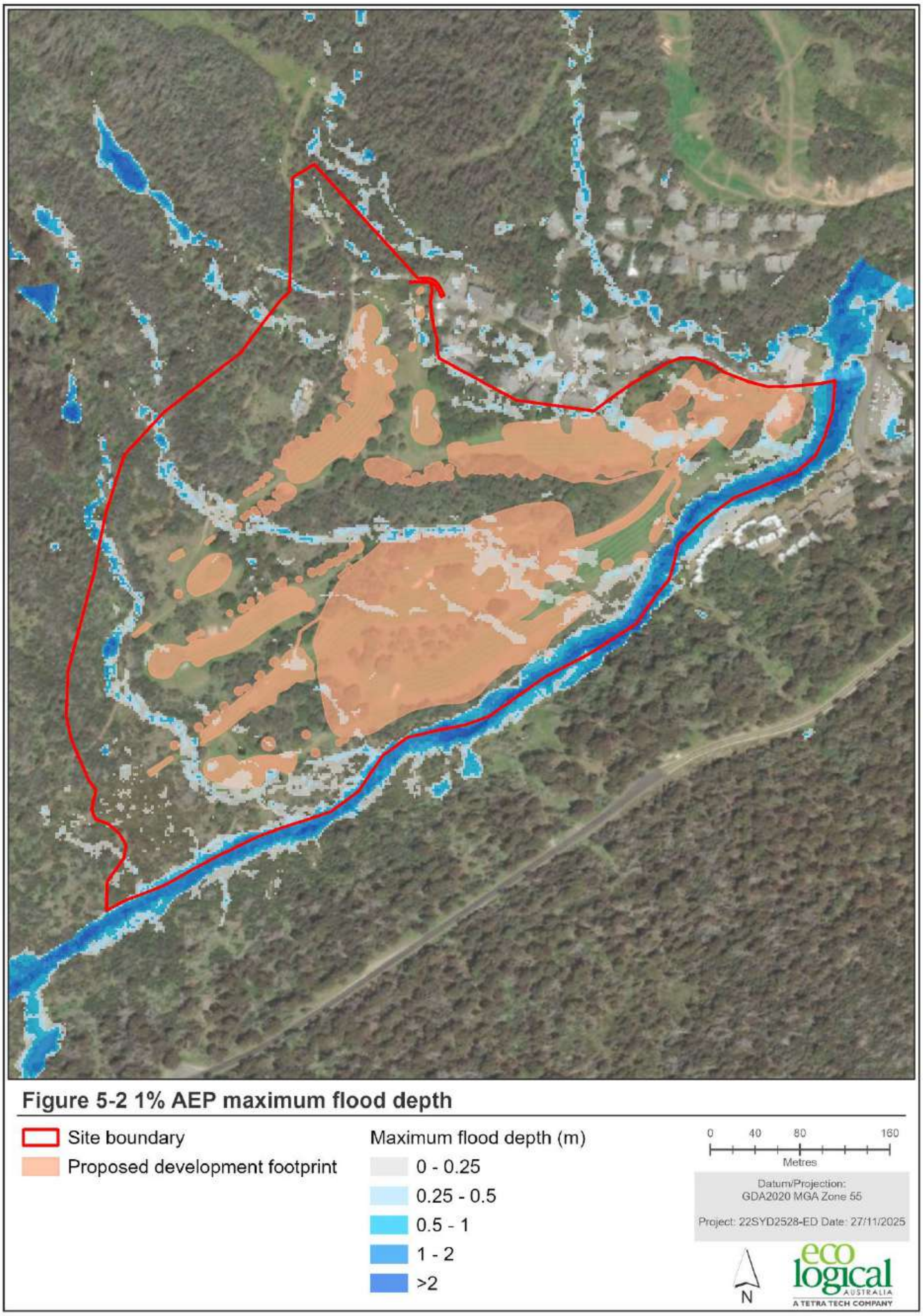

Figure 5-2 1% AEP maximum flood depth

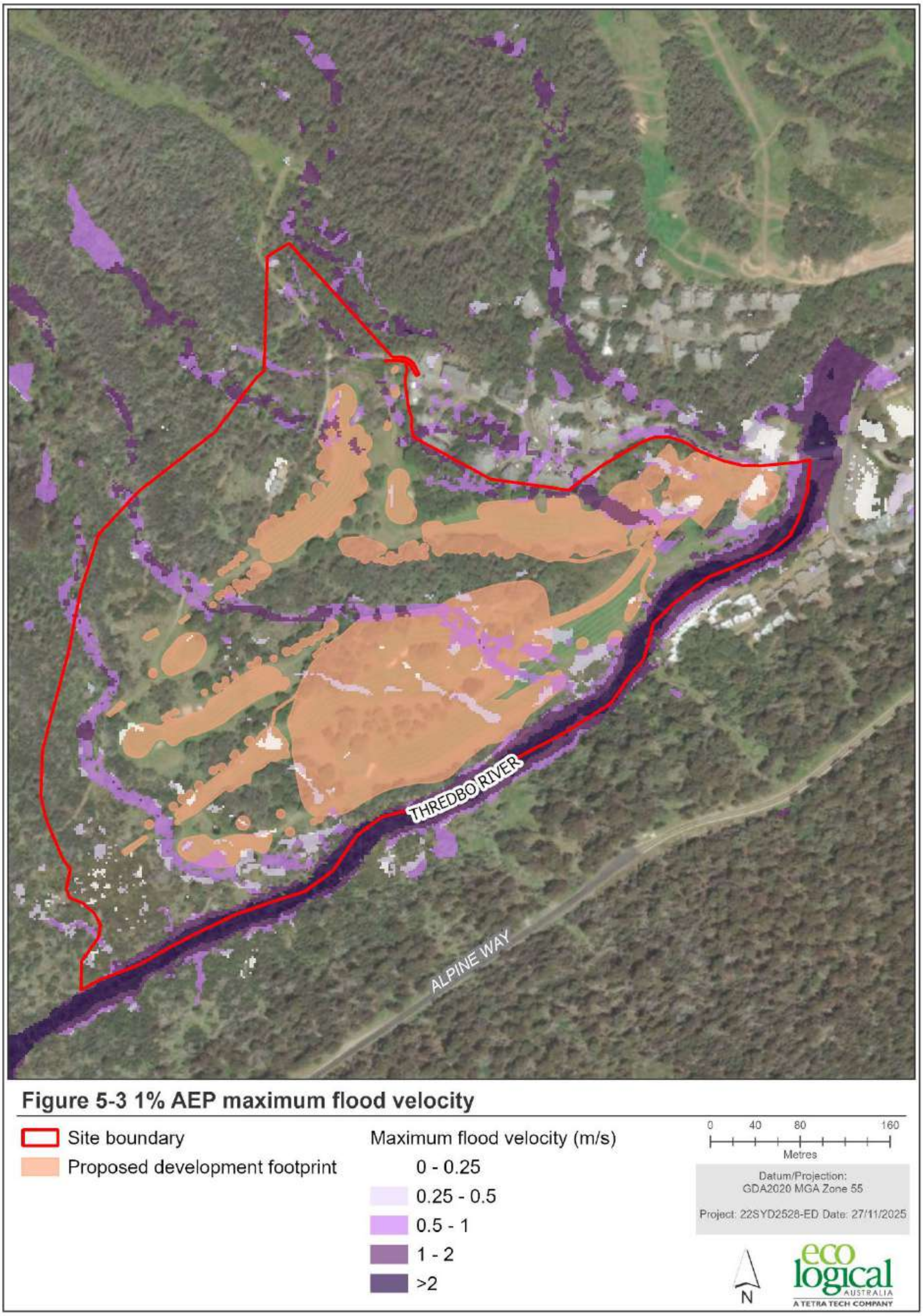

Figure 5-3 1% AEP maximum flood velocity

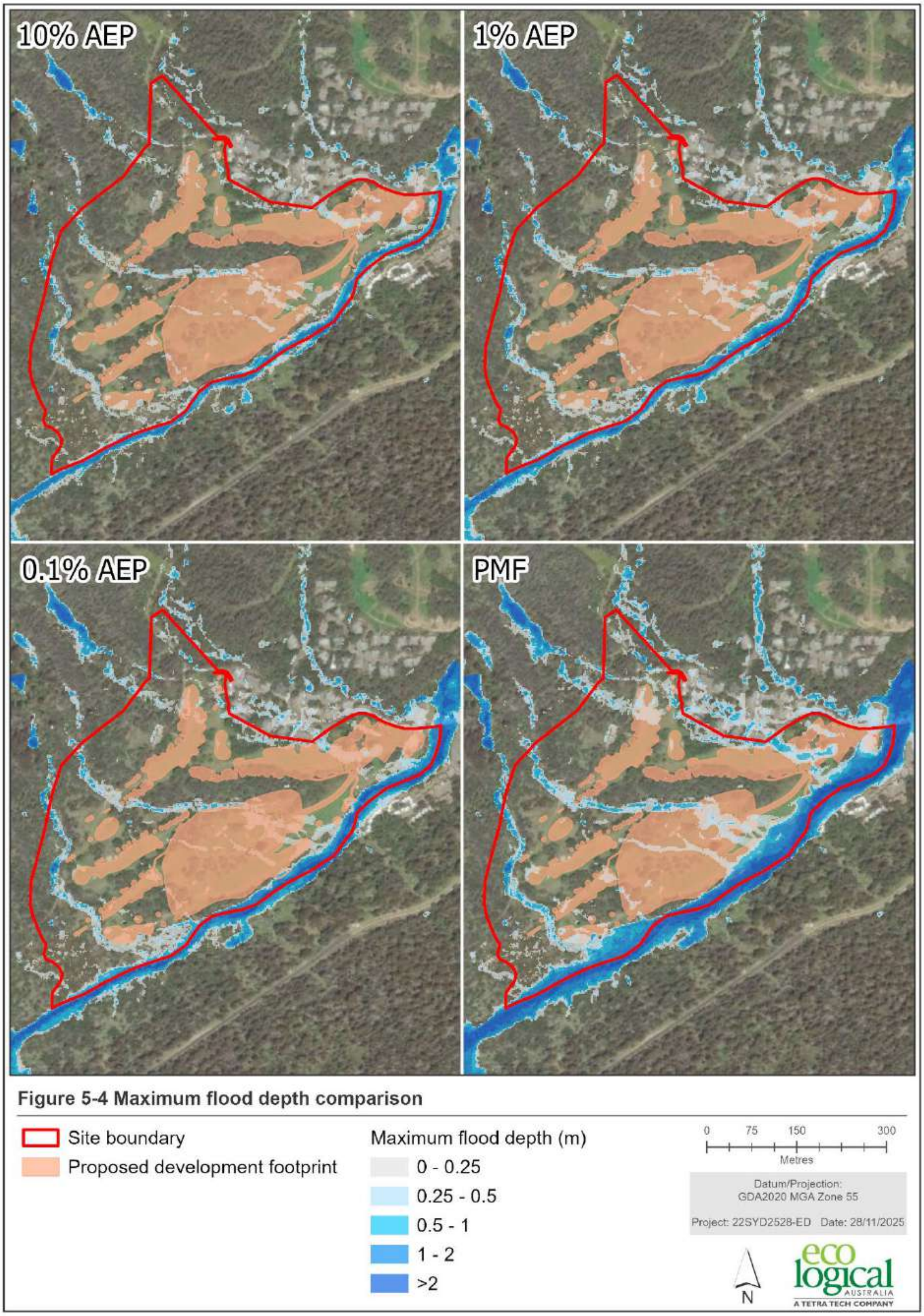

Figure 5-4 Maximum flood depth comparison

5.3. Flood hazard classification

The hydraulic flood modelling results (Section 5.2) were used to classify flood risk at the site in accordance with the NSW DPE (2023b) *Flood impact and risk assessment, Flood risk management guideline LU01* and NSW DPE (2023d) *Flood hazard*, *Flood risk management guideline FB03*.

The guidelines note that flood hazard conditions may exist without flood risk where no human interaction with flooding will occur (i.e. within the main channel of Thredbo River).

To determine maximum flood hazard classification for each design scenario, flood hazard vulnerability curves have been adopted from NSW DPE (2023d) defined thresholds, as summarised in Table 5-3.

Table 5-3 Flood classification vulnerability thresholds

Hazard vulnerability classification	Description	Limiting velocity (V) (m/s)	Limiting depth (D) (m)	Classification limit (m²/s)	Resulting hazard level
H1	Generally safe for vehicles, people and buildings	2.0	0.3	V x D ≤ 0.3	Low
H2	Unsafe for small vehicles	2.0	0.5	V x D ≤ 0.6	Medium
H3	Unsafe for vehicles, children and the elderly	2.0	1.2	V x D ≤ 0.6	High
H4	Unsafe for vehicles and people	2.0	2.0	V x D ≤ 1.0	High
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure	4.0	4.0	V x D ≤ 4.0	Extreme
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure	-	-	V x D > 4.0	Extreme

The maximum modelled depth and velocities at the site under each target AEP and PMF scenario were within the main Thredbo River channel. Therefore, this area has been excluded from the flood hazard classification summary below. However, management and emergency response measures still include consideration of this area given Thredbo River must be crossed to evacuate the site via Alpine Way. The maximum modelled flood depth and velocity for each scenario within the proposed development footprint (including access tracks) was compared to defined thresholds for each respective parameter.

It is noted that the maximum depth and velocity do not occur at the same location under any modelled scenario, therefore the calculated maximum product of velocity and depth is not equal to the product of the individual maximum parameters. Rather, all three identified maximums for each scenario are compared to their respective classification limits to determine the maximum flood hazard classification at the site outside of Thredbo River.

Results are shown relative to flood hazard vulnerability curves in Figure 5-5 with maximum resulting classification summarised in Table 5-4.

Table 5-4 Summary of flood hazard classification for proposed development

Scenario	Maximum V[1] (m/s)	Maximum D[1] (m)	Maximum V x D (m²/s)	Maximum flood hazard classification	Maximum hazard level
10% AEP	1.43	0.59	0.5	H3	High
1% AEP	1.64	0.86	1.1	H5	Extreme
0.1% AEP	2.07	1.15	2.2	H5	Extreme
PMF	3.83	2.27	8.7	H6	Extreme

[1] It is noted that the maximum depth and velocity do not occur at the same location under any modelled scenario, therefore the calculated maximum V x D is not equal to the product of the individual maximum parameters.

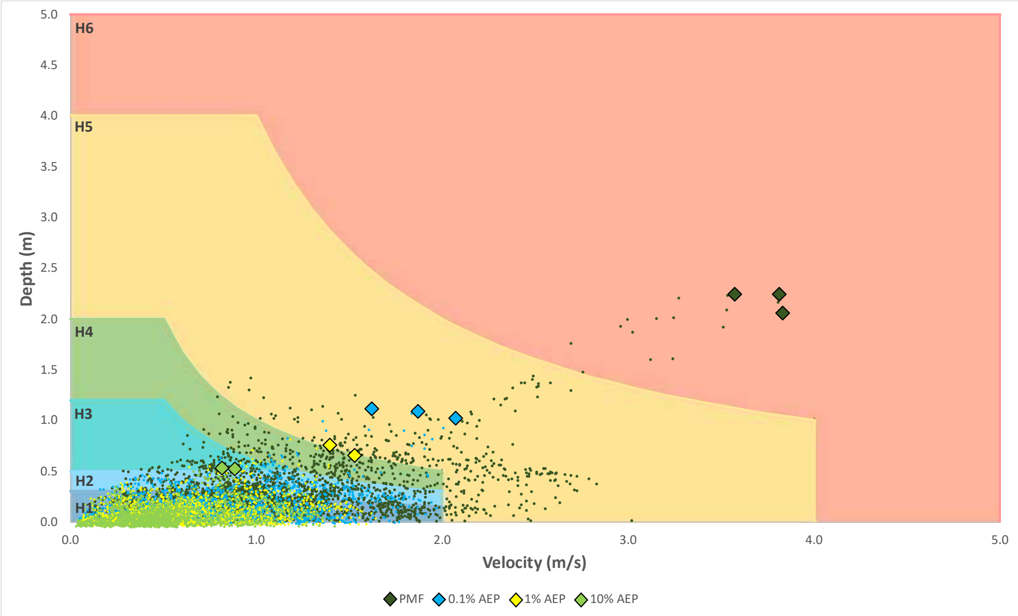

Figure 5-5 Comparison of flood modelling results to flood hazard classification curves (NSW DPE, 2023d)

The maximum flood hazard classification under the 10% AEP scenario was determined as H3 (unsafe for vehicles, children and the elderly) in isolated areas where the proposed access road west of the carpark intersects a natural drainage line. Under the 1% AEP scenario, flood hazard classification in some areas was escalated to H4 with some isolated pockets up to H5 (unsafe for vehicles and people) in the same access road near the carpark in the north-east portion of the site. Some isolated areas with H4 classification were also noted along the left bank of the central drainage feature within the lot development area. The 0.1% AEP scenario maximum flood hazard classification was generally consistent with the 1% AEP scenario, with isolated pockets classified up to H5.

The PMF flood risk is classified up to H6 (unsafe for vehicles and people, with all building types vulnerable to failure) in the areas noted above. As the modelled PMF event has a calculated AEP of <0.0001% (1 in 10,000-year flood scenario), it is considered extremely unlikely to occur within the life of the Project. Therefore, the PMF results are presented for comparative and emergency response purposes only.

It is important to note that although maximum flood hazard was classified as high (H3 for 10% AEP scenario) to extreme (H5 to H6 for 1% AEP, 0.1% AEP and PMF scenarios), the majority of the site and proposed development area is classified as H1 (generally safe for people, vehicles and buildings) as shown in the comparative flood hazard classification map presented as Figure 5-6.

A breakdown of the proportion of inundation area classified under each category by scenario is provided in Table 5-5 and is exemplified in Figure 5-6. Individual flood hazard classification maps for each scenario are included in Appendix D.

