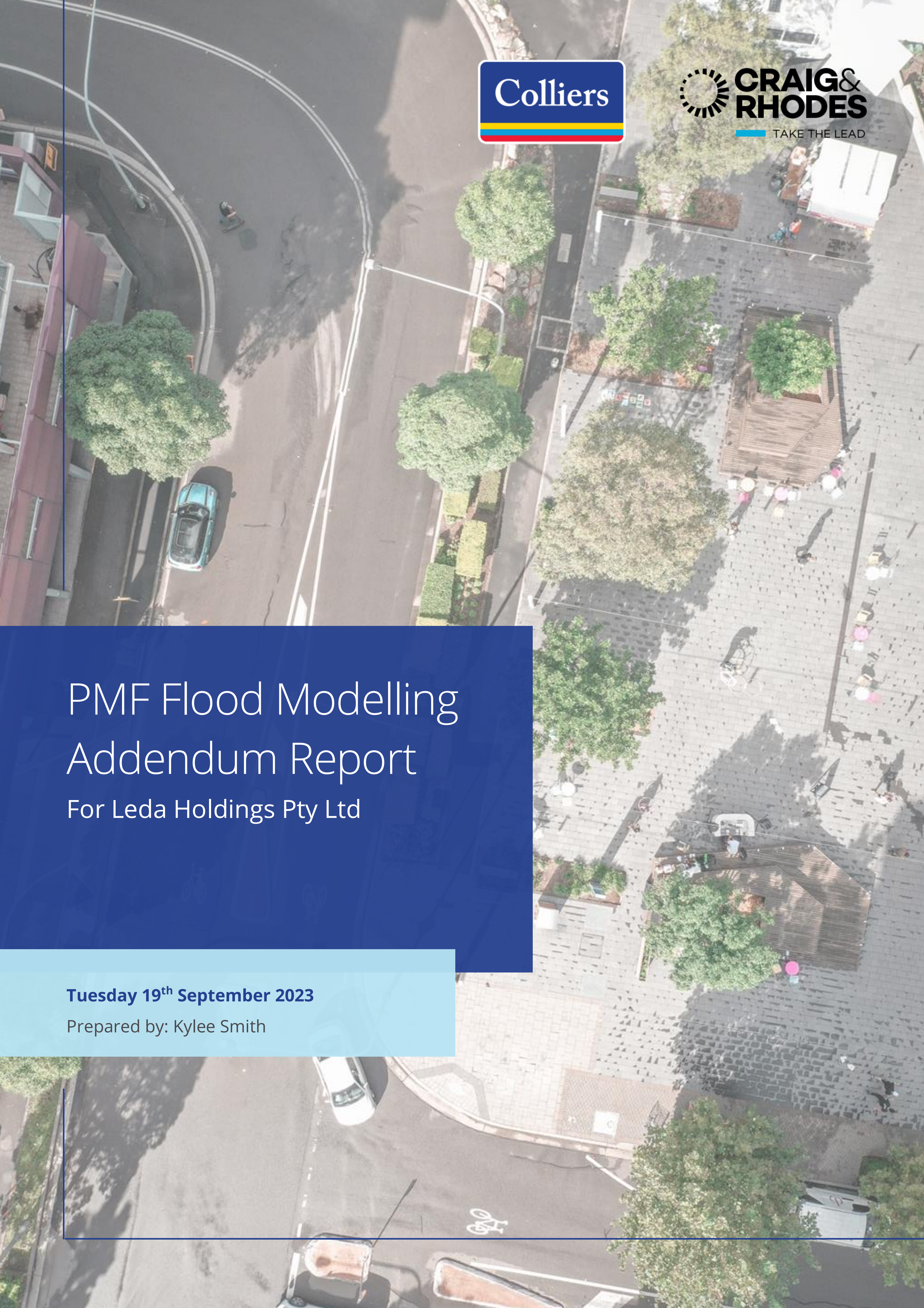


PMF Flood Modelling Addendum Report

For Leda Holdings Pty Ltd

Tuesday 19th September 2023

Prepared by: Kylee Smith

DOCUMENT CONTROL

Issue	Date	Purpose	Author	Approved
A	19/9/2023	Draft for review	KAS	
B				
C				

This report has been prepared by Colliers Engineering & Design (NSW) Pty Ltd and has undergone a quality assurance review. The signatures above confirm review completion.

Acknowledgement of Country

We honour and respect the Aboriginal and Torres Strait Islander Traditional Custodians, Elders and communities of the lands upon which are projects are based. For this project, we honour the spirit sand aspirations of the Dharawal people.

Table of Contents

Table of Figures

Table of Tables

Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AIDR	Australian Institute of Disaster Resilience
ARR2019	Australian Rainfall and Runoff (2019)
BoM	Bureau of Meteorology
CCC	Campbelltown City Council
DEM	Digital Elevation Model
GSDM	Generalised Short-Duration Method
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Services

1. Introduction

A planning proposal was submitted for the development of Rosalind Park at 33 Medhurst Road, 101 and 111 Menangle Road, Menangle Park. The proposal includes a residential estate development of between 1200 and 1650 lots including residential, retail and community uses over an area of approximately 264 ha. The planning proposal included submission of a Water Cycle Management Plan (WCMP) for the 1% AEP storm event, prepared by Craig & Rhodes in 2022.

Campbelltown City Council ('Council') subsequently requested a PMF flooding analysis be undertaken and this report is therefore an addendum to the WCMP (Craig & Rhodes, 2022) and presents an assessment of the PMF flooding at Rosalind Park. Included within this report is the PMP hydrology approach and methodology and assumptions made, as well as the PMF hydraulic analysis, results, and conclusions.

Scope

The scope of works consists of the following tasks and deliverables:

1. Provide an addendum report to the WCMP (Craig & Rhodes, 2022) to assess the extent of flooding within the site for a PMF event.
2. Prepare PMP hydrology to the Bureau of Meteorology Guidelines ((Hydrometeorological Advisory Service, 2003) and ARR2019 Guidelines (Nathan & Weinmann, 2019)
3. Update the developed conditions to the latest layout plan
4. Undertake TUFLOW hydraulic modelling utilising the PMP hydrology
5. Provide discussion on the methodology, approach, assumptions and results
6. Issue flood modelling and flood mapping associated with the PMF analysis

Objectives

The objective of this report is to extend the WCMP prepared by Craig & Rhodes (2022) to include an analysis of the Probable Maximum Flood and discussion regarding risks associated with the PMF.

2. Data Collation

The following data was collated and reviewed for the PMF assessment in addition to the data that was previously collated for the WCMP:

Guidelines and Research:

- The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method (Hydrometeorological Advisory Service, 2003)
- Growth curves and temporal patterns of short duration design storms for extreme events (Jordan, Nathan, Mittiga, & Taylor, 2005)
- Australian Rainfall and Runoff (Nathan & Weinmann, 2019)
- RORB Manual (Laurenson, Mein, & Nathan, 2010)

Previous Reports and Plans:

- Water Cycle Management Report (Craig & Rhodes, 2022)
- Structure Plan Revision J

Data

- ARR Data Hub Rainfall Data Information
- Point Temporal Patterns for Frequent to Rare Events
- Rainfall Depths for Rare Events ((Bureau of Meteorology, 2023)
- Catchment details (latitude, longitude, area, elevation, terrain)

Data Gaps

The following data remains outstanding for the Rosalind Park Planning Proposal:

- Tailwater Conditions at Nepean River – the hydrological models or hydrographs for the section of the Nepean River upstream of Hume Motorway
- Detailed feature and levels survey of the site will be required for detailed design

Study Area

Rosalind Park consists of approximately 264 Ha of predominantly rural land. The site is bounded by Menangle Creek to the east and south, and several tributaries of Menangle Creek traverse the site from north to south-east and north to south. From aerial imagery and site photography (undertaken by the Craig and Rhodes surveyors), the creeks appear to be heavily vegetated. Surveyed cross sections have been obtained for the tributaries to further define the channels. The creeks are unnamed and for the purposes of communication within this report a naming convention has been adopted. The naming convention adopted is illustrated within Figure 1.

At the downstream south-west corner of the site, Menangle Creek confluences with Woodhouse Creek and together these both confluence with the Nepean River a further 700 metres downstream and the confluence with the Nepean River is only 120 metres southwest of the site boundary.

To the northeast of the site is the Mount Gilead Residential Estate, and to the west the site is bounded by the Hume Motorway. A similar residential estate is currently under development to the west of the Hume Motorway – Menangle Park Estate.

Rosalind Park includes a sandstone quarry located in the southern end of the site that is over 60m deep, although, due to raised bunds around most of the quarry, it is not a significant consideration for flooding.

The study area is illustrated in Figure 1 below.

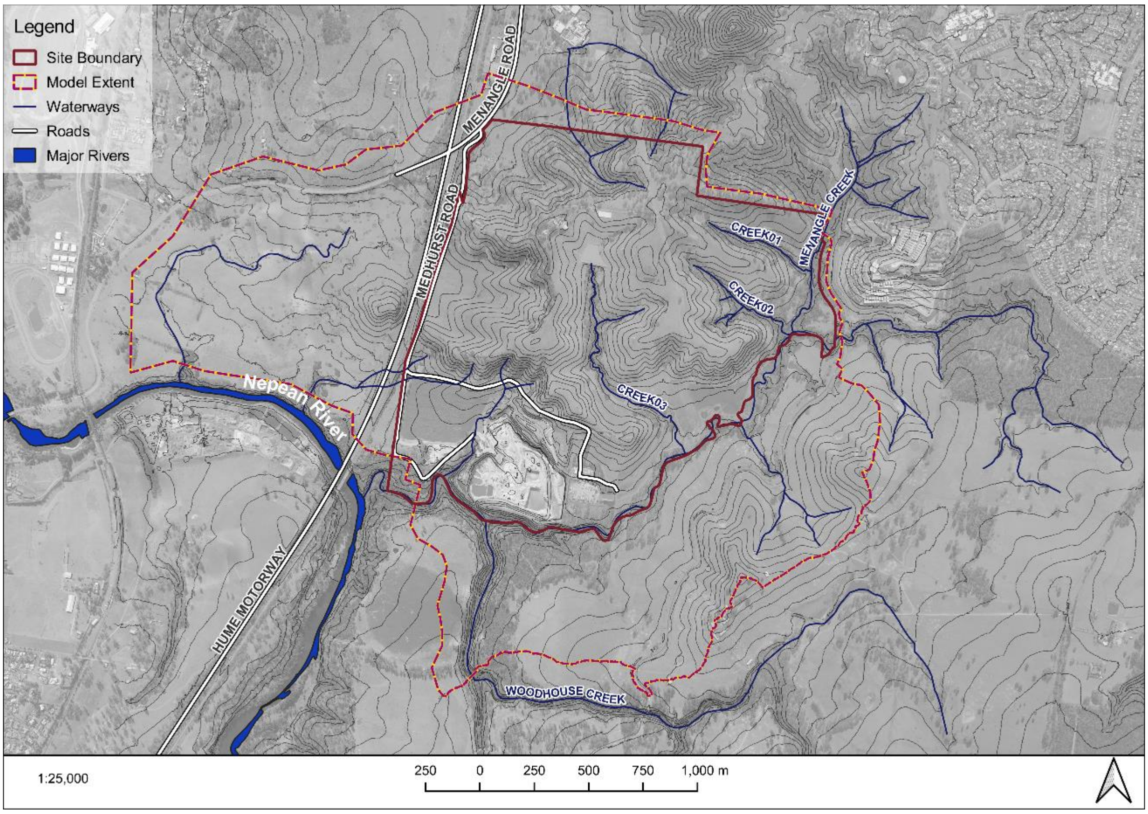


Figure 1 Study Area

3. PMP Hydrology

Methodology

The Generalised Short-Duration Method (GSDM) (Hydrometeorological Advisory Service, 2003) was adopted in conjunction with the temporal patterns developed by Jordan, Nathan, Mittiga and Taylor (2005).

This methodology follows the steps outlined below:

1. Selection of a terrain category (rough or smooth) based on terrain elevation;
2. Determination of an elevation adjustment factor, based on the terrain elevation;
3. Determination of a Moisture Adjustment Factor for adjustment of the standardised Depth-Duration-Area (DDA) curves;
4. Calculation of the PMP rainfall depth estimates using the DDA curves;
5. Determination of the temporal distribution of the PMP depths. Here the 10 ensemble temporal patterns as outlined in (Jordan, Nathan, Mittiga, & Taylor, 2005) were adopted; and
6. Determination of the spatial distribution of the PMP depths using a set of spatial ellipses provided by the Bureau of Meteorology,

The placement of the GSDM Spatial Distribution ellipses over the subject catchment is illustrated in Figure 2 below and the parameters adopted for the key items listed in the methodology above are outlined in Table 4 and Table 5 in Appendix A.

Having determined the PMP rainfall depths, temporal and spatial patterns, the resultant data was manipulated for input into the RORB hydrologic model and the model was simulated for all 10 temporal patterns for the 11 durations outlined in Table 5, Appendix A.

RORB Hydrologic Modelling

A new hydrologic model was developed for the previous WCMP (Craig & Rhodes, 2022) for Menangle Creek and Woodhouse Creek from the outlet at Nepean River to the upper most reaches of the catchments. The modelling also included several small tributaries that flow west under the Hume Motorway, because they traverse the subject site.

Detailed discussion of the hydrological model development, methodology and approach is provided in the WCMP (Craig & Rhodes, 2022) and a short summary is provided here for reference.

The modelling approach followed the latest NSW jurisdictional advice as provided on the ARR2016 Data Hub. The catchment delineation was undertaken utilising the GRASS software included within QGIS in conjunction with the 2011 Wollongong LiDAR. The modelling was undertaken using the industry standard software, RORB. RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce runoff hydrographs at any location (Laurenson, Mein, & Nathan, 2010).

Developed Conditions Hydrology

The changes between the existing conditions and developed conditions RORB models are as follows:

- The fraction impervious values were updated to match the latest Revision J Master Plan
- Some reach types were adjusted to reflect the developed conditions. For example, some natural reaches were changed to lined reaches to reflect flow over roads, and one reach was changed to natural to reflect a developed riparian corridor
- Minor updates were made to the sub area boundaries; however, this is as per the WCMP (Craig & Rhodes, 2022)

The results of the PMP RORB Hydrologic Modelling will be utilised in the TUFLOW hydraulic model to determine flood extent, flood levels, depths, velocities, and hazard for the PMF event.

