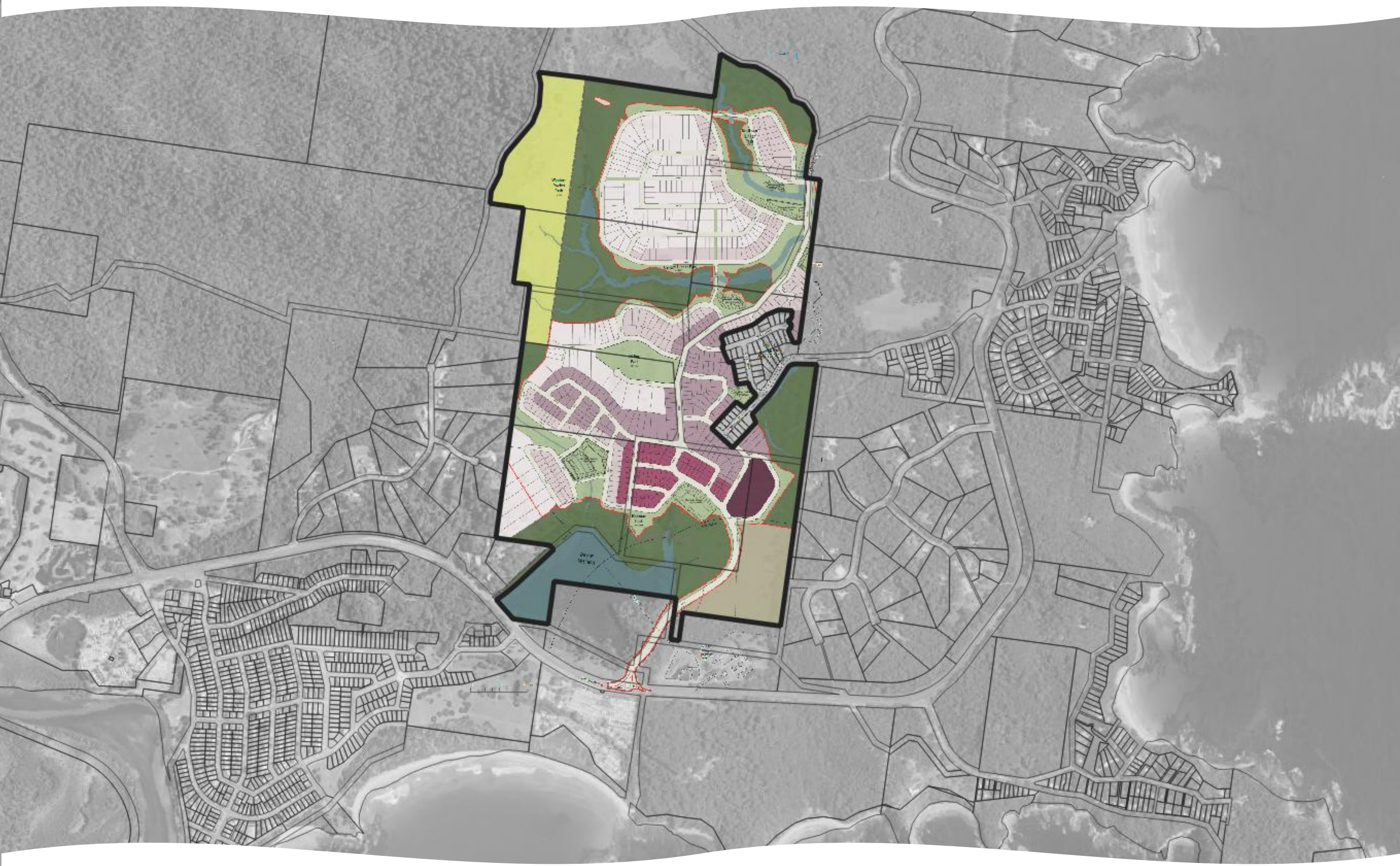
# Concept Plan Approval Modification
# Bevian Road, Rosedale
# Flood Impact and Risk Assessment

R.T2535.001.03



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Final Report

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## Synopsis

Flood Impact and Risk Assessment for Concept Plan Approval Modification Bevian Road, Rosedale.

## Revision History

| Revision | Description | Date |
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| 01 | Draft | 18/06/2024 |
| 02 | Final | 25/06/2024 |
| 03 | Final (RFI mod 1) | 16/04/2025 |
| | | |

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# 1 Introduction

## 1.1 Project Overview

Torrent Consulting was engaged to prepare a Flood Impact and Risk Assessment (FIRA) for the proposed development at Bevian Road, Rosedale NSW (the Site). The FIRA is required to support a modification of the 2008 Part 3A Concept Approval from a Community Title Subdivision for residential development and ancillary commercial and community facilities, ecological stewardship, public roads and open space areas yielding a total of 792 residential lots (reference number 05_0199), to a Torrens title development that includes residential development and ancillary commercial facilities, public roads, public open areas and residual rural lot yielding a total of 792 residential lots inclusive of the 51 Torrens title residential lots recently constructed and registered as part of stage 1 (DA305/18). For the purposes of the modification, stage 1 is excluded from further consideration.