Table 5-5 Flood hazard classification proportion for development footprint

Flood hazard classification	10% AEP	1% AEP	0.1% AEP	PMF	Key
H1	94%	91%	86%	65%	>90%
H2	3%	3%	4%	4%	51-90%
H3	3%	5%	7%	19%	11-50%
H4	0%	0%	1%	6%	2-10%
H5	0%	1%	1%	5%	1%
H6	0%	0%	0%	1%	0%

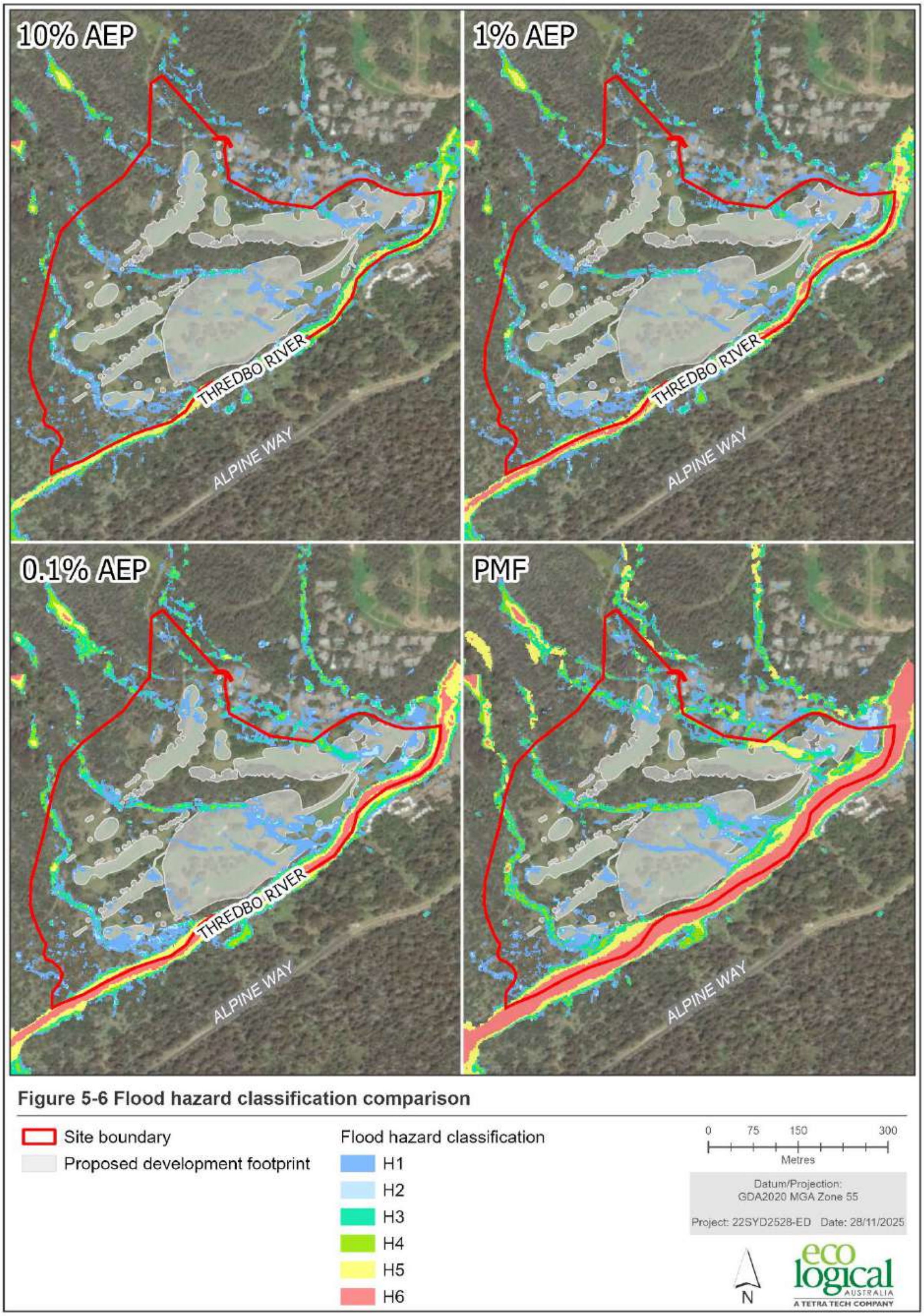

Figure 5-6 Flood hazard classification comparison

5.4. Climate change sensitivity analysis

Climate change sensitivity analysis was undertaken for the 10%, 1% and 0.1% AEP scenarios to assess potential changes under projected intermediate (RCP 4.5) and high-emissions (RCP 8.5) climate scenarios.

The differences in peak flows and hydraulic characteristics compared to baseline condition results are presented in Table 5-6. A comparison of peak flow results is shown in Figure 5-7, with maximum inundation differences exemplified for the 1% AEP scenario in Figure 5-8. Climate scenario sensitivity maps showing comparison of maximum modelled depths and velocities for each AEP event are provided in Appendix E.

Note, climate change sensitivity analysis was not undertaken for the PMF scenario due to the already extreme nature of the PMF event and considering assessment of climate change sensitivity for AEP event scenarios satisfies requirements of specified in Section 11.3 of the Snowy SAP Masterplan.

Table 5-6 Summary of climate change sensitivity results

Scenario	Peak flow (m^3/s)			Maximum depth[1] (m)			Maximum velocity[1] (m/s)		
	Baseline	RCP 4.5	RCP 8.5	Baseline	RCP 4.5	RCP 8.5	Baseline	RCP 4.5	RCP 8.5
10% AEP	42.5	47.6	49.2	0.59	0.61	0.61	1.43	1.49	1.51
1% AEP	81.6	96.8	100.7	0.86	0.95	0.98	1.64	1.74	1.77
0.1% AEP	132.6	162.0	168.4	1.15	1.30	1.33	2.07	2.34	2.39

[1] Maximum modelled depths and velocities extracted from proposed development footprint boundary for comparative purposes. Maximum depths and velocities within the modelled extent and site boundary occurred within the main channel of Thredbo River which borders the site to the south.

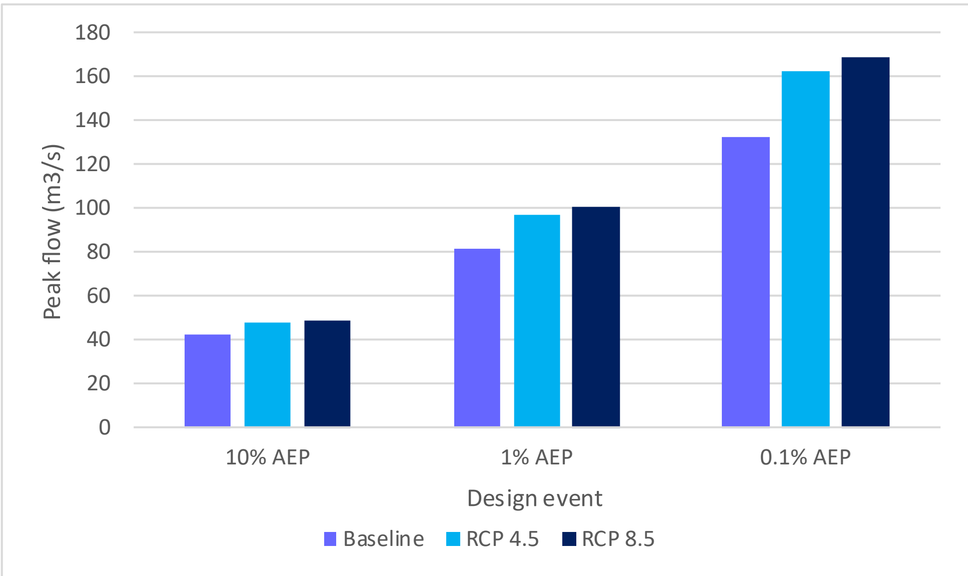

Figure 5-7 Peak flow comparison – climate change sensitivity

Although some hydrologic and hydraulic sensitivity to climate change factors was identified, the flood risk assessment and associated flood emergency management plan included consideration of the PMF event, which showed maximum modelled depth (2.27 m) and velocity (3.83 m/s) within the development footprint that exceeded the most extreme modelled climate change scenario (RCP 8.5 0.1% AEP). Therefore, sensitivity to climate change factors is considered acceptable for the purposes of this assessment.

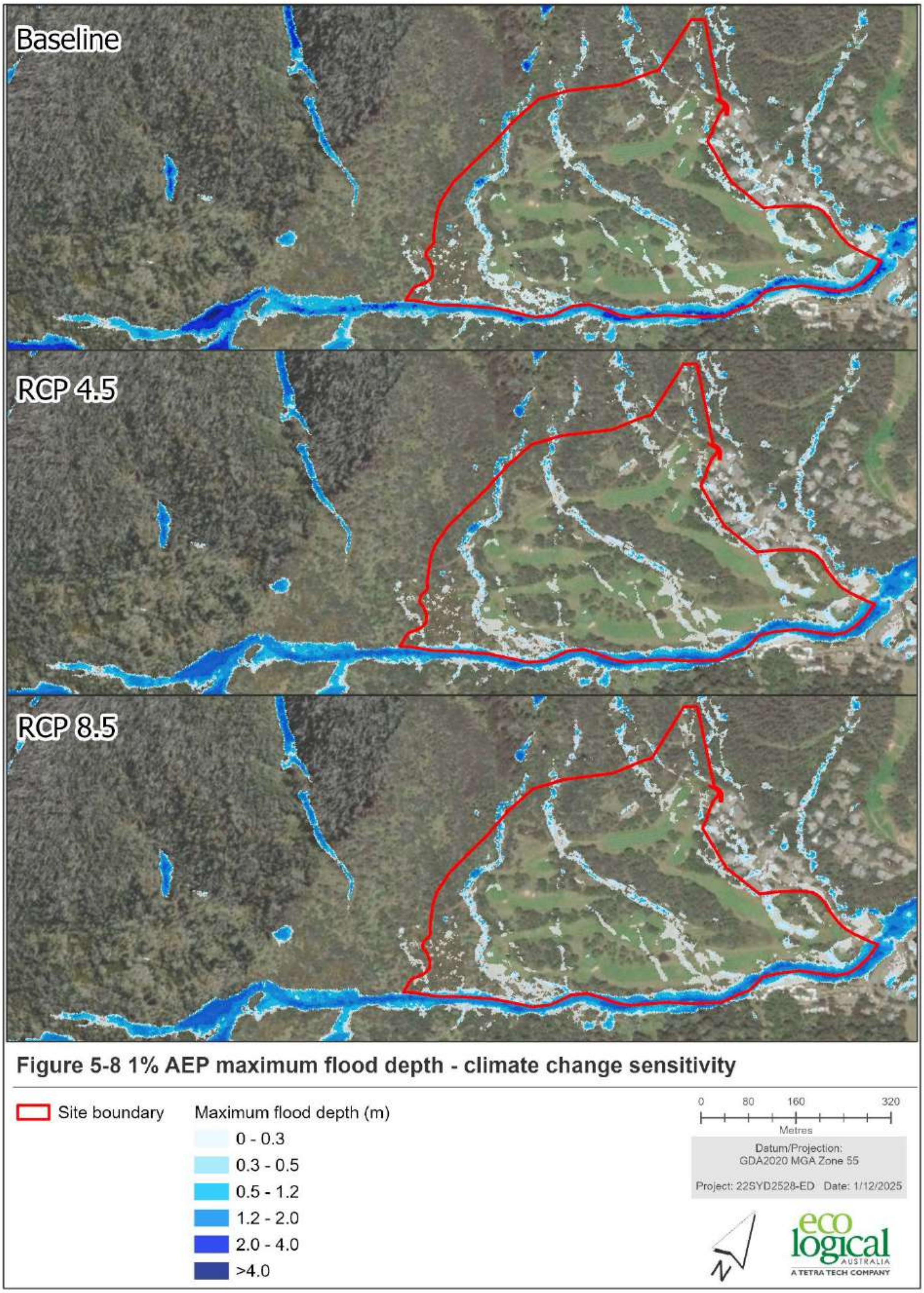

Figure 5-8 1% AEP maximum flood depth – climate change sensitivity

6. Flood risk assessment

6.1. Assessment method

The flood risk assessment was undertaken in accordance with the NSW *Flood risk management manual* (NSW DPE, 2023a) and the *Australian Disaster Resilience Handbook 10* (AIDR, 2015) using the following consecutive method for each design flood scenario (10% AEP, 1% AEP, 0.1% AEP and PMF):

- Consequence level criteria were defined for each type of consequence at the site based on guidance provided in the *Australian Disaster Resilience Handbook 10* (AIDR, 2015) (Section 6.3).
- The maximum flood hazard classification was reviewed against defined consequence level criteria for each category to determine the maximum consequence level under uncontrolled and controlled flood hazard conditions (Section 6.3).
- The highest consequence rating across all consequence categories was assessed against a qualitative risk matrix to determine initial and residual risk (Section 6.4).

6.2. Risk management

Flood risk management can include a combination of prevention, preparedness, response and recovery activities as shown in Figure 6-1.

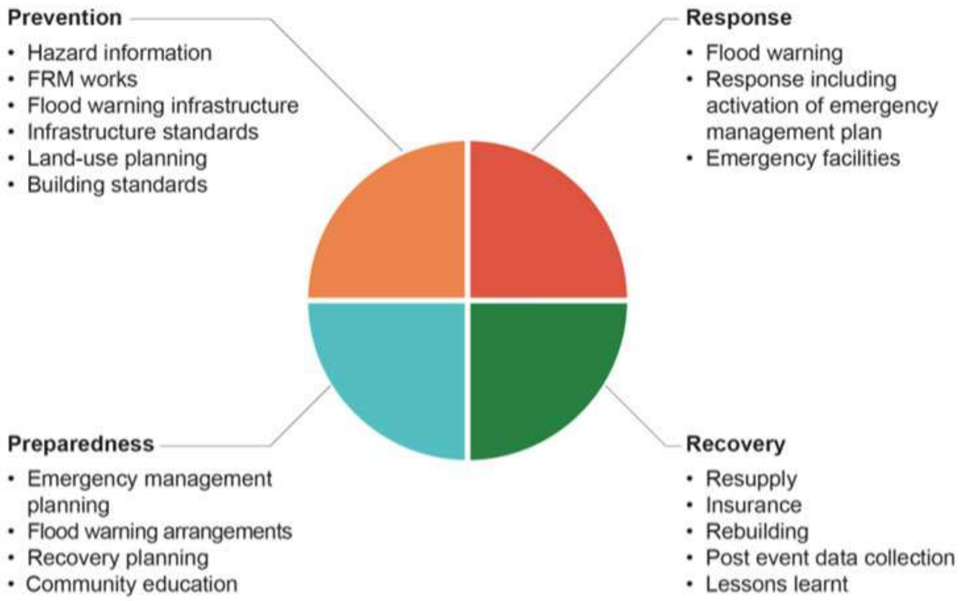

Figure 6-1 Types of flood risk management response (NSW DPE, 2023)

This FRM assessment focuses on prevention and preparedness measures using the following hierarchy:

- Risk avoidance or prevention measures that reduce exposure to flooding and/or limit the frequency or scale of flooding.
- Risk reduction measures that mitigate the consequences or likelihood of flooding.
- Risk acceptance, accepting the residual risk that exists.

This hierarchy has been considered in accordance with NSW DPE (2023) FRM Australian Disaster Resilience guidelines to inform assessment of potential consequences resulting from uncontrolled and controlled flood hazards, discussed in Section 6.3.

The risk management hierarchy has also been utilised to inform development of the site Emergency Management Plan (Section 8 below) which includes both flood risk management and emergency management measures.

6.3. Flood consequence levels

6.3.1. People

The maximum population of the Thredbo Golf Course development site has been conservatively estimated to be 400 people based on the following information:

- Up to 192 visitors based on 48 proposed car parks with capacity of 4 people per car.
- Up to 208 additional people to account for staff and other visitors to the site utilising off-site parking and/or other modes of transport.

Table 6-1 summarises the categorical criterion for level of consequence affecting people adopted and modified to reflect the relatively small maximum estimated population at the site.

Table 6-1 Criteria for people consequence categories

Level of consequence	Deaths[1]	Injuries or illness[2]		
		Critical[3]	Serious[4]	Minor[5]
Catastrophic	≥10	≥10	≥100	n/a
Major	1 - 9	1 - 9	≥10	n/a
Moderate	0	0	5 - 9	≥100
Minor	0	0	1 - 4	≥10
Insignificant	0	0	0	1 - 9

[1] Deaths include fatal or mortal injury that is certain to lead to death regardless of available treatments.

[2] Injuries or illness criteria apply to one or more injury/illness defined threshold for each consequence level.

[3] Critical injury/illness is defined as those that pose an immediate life-threatening condition if not treated adequately and expeditiously (i.e. uncontrolled bleeding, punctured organ, internal injuries, spinal column injuries, or crush syndrome).

[4] Serious injury/illness is defined as requiring medical care and medical technology but are not expected to press to life-threatening status (i.e. full thickness burns, loss of consciousness, bone fractures, dehydration, or exposure).

[5] Minor injury/illness is defined as requiring basic medical aid, bandages or observation that could be administered by paraprofessionals (i.e. sprain, severe cut requiring stitches, minor burns, or concussion without loss of consciousness).

Assessment of level of consequence for people based on the above criteria for both uncontrolled and managed flood hazard conditions at the site is summarised in Table 6-2.

Table 6-2 Potential people consequences

Scenario	Unsafe for[1]	Uncontrolled hazard			Controlled hazard		
		Deaths	Injuries	Level	Deaths	Injuries	Level
10% AEP	Small vehicles	0	1 - 4 serious	Minor	0	1 - 9 minor	Insignificant
1% AEP	Vehicles, children, elderly	1 - 9	1 – 9 critical	Major	0	1 - 9 minor	Insignificant
0.1% AEP	Vehicles, people	1 - 9	1 – 9 critical	Major	0	1 - 9 minor	Insignificant
PMF	Vehicles, people, buildings	≥10	≥10 critical	Catastrophic	0	1 - 9 minor	Insignificant

[1] Based on maximum flood hazard classification determined from hydraulic flood modelling results for the site excluding the main channel of Thredbo River.

6.3.2. Economy

Site-specific quantitative economic impact criteria cannot be specified as total activity, asset and industry value of the proposed development is unknown. A qualitative assessment of potential economic consequence has been undertaken based on default criteria as presented in Table 6-3.

Table 6-3 Criteria for economic consequence categories

Level of consequence	Economic impact[1]	
	Activity and assets[2]	Industry
Catastrophic	4%	Failure of a significant industry or sector in area of interest as a direct result of emergency event
Major	0.4%	Significant structural adjustment required by identified industry to respond and recover from emergency event
Moderate	0.04%	Significant industry or business sector disruption resulting in medium-term (i.e. more than one year) profit reductions directly attributable to the event
Minor	0.004%	Significant industry or business sector disruption resulting in short-term (i.e. less than one year) profit reductions directly attributable to the event
Insignificant	0.004%	Inconsequential business sector disruption

[1] Economic impact consequence level met when criteria for both activity/assets and industry impacts are met.

[2] Decline of economic activity and loss of asset value greater than specified percentage of gross product produced by area of interest.

Assessment of level of economic consequence based on the above criteria for both uncontrolled and managed flood hazard conditions at the site is summarised in Table 6-4.

Table 6-4 Potential economic consequences

Scenario	Uncontrolled hazard			Controlled hazard		
	Activity and assets	Industry	Level	Activity and assets	Industry	Level
10% AEP	<0.004%	Inconsequential	Insignificant	<0.004%	Inconsequential	Insignificant
1% AEP	Up to 0.004%	Short-term reduction	Minor	<0.004%	Inconsequential	Insignificant
0.1% AEP	Up to 0.04%	Medium-term reduction	Moderate	<0.004%	Short-term reduction	Minor
PMF	Up to 0.4%	Significant	Major	<0.004%	Medium-term reduction	Moderate

6.3.3. Environment

Environmental consequences criteria have been defined by state and national, regional and local risk considering loss of species and/or landscapes and loss of environmental values parameters. Local risks are considered to be most applicable to the site based on previous environmental investigations (ELA, 2023a) and the relatively small size of the proposed development.

In the context of emergency-related risk assessment, species and landscape loss includes destruction and degradation of environmental assets, species extinction and/or habitat range reduction (AIDR, 2015). Environmental values are defined as ecosystems with legislation- or policy-derived conservation statuses or conservation values recognised through legislation or policy.

Environmental consequence levels are determined by potential degree of permanent or long-term damage and relative importance of environmental assets, comprising both species/landscapes and environmental values. Degree of damage is categorised as follows:

- Permanent destruction – permanent loss of a species or ecosystem.
- Severe damage or loss – unlikely to return to pre-existing state but may recover to a steady stable state with assistance.
- Significant loss or impairment – high likelihood of recovery to pre-existing state with assistance or unassisted recovery over a long timeframe.
- Minor damage – unassisted recovery to a pre-existing state likely within a short timeframe, with impacts causing minimal disruption.