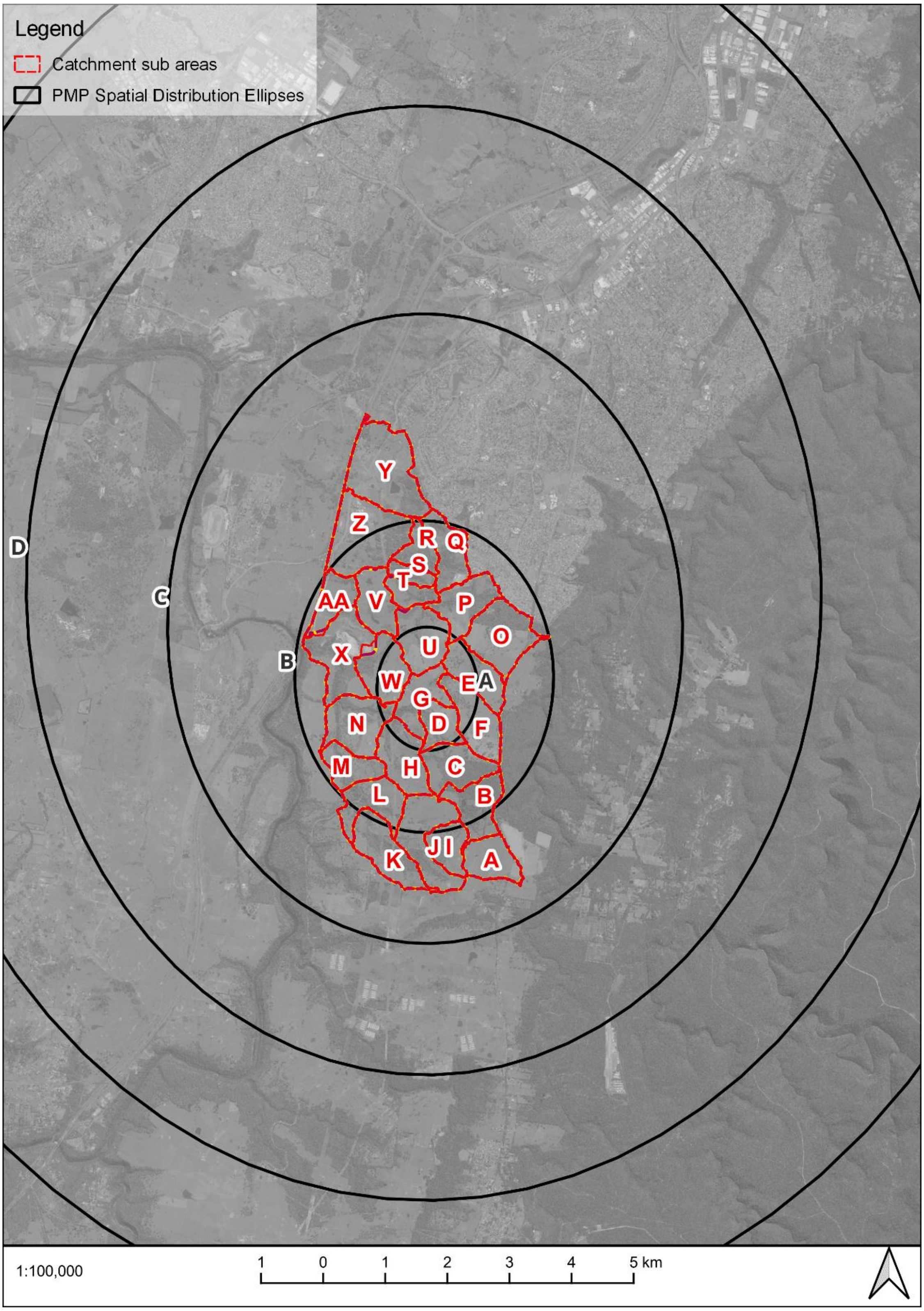


Figure 2 PMP Spatial Distribution Ellipses

Assumptions and Limitations

The following assumptions were made to undertake the PMP hydrologic analysis as per the GSDM Guidelines (Hydrometeorological Advisory Service, 2003).

1. That the terrain is wholly rough because it is located within 20km of rough terrain (where rough terrain is classified as changes in elevation of 50m or more within horizontal distances of 400m).
2. That interpolation is appropriate between the moisture adjustment factor lines provided by the Bureau of Meteorology.
3. The ellipses were placed at the centroid of the catchment, and such that they are capturing as much of the catchment as possible in the smallest ellipses as possible, as per the guidelines.
4. The catchment area value on the Depth-Duration-Area curves can only be best estimation if the value of the catchment is not a whole number that aligns with the horizontal axis.

Limitations

ARR2019 (Nathan & Weinmann, 2019) notes that the procedures for estimating the PMP and PMF are based on the recognition that the uncertainties involved with the flood estimation process increase with increasing size of the flood (or reducing AEP). The notional event classes are illustrated in Figure 3 and the PMP/PMF estimate typically falls within the Extreme event class. As can be seen from Figure 3 below, the upper and lower limits of uncertainty are much wider than for the rare and very rare floods. ARR2019 (Nathan & Weinmann, 2019) provides an approach that is intended to yield estimates within the mid-range of the notional uncertainty band, and it is recommended that this best estimate be adopted rather than values at the limits of the uncertainty bands. It is these best-estimate procedures that have been adopted for determination of the PMP/PMF for this report, however the uncertainty outlined here should also be taken into consideration when assessing the results of this study.

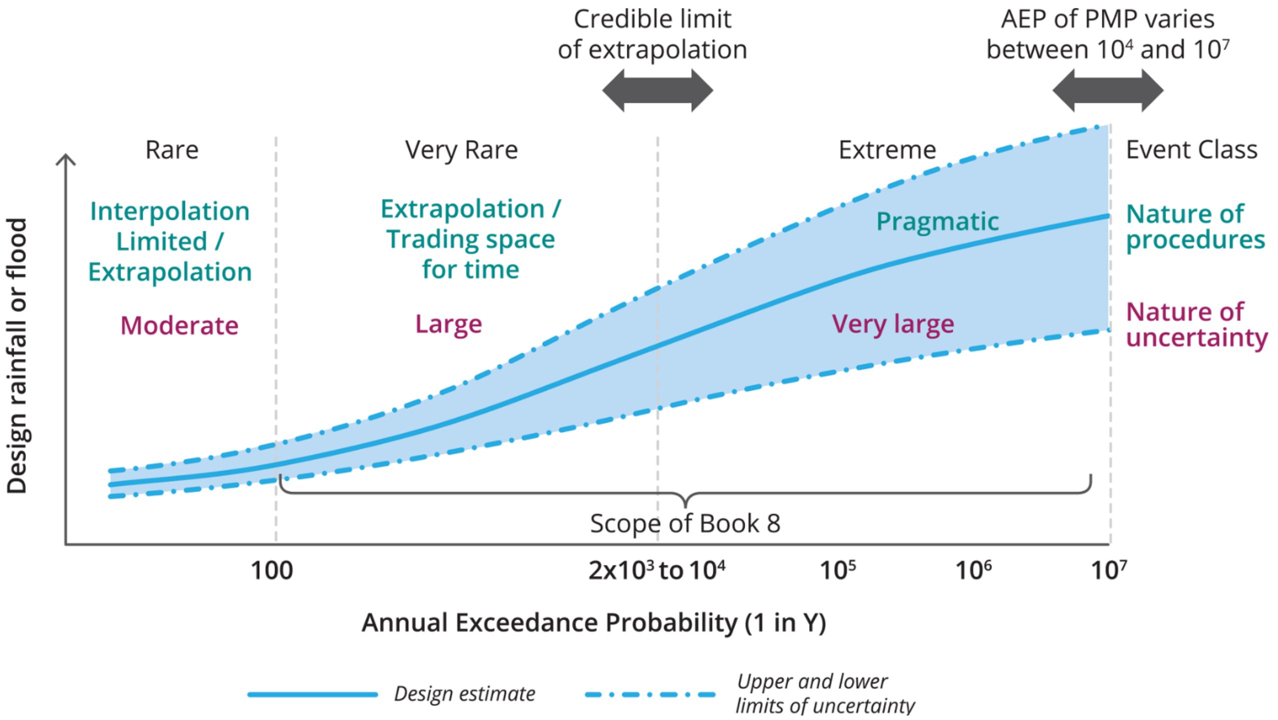


Figure 3 Design Characteristics of Notional Event Classes (Source: ARR2019 (Nathan & Weinmann, 2019))

Critical Storm Event

The hydrologic modelling was analysed to determine the "1-up" median temporal pattern and the maximum (of the medians) duration. This analysis determines the critical duration of the catchment, and the resultant critical duration hydrographs will be utilised in the TUFLOW hydraulic modelling. This process for determining the critical event is outlined in Figure 4 below.

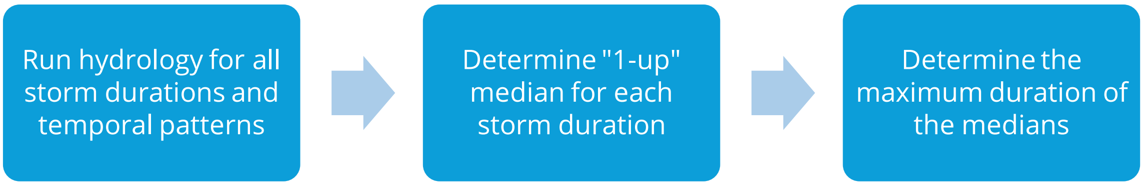


Figure 4 Process for determination of critical storm event

Based on the RORB simulation, the following critical storm events outlined in Table 1, were adopted for simulation in the TUFLOW hydraulic model.

Table 1 Critical storm events

Storm Event	Duration	Median Temporal Pattern
PMP	15-minute – critical for all hyetograph sub areas	TP03
	240-minute – critical for all hydrograph inflows	TP04

Hydrologic Results

Results at key locations in the catchment are outlined in Table 2 and the key locations are illustrated in Figure 5 below.

Table 2 PMP Hydrologic Results at key locations

Location	Existing Conditions Flow (m^3/s) (Critical Duration)	Developed Conditions Flow (m^3/s) (Critical Duration)
Q1 TUFLOW Inflow	98.4 (4 Hour)	98.4 (4 Hour)
P1 TUFLOW Inflow	132.5 (4 Hour)	132.5 (4 Hours)
N2 TUFLOW Inflow	635.9- (4 Hours)	635.9 (4 Hours)
Menangle Creek Total Outflow	372.6 (4 Hour)	371.7 (4 Hours)
Confluence of Menangle Creek & Woodhouse Creek	975.7 (4 Hours)	975.2 (4 Hours)
Outflow to Nepean River	950.2 (4 Hours)	951.0 (4 Hours)

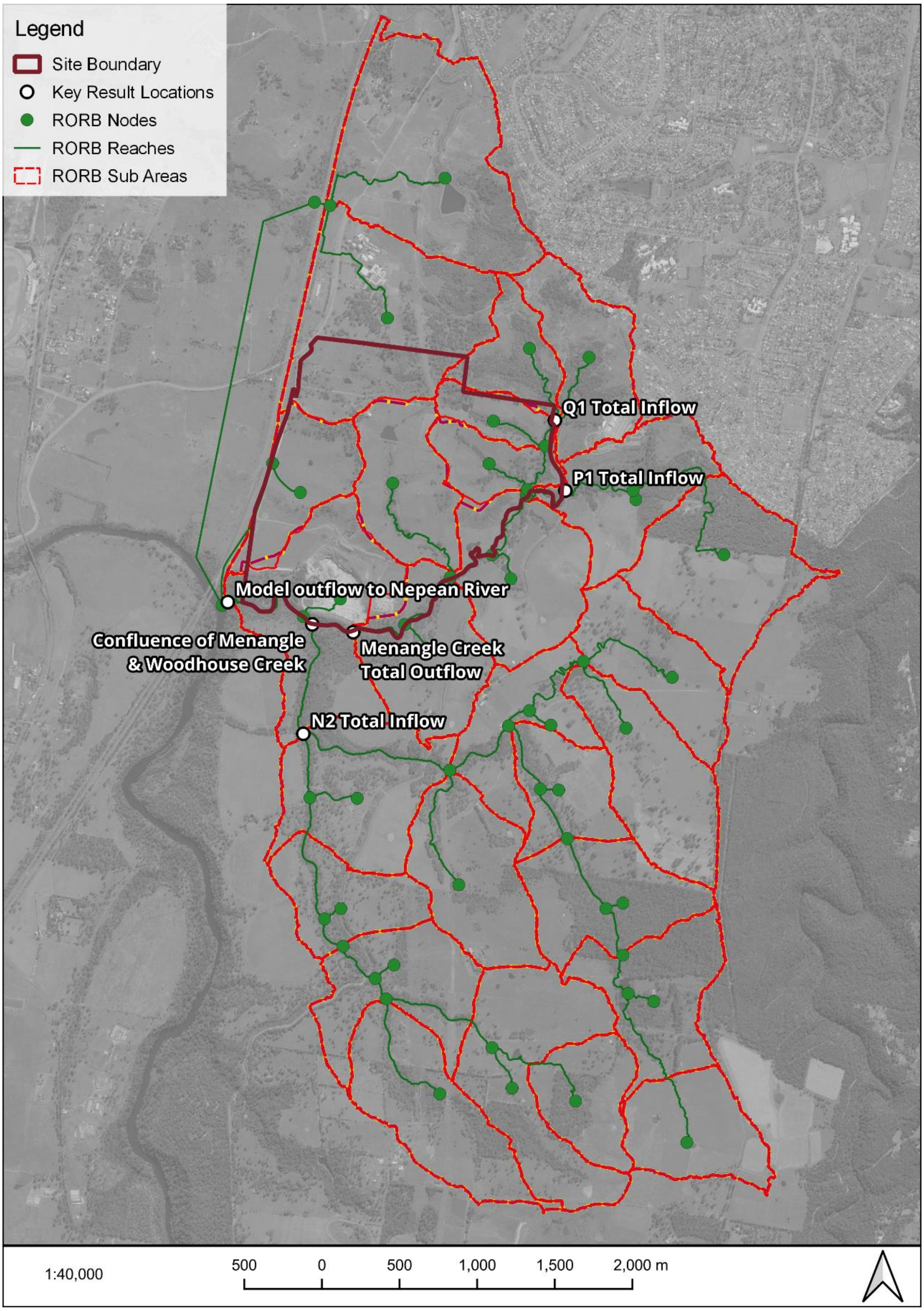


Figure 5 Key hydrologic results locations

4. PMF Hydraulic Modelling

The TUFLOW hydraulic model developed for the Water Cycle Management Report (Craig & Rhodes, 2022) was utilised for the simulation of the Probable Maximum Flood (PMF) analysis. The purpose of the model is to understand the catchment conditions and existing flood regime to understand the high-level impacts of the proposed development, if any during the PMF storm event.