The FIRA addresses the flood related issues detailed in the Secretary's Environmental Assessment Requirements (SEARs) MP 05_0199 for the modification. For clarity in preparation of this response, the conditions are repeated below:

- *Item 15 – Flooding:*
  - *include a flood impact and risk assessment (FIRA) that assesses the changes in overland flooding resulting from the change in subdivision layout to determine the flood behaviour and impacts associated with the development for the full range of events up to the probable maximum flood.*
  - *Address matters raised by BCD at Appendix A*

The matters to be addressed as raised by the Biodiversity and Conservation Division (BCD) are specified in Appendix A of the SEARs under the Flooding and Coastal Hazards:

- *Item 17 The EIS shall include a flood impact and risk assessment (FIRA). As a minimum the FIRA must:*
  - *Consider the relevant provisions of the NSW Flood Risk Management Manual (2023) and associated guides, and existing council and government studies, information and requirements.*
  - *Identify and describe existing flood behaviour on the site and its surrounding areas for the full range of events, including 5% AEP, 1% AEP, PMF and 0.5% AEP or 0.2% AEP and provide an assessment of the compatibility of the development and its users with flood behaviour. This may require flood modelling where existing flood information is not available.*
  - *Determine and describe changes in post development flood behaviour, impacts of flooding on existing community and on the development and its future community for full range of events, 5% AEP, 1% AEP, PMF and 0.5% AEP or 0.2% AEP. This will typically require flood modelling.*
  - *Consider impacts of climate change due to both sea level rise and increase in rainfall intensities considering relevant Council and government advice. The 0.5% AEP or 0.2% AEP events can be used to provide an understanding of the scale of change of flood behaviour relative to the 1% AEP event.*

- *Propose and assess the effectiveness of management measures required to minimise the impacts and risks of flooding to the development and its users and existing community.*
- *Note:*
  - *The scope of a FIRA is intended to be consistent with the Draft EHG FIRA Guide, which is being finalised currently.*
  - *The FIRA will need to be tailored to suit the project being considered, whilst maintaining consistency with the FIRA guide.*

# 2 Existing Approval

## 2.1 Approved Concept Plan

The concept plan for the existing approval is shown in Figure 2-1. The layout provides for various zones of residential lot development with an interconnecting road network. The key observations of the layout from a floodplain risk management perspective include:

- Wide corridors noted as either "Conservation Area" or "Open Space, Recreation and/or Facilities (Ecological Zone)" are retained along the alignment of existing watercourses.
- Numerous online water storages noted as "Lakes and Dams".
- Bevian Wetland being the receiving waterbody at the southern extent of the development.

The existing approval was supported by the Bevian Road Concept Application - Flood Impact Assessment (Patterson Britton & Partners (PBP), 2007). This assessment included the development of hydrological (XP-RAFTS software) and hydraulic (HEC-RAS) models to define the local catchment flooding conditions and consider potential impacts of the proposed development.

The mapped flood inundation extents by PBP (2007) are shown in Figure 2-2 for the northern section of the development and Figure 2-3 for the southern section. The mapping includes the extents for the 20-year and 100-year Average Recurrence Interval (ARI) events and the Probable Maximum Flood (PMF). Note the 20-year ARI and 100-year ARI are equivalent to the 5% and 1% Annual Exceedance Probability (AEP) events respectively.

The northern section flood mapping shows three key waterway alignments noted as Tributary 1, Tributary 2 and Saltwater Creek. The proposed development footprint in the most part lies well outside the mapped PMF flood extent, except for a small area in the north on Tributary 1 for which the development footprint slightly encroaches on the PMF extent only. The flood mapping also shows relatively small change in the inundation extents between the 5% AEP, 1% AEP, PMF events.

The southern section flood mapping is limited to the predicted flood extents within the Bevian Wetland waterbody, with no waterway mapping in the upstream contributing catchments. No hydraulic modelling along these waterway alignments was undertaken with PBP (2007) noting that the typical flow in the broad gullies would be characterised by shallow depth sheet flow and accordingly not propose any significant flood hazard. The mapped flood inundation extents for Bevian Wetland do not impact on the development footprint, and it is similarly noted that there is only minor change in flood inundation areas between the 5% AEP, 1% AEP, PMF events.