The adopted environmental consequences criteria for local risks are detailed in Table 6-5.

Table 6-5 Criteria for environmental consequence categories

	Species and/or landscapes[1]			
Level of consequence	**National[2]**	**State[3]**	**Regional/local[4]**	**Environmental values[5]**
Catastrophic	Significant loss or impairment	Severe damage or loss	Permanent destruction	Permanent destruction
Major	Minor damage	Significant loss or impairment	Severe damage or loss	Severe damage
Moderate	No damage or loss	Minor damage	Significant loss or impairment	Significant damage
Minor	No damage or loss	No damage or loss	Minor damage	Minor damage
Insignificant	No damage or loss	No damage or loss	No damage or loss	Inconsequential damage

[1] Species and/or landscape includes plant, animal, air, water and soils within an ecosystem.
[2] National environmental assets relevant to the site defined by the *Environment Protection and Biodiversity Conservation Act 1999* (DCCEEW, 2000).
[3] State environmental assets relevant to the site defined by the NSW *Biodiversity Conservation Act 2016* (NSW DPE, 2016).
[4] Regional/local environmental assets for the site defined by NSW South East Local Land Services (2022) and South East Region Conservation Alliance (2012).
[5] Environmental value includes environmental goods and services, including aesthetic and recreational facilities and resources.

Assessment of level of environmental consequence based on the above criteria for flood hazard conditions at the site is summarised in Table 6-6. Note, the level of environmental consequence is likely the same under uncontrolled and managed conditions due to the nature of potential impacts (i.e. the level of damage to local species/landscapes and environmental values downstream of the site will be the same regardless of flood risk controls on site).

Table 6-6 Potential environmental consequences

Scenario	**National**	**State**	**Regional/local**	**Environmental values**	**Level Of Consequence**
10% AEP	No damage or loss	No damage or loss	Minor damage	Minor damage	Minor
1% AEP	No damage or loss	Minor damage	Significant loss or impairment	No damage or loss	Moderate
0.1% AEP	Minor damage	Significant loss or impairment	Severe damage or loss	Minor damage	Major
PMF	Significant loss or impairment	Severe damage or loss	Permanent destruction	Permanent destruction	Catastrophic

6.3.4. Public administration

Potential public administration consequences are considered to be insignificant based on the assumption that flood conditions at the site will not affect governing bodies' ability to deliver core functions. Table 6-7 presents default criteria for reference.

Table 6-7 Criteria for public administration consequence categories

	Impact to governing bodies' core functions		
Level of consequence	**Delivery**	**Resource diversion**	**Requires external assistance**
Catastrophic	Unable to deliver	n/a	n/a
Major	Severe reduction	Significant	Majority
Moderate	Significant reduction	Some	Some
Minor	Limited reduction	None	None
Insignificant	Unaffected	None	None

6.3.5. Social setting

Social setting consequences are determined based on the following components, not to be confused with individual impacts assessed under people consequences criteria (Section 6.3.1):

- Community wellbeing – the ability of a community to support itself without the need for alternative arrangements.
- Cultural importance – destruction or loss of culturally important objects or events.

Although difficult to quantify, social setting consequences are considered applicable in consideration of emergency-related risks based on the assumption that culturally important gatherings and/or events may be held at the site. The adopted social setting consequence criteria are summarised in Table 6-8.

Table 6-8 Criteria for social setting consequence categories

	Community wellbeing			Cultural importance	
Level of consequence	**Social[1]**	**External resources[2]**	**Permanent dispersal**	**Object**	**Event**
Catastrophic	Irreparably broken	n/a	Entire	Widespread/ permanent loss	Permanent cancellation
Major	Significantly broken	Extraordinary	Significant	Widespread damage/loss	Temporary cancellation
Moderate	Broken	Significant	Some	Localised widespread damage	Delay
Minor	Damaged	Some	None	Damage	Reduced scope
Insignificant	Disrupted	Reallocation of existing	None	Minor damage	Minor delay

[1] Refers to social connectedness.

[2] Refers to external resources required to return the community to functioning effectively.

Assessment of level of social setting consequence based on the above criteria for flood hazard conditions at the site is summarised in Table 6-9. Note, the level of social setting consequence is considered the same under uncontrolled and managed conditions due to the nature of potential impacts (i.e. the level of consequence from impact to community wellbeing or cultural importance are unlikely to be affected by implementation of flood risk controls).

Table 6-9 Potential consequences for social settings

Scenario	Community wellbeing			Cultural importance		Level of Consequence
	Social[1]	External resources[2]	Permanent dispersal	Object	Event	
10% AEP	Broken	Significant	Some	Localised widespread damage	Delay	Moderate
1% AEP	Significantly broken	Extraordinary	Significant	Widespread damage/loss	Temporary cancellation	Major
0.1% AEP	Irreparably broken	Extraordinary	Significant	Widespread damage/loss	Temporary cancellation	Major
PMF	Up to Irreparably broken	n/a	Entire	Widespread Damage	Permanent cancellation	Catas-trophic

6.4. Flood risk assessment results

The maximum flood hazard classification was reviewed in the context of flood consequence level criteria for each type of consequence. The highest potential level of consequence was determined for both uncontrolled and managed flood hazard conditions to determine initial and residual risk. A summary of results is presented in Table 6-10.

Note, initial and residual consequences for environmental, public administration and social setting were considered consistent regardless of site flood risk management controls.

Therefore, the highest potential consequence rating for people and economic impacts was applied within the qualitative risk assessment matrix adopted from NSW DPE (2023c) to determine initial and residual risk ratings for the site.

The maximum initial consequence used is highlighted in red, while the maximum residual consequence is indicated in blue. The resulting relative initial and residual risk ratings are indicated in Table 6-11.

Table 6-10 Flood risk assessment summary

Scenario	Maximum hazard level (classification[1])	Initial					Residual	
		People	Economic	Env.	Public admin	Social	People	Economic
10% AEP	High (H3)	**Minor**	**Insig-nificant**	Minor	Insig-nificant	Moderate	**Insig.**	**Insig.**
1% AEP	Extreme (H5)	**Major**	**Minor**	Moderate	Insig-nificant	Major	**Insig.**	**Insig.**
0.1% AEP	Extreme (H5)	**Major**	**Moderate**	Major	Insig-nificant	Major	**Insig-nificant**	**Minor**
PMF	Extreme (H6)	**Catas-trophic**	**Major**	Catas-trophic	Insig-nificant	Catastr.	**Insig-nificant**	**Moderate**

[1] Flood hazard classification notes: H3 – unsafe for vehicles, children and the elderly; H5 – Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure; H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 6-11 Qualitative flood risk assessment results

Scenario	Likelihood of consequence	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
10% AEP	Likely	Low	**Medium**	High	Extreme	Extreme
1% AEP	Unlikely	Low	Low	Medium	**High**	Extreme
0.1% AEP	Rare to very rare	Very low	Low	Medium	**High**	High
PMF	Extremely rare	Very low	Very low	Low	Medium	**High**

Initial risk rating is indicated in red text. Residual risk is indicated in blue.

6.5. Flood emergency management plan

A flood emergency management plan has been developed for the site in accordance with NSW DPE (2023) FRM guidelines. In general, flood emergency management comprises three phases:

1. Preparation – this includes education and awareness of potential flood hazards before commencement of a flood event, identification of emergency response measures and designation of responsible personnel to implement emergency response.
2. Response – implementation of emergency response procedures before and during a flood event.
3. Recovery – physical and psychological repair following a flood event, including repair and maintenance of assets and access to counselling services for emergency response personnel and affected parties.

The emergency management plan developed for the site is attached to this FRM assessment report in Appendix F.

7. Limitations and uncertainties

The following uncertainties and limitations are inherent to flood behaviour modelling and should be considered in the context of this FRM assessment:

- Flood modelling was based on publicly available 2 m by 2 m LiDAR data supplemented by site survey information provided by KT. The resolution of model results is therefore commensurate to the highest resolution of underlying terrain data at any given location and may not reflect localised factors between terrain grid data or survey point locations, resulting in potential differences between predicted and actual flood levels at the site.

- 1D and 2D flood modelling assumes flat water surfaces as runoff propagates throughout the system, with no incorporation of wave action from wind or other potential sources of surface undulation. Due to the nature of the proposed development site in an alpine region with relatively high terrain relief, this limitation is considered of low risk in affecting modelled outcomes.

- No historical streamflow data was available for Thredbo River within the immediate vicinity of the site for model calibration purposes. Therefore, the model was calibrated to RFFE based on the nearest historical gauge located approximately 30 km downstream of the site, which has a much larger contributing catchment area.

- Although the hydrologic and hydraulic models for the site have been calibrated to RFFE and validated against historical streamflow downstream of the site and for nearby gauged catchments, there are inherent uncertainties in predictive modelling that are not completely removed by calibration. However, modelling for a range of events including the PMF scenario provides a conservative assessment of potential flood risk at the site, and there is overall high certainty in analysis of flood peak flows, inundation depths and velocities at the site.

- The evacuation and emergency response measures presented are based on results of modelling as calibrated to expected peak flows based on nearby gauged catchments and RFFE for the site. Although predictive modelling inherently carries some level of uncertainty, there is a reasonable level of confidence in the results based on the methods employed; therefore, the proposed emergency response measures are considered suitable for the proposed development.

8. Conclusion and recommendations

ELA was engaged by KT to assess potential flood impacts and associated flood risk under the 10%, 1%, 0.1% AEP and PMF events to support Development Application for expansion of the Thredbo Golf Course.

Hydrologic modelling was undertaken using the RORB software package to determine sub-catchment peak flows and verify peak flows from subsequent hydraulic modelling. Hydraulic modelling was conducted representing existing conditions using the HEC-RAS software package. HEC-RAS models were developed using a 2D rain-on-grid analysis to determine inundation extent, flood depth levels, flow velocities and flood hazard classification. The modelling methods were calibrated using best initial loss estimates based on previous similar modelling and RFFE analysis for the region.

The modelled flood depths showed that, in general, the flows are concentrated to the waterways and defined overland flow paths within the site with sufficient terrain relief to limit the amount (depth and velocity) of sheet flow. The primary flood features comprise Thredbo River, which borders the site to the south, and minor tributaries that intersect the site and proposed development footprint. The model predicts that these features stay largely confined to their banks and defined flood plains and their most significant impact is likely to affect access tracks at the site.

Maximum modelled depth outside these channels across the site were generally shallow (< 0.4 m) under each AEP scenario. However, greater inundation exceeding 0.5 m depth and 1.5 m/s velocity is likely under intense storm conditions (>1% AEP or approximately 206 mm rainfall in 24--hours) resulting in a maximum flood hazard classification up to H5 (unsafe for vehicles and people with buildings vulnerable to structural damage) in some isolated areas of site.

Although maximum flood hazard classification and associated risk based on assessment of potential consequences was medium to high under modelled events, the flood hazard across the majority of the site and proposed development footprint was much lower with over 85% of the inundation areas classified as H1 (generally safe for vehicles, people and buildings) up to the 0.1% AEP event. Emergency response measures to manage flood risk include flood hazard awareness education, monitoring of flood warning systems, early communications and evacuation/shelter response implementation, as required, and post-flood recovery including asset inspection and repair.

Table 8-1 Summary of qualitative relative flood risk

Scenario	Summary of potential flood impacts	Initial risk rating	Residual risk rating
10% AEP	Maximum flood hazard of H3 (unsafe for vehicles and people) in limited area north of carpark. Primarily safe for vehicles and people across site.	Medium	Low
1% AEP	Maximum flood hazard of H5 (unsafe for vehicles and people, buildings subject to failure) in limited area north of carpark. Emergency management procedures adequately limit risk to low.	High	Low
0.1% AEP	Maximum flood hazard of H5 (unsafe for vehicles and people, buildings subject to failure) in limited area north of carpark. Emergency management procedures adequately limit risk to low.	High	Low
PMF	Maximum flood hazard of H6 (unsafe for vehicles and people, buildings subject to failure). Emergency management procedures adequately limit risk to low and scenario is highly unlikely to occur within life of project.	High	Low

Based on results of the FRM assessment, it is considered that the proposed design meets design requirements specified in the Snowy SAP Masterplan from a flood risk perspective.

9. References

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Appendix A AR&R inputs

A1 IFD table

Table A- 1 Rainfall depths for 50% to 0.1% design rainfall events

Duration	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%
1 min	1.63	2.26	2.72	3.21	3.91	4.49	5.03	5.71	6.25
2 min	2.74	3.73	4.42	5.11	6.03	6.74	7.53	8.58	9.42
3 min	3.77	5.14	6.12	7.11	8.43	9.48	10.6	12.1	13.2
4 min	4.66	6.39	7.64	8.91	10.7	12.1	13.5	15.3	16.8
5 min	5.42	7.47	8.97	10.5	12.7	14.4	16.1	18.3	20.1
10 min	8.11	11.3	13.7	16.2	19.9	22.9	25.7	29.1	31.8
15 min	9.83	13.7	16.6	19.7	24.3	28.1	31.5	35.7	39
20 min	11.1	15.5	18.8	22.3	27.3	31.6	35.4	40.2	43.9
25 min	12.2	17	20.5	24.3	29.7	34.2	38.4	43.6	47.7
30 min	13.1	18.2	22	25.9	31.7	36.4	40.8	46.3	50.7
45 min	15.5	21.3	25.5	30	36.2	41.3	46.2	52.5	57.5
1 hour	17.5	23.9	28.5	33.2	39.8	45.1	50.5	57.4	62.8
1.5 hour	21	28.4	33.6	38.9	46	51.6	57.7	65.6	71.8
2 hour	24.1	32.4	38.1	43.9	51.5	57.4	64.2	73	79.9
3 hour	29.9	39.7	46.4	52.9	61.5	68.1	76.3	86.5	94.6
4.5 hour	37.5	49.4	57.3	65.1	75.2	82.9	92.8	105	115
6 hour	44.2	58	67.2	76	87.7	96.5	108	123	134
9 hour	55.8	72.9	84.2	95.1	110	121	136	154	168
12 hour	65.5	85.4	98.7	111	129	142	160	181	197
18 hour	80.7	105	122	138	160	178	199	226	247
24 hour	92	120	139	158	185	206	230	261	286
30 hour	101	132	153	174	204	228	259	296	326
36 hour	108	141	164	186	220	246	280	321	354
48 hour	118	155	180	205	243	273	308	354	390
72 hour	130	172	201	228	271	305	339	388	427
96 hour	139	184	214	243	288	324	358	408	448
120 hour	146	193	225	255	301	338	373	424	464
144 hour	154	202	235	266	313	350	388	440	481
168 hour	162	212	246	278	325	362	402	455	497

A2 Available temporal patterns

Available durations of point and areal temporal patterns are shown in Table A- 2 and Table A- 3 , respectively, compared to available IFD information. The shaded boxes are those where IFD information is available, but for which no temporal pattern durations are available. Point (local) temporal patterns are typically used for catchments less than 75 km² in size. Using the point temporal patterns over the areal patterns generally produces a more conservative (higher) estimation of the peak flows within the catchment and is considered suitable in this instance as the relevant catchment size is less than 75 km².

Table A- 2 Available point temporal pattern durations from AR&R

Durations				
1 minute	15 minutes	1.5 hours	12 hours	72 hours
2 minutes	20 minutes	2 hours	18 hours	96 hours
3 minutes	25 minutes	3 hours	24 hours	120 hours
4 minutes	30 minutes	4.5 hours	30 hours	144 hours
5 minutes	45 minutes	6 hours	36 hours	168 hours
10 minutes	1 hour	9 hours	48 hours	

Table A- 3 Available areal temporal pattern durations from AR&R

Durations				
1 minute	15 minutes	1.5 hours	12 hours	72 hours
2 minutes	20 minutes	2 hours	18 hours	96 hours
3 minutes	25 minutes	3 hours	24 hours	120 hours
4 minutes	30 minutes	4.5 hours	30 hours	144 hours
5 minutes	45 minutes	6 hours	36 hours	168 hours
10 minutes	1 hour	9 hours	48 hours	

A3 Data Hub results

Data

River Region

Division	South East Coast (Victoria)
River Number	2
River Name	Snowy River

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v1

ARF Parameters

$$
\begin{aligned}
ARF = Min\Big\{1, \Big[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} \\
+ eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) \\
+ h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\Big]\Big\}
\end{aligned}
$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v1

Short Duration ARF

$$
\begin{aligned}
ARF = Min\Big[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).\,Duration^{-0.36} \\
+ 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.\,Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) \\
+ 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\Big]
\end{aligned}
$$

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	9982.0
Storm Initial Losses (mm)	29.0
Storm Continuing Losses (mm/h)	5.4

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v1

Temporal Patterns | Download (.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v2

BOM IFDs

Click here to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	12 June 2025 12:21PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.005)	0.3 (0.007)
90 (1.5)	0.8 (0.038)	0.6 (0.022)	0.5 (0.016)	0.4 (0.011)	0.6 (0.012)	0.7 (0.013)
120 (2.0)	3.0 (0.124)	2.6 (0.080)	2.3 (0.060)	2.0 (0.047)	0.9 (0.018)	0.0 (0.001)
180 (3.0)	3.8 (0.126)	2.4 (0.061)	1.5 (0.033)	0.7 (0.013)	0.7 (0.011)	0.7 (0.010)
360 (6.0)	4.2 (0.096)	8.1 (0.139)	10.6 (0.158)	13.1 (0.172)	12.4 (0.142)	12.0 (0.124)
720 (12.0)	3.1 (0.047)	8.6 (0.101)	12.3 (0.125)	15.9 (0.142)	18.5 (0.144)	20.6 (0.144)
1080 (18.0)	1.7 (0.021)	6.4 (0.060)	9.4 (0.078)	12.4 (0.090)	16.1 (0.101)	18.9 (0.107)
1440 (24.0)	0.8 (0.009)	4.6 (0.038)	7.1 (0.051)	9.5 (0.060)	10.4 (0.056)	11.0 (0.054)
2160 (36.0)	0.0 (0.000)	0.8 (0.005)	1.3 (0.008)	1.8 (0.009)	2.2 (0.010)	2.6 (0.011)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.3 (0.004)	0.5 (0.006)	0.8 (0.007)	0.6 (0.005)	0.5 (0.003)
1080 (18.0)	0.0 (0.000)	0.6 (0.006)	1.1 (0.009)	1.5 (0.011)	0.9 (0.006)	0.5 (0.003)
1440 (24.0)	0.0 (0.000)	0.2 (0.002)	0.3 (0.002)	0.5 (0.003)	0.3 (0.002)	0.2 (0.001)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.3 (0.590)	8.6 (0.361)	7.5 (0.263)	6.4 (0.193)	10.6 (0.265)	13.7 (0.303)
90 (1.5)	15.0 (0.715)	15.7 (0.552)	16.1 (0.479)	16.5 (0.425)	14.8 (0.322)	13.5 (0.261)
120 (2.0)	15.4 (0.636)	17.6 (0.544)	19.1 (0.501)	20.6 (0.469)	15.5 (0.302)	11.8 (0.205)
180 (3.0)	17.2 (0.575)	17.0 (0.427)	16.8 (0.363)	16.7 (0.315)	18.3 (0.298)	19.6 (0.287)
360 (6.0)	17.7 (0.401)	27.3 (0.471)	33.7 (0.502)	39.8 (0.524)	35.5 (0.405)	32.3 (0.335)
720 (12.0)	15.8 (0.241)	28.9 (0.338)	37.5 (0.380)	45.8 (0.411)	56.3 (0.436)	64.1 (0.450)
1080 (18.0)	9.0 (0.112)	20.9 (0.199)	28.9 (0.237)	36.4 (0.265)	41.8 (0.261)	45.8 (0.258)
1440 (24.0)	10.2 (0.111)	18.2 (0.151)	23.5 (0.169)	28.6 (0.181)	29.5 (0.159)	30.1 (0.146)
2160 (36.0)	6.2 (0.057)	10.0 (0.071)	12.5 (0.076)	14.9 (0.080)	18.1 (0.082)	20.5 (0.083)
2880 (48.0)	1.1 (0.009)	3.5 (0.023)	5.2 (0.029)	6.8 (0.033)	7.2 (0.030)	7.5 (0.027)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.4 (1.168)	21.7 (0.908)	22.5 (0.790)	23.3 (0.702)	22.8 (0.574)	22.5 (0.498)
90 (1.5)	25.7 (1.227)	28.4 (1.002)	30.2 (0.900)	31.9 (0.822)	31.2 (0.678)	30.6 (0.593)
120 (2.0)	32.2 (1.333)	36.4 (1.123)	39.2 (1.027)	41.8 (0.954)	43.5 (0.846)	44.8 (0.781)
180 (3.0)	32.0 (1.071)	34.0 (0.857)	35.3 (0.762)	36.6 (0.692)	44.0 (0.715)	49.5 (0.726)
360 (6.0)	39.8 (0.900)	56.6 (0.976)	67.7 (1.008)	78.4 (1.031)	77.0 (0.879)	76.1 (0.788)
720 (12.0)	32.6 (0.498)	49.7 (0.582)	61.0 (0.618)	71.9 (0.645)	97.7 (0.758)	117.1 (0.823)
1080 (18.0)	28.5 (0.353)	48.2 (0.458)	61.2 (0.503)	73.7 (0.535)	82.1 (0.512)	88.5 (0.498)
1440 (24.0)	26.6 (0.289)	45.5 (0.378)	58.0 (0.416)	70.0 (0.444)	70.6 (0.383)	71.1 (0.346)
2160 (36.0)	35.7 (0.332)	36.1 (0.255)	36.3 (0.221)	36.5 (0.196)	42.3 (0.193)	46.7 (0.190)
2880 (48.0)	8.5 (0.073)	18.5 (0.119)	25.1 (0.139)	31.4 (0.153)	35.0 (0.144)	37.7 (0.138)
4320 (72.0)	10.1 (0.078)	9.9 (0.058)	9.8 (0.049)	9.6 (0.042)	21.2 (0.078)	29.9 (0.098)