Digital Elevation Model

The base digital elevation model (DEM) for existing condition was developed from the Wollongong 2011 LiDAR in conjunction with cross sectional survey of the open channels. The developed conditions DEM was formed from the above base plus a design tin formed from the civil bulk earthworks modelling. The design tin was not significantly changed for this iteration of the report.

Boundary Conditions

The model extents and accordingly, the outflow boundaries were slightly modified to ensure the full extent of the PMF flooding was captured. In addition, inflow sub area Z was extended further north to capture the full sub area and to cover a residential area to the north of the proposed development that may be impacted by PMF flooding.

The model boundary changes are illustrated in Figure 6 below.

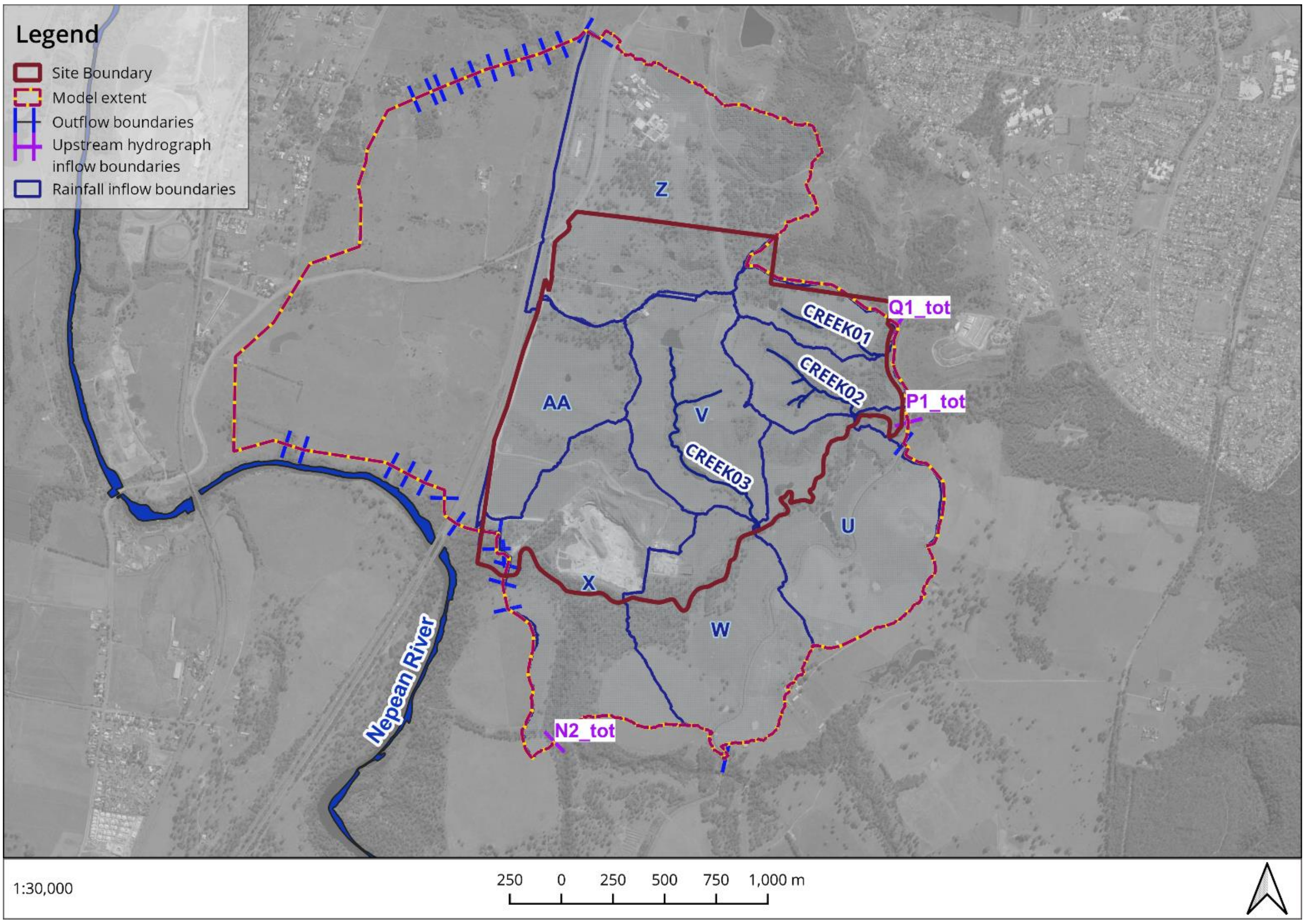


Figure 6 Model boundary conditions – existing and developed conditions

Manning's Roughness

The same Mannings roughness values as those adopted in the WCMP (Craig & Rhodes, 2022) were used for this iteration of the modelling, and minor modifications were made to the developed conditions Manning's 'n' roughness layout to reflect the latest Revision J Masterplan.

The resultant Mannings 'n' roughness layer is illustrated in Figure 7 below.

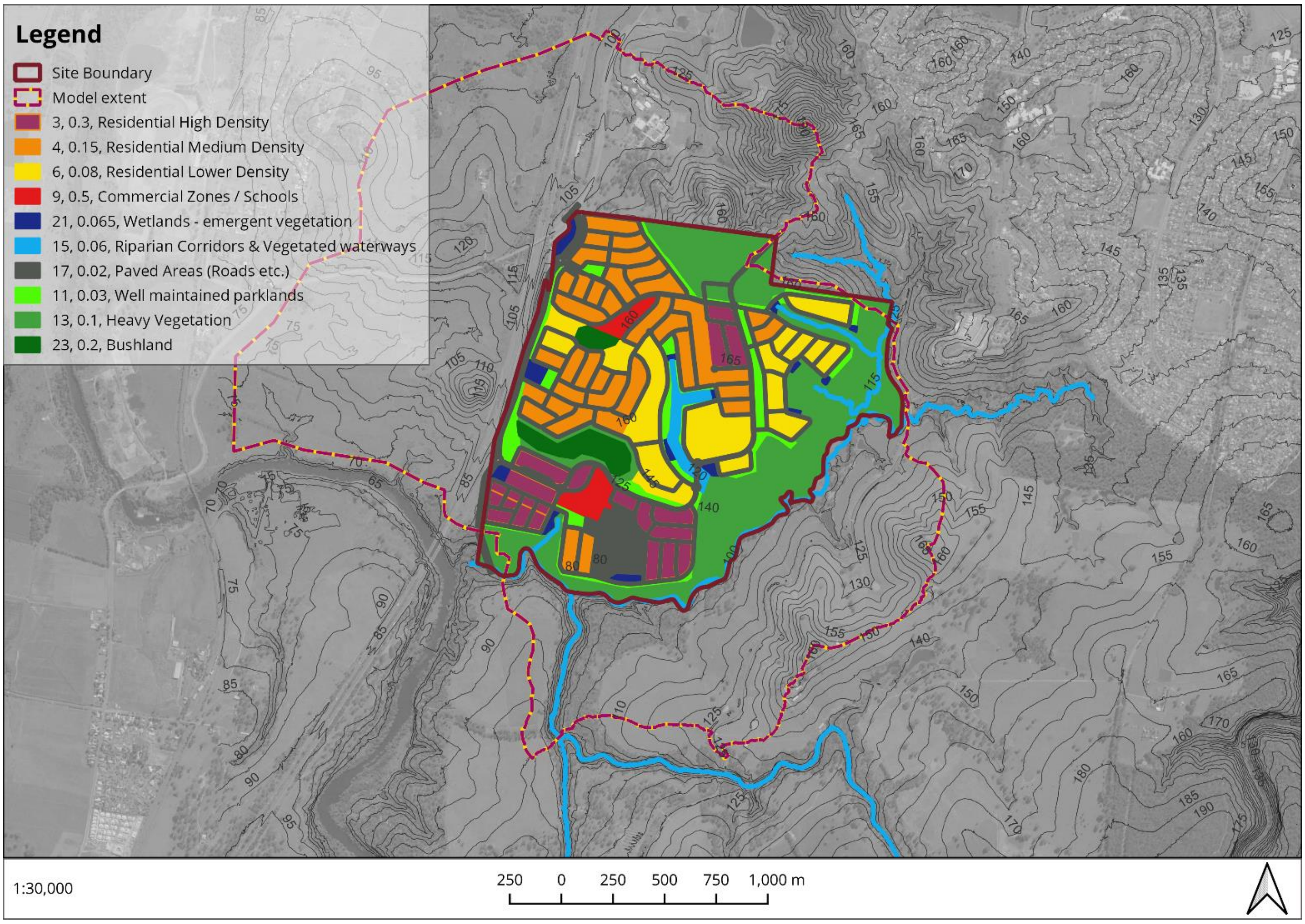


Figure 7 Mannings 'n' roughness – developed conditions

Storm Events

The following storm events were simulated in the TUFLOW hydraulic model, based on the results of the RORB hydrologic modelling.

Table 3 Storm events modelled

Storm Event	Duration	Median Temporal Pattern
PMF	15-minute	TP03
	240-minute	TP04

No additional changes were made to any other aspect of the TUFLOW model such as farm dams or structures.

5. Results

The flooding results for the PMF storm are discussed in the following sections and flood maps for levels, depths, velocity, and hazard are provided in Appendix B.

Critical Duration

As demonstrated in the hydrologic modelling, the 15-minute duration is critical for overland flow and the 240-minute storm duration is critical for riverine flow in Menangle and Woodhouse Creeks for both existing and developed conditions.

Existing Conditions

Existing conditions PMF flood modelling results illustrates that in the PMF storm event, flooding is typically contained within the channels across the proposed development site. This is because the channels are heavily incised and quite deep.

The following flood depth results are observed:

- Flood depths in Creek01 range between 1.2 and 1.6m
- Flood depths in Creek02 range between 1.0 and 2.2m
- Flood depths in Creek03 range between 0.8 and 2.0m
- There is shallow sheet overland flooding with depths up to 0.5m but is typically closer to 0.25-0.3m
- North of the site, there is ponding behind Menangle Road on the Broughton Anglican College, with depths over 1.0m. However, there are no culvert details available at this location, and it is therefore assumed that the flooding would not be this deep if culverts were present in the model.
- At the same location, flood waters pond behind the Hume Motorway to depths of up to 1.5m, however there are also no culvert details available for the Hume Motorway and therefore it assumed that flood depths both behind the Hume Motorway and behind Menangle Road would be less significant.
- Shallow sheet flows pass through a new development to the west of the Hume Motorway, with depths of approximately 0.25m.
- Minor flooding overtops the Hume Motorway at the south of the proposed development and traverses downstream to the outlet at the Nepean River, typically remaining within the low-lying valleys.
- Upstream (southeast) of the proposed development, there is shallow sheet overland flowing, but this is typically contained within undeveloped rural land, although it appears that PMF flooding may overtop into the Sydney Water irrigation channels in existing conditions at one location.
- Due to the steep terrain, velocities across the site can be high, greater than 2.0 m/s, particularly within the channels.
- Despite the shallow depths outside of the channels, the velocities can be high due to the steep terrain, this results in areas of high hazard in existing conditions. However, the high hazard areas are typically contained within the valleys.
- Within the existing quarry, flood depths are greater than 5m, but the velocities are very low. Nevertheless, due to very high depths, high hazard results within the quarry.
- Depths within Woodhouse Creek are very high, greater than 10m and therefore Woodhouse Creek also demonstrates high hazard flooding.

The existing conditions flood depth results are illustrated in Figure 8 below.