**Figure 2-1 2008 Approved Concept Layout**

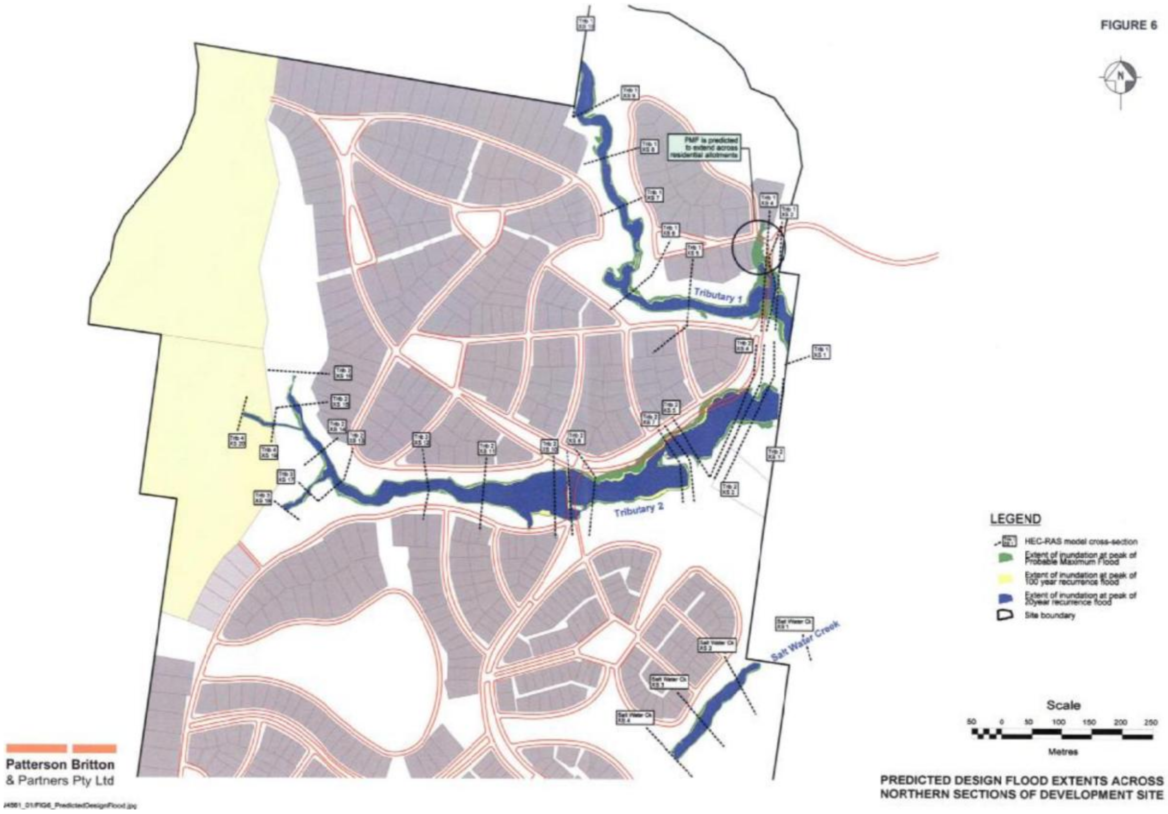


Figure 2-2 Design Flood Inundation Extents - Northern Section (PBP, 2007)


Figure 2-3 Design Flood Inundation Extents - Northern Section (PBP, 2007)

## 2.2 Supporting Flood Impact Assessment

The PBP (2007) flood impact assessment indicated that all habitable areas of the proposed development are above the 1% AEP and PMF level. Accordingly, flood risk to property and risk to life were adequately addressed and provided the basis of the approval with respect to flood risk management considerations.

In reviewing the appropriateness of the PBP (2007) flood mapping the model files have not been available. In lieu of a detailed model review, a high-level review based on the details of model configuration, adopted parameters and assumptions is based on the report only. The following observations are noted with respect to model configurations:

**XP-RAFTS Hydrologic Model**

- Subcatchment delineation – modelled Saltwater Creek catchment area of 183.9 ha represented by 20 subcatchments, and modelled Bevian Wetland catchment area of 124.5ha represented by 7 subcatchments. The adopted subcatchments delineation is consistent with the topography and at adequate resolution to define inflow distribution to the hydraulic model.
- Subcatchment parameters – whist the estimation
  - Slope – subcatchments slope value vary between 2% and 14% and appear to be representative of the local topography.
  - Impervious Areas – a nominal 5% impervious area was uniformly adopted for the undeveloped catchment area. With only minor existing development in the modelled catchment area, this was represented in relevant sub-catchments with a defined second sub-area and corresponding increase in impervious percentage (35% to 39%)
  - Roughness (PERN value) – a uniform value of 0.035 was generally adopted with a small number of subcatchments applied a 0.025 value. These values are possibly on the low side for a combination of cleared pastureland and forested areas, however, are likely to be conservative in producing higher simulated peak flows for the catchment.
- Routing parameter (BX value) – default value of 1.0 adopted which is appropriate in lieu of hydrograph calibration data.
- Link lag – the model output data indicates use of the link lag function, however, there is no detail on the estimation procedures. These are likely to be derived based on an assumed velocity and link length to estimate the lag time to translate hydrographs to downstream node junctions.
- Design rainfall – design rainfall and loss inputs were derived using Australian Rainfall and Runoff 1987 (ARR 1987) noting this was the appropriate procedures at the time of the assessment. The model output in the report included adopted design rainfall intensities of 73mm/hr for the 20yr ARI 60minute duration, and 100mm/hr for the 100yr ARI 60minute duration. These values have been cross-checked using the BoM ARR1987 Intensity-Frequency-Duration (IFD) portal (http://www.bom.gov.au/water/designRainfalls/ifd-arr87/index.shtml). The PMF event rainfall was appropriately derived using the "*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method*" (2001). The derived 60-minute duration PMP was 310mm, however, no detail was provided on the estimation parameters used. A cross-check calculation of the PMP using the GSDM confirmed the adopted value.


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- Rainfall losses – the adopted initial and continuing losses of 10mm and 2.5mm/hr respectively for previous areas, and 1mm and 0mm/hr for impervious areas are consistent with ARR1987 guidelines.
- Critical duration – the reporting notes a range of different storm durations were considered to establish the critical storm duration determined as 120 minutes for the Saltwater Creek, Tributary 1 and Tributary 2 catchments and 90 minutes for the Bevian Wetland catchment. The model outputs presented in the appendices appear to be the 60-minute duration. Notwithstanding, it is expected to be only minor differences in inundation extents across the 60-minute to 120-minute durations.

**HEC-RAS Hydraulic Model**

- Model network – the HEC-RAS model comprises three separate reaches run independently being Tributary 1, Tributary 2 and Saltwater Creek. The typical cross section spacing along the reaches is of the order of 100m to 150m which is considered appropriate for the assessment. There is no detail on cross section profiles with the report noting creek cross-sections were extracted from contour information, however, the source and accuracy/resolution is not confirmed.
- Hydraulic Roughness – represented by a Manning's' n value of 0.06 for in-channel areas along creek profiles (characterised as reeds and long grass with isolated trees and willows) and 0.05 for overbank areas (characterised as medium length grass with isolated trees and shrubs). In the absence of cross-section data there is no detail on adopted width of application of "in-bank" areas. However, in general the adopted values are considered to be within appropriate ranges.
- Model Inflows – subcatchments flows derived from the XP-RAFTS model are applied at corresponding cross-section locations along the modelled reaches. The HEC-RAS model has been run in steady-state mode (i.e. constant /non-time varying) such that the inflows applied are the peak flow condition. Accordingly, no flow routing is undertaken within the hydraulic model, thereby relying on the hydrograph translation from the XP-RAFTS model based on the link lag assumptions.
- Downstream Boundary Conditions – there is no documented detail of adopted boundary conditions for the downstream modelled reaches. It is assumed the boundary would comprise a uniform flow boundary driven by an adopted hydraulic slope. The modelled 1% AEP results in the downstream reaches of Tributary 1, Tributary 2 and Saltwater Creek have simulated energy grade line of 0.037m/m, 0.022m/m and 0.083m/m respectively. These simulated gradients appear to be somewhat consistent with local topography, and moreover do not suggest an inappropriate boundary condition that would influence flood mapping results in the broader development area.

As previously noted, no HEC-RAS hydraulic modelling was undertaken for the Bevian Wetland catchment. Design peak flood levels in the wetland were calculated based on the assumption that overtopping of George Bass Drive is the critical control, with a flow over the road profile being representative of a broad-crested weir flow condition. No detail of the adopted weir profile is provided in the report, nor any consideration of potential weir flow submergence. It is noted that estimated depth of overtopping is relatively shallow, being 0.12m, 0.15m and 0.31m for the 5% AEP, 1% AEP and PMF events respectively. Accordingly, estimated peak flood levels at the proposed development area upstream of the roadway maybe relatively insensitive to the adopted parameters.

The assessment of potential climate change influence in PBP (2007) is limited to the consideration of potential sea level rise and the corresponding backwater influence on peak flood levels in the coastal zone. The elevation of the Saltwater Creek tributaries in the development area are well above any oceanic influence. For the Bevian Wetland catchment, the overtopping point of George Bass Drive is the principal hydraulic control being at an elevation of 4.2m AHD which is also above potential sea level rise influence considering a nominal present day extreme water level of 2.6m AHD and additional 0.9m sea level rise allowance for year 2100 planning horizon.