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	**1.22**	**1.2**	**1.18**	**1.17**	**1.15**	**1.15**	**1.14**	**1.13**	**1.12**	**1.11**
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	**1.23**	**1.21**	**1.2**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**	**1.13**	**1.12**
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	**1.27**	**1.24**	**1.23**	**1.21**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	**1.4**	**1.36**	**1.34**	**1.31**	**1.28**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	**1.29**	**1.26**	**1.24**	**1.22**	**1.2**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	**1.59**	**1.53**	**1.49**	**1.44**	**1.4**	**1.38**	**1.35**	**1.33**	**1.3**	**1.29**
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.05**
2040	1.05	1.06	1.06	1.07
2050	**1.06**	**1.07**	**1.07**	**1.08**
2060	1.06	1.07	1.09	1.1
2070	1.06	1.08	1.1	1.12
2080	1.06	1.09	1.12	1.14
2090	**1.06**	**1.09**	**1.13**	**1.17**
2100	1.06	1.1	1.15	1.19

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.1**	**1.1**	**1.1**	**1.11**
2040	1.12	1.12	1.13	1.14
2050	**1.12**	**1.15**	**1.16**	**1.18**
2060	1.13	1.17	1.19	1.23
2070	1.13	1.18	1.23	1.28
2080	1.13	1.2	1.27	1.33
2090	**1.13**	**1.21**	**1.31**	**1.39**
2100	1.12	1.22	1.34	1.44

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	17.4	13.0	11.6	12.0	11.7	11.2
90 (1.5)	20.8	11.6	10.5	10.9	10.9	9.6
120 (2.0)	19.5	11.1	9.9	10.0	9.7	8.8
180 (3.0)	19.3	12.4	11.2	11.8	10.4	8.5
360 (6.0)	17.4	11.2	9.9	8.9	7.6	5.4
720 (12.0)	19.2	12.5	11.4	9.7	7.5	3.6
1080 (18.0)	21.9	14.6	13.5	11.9	11.3	5.0
1440 (24.0)	22.7	16.2	15.0	14.2	14.6	6.6
2160 (36.0)	23.5	19.0	20.4	20.1	18.9	10.3
2880 (48.0)	28.4	22.7	23.0	24.6	22.9	12.7
4320 (72.0)	28.7	25.1	27.1	30.7	25.5	16.2

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

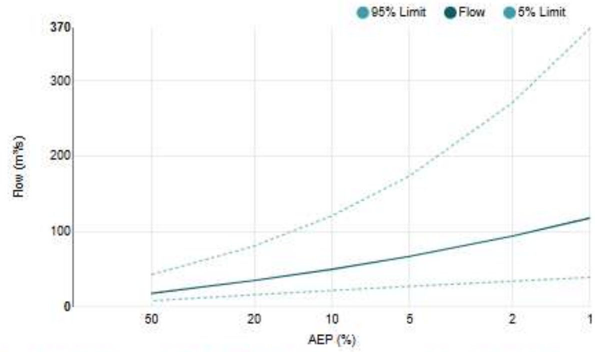
Downstream	10987
Area (km2)	785.663808
Catchment Number	10960
Volume Factor	0.328779
Peak Factor	0.081421

Layer Info

Time Accessed	12 June 2025 12:21PM
Version	2016_v1

A4 RFFE Results

Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	18.1	8.14	42.9
20	35.1	16.3	80.8
10	50.0	21.9	121
5	67.2	27.4	174
2	94.2	34.2	271
1	118	39.3	370

Input Data	
Date/Time	2025-06-12 12:31
Catchment Name	Thredbo River
Latitude (Outlet)	-36.5052
Longitude (Outlet)	148.3015
Latitude (Centroid)	-36.5266
Longitude (Centroid)	148.2887
Catchment Area (km^2)	36.2
Distance to Nearest Gauged Catchment (km)	27.5
50% AEP 6 Hour Rainfall Intensity (mm/h)	7.674166
2% AEP 6 Hour Rainfall Intensity (mm/h)	15.176097
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.44*
Interpolation Method	Natural Neighbour
Bias Correction Value	-0.217

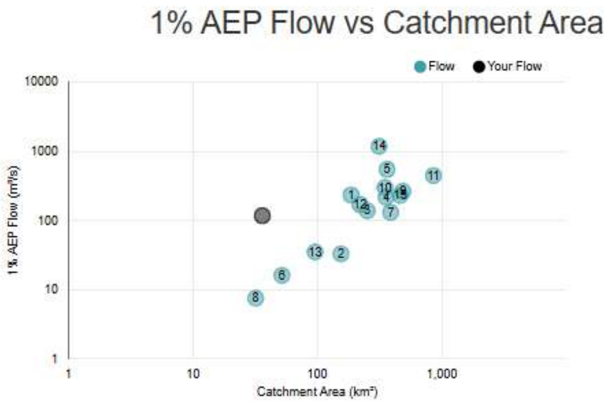
Statistics

Variable	Value	Standard Dev
Mean	2.734	0.651
Standard Dev	0.783	0.328
Skew	0.087	0.027

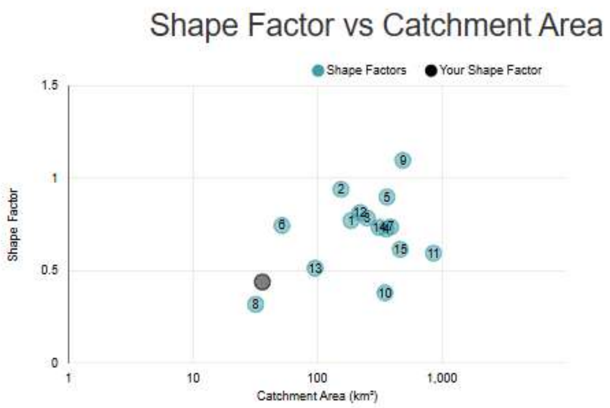
Note: These statistics come from the nearest gauged catchment. Details.

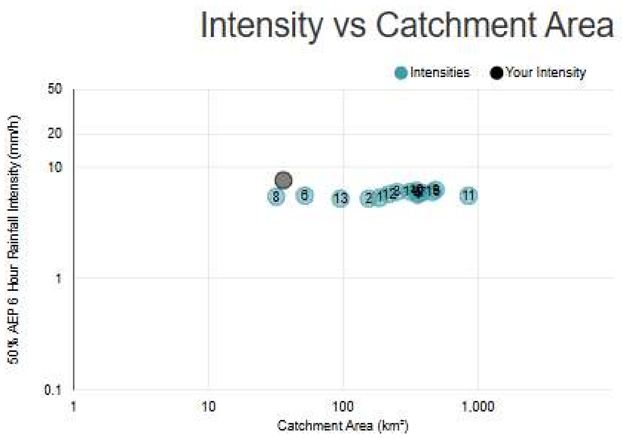
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

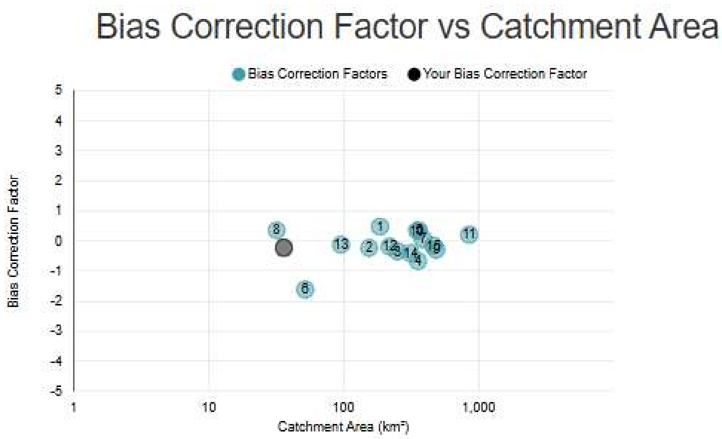
Note: These statistics are common to each region. Details.


1% AEP Flow vs Catchment Area
Flow
Your Flow
10000
1000
100
10
1
1% AEP Flow (m³/s)
1
10
100
1,000
Catchment Area (km²)


Canberra
Albury
Leaflet | © OpenStreetMap contributors


Shape Factor vs Catchment Area
Shape Factors
Your Shape Factor
1.5
1
0.5
0
Shape Factor
1
10
100
1,000
Catchment Area (km²)


Intensity vs Catchment Area
Intensities
Your Intensity
50% AEP 6 Hour Rainfall Intensity (mm/h)
Catchment Area (km²)


Bias Correction Factor vs Catchment Area
Bias Correction Factors
Your Bias Correction Factor
Bias Correction Factor
Catchment Area (km²)

Appendix B RORB hydrologic model details

Table B- 1 RORB reach details

No.	Reach Name	Reach Type	Reach Length (km)
1	DS A	1. Natural	1.556
2	A-B	1. Natural	2.388
3	DS B	1. Natural	1.808
4	B-C	1. Natural	0.207
5	DS C	1. Natural	1.069
6	C-D	1. Natural	2.613
7	DS D	1. Natural	1.717
8	DS E	1. Natural	1.085
9	DS F	1. Natural	1.771
10	E-G	1. Natural	0.611
11	DS G	1. Natural	0.334
12	G-H	1. Natural	3.072
13	DS H	1. Natural	1.335
14	DS I	1. Natural	1.583
15	H-J	1. Natural	0.802
16	DS J	1. Natural	0.267

Table B- 2 RORB sub-catchment area details

No.	Node Name	Node Area (km²)
1	SA A	6.786
2	SA B	2.943
3	SA C	3.223
4	SA D	7.443
5	SA E	1.105
6	SA F	3.791
7	SA G	0.381
8	SA H	6.761
9	SA I	1.195
10	SA J	2.585
11	AB	n/a
12	BC	n/a
13	CD	n/a
14	DGH	n/a
15	EFG	n/a
16	HIJ	n/a
17	Outlet	n/a