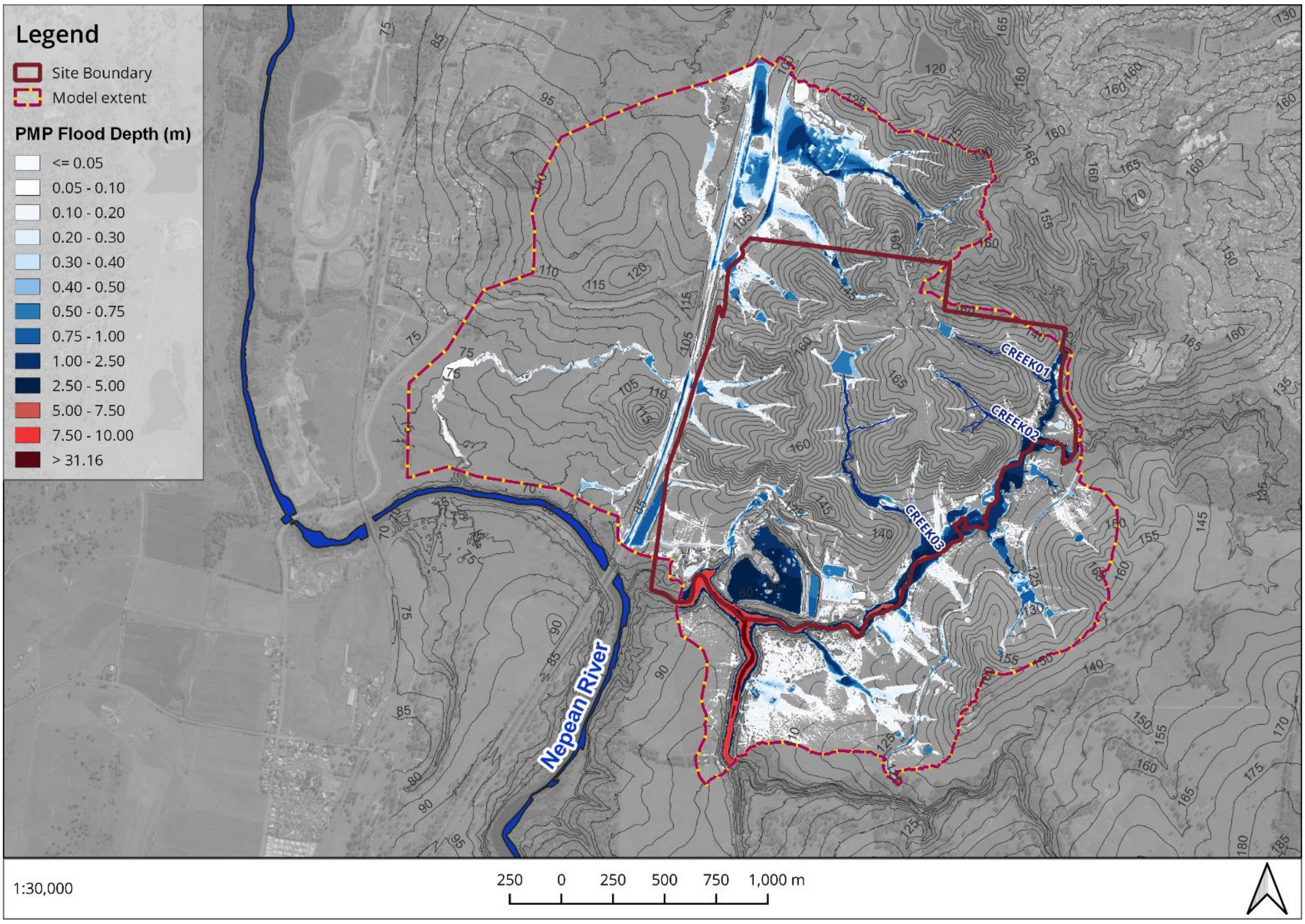


Figure 8 Existing conditions PMF flood depth

Developed Conditions

Developed conditions PMF flood modelling results illustrate that in the PMF storm event, flooding is typically contained within the channels for Creek01, Creek02, Creek03, Menangle Creek and Woodhouse Creek. This is because the channels are heavily incised and quite deep. However, there are valley lines present in the existing conditions, which are now proposed to be residential areas, and these are showing flooding of depths up to 0.5m.

The following flood depth results are observed for developed conditions:

- Flood depths in Creek01 range between 0.5 and 1.3m
- Flood depths in Creek02 range between 0.5 and 2.5m
- Flood depths in Creek03 range between 1.2 and 1.9 m
- There is shallow sheet overland flooding with depths up to 0.5m but is typically closer to 0.25m or less.
- North of the site, there is ponding behind Menangle Road on the Broughton Anglican College, with depths over 1.0m. However, there are no culvert details available at this location, and it is therefore assumed that the flooding would not be this deep.
- At the same location, flood waters pond behind the Hume Motorway to depths of 1.5m, however there are also no culvert details available at this location and therefore it assumed that flood depths both behind the Hume Motorway and behind Menangle Road would be less significant if the culverts were incorporated into the model.

- Shallow sheet flows pass through a new development to the west of the Hume Motorway, with depths of approximately 0.25m
- Minor flooding overtops the Hume Motorway and traverses downstream to the outlet at the Nepean River, southwest of the site, typically remaining within the low-lying valleys.
- Upstream (southeast) of the proposed development, there is shallow sheet overland flowing, but this is typically contained within undeveloped rural land, although it appears that PMF flooding may overtop into the Sydney Water irrigation channels in at least one location.
- Due to the steep terrain, velocities across the site can be high, greater than 2.0 m/s, particularly within the channels.
- Despite shallow depths outside of the channels, the velocities can be very high due to the steep terrain, made steeper in parts by the bulk earthworks grading, and this results in areas of high hazard.
- The existing quarry is proposed to be filled in developed conditions and will become active open space and low density residential. Flood depths range between 0.05m and 0.5m. Velocities now range between 0.15m/s to greater than 4.5m/s, and due to the high velocities, hazard can be as high as H6 across the active open space but is typically H1 or H2 within the residential area.
- Depths within Woodhouse Creek are very high, greater than 10m and therefore Woodhouse Creek also demonstrates high hazard flooding.

It should be noted that in developed conditions, the stormwater drainage network and minor road system has not yet been designed, and therefore it is anticipated that a significant portion of the shallow sheet flows would be taken up by these networks, reducing the significance of the overland flooding and likely also reducing areas of high hazard.

The developed conditions flood depth results are illustrated in Figure 9 below and the full extent of flood mapping for levels, depths, velocity, and hazard is provided in Appendix B.

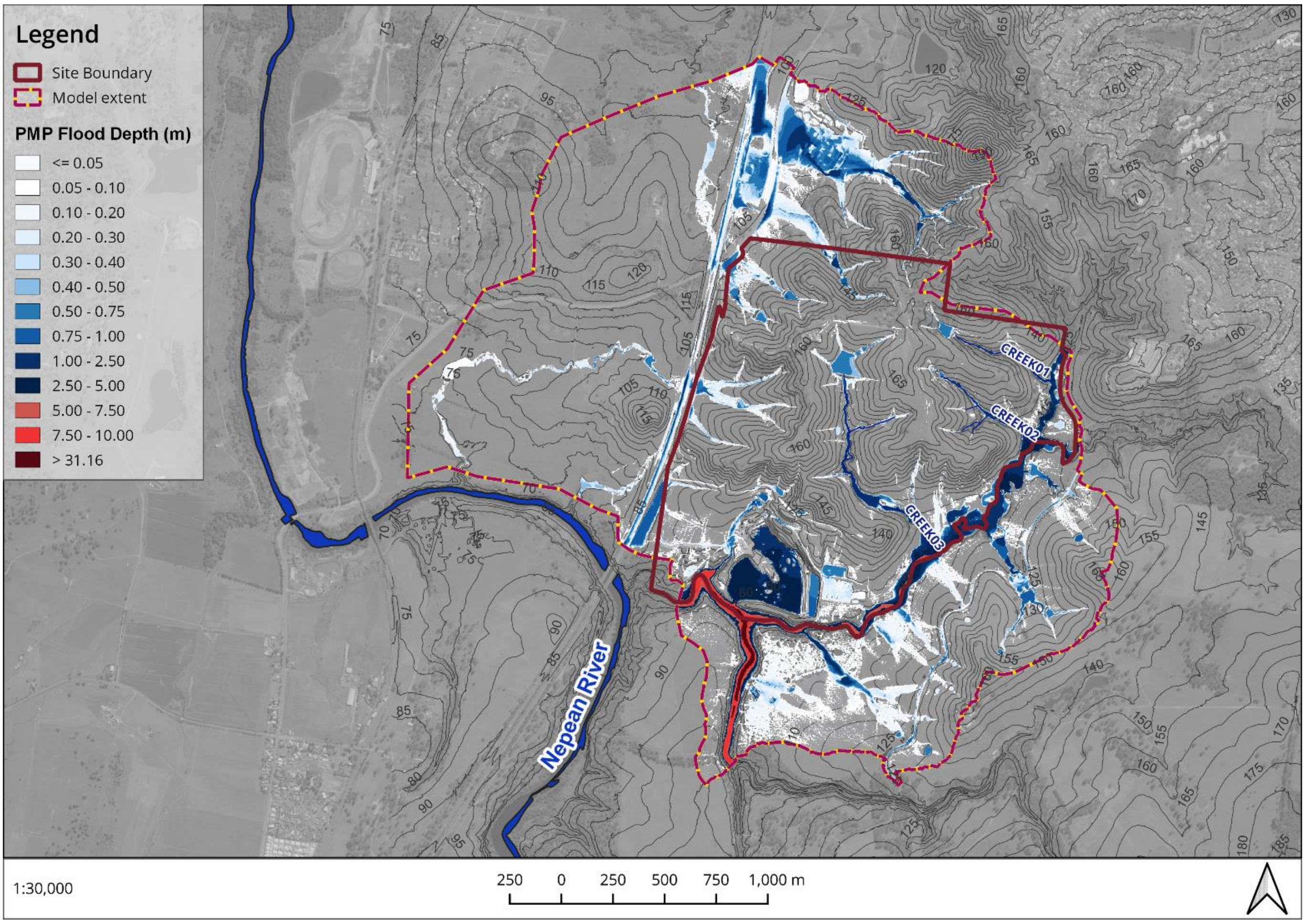


Figure 9 Developed conditions PMF flood depth

Afflux

Afflux is the difference between the developed conditions flood levels and the existing conditions flood levels.

The afflux map is illustrated in Figure 10 below and illustrates that offsite impacts are negligible. There are reductions in flooding to the north of the site, between Menangle Road and the Hume Motorway of up to 0.12m, with a small increase of up to 0.06m slightly south of the same location and a reduction of 0.5m^3/s overtopping the Hume Motorway.

The afflux mapping shows the following:

- At the southwest corner of the site, adjacent to Hume Motorway there is decrease in flood levels of up to 0.12m
- Menangle Creek demonstrates a decrease in flood levels at the downstream end of up to 0.55m, this is likely due to flood waters becoming trapped within the development behind roads in the vicinity of the quarry, and due to the lack of drainage and minor road network that conveys flooding downstream.
- Menangle Creek at the upstream end of the development has an increase in flood levels of up to 0.16m, due to increase runoff from the development at this location.
- Woodhouse Creek shows a reduction in flood levels of up to 0.6m, partly due to changes in the hydrologic model and partly due to reductions in the downstream Menangle Creek flood levels.
- Across the proposed development site, the flood regime changes due to changes in the terrain and Mannings roughness that reflect the proposed development. The most significant change is a

perceived increase in flood levels at the location of the quarry, however, this is due to the proposed filling of the quarry, rather than an actual flood level increase. However, there is also an increase in flood levels surrounding the quarry, where flooding may have otherwise runoff into the quarry or into Menangle Creek previously and is now trapped adjacent to the quarry behind proposed roads where drainage and culverts are yet to be designed.

- There are increased flood levels in both Creek02 and Creek03 due to increased runoff from the development.
- On the western side of the development there is an increase in flood levels of up to 1.5m, but typically 0.2 – 0.3m on residential lots, where there are changes to the terrain. It is likely that there would be culverts under the Hume Motorway at this location that would allow flood waters to flow downstream, decreasing the significance of the impacts at this location.
- The northwest corner displays similar flood behaviour to the flow regime on the western side. Increases of up to 1.4m are observed but is more typically around 0.5 – 1.0m, immediately adjacent to the proposed new ring road, a significant decrease in flood levels of up to 1.3m is also observed. Noting here, that culverts under the ring road have not yet been designed that will allow water to flow downstream.

It should be noted that due to the proposed changes in terrain within the development boundary, there are noticeable changes in flood levels and flow regime, with both increases and decreases in flood levels observed, however the impacts offsite are negligible, resulting mostly in decreased flood levels. The internal change in flow regime will be less significant once stormwater drainage, culverts and the minor road networks are incorporated.

The afflux map is illustrated in Figure 10 below, with full afflux mapping provided in Appendix B.

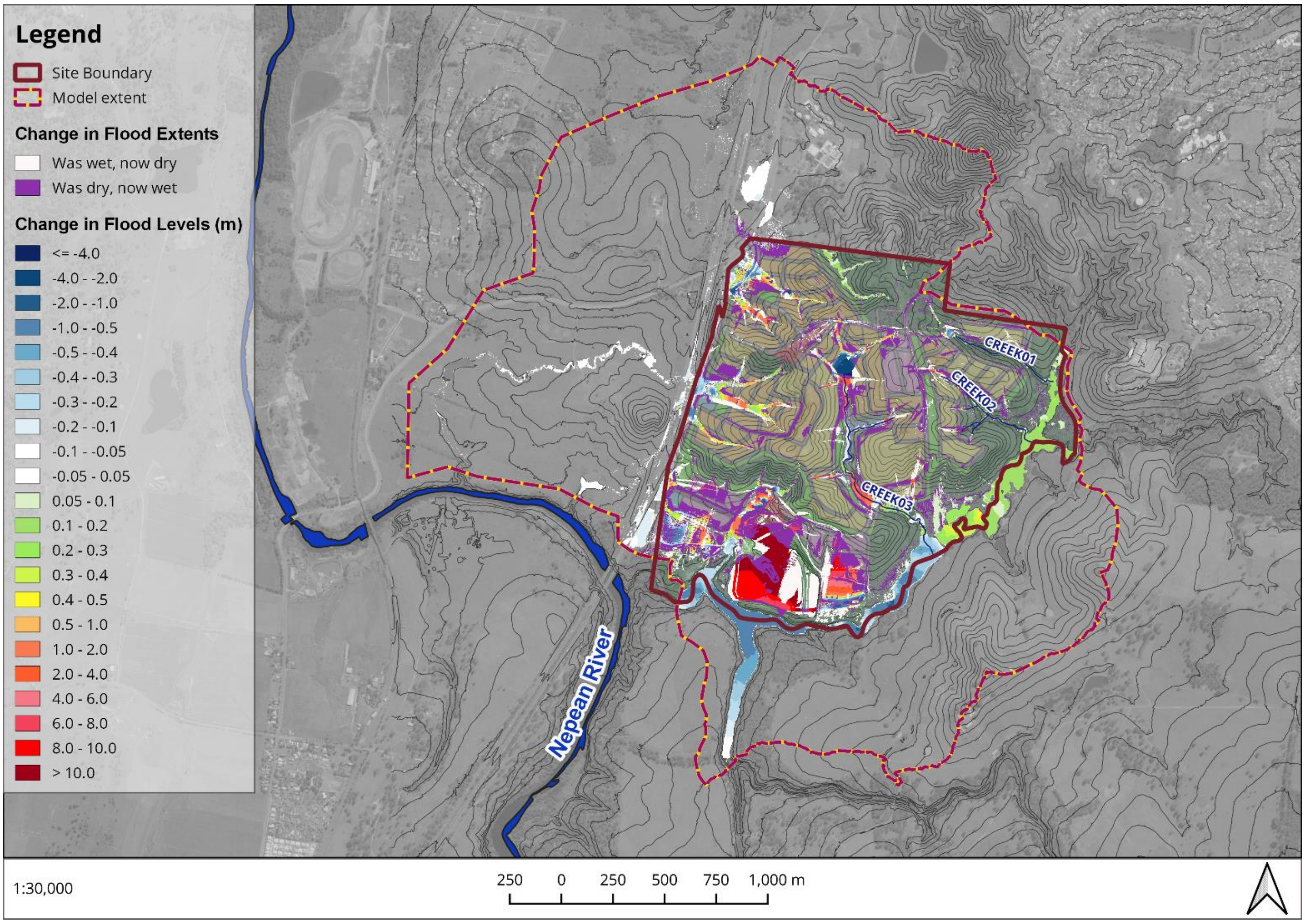


Figure 10 Afflux map

Results Summary

Results of the PMF flood analysis demonstrates that flooding is typically contained within the heavily incised creeks that traverse the site and Menangle and Woodhouse Creek. However, due to the bulk earthworks, and the masterplan layout, there is some flooding that is shown across residential lots in developed conditions. This flooding is typically quite shallow and would easily be catered for by the stormwater drainage and minor road network, which has not yet been developed or included within the TUFLOW model. The stormwater drainage network and minor road network will likely grade towards the three internal tributaries of Menangle Creek, Creek01, Creek02 and Creek03, which ultimately drain to Menangle Creek. Given there is currently a decrease in flood levels shown in the downstream end of Menangle Creek, it is envisaged that the resultant offsite afflux upon inclusion of these structural elements will be neutral on the eastern side of the development.