# 3 Proposed Modification

## 3.1 Modified Layout

The FIRA requirements for the current assessment appear to be the standard wording for inclusion with the SEARs, and do not indicate any specific consideration of the context of the proposal as a modification to the existing approval. Accordingly, it is unknown to what extent the flood information relating to the original approval can be relied upon for the modification. Notwithstanding, the flood risk for the modification layout can be initially reviewed in consideration of the established PBP (2007) flood mapping.

The proposed modification layout is shown in the Landscape Masterplan at Figure 3-1. As similarly noted for the approved layout, the wide corridors along the waterway alignments are maintained which provide for the effective conveyance of floodwater, with proposed residential areas occupying existing flood free land.

## 3.2 Existing Flood Risk

The PBP (2007) flood inundation extents are shown in Figure 3-2 as an overlay on the proposed modification layout.

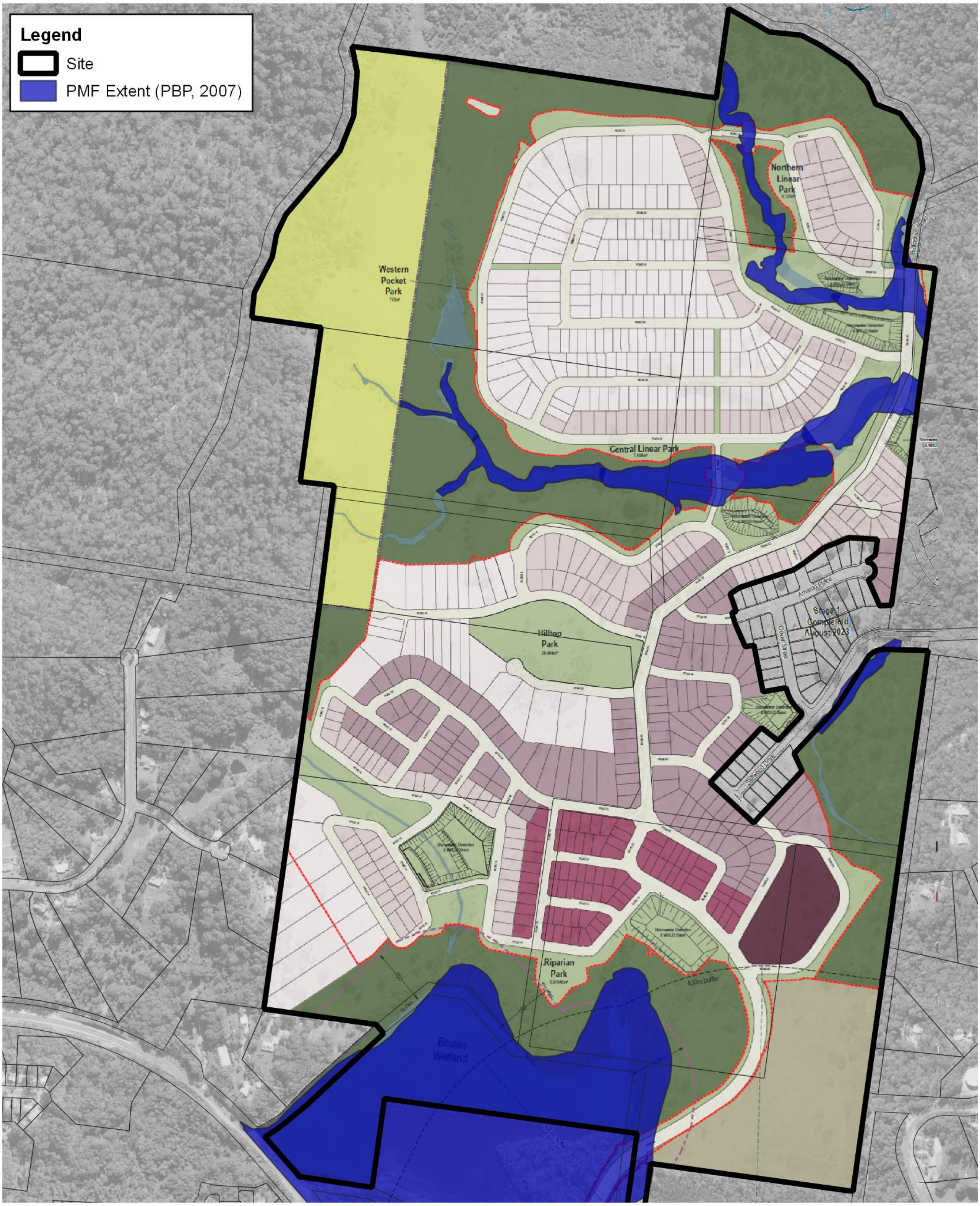
In reviewing the approved and modification layouts, they appear to be sufficiently similar from a flood risk management perspective such that the compatibility of the modification with the existing flood risk environment does not deviate from the basis of the current approval. Accordingly, if the established PBP (2007) flood mapping is considered fit for purpose, the proposed modification is expected to be acceptable in line with the existing approval.