Appendix C Hydraulic results maps

C1 Depth

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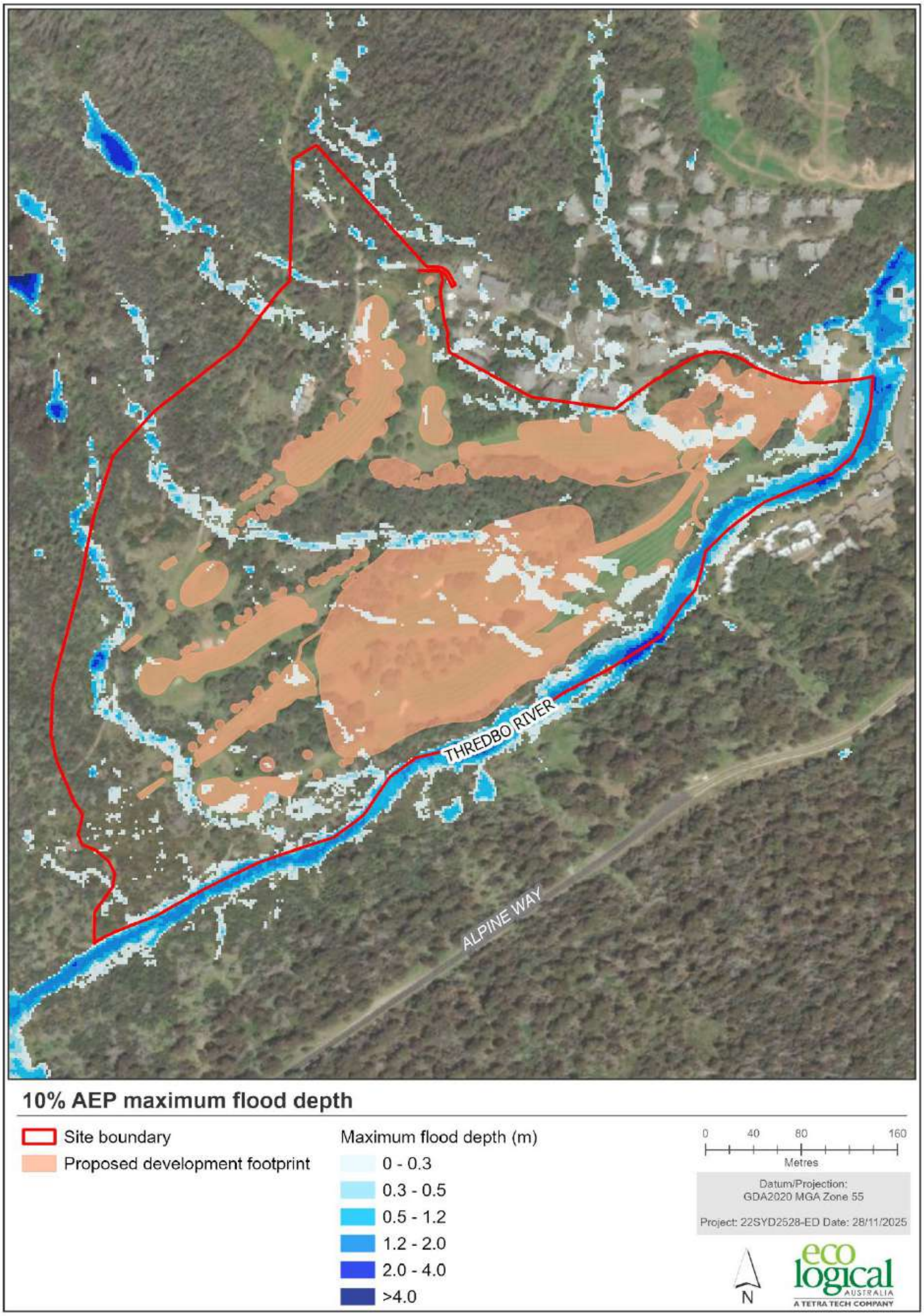
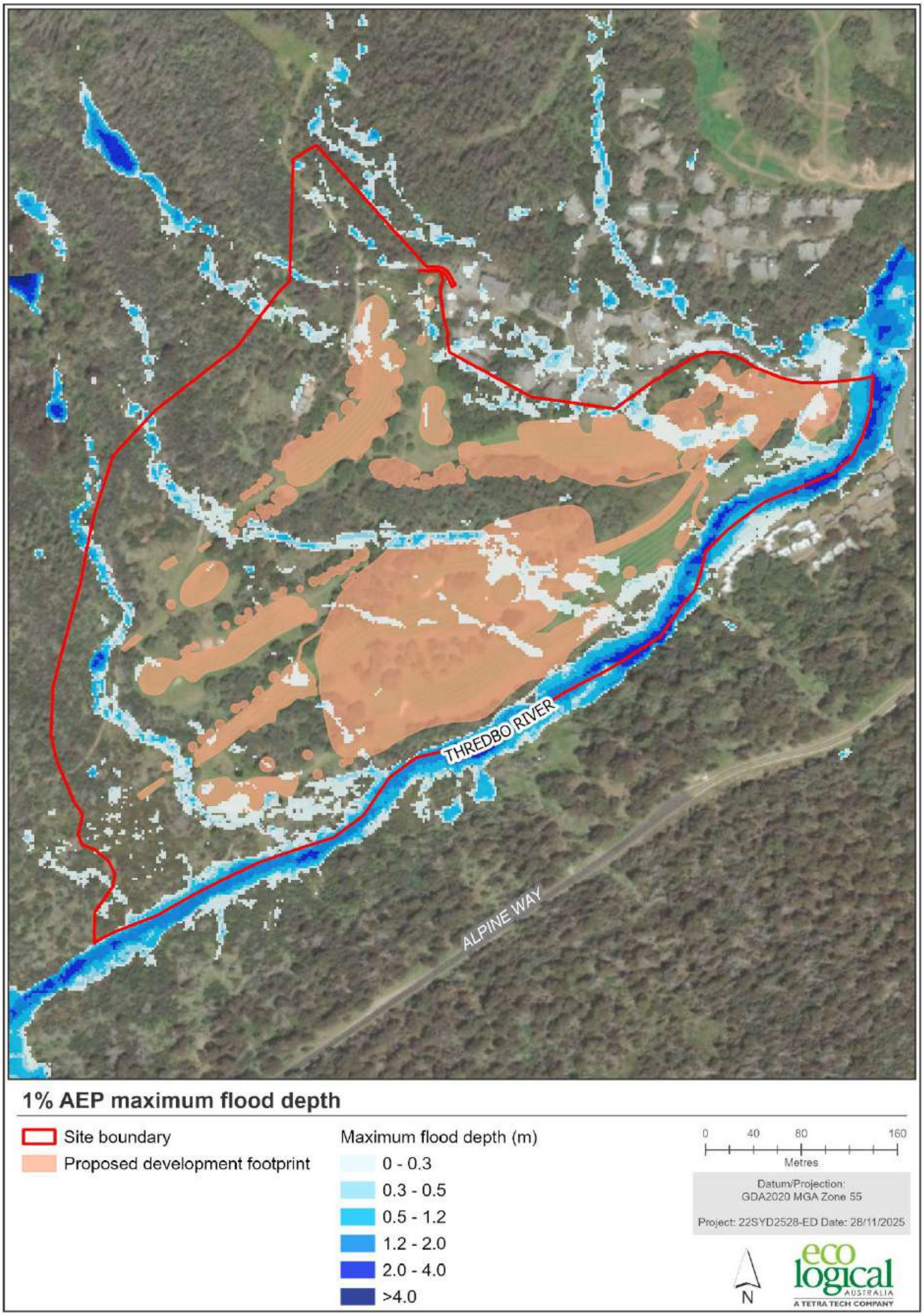
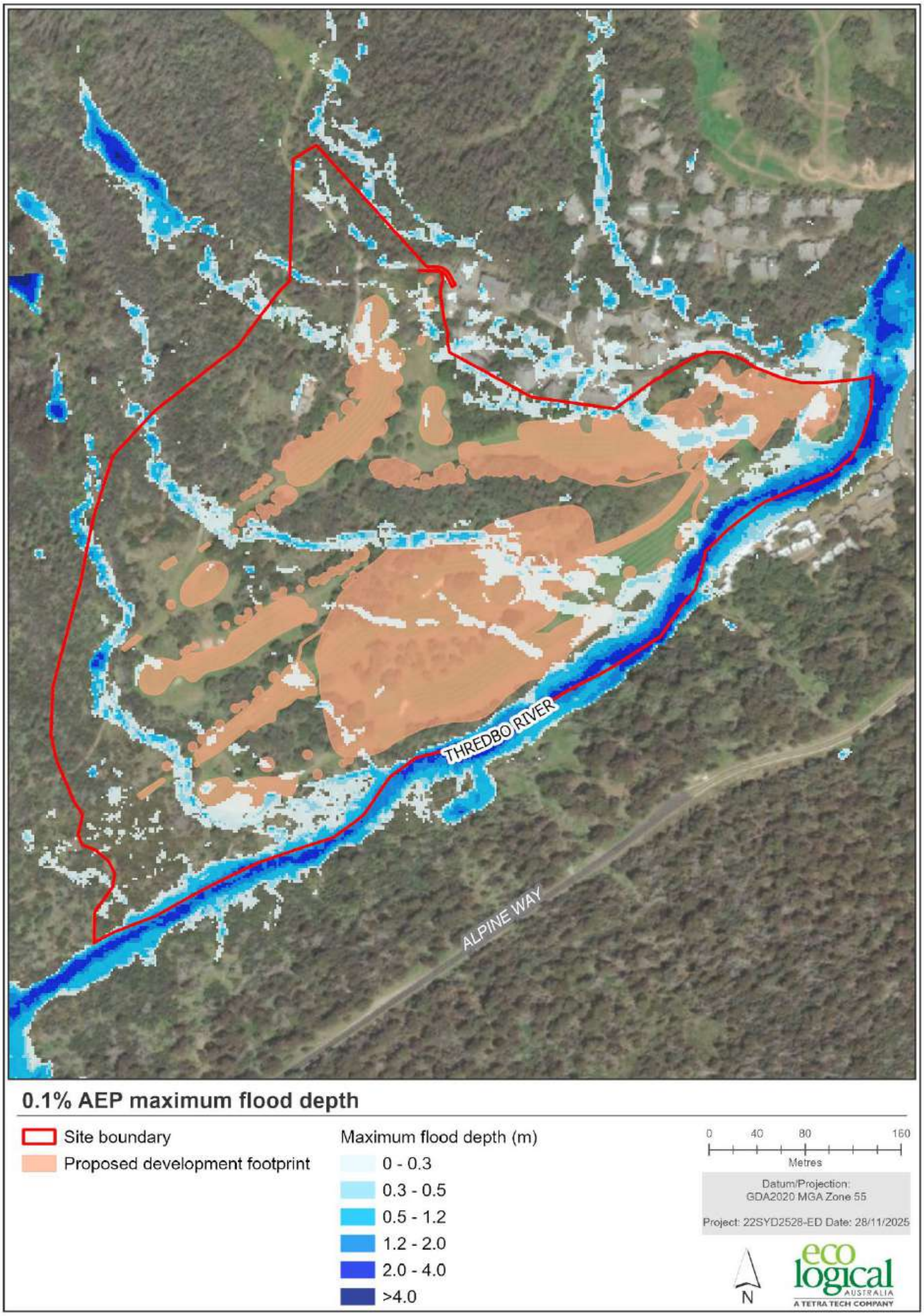
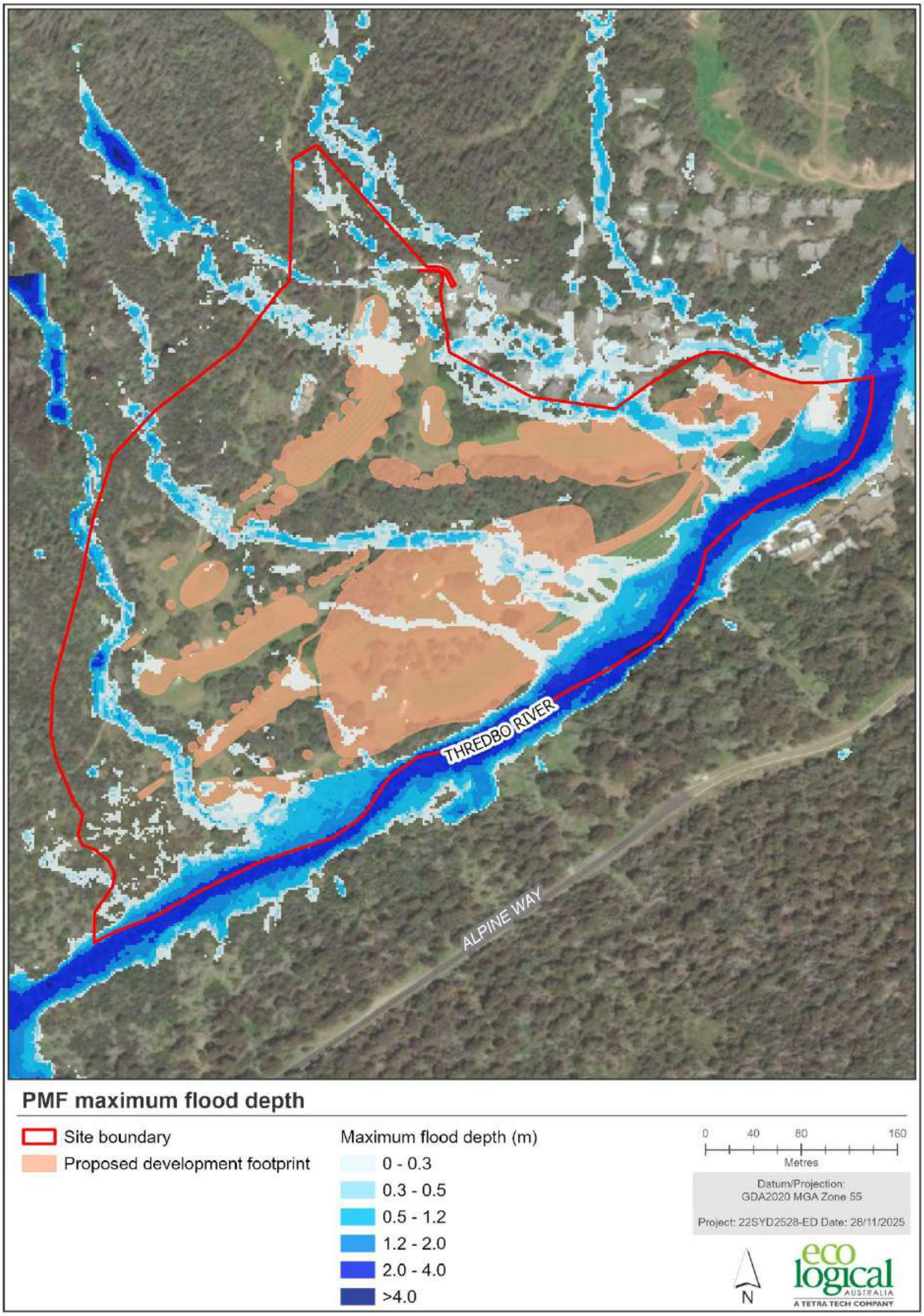

THREDBO RIVER
ALPINE WAY
10% AEP maximum flood depth
Site boundary
Proposed development footprint
Maximum flood depth (m)
0 - 0.3
0.3 - 0.5
0.5 - 1.2
1.2 - 2.0
2.0 - 4.0
>4.0
0 40 80 160
Metres
Datum/Projection: GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
1% AEP maximum flood depth
Site boundary
Proposed development footprint
Maximum flood depth (m)
0 - 0.3
0.3 - 0.5
0.5 - 1.2
1.2 - 2.0
2.0 - 4.0
>4.0
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
0.1% AEP maximum flood depth
Site boundary
Proposed development footprint
Maximum flood depth (m)
0 - 0.3
0.3 - 0.5
0.5 - 1.2
1.2 - 2.0
2.0 - 4.0
>4.0
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
PMF maximum flood depth
Site boundary
Proposed development footprint
Maximum flood depth (m)
0 - 0.3
0.3 - 0.5
0.5 - 1.2
1.2 - 2.0
2.0 - 4.0
>4.0
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
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C2 Velocity

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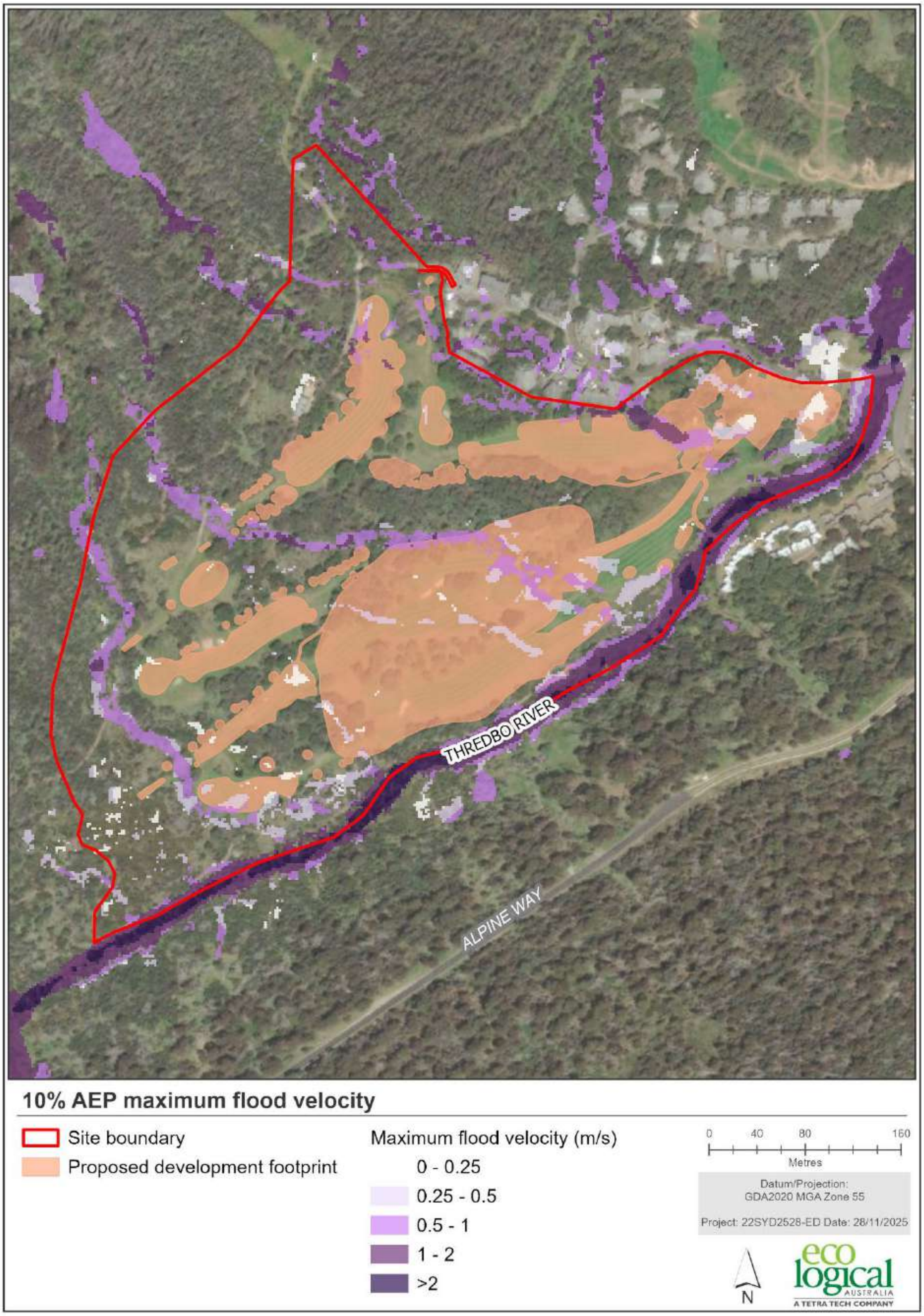
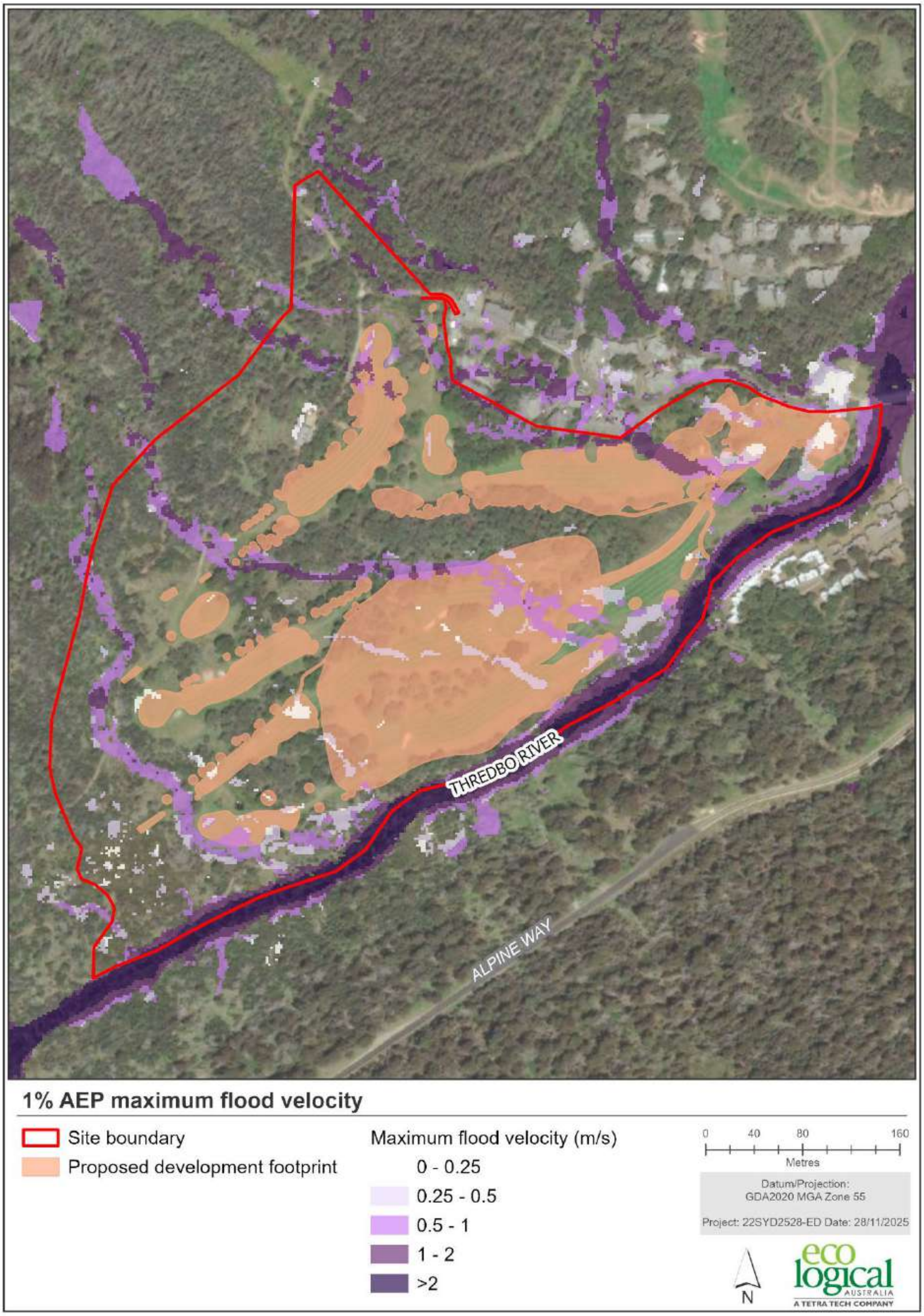
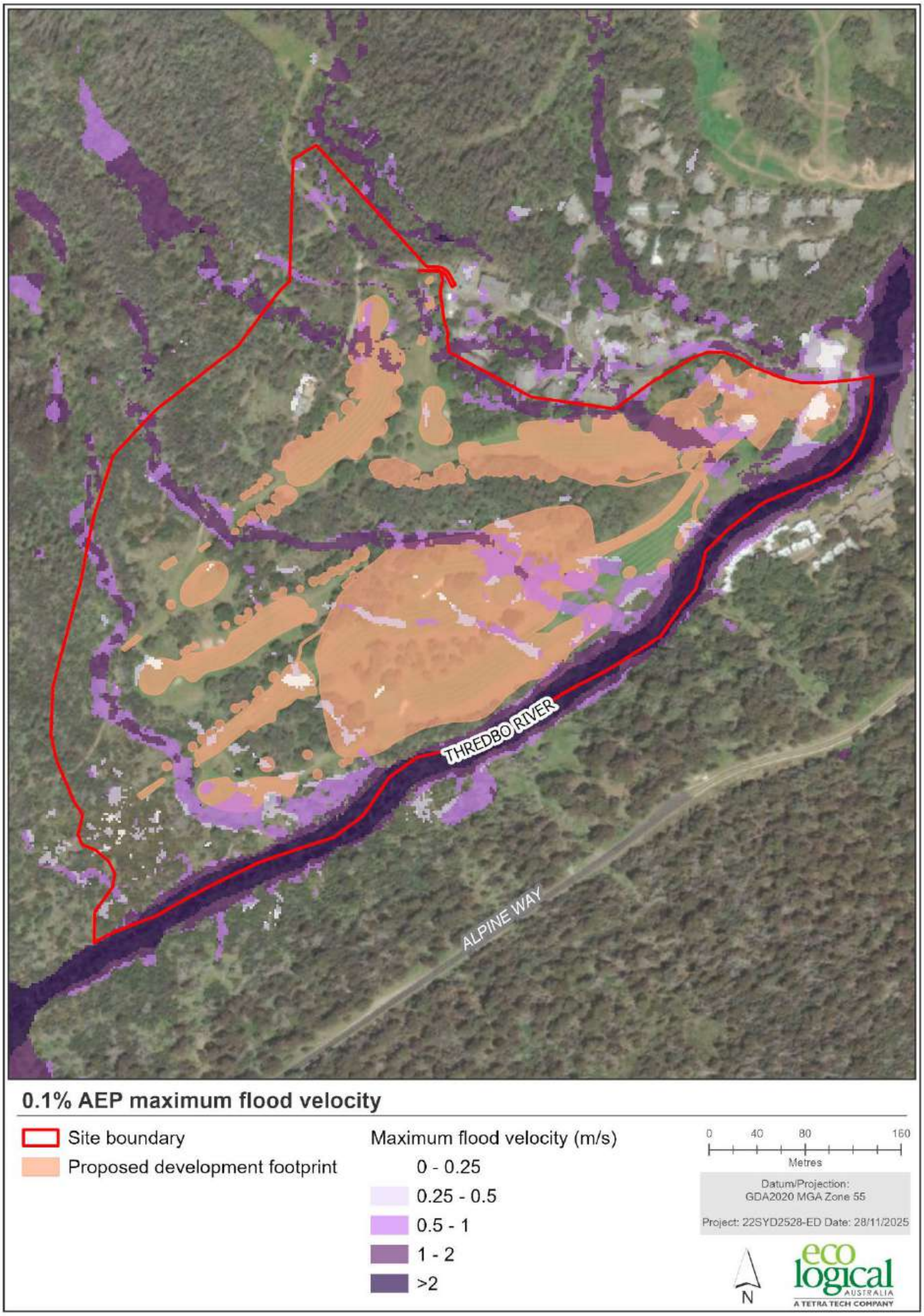
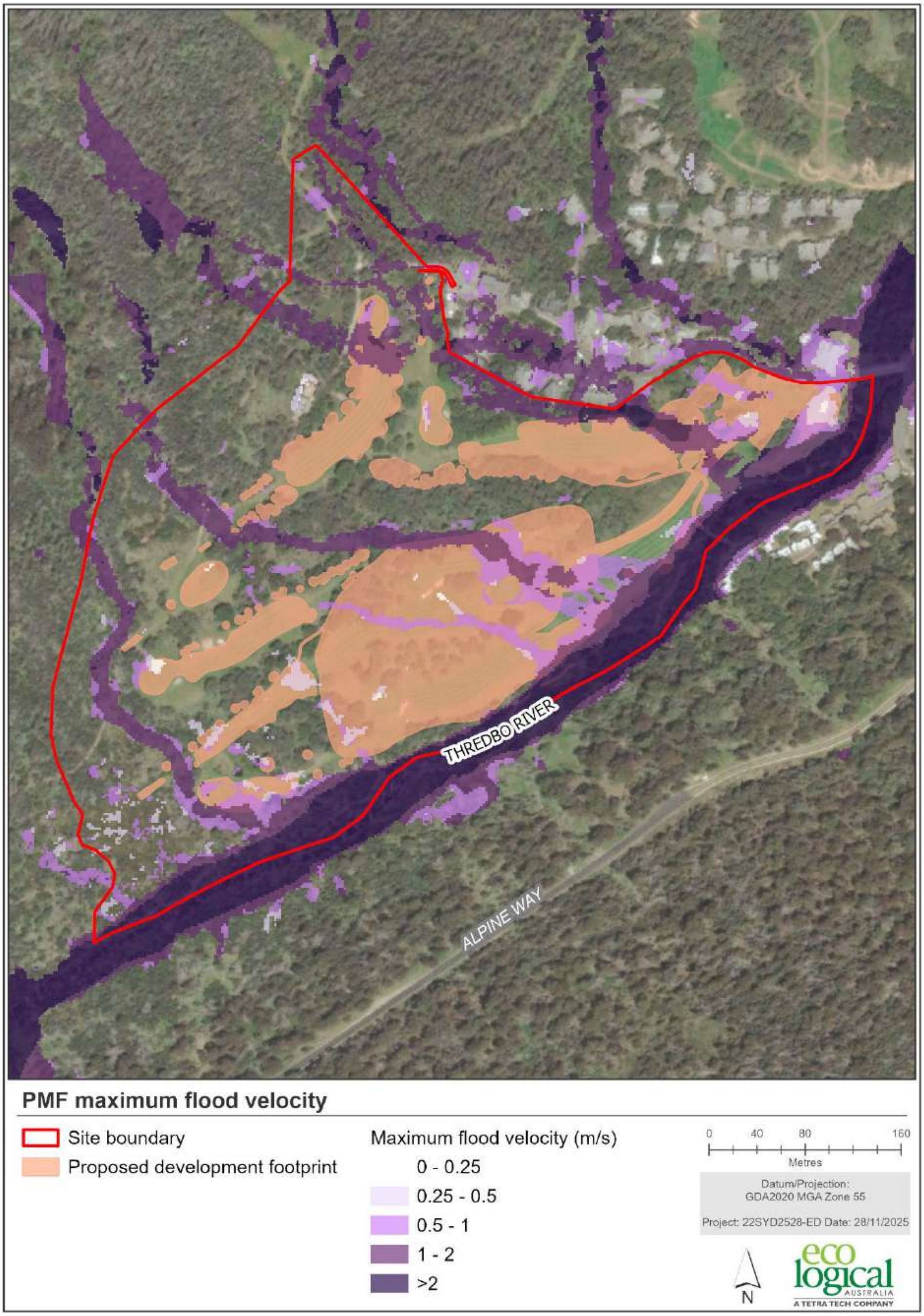