On the western side of the development, noting that the bulk earthworks terrain model has not been updated to reflect the latest Masterplan, therefore shows flooding and afflux on residential lots. It is anticipated that once the bulk earthworks has been further developed to match the current masterplan, this flooding will be redirected to the minor road network and the stormwater drainage. Additionally, incorporation of culverts under the proposed ring road, Menangle Road and the Hume Motorway will allow flood waters to flow downstream at these two western locations. It is envisaged, that even though additional water may flow downstream at these locations on the western side of the proposed development, flows will nevertheless be contained within the existing channels downstream of the Hume Motorway. With the culverts missing under Menangle Road and the Hume Motorway, which is currently showing ponding behind these roads, flooding on the proposed development site may be more conservative than would otherwise occur.

Finally, a detention basin analysis was undertaken within the WCMP (Craig & Rhodes, 2022) and this highlighted the need to avoid detention basins so that runoff from the site would flow to both Menangle Creek and the Nepean River at various locations prior to the peak of these catchments occurring, particularly given that the development site is at the downstream end of both catchments, therefore detention basins are not included as part of the Flooding and Water Cycle Management strategy.

6. Flood Risk Assessment

This report has adopted the general flood hazard vulnerability curves outlined in the Australian Disaster Resilience Handbook Collection (Commonwealth of Australia, 2017), as illustrated in Figure 11 below. The figure demonstrates that hazard category H1 is generally safe for people, vehicles and buildings and is the ideal flood risk category, however H2 hazard category can also be acceptable in some cases, from a flood risk perspective.

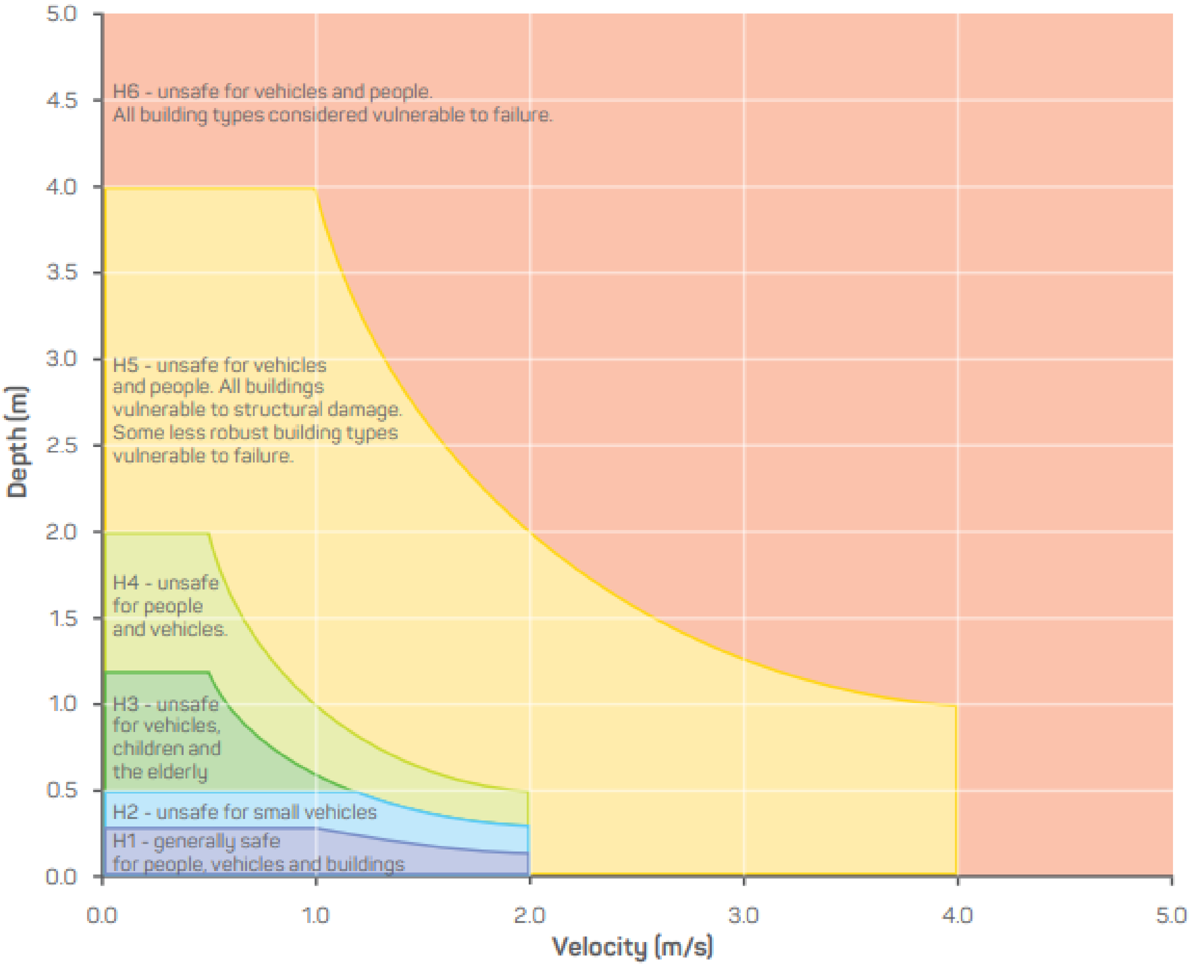


Figure 11 General flood hazard vulnerability curves (Commonwealth of Australia, 2017)

The results of the PMF flood analysis show that the PMF flood hazard in developed conditions demonstrates that outside of the main waterways, within trafficable and residential areas, flood hazard is most typically H1, however, due to steep terrain across the site causing higher velocities, there are some areas of high hazard. These occur most notably on the road network, but as the majority of these higher velocity flows are also very shallow, most of the flows will be taken up by the underground drainage network and therefore, ultimately the hazard conditions will be less significant at DA stage.

Nevertheless, at DA stage, once the stormwater drainage, culverts and minor road network have been incorporated, plus further refinements to the bulk earthworks tin, if areas of high hazard remain a Flood Emergency Response Plan may be required to be prepared.

The PMF developed conditions flood hazard is illustrated in Figure 12 below and the full mapping is provided in Appendix B.

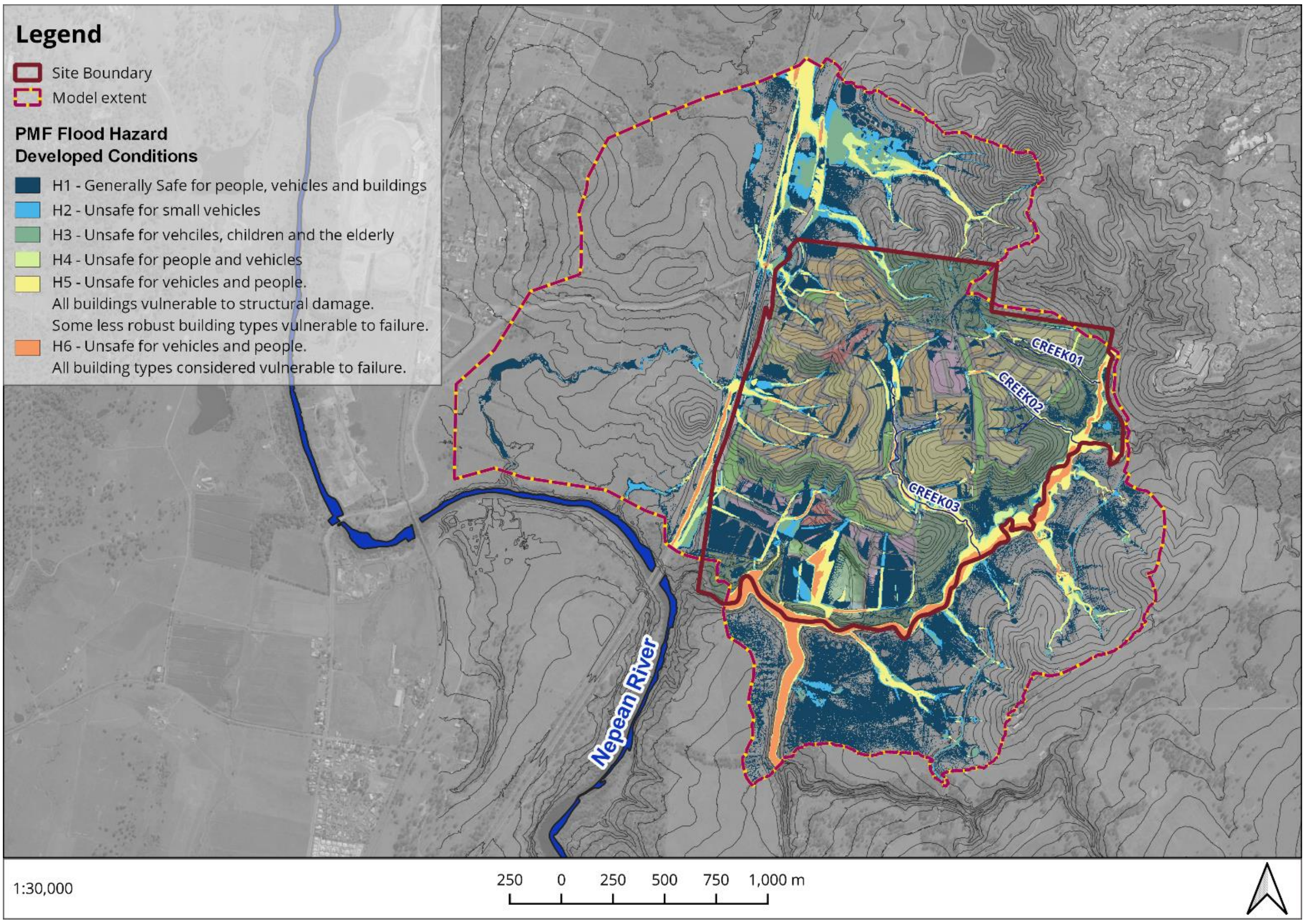


Figure 12 Developed conditions PMF Flood Hazard

7. Conclusion and Recommendations

A planning proposal was submitted for the development of Rosalind Park at 33 Medhurst Road, 101 and 111 Menangle Road, Menangle Park for the 1% AEP event. Council subsequently requested analysis and inclusion of the PMF storm event. This report presents an analysis of the PMF flood modelling, approach, assumptions, results, and recommendations.

Hydrologic and hydraulic flood modelling was undertaken for the proposed Rosalind Park development utilising the RORB hydrologic and the TUFLOW hydraulic models that were prepared for the Water Cycle Management Plan (Craig & Rhodes, 2022).

Minor changes to the RORB hydrologic model for developed conditions included reach types and reach slopes as well as fraction impervious values within the vicinity of the proposed development.

Changes to the TUFLOW hydraulic model included addition of the PMP hydrology developed within the RORB hydrologic model. Negligible changes were made to the developed conditions bulk earthworks tin. Changes were made for the developed conditions to the inflow and outflow boundaries and the model extents and changes to the Mannings 'n' roughness layers. These changes were incorporated to reflect the latest masterplan, Revision J.

Results of the PMF flood analysis demonstrate that flooding is typically contained within the heavily incised creeks that traverse the site and Menangle and Woodhouse Creek. However, due to the bulk earthworks, and the masterplan layout, there is some flooding that is shown across residential lots in developed conditions. This flooding is typically quite shallow and would easily be catered for by the stormwater drainage and minor road network, which has not yet been developed or included within the TUFLOW model. It should also be noted that there are culverts missing under Menangle Road and the Hume Motorway, which is showing ponding behind these roads and therefore flooding on the site may be more conservative than would occur. Finally, incorporation and optimisation of internal culverts would better allow flow to traverse downstream to the channels and creeks and would also reducing the significance of onsite flooding. As discussed in Section 5, once the stormwater drainage and minor road network have been incorporated, it is envisaged that afflux on the eastern side of the proposed development will be neutral and on the western side of the proposed development, it is expected that increase in flood levels would be very minor and would likely be contained within the existing channels that flow to the Nepean River.

Due to steep terrain, velocities can be high across the site and therefore there are some areas of high hazard, but as these flows are typically shallow, it is likely they will get taken up by the underground stormwater drainage and flow towards the internal tributaries of Menangle Creek. However, as discussed in Section 6, if areas of high hazard remain after updates to the bulk earthworks tin, incorporation of culverts and the stormwater drainage network and the minor road network, then a Flood Risk Management Plan and Evacuation Plan may be required at DA stage.