The PBP (2007) assessment is overall considered to be fit-for-purpose in establishing the design flood inundation extents for assessment of the proposed development including the modification. This is particularly the case given the development footprint in the context of the PMF inundation extent.

However, given the date of the assessment it is noted there are some potential deficiencies in relation to contemporary flood risk assessment procedures. Given the advancement of modelling software, computational capability, and the availability of catchment-wide LiDAR topographical data, contemporary flood modelling assessment is typically undertaken using 2-dimensional hydraulic modelling of the flow distribution. Notwithstanding, the modelling techniques employed in PBP (2007) remain a valid approach to flood level estimation and broad scale inundation mapping suitable to the current assessment.

The release of the ARR2019 update to the flood estimation guideline provides for different design flood estimation techniques including changes to design rainfall and loss estimates, and use of ensemble temporal patterns. Climate change provisions, particularly for potential increase in rainfall intensity have evolved, whilst sea level rose allowance remain somewhat similar to those previously considered for the year 2100 planning horizon.


**Figure 3-1 Modification Concept Layout**

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## Modified Layout and PMF Inundation Extent

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Significantly, the PMP estimation technique using the GSDM employed in PBP (2007) remains the current industry standard. On the basis of the mapped PMF extents, both the approved and modification layouts have limited encroachment on the floodplain and represent a viable development footprint with respect to flood risk considerations. There are no proposed residential lots within the PMF extent. Accordingly, it is considered that the proposed modification is consistent with the existing approval, and moreover, consistent with contemporary flood risk management as per the NSW Flood Risk Management Manual and requirements for new development.

# 4 Design Flood Conditions

The high-level review of the existing PBP (2007) flood impact assessment has found it an appropriate assessment of the design flood conditions and fit-for-purpose in assessing the proposed development. Notwithstanding, additional modelling has been undertaken to confirm the general design flood inundation extents in the catchment in line with contemporary design flood estimation techniques and compatibility of the proposed modification.

## 4.1 Model Development

A TUFLOW two-dimensional (2D) hydraulic model of the local flow catchments contributing to surface runoff through the Site has been developed. A summary of the key model configuration parameters is presented below.

### 4.1.1 Model Extent and Topography

A TUFLOW hydraulic model was developed covering the local watercourse and overland flow catchments impacting on the Site. The modelled boundary is shown in Figure 4-1 extending from the upper catchment boundary to the west and north of the Site, to downstream of the Site on the local watercourse alignments including the tributaries of Saltwater Creek and Bevian Wetland.

The adopted TUFLOW grid model resolution was 2m. The adopted resolution is sufficient to model the overland flow distribution through the Site and define the hydraulic flow characteristics including peak inundation extents. The model topography is based on the available NSW Spatial Services LiDAR data product, downloaded via the ELVIS Foundation Spatial Data portal. The derived LiDAR DEM is at a 1m resolution and shown in Figure 6.

The topography and mapped watercourse alignments shows the local catchments contributing to surface runoff through the Site. The upper catchment boundary to the west and north of the Site sits at elevations up to 120m AHD, falling relatively steeply to the lower watercourse alignments and associated floodplain through the Site. The northern tributaries of Saltwater Creek at the eastern Site boundary are at an approximate elevation of 10m AHD. These northern tributaries of Saltwater Creek have a well-defined floodplain between spurs in the local topography. It is noted that the proposed development footprint largely occupies the higher ground in this location.

The Bevian Wetland catchment sits lower in the topography with the normal water level in the wetland being around 2.2m AHD. As noted, the elevation of George Bass Drive is just above 4m AHD and accordingly represents a significant hydraulic control for discharges from the upper catchment through to the downstream creek outlet at the coastal boundary.

### 4.1.2 Boundary Conditions

Rainfall is the key boundary inflow for the direct-rainfall modelling approach. Further detail on design rainfall inputs is provided in Section 4.1.4.