THREDBO RIVER
ALPINE WAY
10% AEP maximum flood velocity
Site boundary
Proposed development footprint
Maximum flood velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N


THREDBO RIVER
ALPINE WAY
1% AEP maximum flood velocity
Site boundary
Proposed development footprint
Maximum flood velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
0.1% AEP maximum flood velocity
Site boundary
Proposed development footprint
Maximum flood velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0
40
80
160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical
AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
PMF maximum flood velocity
Site boundary
Proposed development footprint
Maximum flood velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY

Appendix D Flood hazard classification maps

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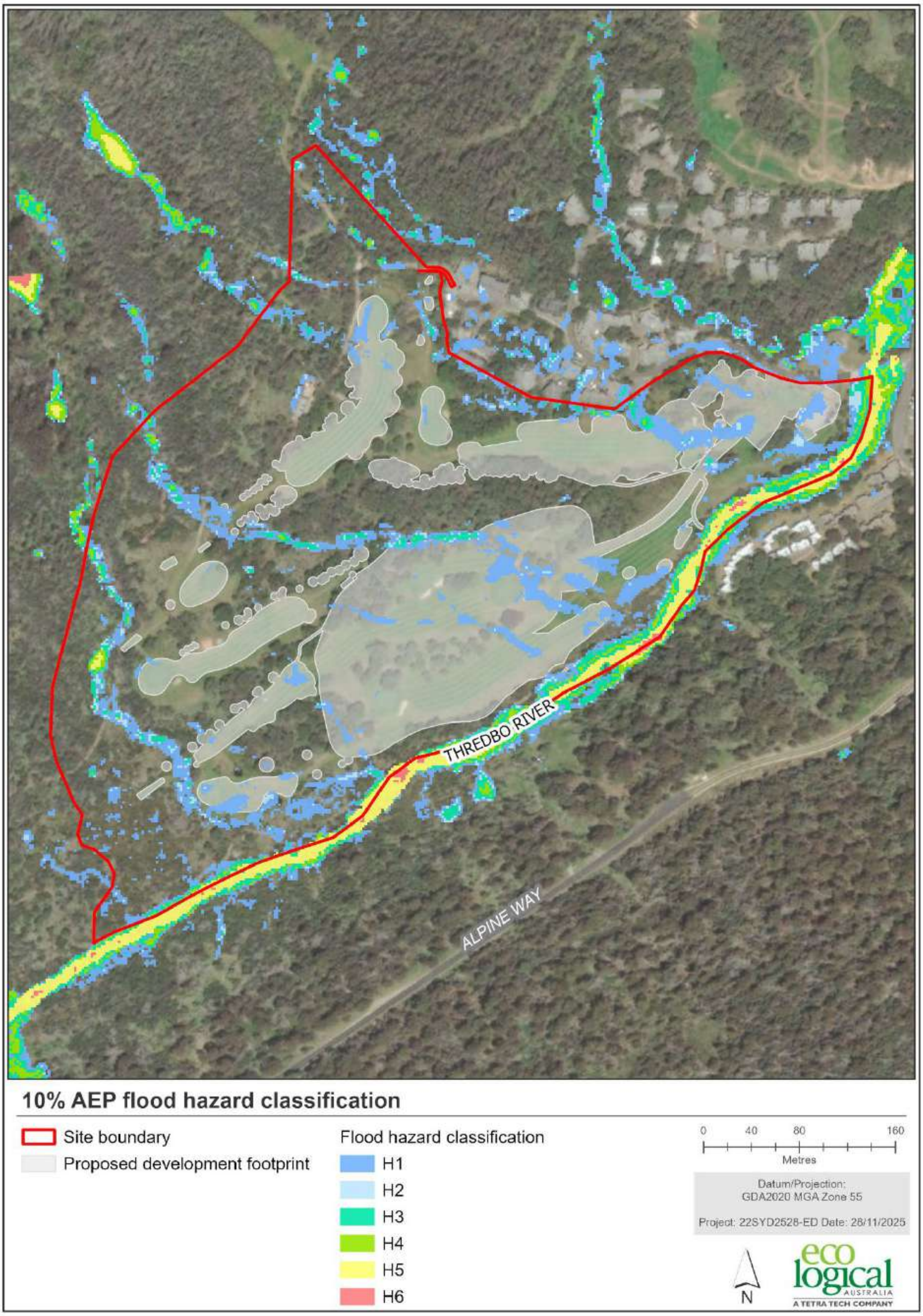
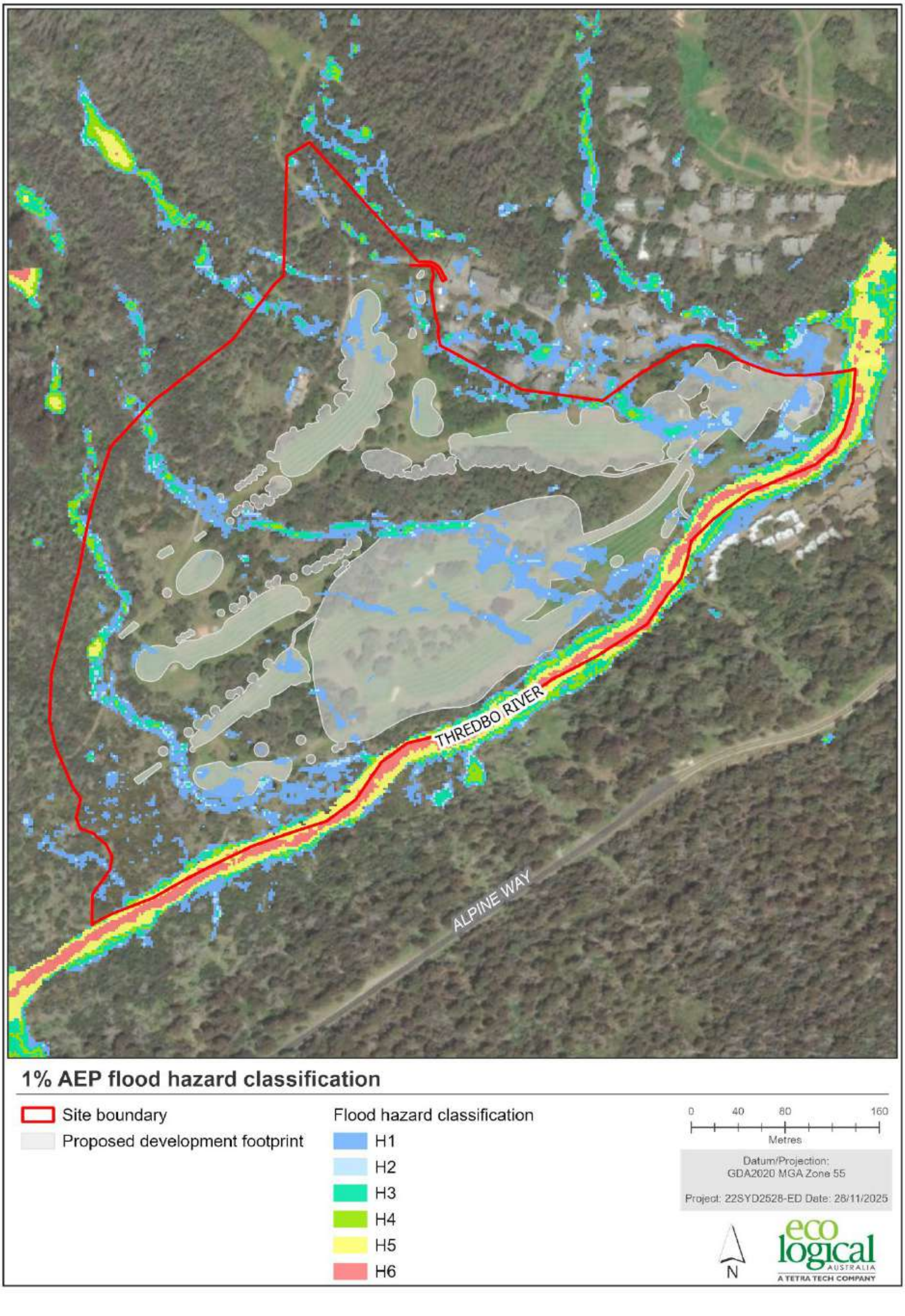
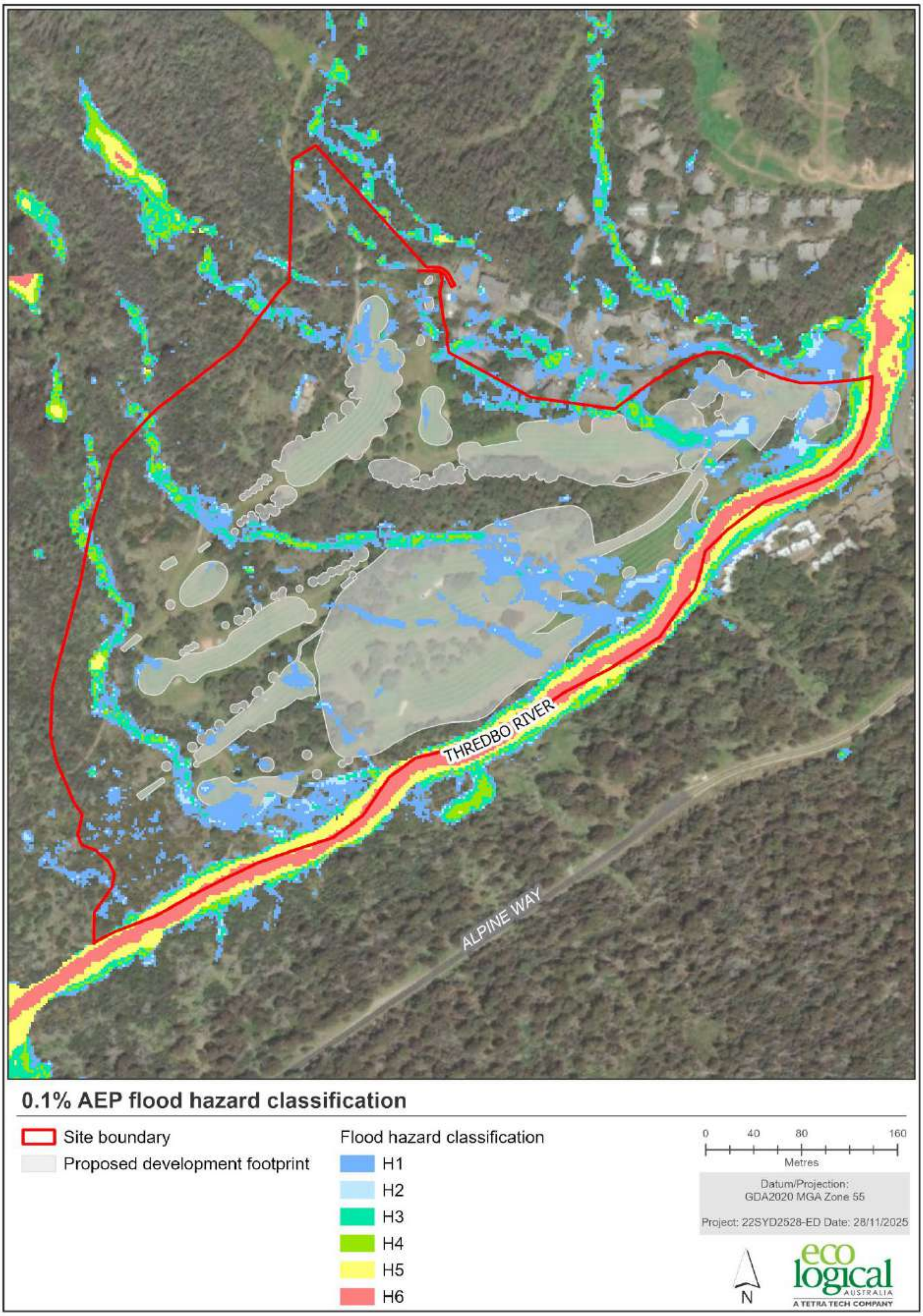
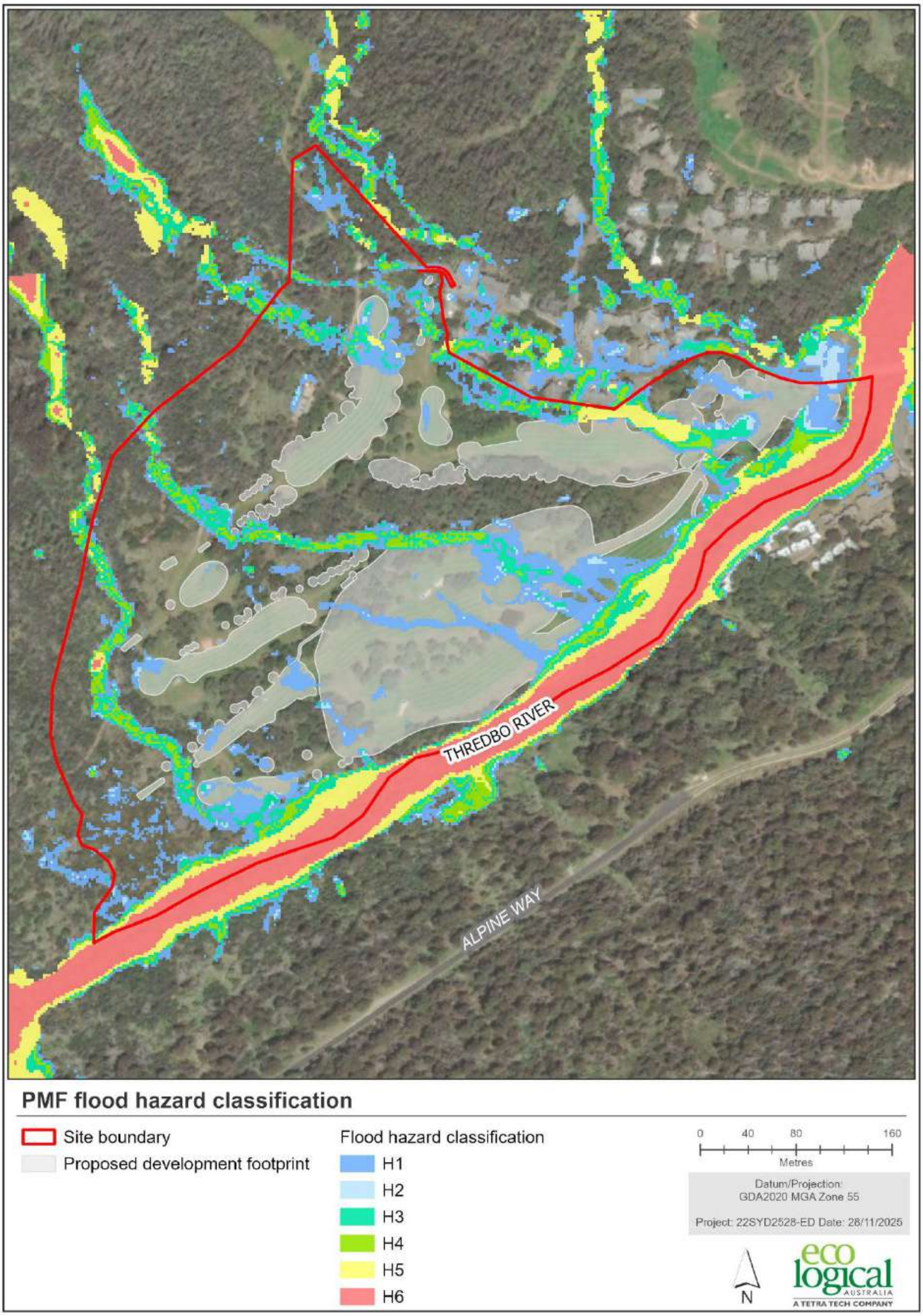