8. References

Bureau of Meteorology. (2023). *Design Rainfall Data System (2016)*. Retrieved June 16, 2023, from Australian Government Bureau of Meteorology: http://www.bom.gov.au/water/designRainfalls/revised-ifd/

Commonwealth of Australia. (2017). Australian Disaster Resilience Handbook Collection, Guideline 7-3 Flood Hazard. (A. I. Resilience, Ed.) Australian Institute for Disaster Resilience on behalf of the Attorney-General's Department. Retrieved September Monday 18th, 2023, from https://knowledge.aidr.org.au/media/3518/adr-guideline-7-3.pdf

Craig & Rhodes. (2022). *Water Cycle Management Report.* Sydney.

Hydrometeorological Advisory Service. (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method.* (A. G. Meteorology, Ed.) Retrieved September 01, 2023, from Download the Generalised Short-Duration Method: http://www.bom.gov.au/water/designRainfalls/pmp/gsdm_document.shtml

Jordan, P., Nathan, R., Mittiga, L., & Taylor, B. (2005). Growth Curves and temporal patterns of short duration design storms for extreme events. *Australasian Journal of Water Resources, 9:1*, 69-80. doi:10.1080/13241583.2005.11465265

Laurenson, E., Mein, R. G., & Nathan, R. J. (2010). *RORB Version 6, Runoff Routing Program User Manual.* Monash University and Hydrology and Risk Consulting Pty Ltd.

Nathan, R., & Weinmann, E. (2019). *Procedures for Estimating Very Rare to Extreme Floods, Book 8 in Australian Rainfall and Runoff - A Guide to Flood Estimation.* Commonwealth of Australia.

Appendix A. PMP Hydrology Parameters

Table 4 PMP Hydrology Parameters

Parameter	Value
Catchment Area	17.74 km^2
Co-ordinates	-34.13° latitude, 150.78° longitude
Terrain Category	100% Rough
Elevation Adjustment Factor	1 (Terrain is lower than 1500m AHD)
Moisture Adjustment Factor	0.69 by interpolation between 0.6 and 0.7 lines

Table 5 PMP Depth Estimates

Duration (hours)	Initial Depth Smooth	Initial Depth Rough	PMP Estimate $(D_s*S + D_r*R)*MAF*EAF$	Rounded PMP Depth Estimate
0.25	205	205	141.45	140.00
0.50	300	300	207.00	210.00
0.75	385	385	265.65	270.00
1.0	450	450	310.50	310.00
1.5	515	575	396.75	400.00
2.0	575	670	462.30	460.00
2.5	610	740	510.60	510.00
3.0	640	810	558.90	560.00
4.0	710	925	638.25	640.00
5.0	765	1020	703.80	700.00
6.0	810	1085	748.65	750.00

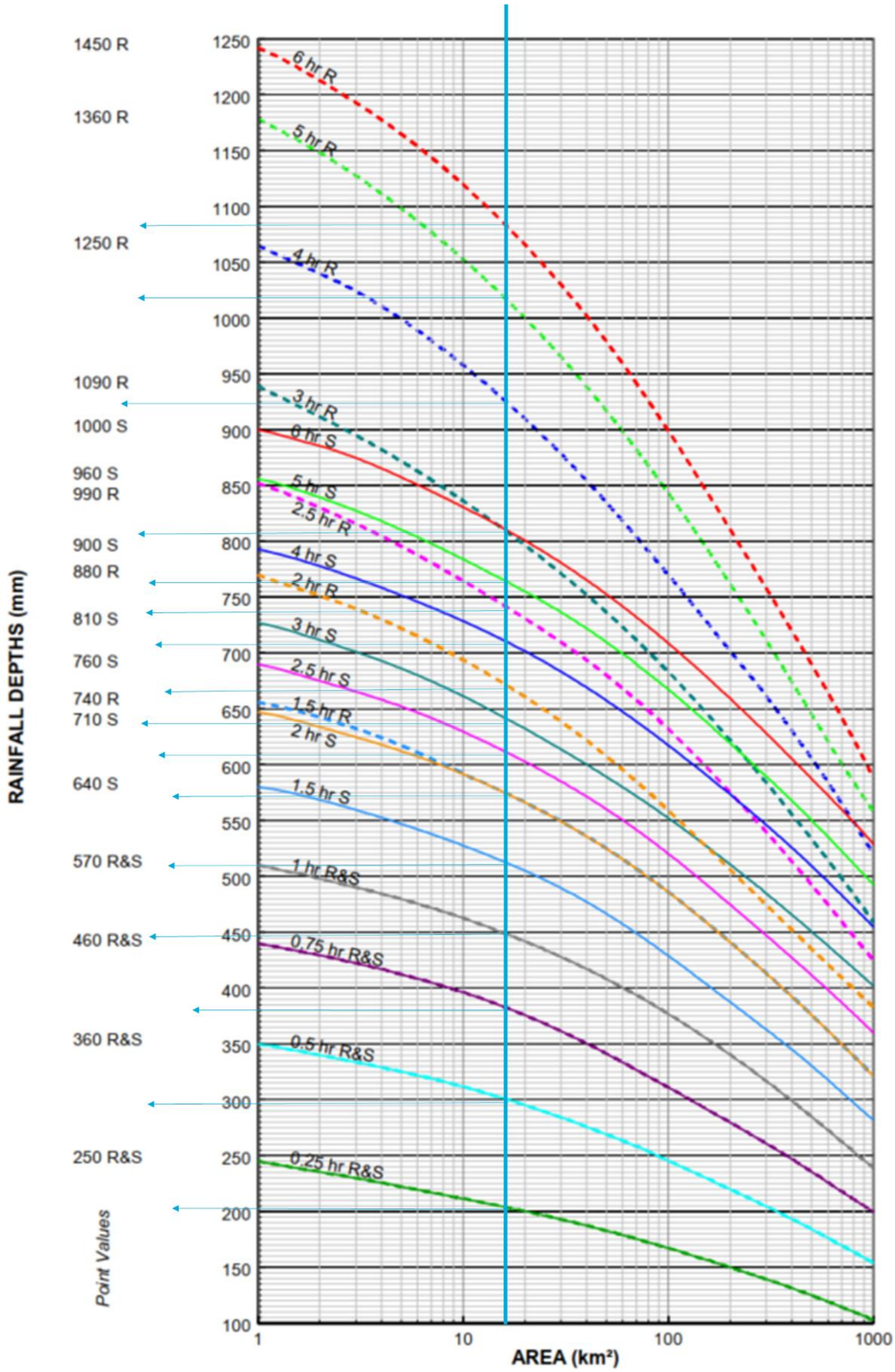


Figure 4: Depth-Duration-Area Curves of Short Duration Rainfall

Figure 13 Depth-Duration-Area Curves for determination of PMP Depths (Source (Bureau of Meteorology, 2023))