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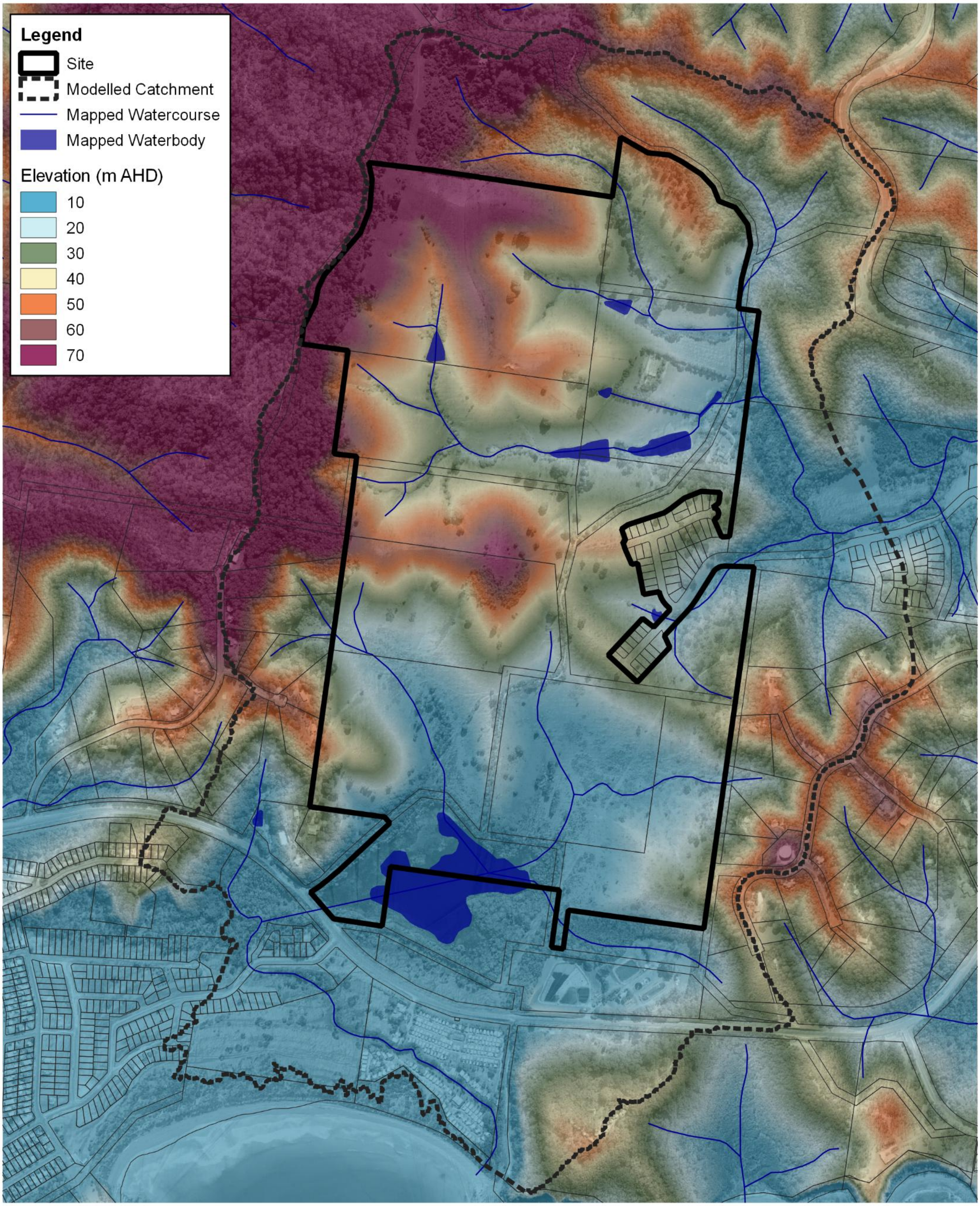


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**Catchment Topography**

Figure: **4-1**

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The downstream model boundary extends some 500m downstream of the Site on the Saltwater Creek alignment. A model derived stage-discharge relationship based on estimated hydraulic slope is adopted for the model outflow boundary. For the Bevian Wetland catchment the model area extends to the coastal boundary where the local creek channel discharges south of George Bass Drive. Whilst this represents a tidally influence boundary, the narrow creek channel at the outlet provides for conveyance limited outlet represented by a stage-discharge relationship.

### 4.1.3 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (e.g., roads, urban areas, park lands, open space etc.) for modelling the variation in flow resistance.

Table 4-1 summarises the adopted Manning's 'n' coefficients for hydraulic roughness based on the land use. Whilst there is no specific calibration data available for catchment, the adopted values are within typical industry adopted ranges.

Table 4-1 Hydraulic Model Surface Roughness Parameter

| Land Use | Manning's 'n' |
|---|---|
| Forested / Dense Vegetation | 0.10 |
| Cleared floodplain | 0.05 |
| Roadways | 0.02 |
| Bevian Wetland | 0.03 |
| Urban Lots (future) | 0.06 |

Note that the urban lots for the future developed case adopts a higher representative composite Manning's 'n' to account for flow impedance from building, fences, landscaping etc.