THREDBO RIVER
ALPINE WAY
10% AEP flood hazard classification
Site boundary
Proposed development footprint
Flood hazard classification
H1
H2
H3
H4
H5
H6
0
40
80
160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
1% AEP flood hazard classification
Site boundary
Proposed development footprint
Flood hazard classification
H1
H2
H3
H4
H5
H6
0
40
80
160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical
AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
0.1% AEP flood hazard classification
Site boundary
Proposed development footprint
Flood hazard classification
H1
H2
H3
H4
H5
H6
0 40 80 160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical
AUSTRALIA
A TETRA TECH COMPANY


THREDBO RIVER
ALPINE WAY
PMF flood hazard classification
Site boundary
Proposed development footprint
Flood hazard classification
H1
H2
H3
H4
H5
H6
0
40
80
160
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 28/11/2025
N
eco logical
AUSTRALIA
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Appendix E Climate change sensitivity maps

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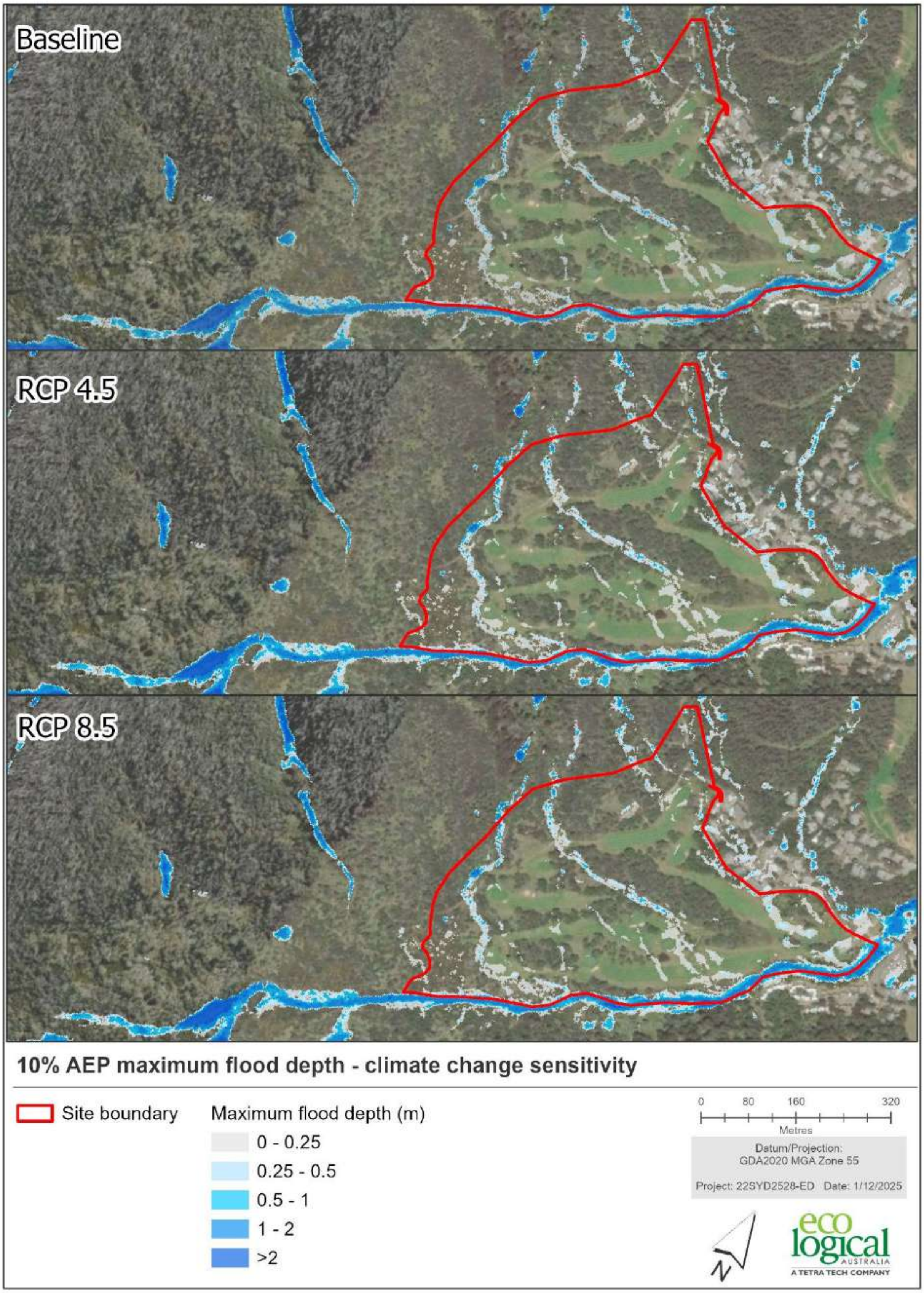
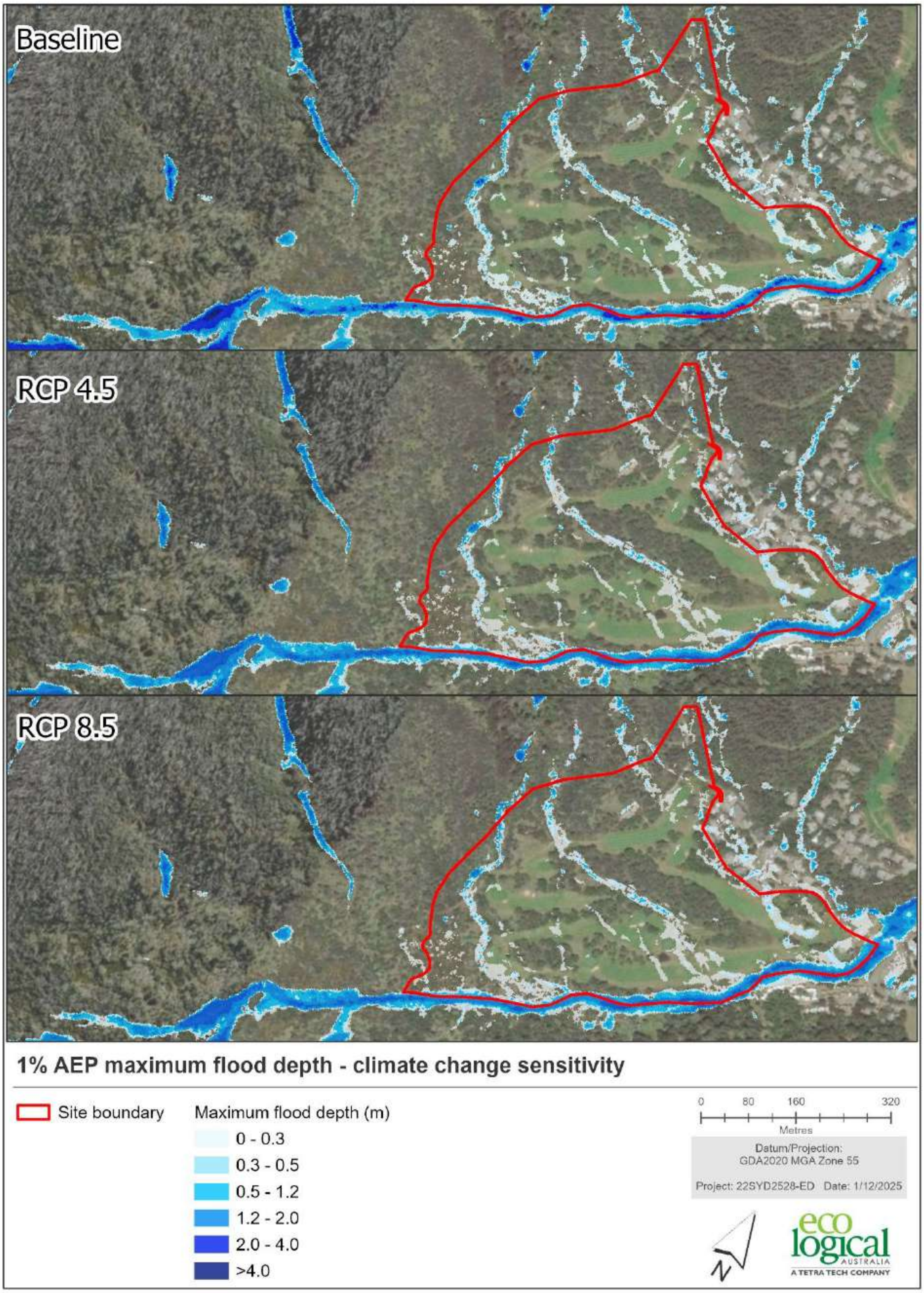
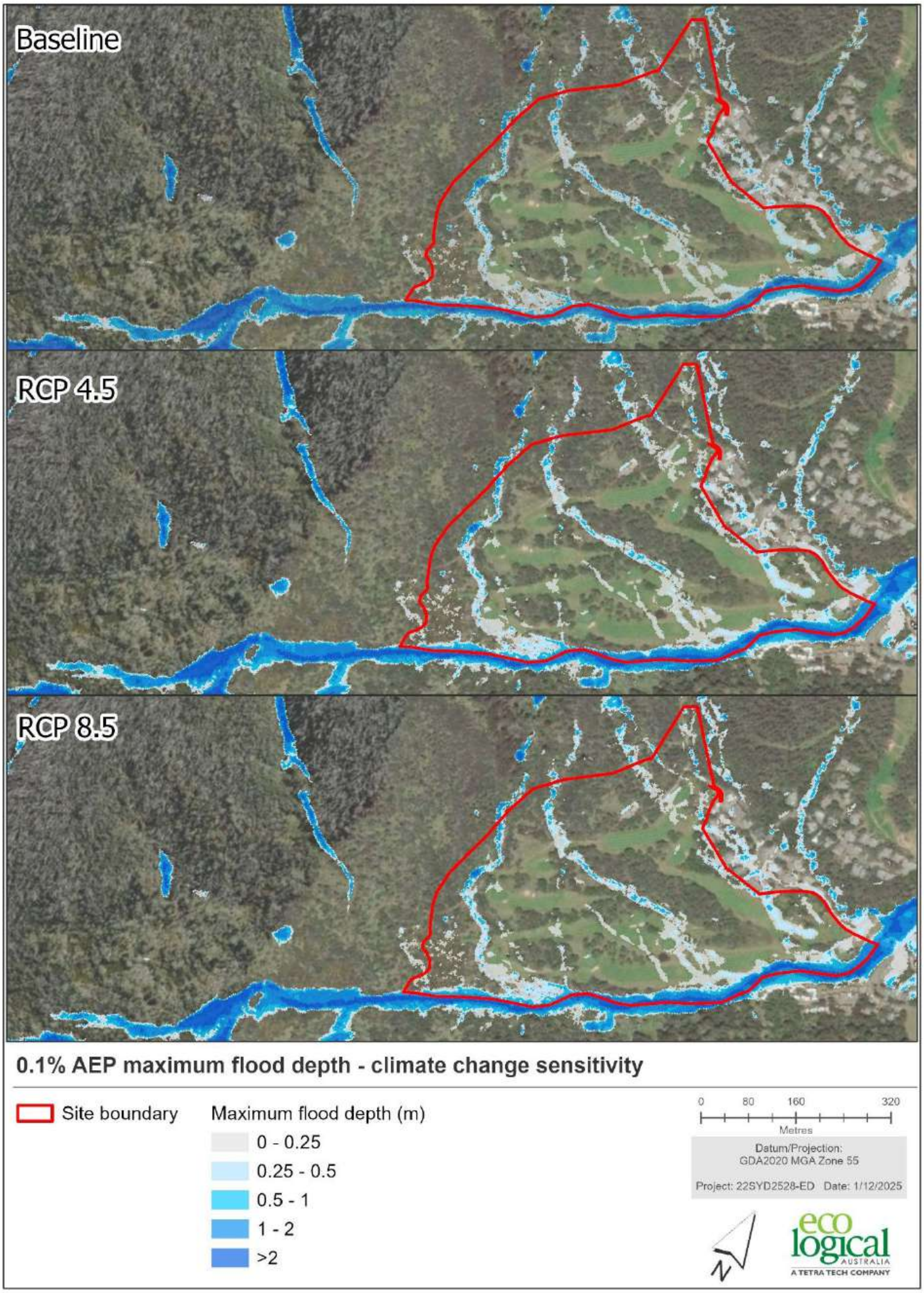
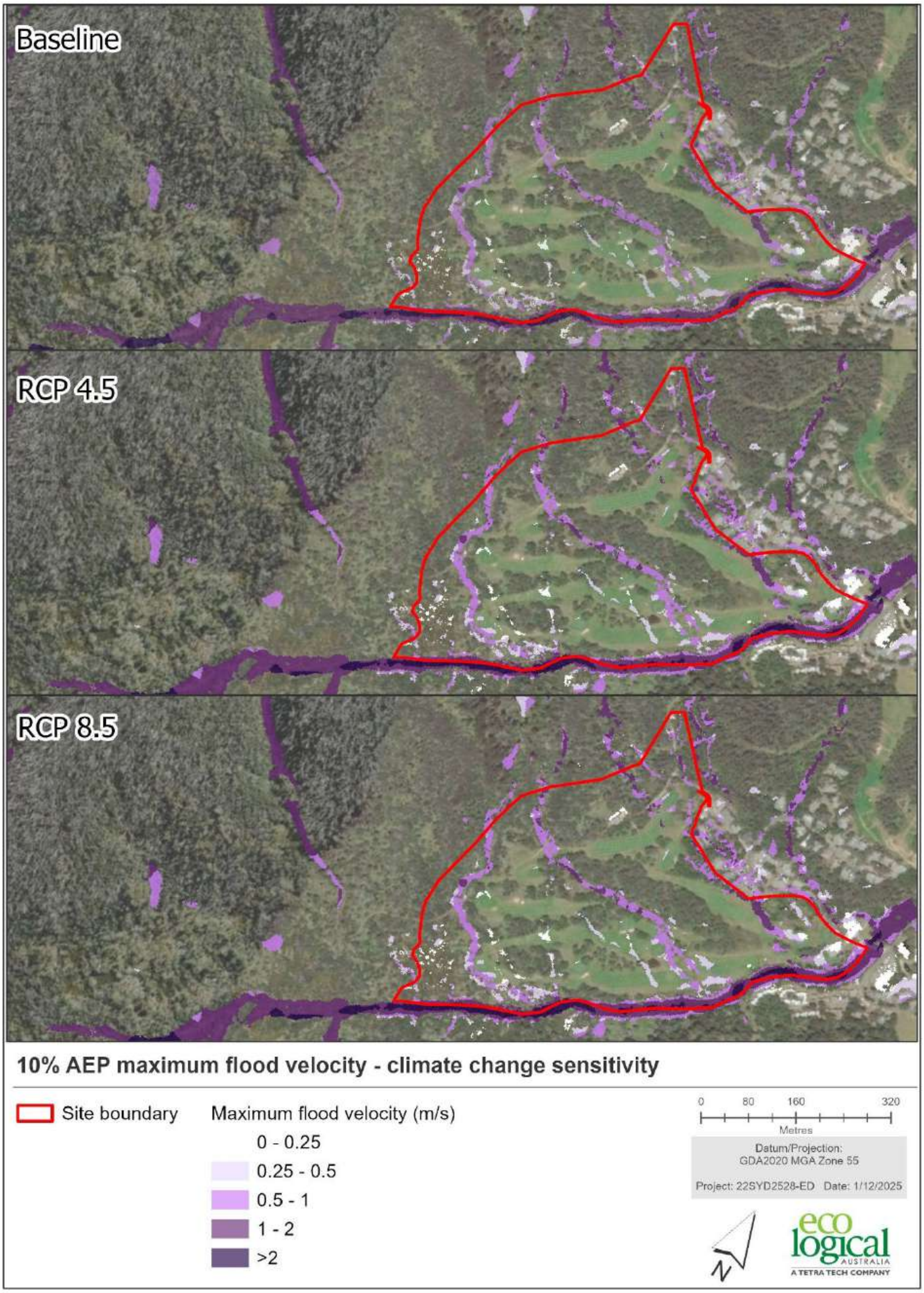


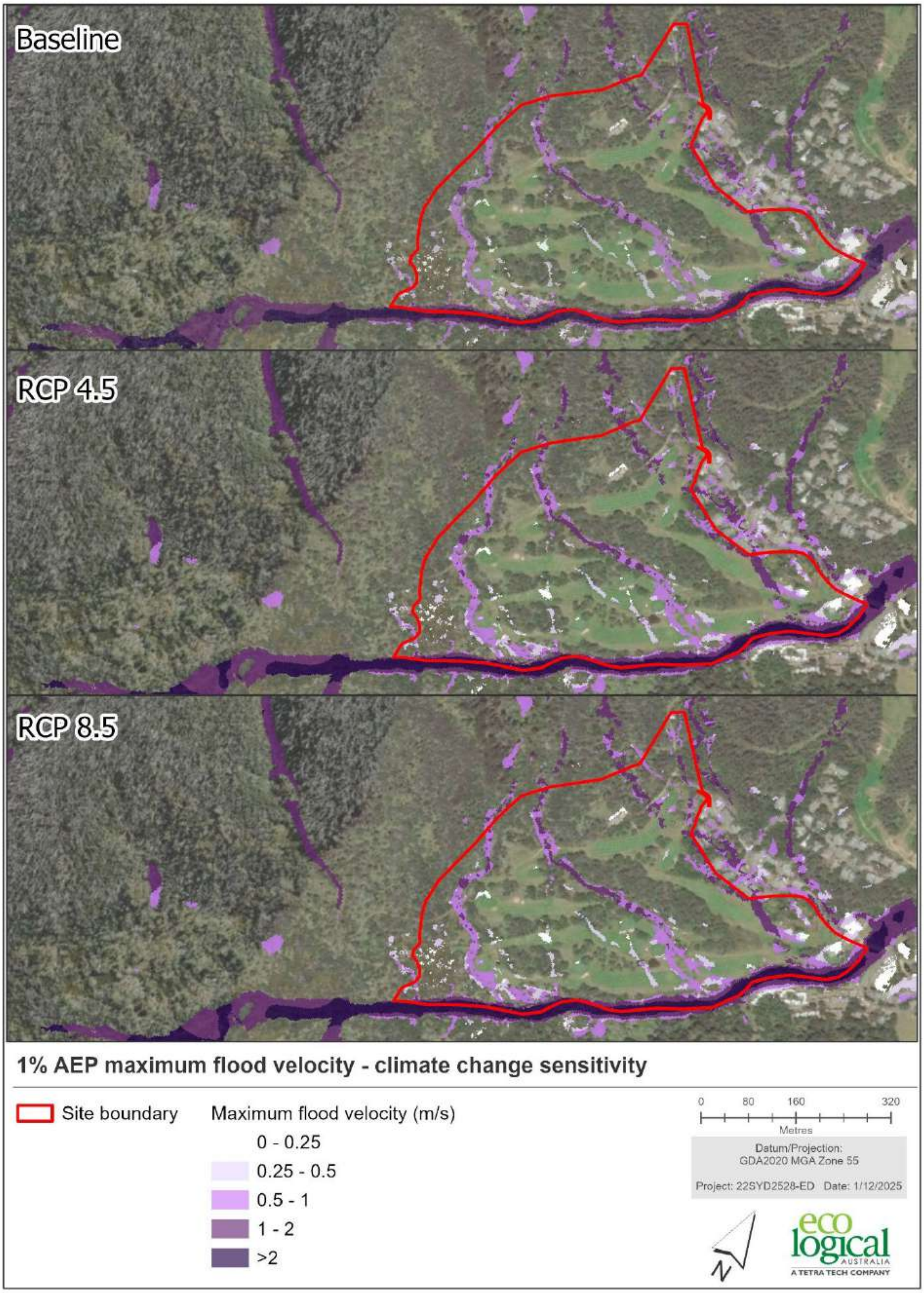
10% AEP maximum flood depth - climate change sensitivity