Appendix B. Flood Mapping

B.1 Existing Conditions

B.1.1 PMF Flood Levels – Map 1

B.1.2 PMF Flood Depths – Map 2

B.1.3 PMF Flood Velocity – Map 3

B.1.4 PMF Flood Hazard – Map 4

B.2 Developed Conditions

B.2.5 PMF Flood Levels – Map 5

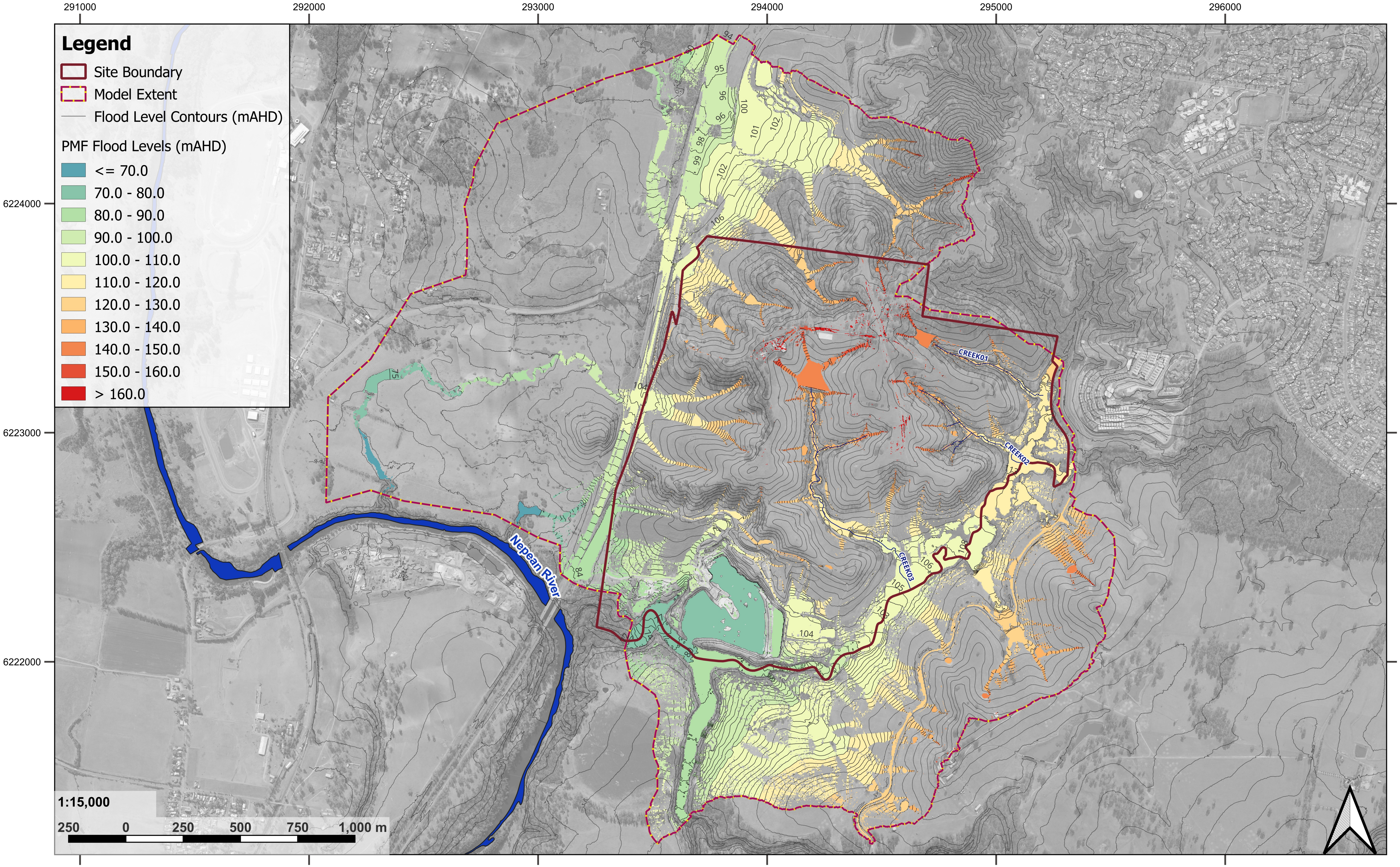
B.2.6 PMF Flood Depths – Map 6

B.2.7 PMF Flood Velocity – Map 7

B.2.8 PMF Flood Hazard – Map 8

B.3 Afflux Mapping

B.3.9 Afflux Mapping – Map 9

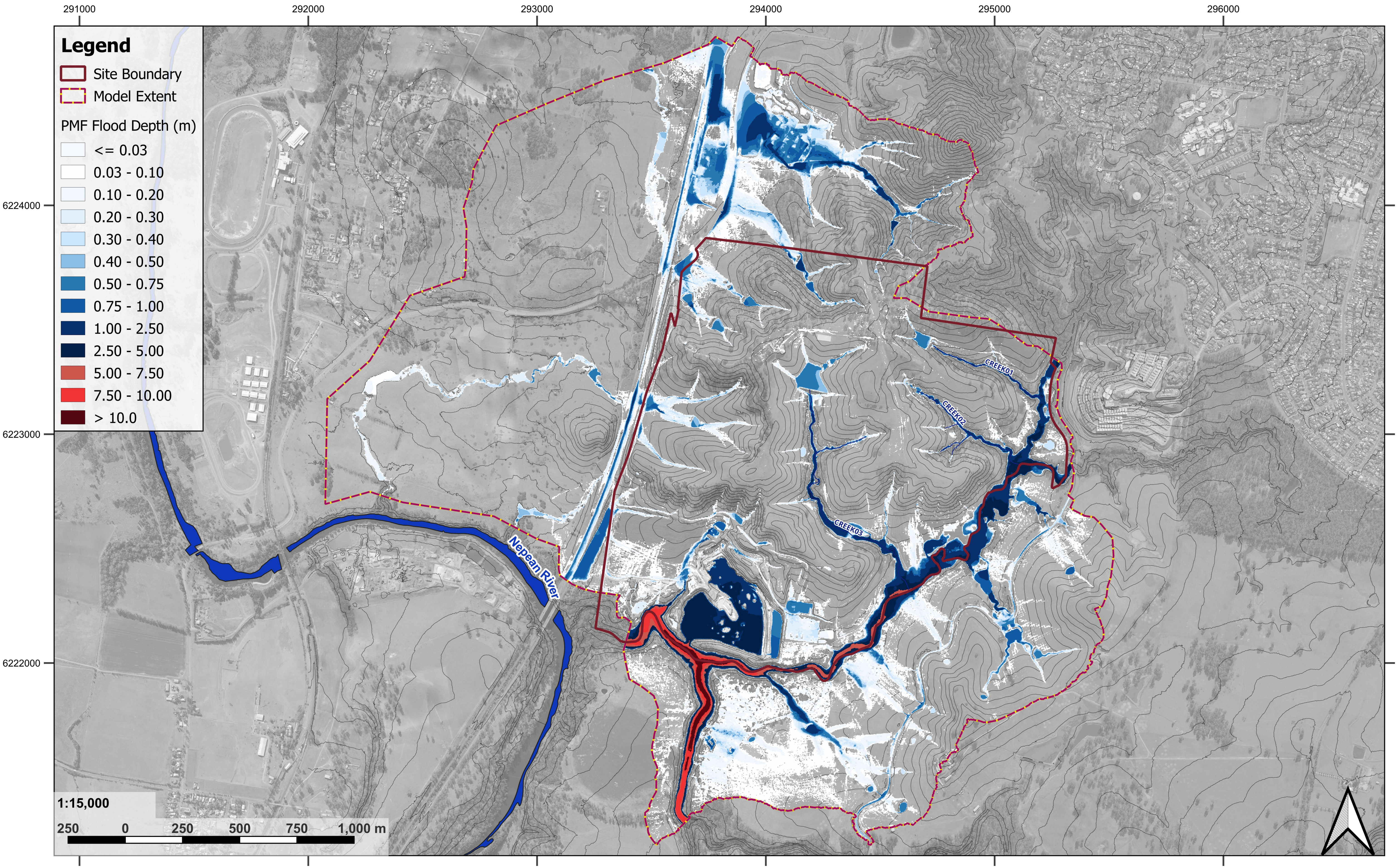


Colliers

CRAIG& RHODES
TAKE THE LEAD

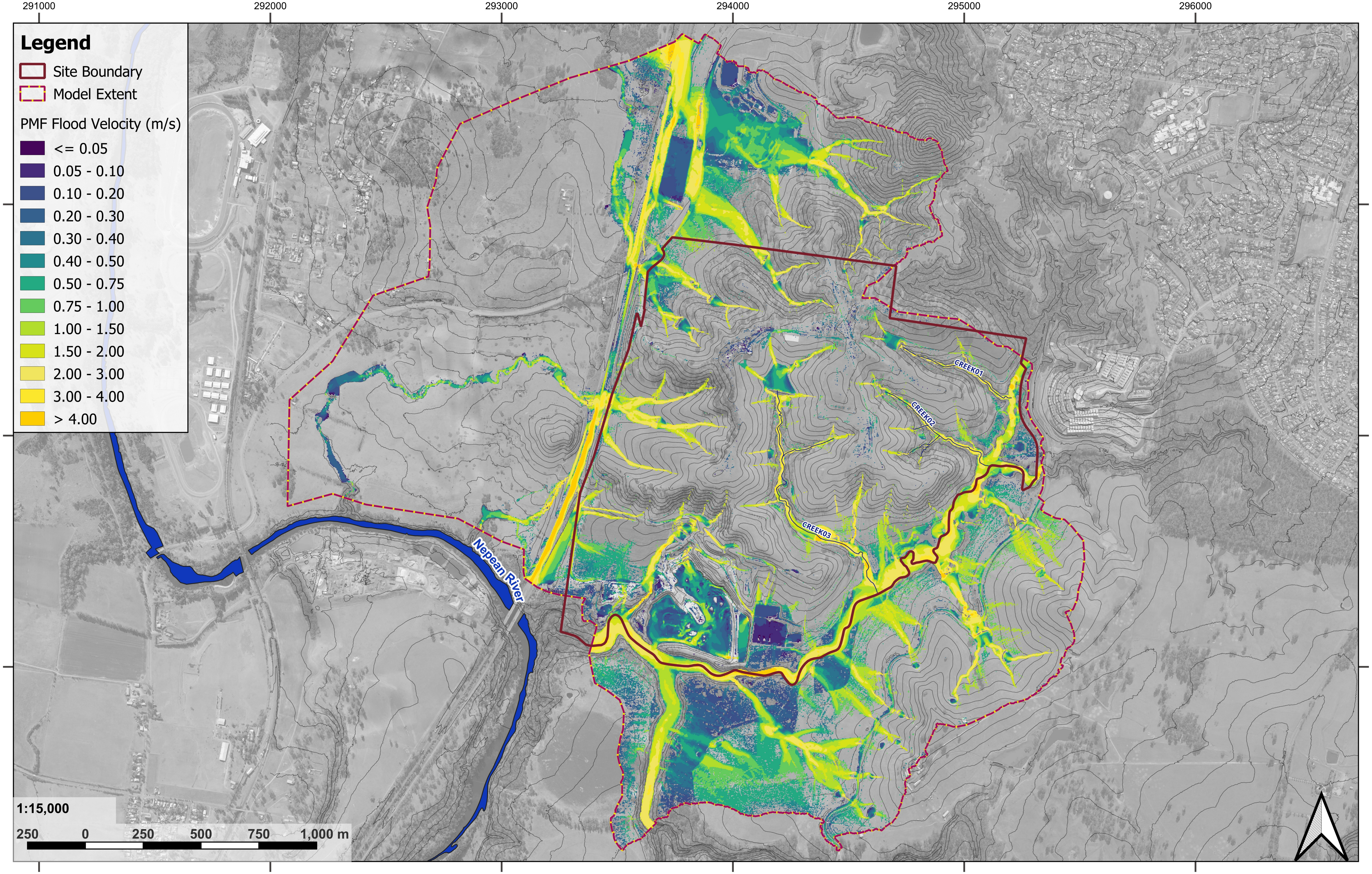
Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information
provided in this map is correct at the time of
publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 1: PMF Flood Levels Existing Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd

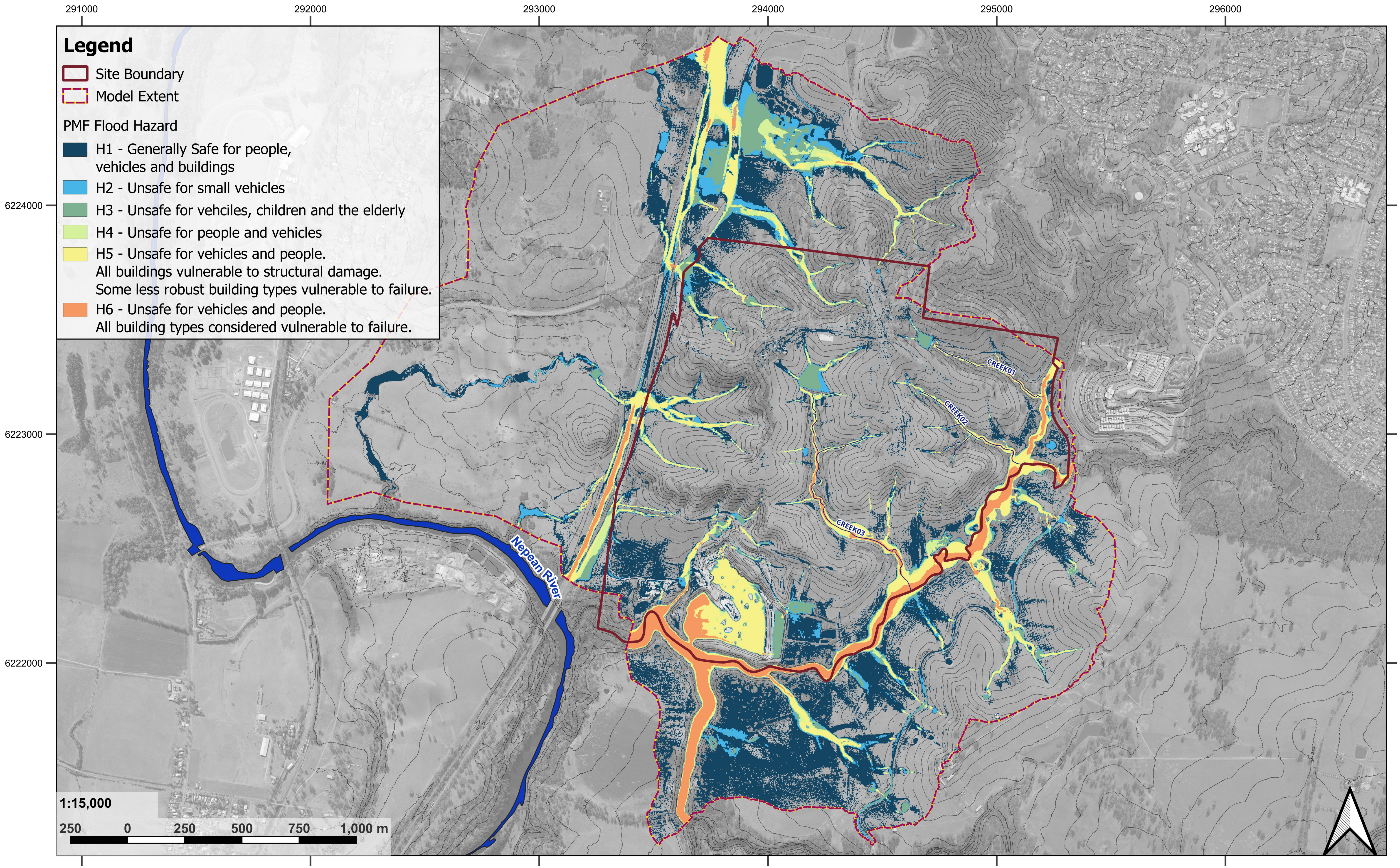


Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information provided in this map is correct at the time of publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 2: PMF Flood Depth Existing Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd

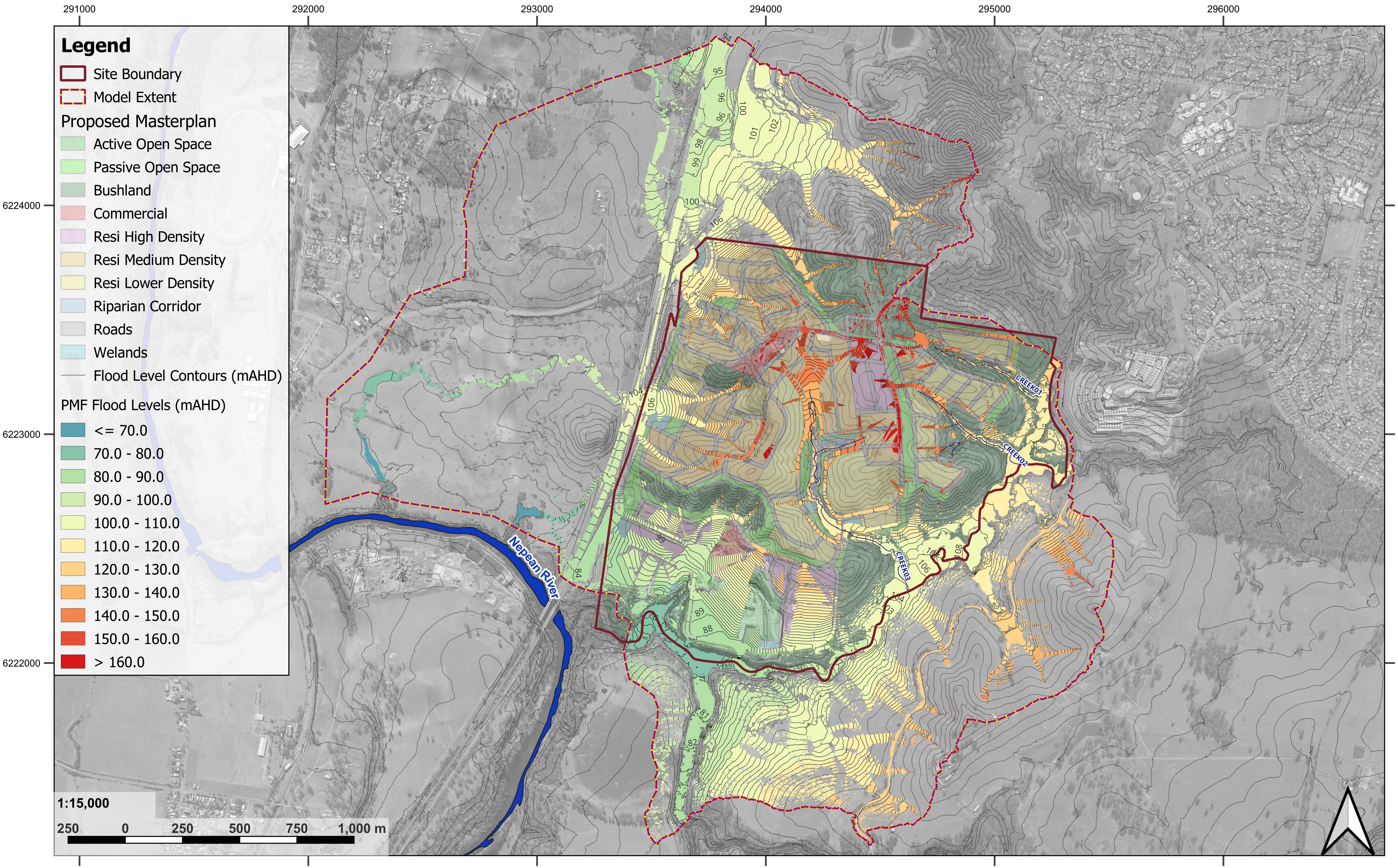


Map 3: PMF Flood Velocity Existing Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd



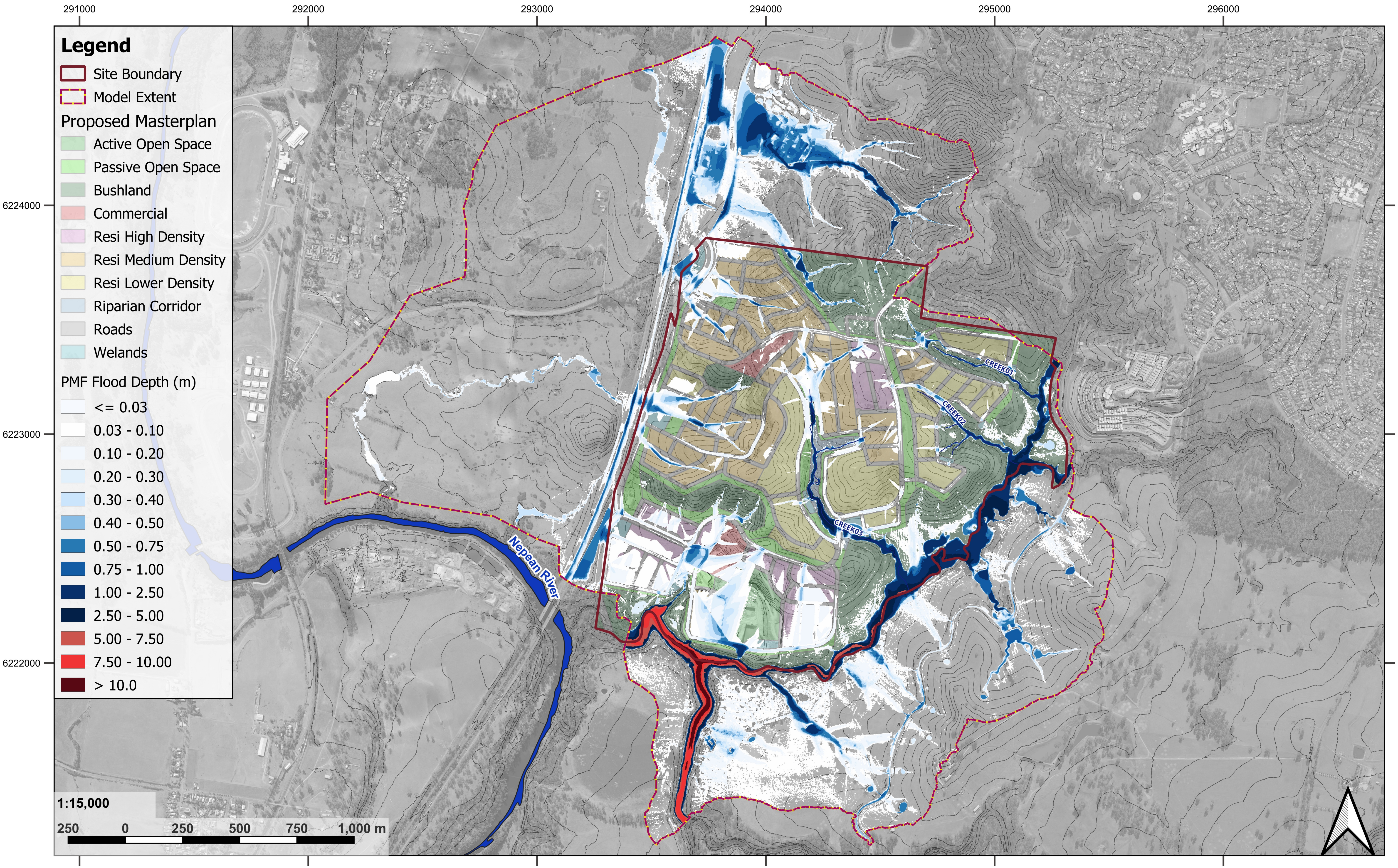
Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information
provided in this map is correct at the time of
publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 4: PMF Flood Hazard Existing Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd



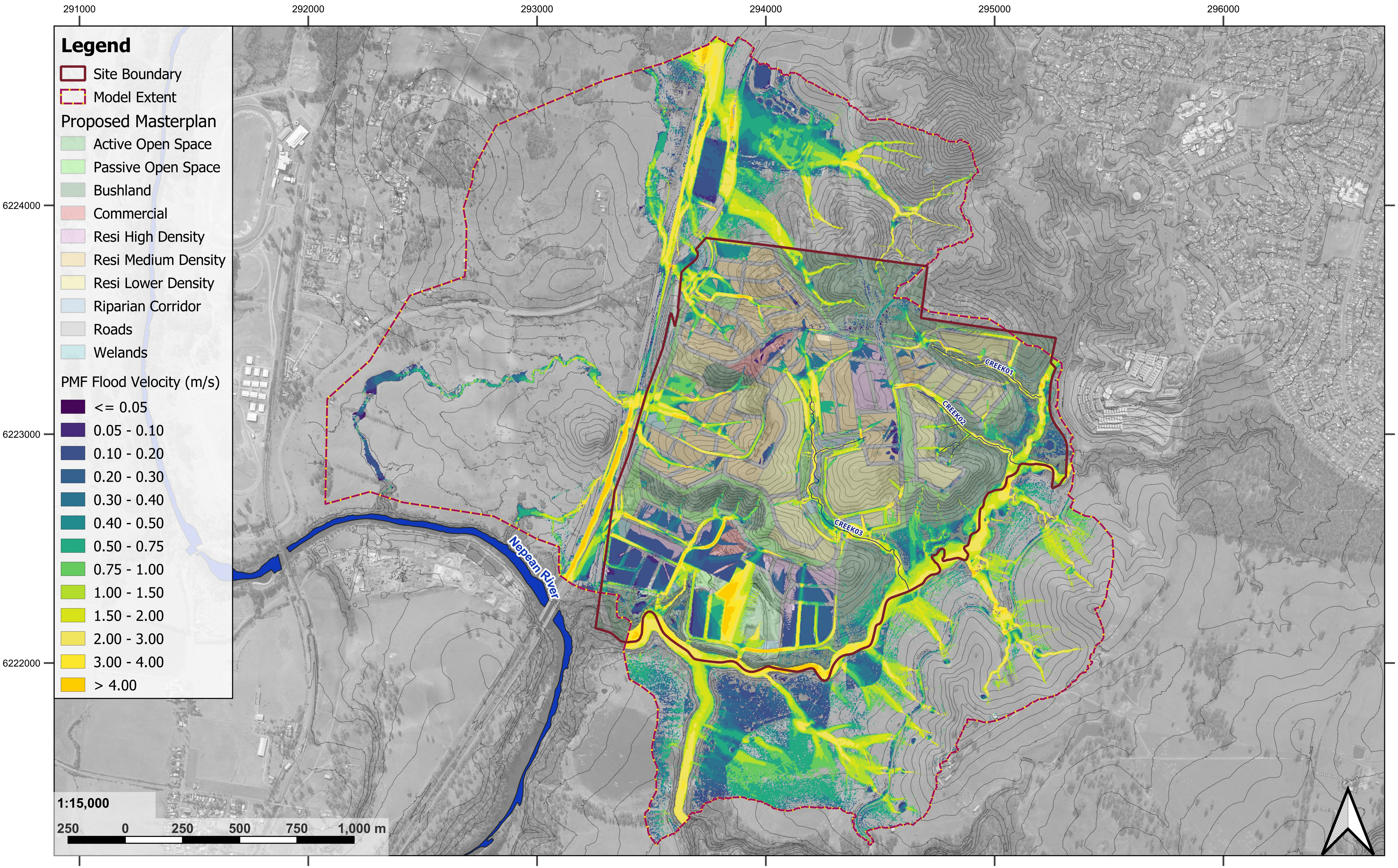
Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information
provided in this map is correct at the time of
publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 5: PMF Flood Levels Developed Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd



Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information
provided in this map is correct at the time of
publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 6: PMF Flood Depth Developed Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd

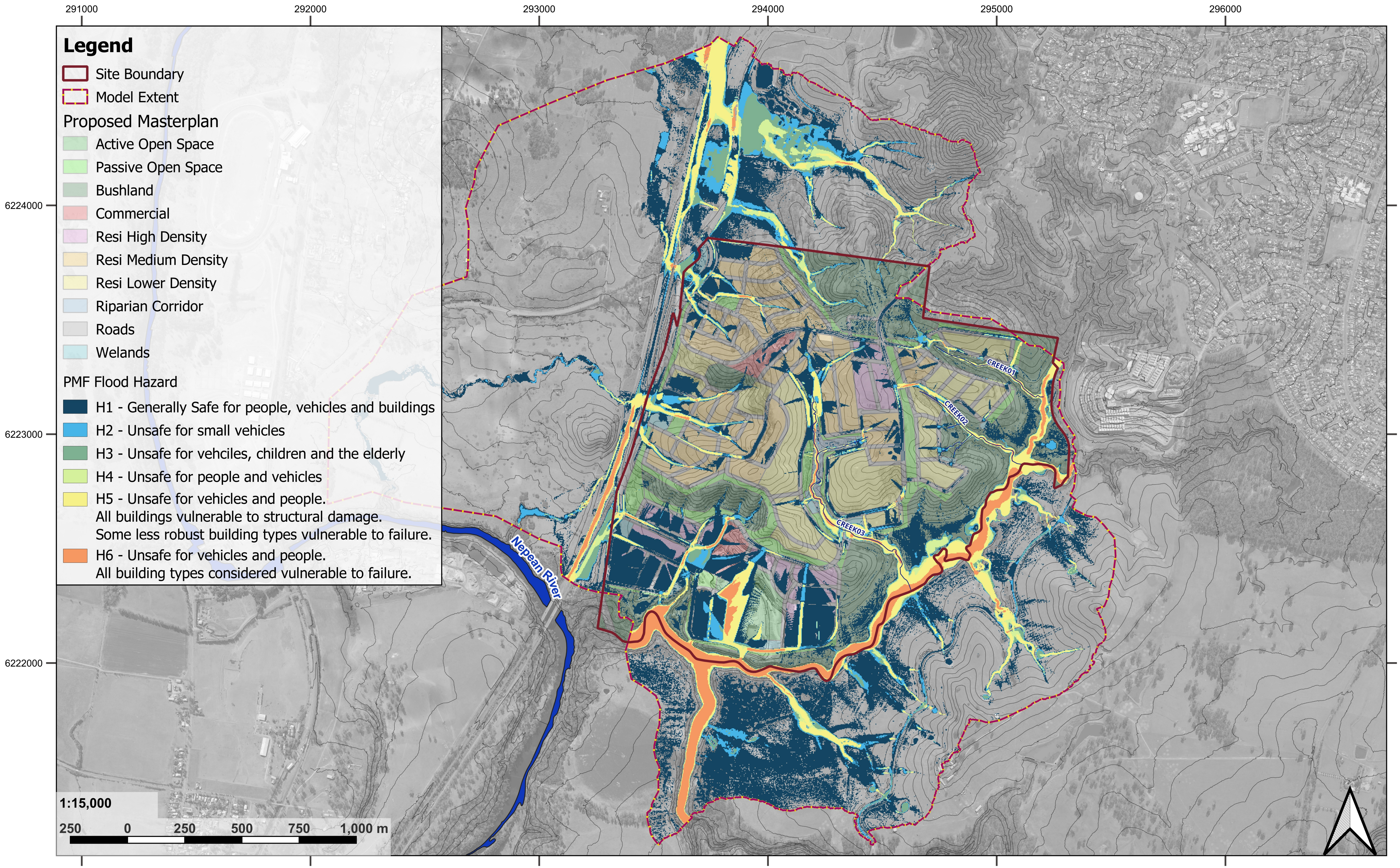


Map 7: PMF Flood Velocity Developed Conditions

Project: Rosalind Park PMF Analysis

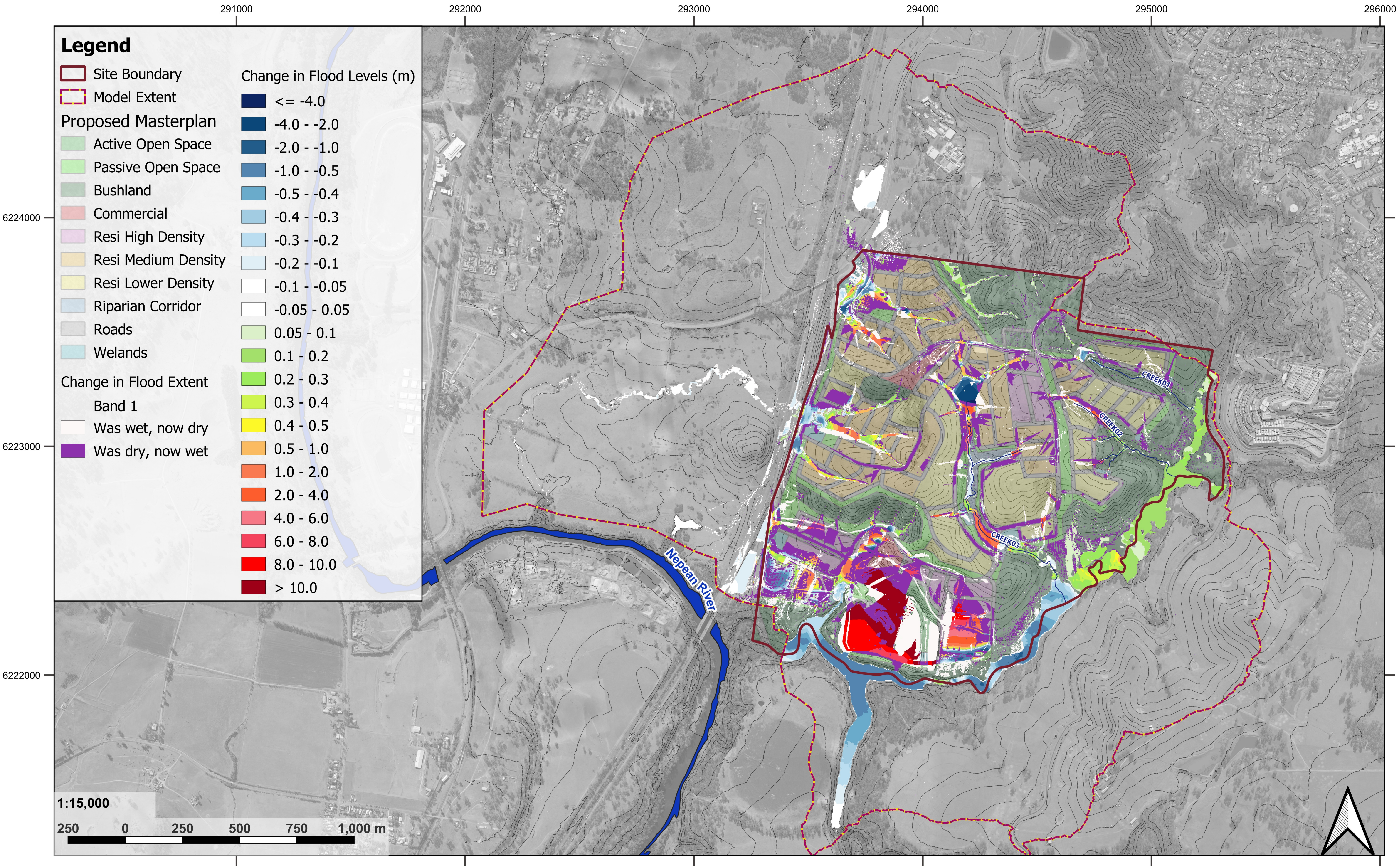
Project Number: 467-21

Client: Leda Holdings Pty Ltd



Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information provided in this map is correct at the time of publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 8: PMF Flood Hazard Developed Conditions
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd



Colliers

CRAIG& RHODES
TAKE THE LEAD

Colliers Engineering and Design (NSW) Pty Ltd endeavours to ensure that the information
provided in this map is correct at the time of
publication. Colliers Engineering and Design (NSW) Pty Ltd does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 9: PMF Afflux
Project: Rosalind Park PMF Analysis
Project Number: 467-21
Client: Leda Holdings Pty Ltd