Baseline
RCP 4.5
RCP 8.5
1% AEP maximum flood depth - climate change sensitivity
Site boundary
Maximum flood depth (m)
0 - 0.3
0.3 - 0.5
0.5 - 1.2
1.2 - 2.0
2.0 - 4.0
>4.0
0
80
160
320
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 1/12/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY

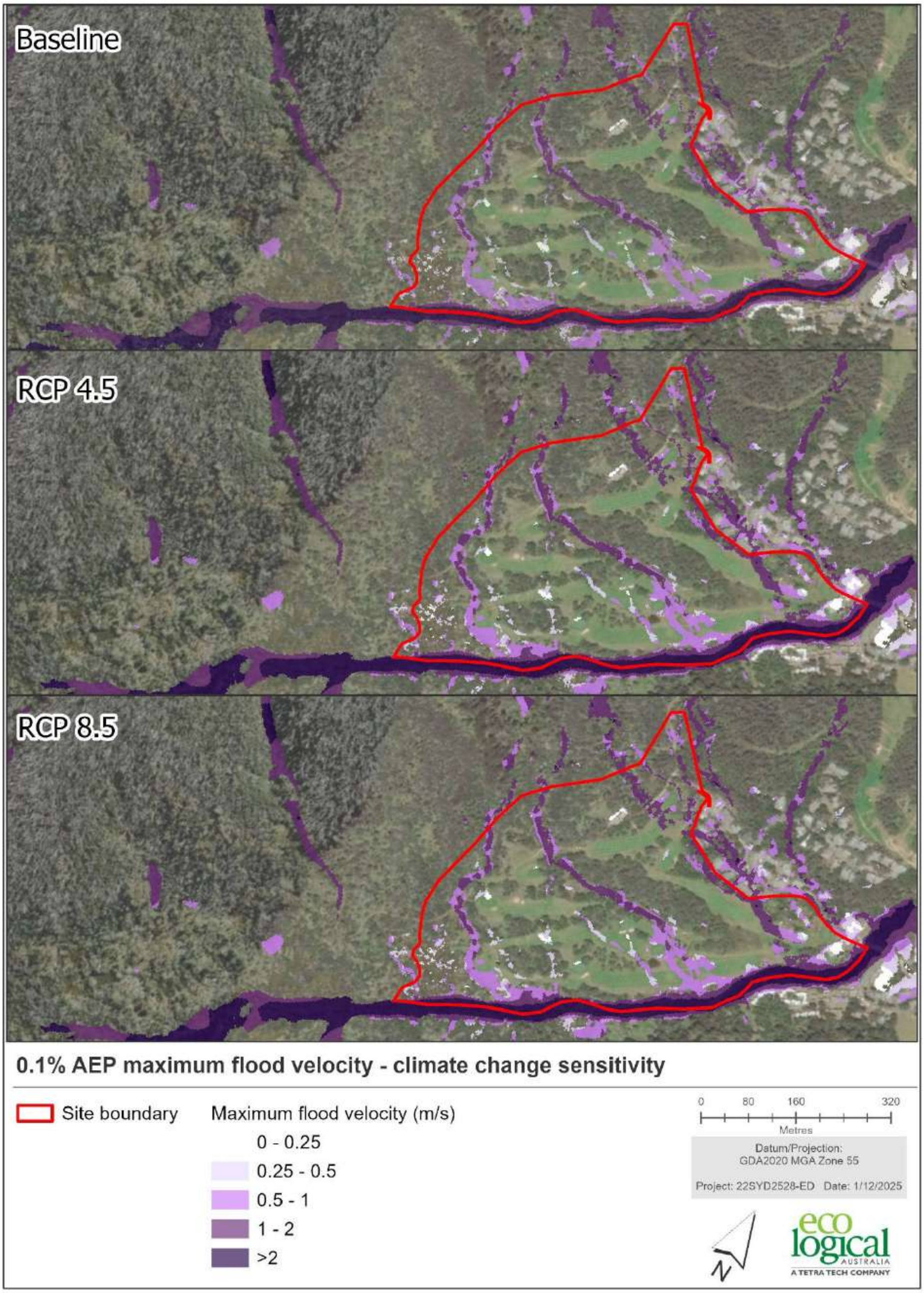

Baseline
RCP 4.5
RCP 8.5
0.1% AEP maximum flood depth - climate change sensitivity
Site boundary
Maximum flood depth (m)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0
80
160
320
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 1/12/2025
N
eco logical AUSTRALIA
A TETRA TECH COMPANY



10% AEP maximum flood velocity - climate change sensitivity



1% AEP maximum flood velocity - climate change sensitivity


Baseline
RCP 4.5
RCP 8.5
0.1% AEP maximum flood velocity - climate change sensitivity
Site boundary
Maximum flood velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
>2
0
80
160
320
Metres
Datum/Projection:
GDA2020 MGA Zone 55
Project: 22SYD2528-ED Date: 1/12/2025
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Appendix F Emergency management plan

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Thredbo Golf Course Flood Emergency Management Plan

This emergency management plan has been developed for the site in accordance with NSW DPE (2023) Flood Risk Management guidelines. In general, flood emergency management comprises three phases:

1. Preparation – this includes education and awareness of potential flood hazards before commencement of a flood event, identification of emergency response measures and designation of responsible personnel to implement emergency response.
2. Response – implementation of emergency response procedures before and during a flood event.
3. Recovery – physical and psychological repair following a flood event, including repair and maintenance of assets and access to counselling services for emergency response personnel and affected parties.

Site-specific details for each key component of the flood emergency management plan are provided in each sub-section below.

Flood emergency preparedness

Flood hazard awareness and education

Roles and responsibilities for flood awareness and response management must be clearly defined. Typically, a Site Warden will be designated to manage and implement flood preparedness, response and recover measures.

Flood awareness and response training should be administered as part of site inductions for all KT staff and contractors.

An annual flood emergency response drill should be undertaken to ensure adequate communications and evacuation and/or flood risk protection shelter instructions and identify potential improvements to the Emergency Management Plan.

Flood warning and notification

Peak flood flows within Thredbo River are predicted to occur within 18- to 24-hours from the beginning of a storm event but may be much shorter within local drainages that intersect the development footprint within the site.

Early warning systems should be monitored daily by responsible personnel including:

- BoM Thredbo Village weather station (gauge number 071041)
- Hazard Watch
- Hazards Near Me
- NSW State Emergency Services (SES) alerts

The SES uses nationally recognised disaster warning icons adopted from the Australian Warning System (AWS) as shown in Figure F- 1.

Figure F- 1 AWS warning icons

The following actions should be taken by responsible personnel in response to AWS warnings received:

- Advice warning – monitor warning systems hourly until alert has changed
- Watch and Act – monitor warning systems every 30 minutes until alert has changed and follow appropriate emergency response protocol (Section 7.2).
- Emergency Warning – implement appropriate emergency response protocols immediately (Section 7.2).

Although flood hazard within Thredbo River is elevated under high flows, the associated risk of impact to site infrastructure, people and vehicles on site is minimal. Therefore, it is not considered a requirement for installation of a telemetered stream gauge on Thredbo River upstream of the site, and existing warning systems are considered adequate for the purposes of emergency response preparation and information.

Emergency response actions

Trigger action response plan

Emergency response measures based on modelled probable maximum flood (PMF) conditions are highly conservative as the PMF identifies the limiting value of a flood that could reasonably be expected to occur. In reality, flood peaks at the site are likely to be much lower than PMF estimations.

The proposed emergency response actions appropriate for various levels of predicted storm activity and resulting flood events at the site are summarised in Table F- 1. Flood hazard classification mapping is provided for reference in Figure F- 2.

Table F- 1 Flood hazard trigger action response plan

Scenario	Forecasted rainfall (mm)[1]	Maximum flood hazard classification[2]	Action
10% AEP	122	Medium (H3)	Evacuate all areas of the site classified as H2 and H3.
1% AEP	206	Extreme (H5)	Evacuate all areas of the site classified as H2, H3, H4 and H5.
0.1% AEP	286	Extreme (H5)	Evacuate all areas of the site classified as H2, H3, H4 and H5.
PMF	800	Extreme (H6)	Evacuate all areas of the site classified as H2, H3, H4, H5 and H6.

[1] Rainfall forecast for less than or equal to 24-hour period.

[2] Maximum flood hazard classification determined based on results of conservative hydraulic modelling of the site (NSW DPE, 2023d). Listed maximum classification does not represent flood hazard classification in all areas of the proposed development footprint or site.

The appropriate evacuation procedure will be dictated by predicted total rainfall, storm duration and temporal pattern. Responsible personnel should liaise with police and NSW SES to determine the safest course of action to minimise harm to people, critical infrastructure and assets. Importantly, personnel and other persons on site must adhere to the following:

- Do not attempt to wade or swim across flood waters.
- Do not drive over any flooded tracks, roadways or bridges.

Sandbags may be applied to protect on site infrastructure or areas of the site so long as they do not impede natural flow paths and preparation activities can occur at least two hours before the expected flood peak.

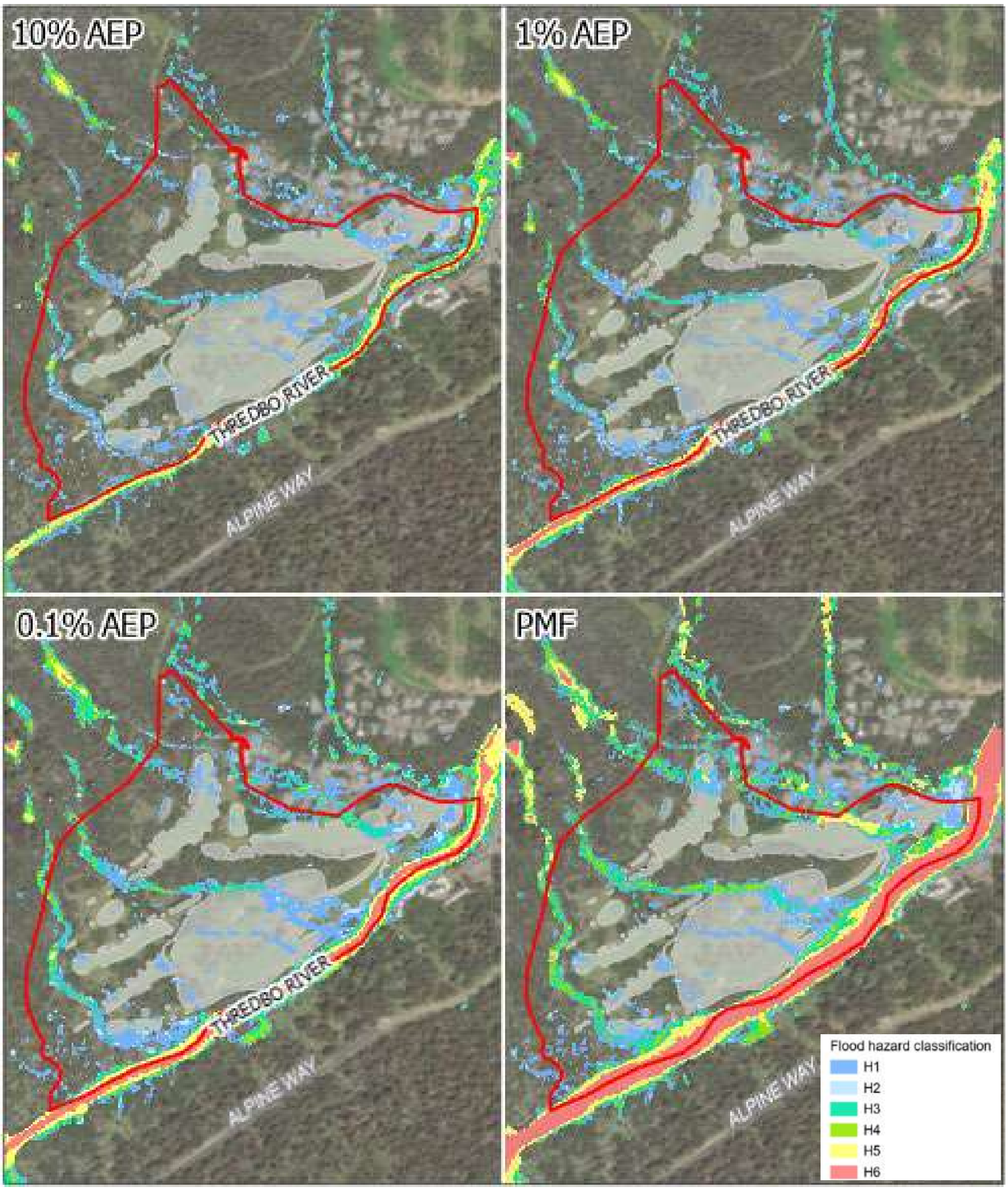

Figure F- 2 Thredbo Golf Course flood hazard classification

Assembly points and evacuation route

If a severe weather warning, Watch and Act and/or Emergency Warning alerts are issued, early evacuation should be undertaken using the existing bridge crossing Thredbo River to Alpine Way.

If flood waters within Thredbo River are such that flood hazard and risk exceeds safe evacuation for people in vehicles, evacuation procedures should be to remain on site within designated assembly areas on high ground outside of flow paths. Responsible personnel should liaise with police and NSW SES regarding road conditions and safe evacuation routes.

The designated evacuation route and suitable assembly areas to shelter on site are indicated in Figure F- 3. Note, emergency shelter structures must be designed and validated by a qualified engineer.

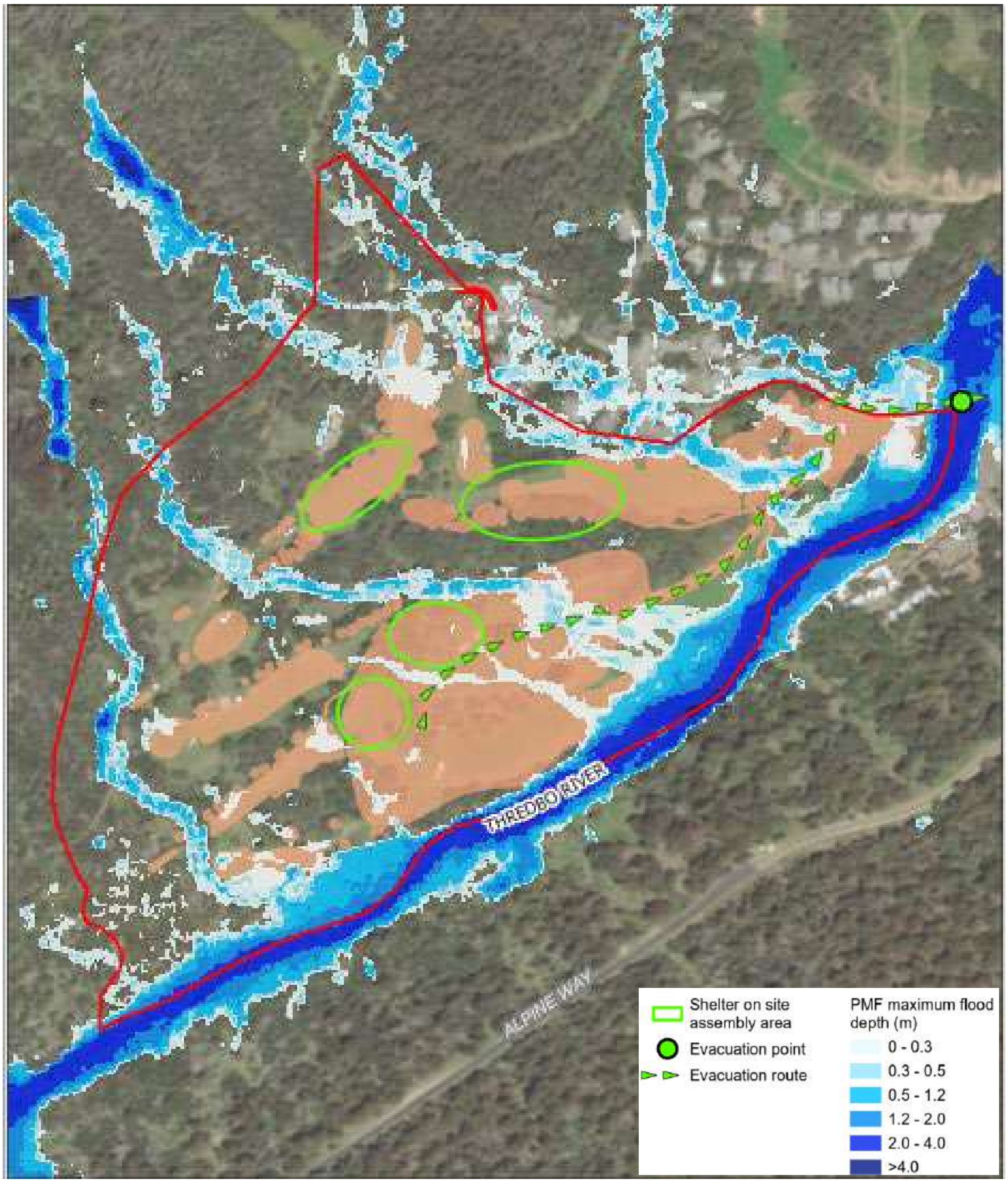

Figure F- 3 Thredbo Golf Course evacuation route and flood risk management assembly areas

Post-flood recovery measures

Asset assessment and repair

A structural and services assessment should be undertaken as soon as practicable after a rainfall event has ceased and flood waters have receded such that access for inspections is safe for vehicles and people.

Observations and photos should be recorded in a designated flood risk management register to document incidents and damages resulting from flooding.

Psychological first aid

Access to government services for emergency responders and anyone affected by the flood event should be provided within a timely manner. Ongoing psychological support may be required.

Adaptive management and review of FRM response measures

A review of the FRM and emergency response plan shall occur every five years, at a minimum. Review and amendment shall be undertaken more frequently should the following occur:

- Significant flooding event (>10% AEP rainfall event, 78.3mm over 72 hours).
- Occurrence of a flood event triggering evacuation and/or emergency response actions.
- Changes to site conditions.
- Additional development of infrastructure at the site.

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