### 4.1.4 Design Rainfall and Losses

The release of the Australian Rainfall and Runoff 2019 (ARR 2019) guidelines provides updated procedures for design flood estimation. This includes updated intensity-frequency-duration (IFD) rainfall estimates and application of a suite of revised temporal patterns for establishing critical design flood conditions.

The design rainfall depths were sourced from the BoM IFD portal and are summarised in Table 4-2 for various design event magnitudes and storm durations. Note that only the 1% AEP event has been simulated for the assessment, with other design rainfalls provided for reference.

Design rainfall losses considered the recent NSW-specific guidance with an initial loss of 5-10 mm (depending on storm event) and a continuing loss of 3.0 mm/h for the undeveloped catchment. For future developed urban areas these losses were reduced to account for ~50% impervious area providing an initial loss of 2.5-5.0 mm (depending on storm event) and a continuing loss of 1.5 mm/h. Losses for road corridors were adopted as 1 mm initial loss and 0 mm/h continuing loss.

The Probable Maximum Precipitation (PMP) for the simulation of the Probable Maximum Flood (PMF) condition was estimated using the Generalised Short Duration Method (GSDM) published by the Bureau of Meteorology (BoM). The design PMP rainfall estimate of 320mm for the 60-minute duration is consistent with that derived in PBP (2007).

Table 4-2 Design IFD Rainfall

| Duration (mins) | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP |
|---|---|---|---|---|---|
| **30** | 32.2 | 38.1 | 46.3 | 52.7 | 61.3 |
| **45** | 38.5 | 45.4 | 54.9 | 62.5 | 72.5 |
| **60** | 43.6 | 51.4 | 61.9 | 70.3 | 81.4 |
| **90** | 52 | 61.3 | 73.4 | 83 | 96 |
| **120** | 59.3 | 69.6 | 83.1 | 93.7 | 108.4 |
| **180** | 71.9 | 84 | 100 | 112 | 130.6 |
| **270** | 88.3 | 103.2 | 122.1 | 138 | 159.7 |
| **360** | 102.2 | 119.6 | 142.7 | 160.9 | 186.8 |
| **540** | 127.4 | 148 | 178.3 | 200.7 | 233.9 |
| **720** | 147.4 | 173 | 207.2 | 235.5 | 273.6 |

As per the updated ARR 2019 climate change guidance, an adjustment was made to the adopted design rainfall to account for potential increases in rainfall intensity. The rainfall adjustment is determined through a combination of an expected increase in global mean temperature and an associated percentage increase in design rainfall intensity per degree of warming.

For this assessment the Shared Socioeconomic Pathway SSP2 was adopted, which represents a continuation of historic global attitudes towards climate policy, i.e. a neutral rather than optimistic or pessimistic outlook. The SSP2-4.5 climate scenario has a best-estimate warming of around 2.7ºC by 2100. For the expected increase in design rainfall, the 7% per degree warming recommended in the NSW Flood Risk Management Manual (2023) was adopted. This gives a total increase in design rainfall intensity of 20% when using Equation 1.6.1 of ARR 2019. Therefore, the hydrological assessment applied a factor of 1.2 to the BoM IFD and PMP rainfall depths.

### 4.1.5 Critical Duration and Temporal Pattern

The ARR 2019 guidelines ensemble method to design flood hydrology involves the simulation of ten rainfall temporal patterns for each design event magnitude and duration, with the average condition of the ten being adopted for design purposes. The point rainfall temporal patterns provided for the East Coast South temporal rainfall region were adopted for the ensemble method accordingly.

The TUFLOW model simulations were analysed at the local creek outlets to identify the critical duration, i.e., that which produces the peak flood flows for each design event magnitude. This is undertaken by calculating the average peak flood flow and the peak flood flow variance of the ten simulated hydrographs for each design event duration and magnitude.

The 30 to 60-minute durations were found to provide the critical peak flow conditions throughout the catchments. The 30-minute duration with the design temporal pattern ID 5910 was selected as producing hydrographs most representative of the mean design 1% AEP condition from the results of the ensemble method.

## 4.2 Existing Peak Flood Conditions

The developed model has been simulated for a range of events including the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design condition. The model output includes the peak flood inundation extents and levels, peak flood depth, velocity, and flood hazard distributions. The flood hazards have been determined in accordance with Guideline 7-3 of the Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017). This produces a six-tier hazard classification, based on modelled flood depths, velocities, and velocity-depth product. The hazard classes relate directly to the potential risk posed to people, vehicles, and buildings, as presented in Figure 4-2.

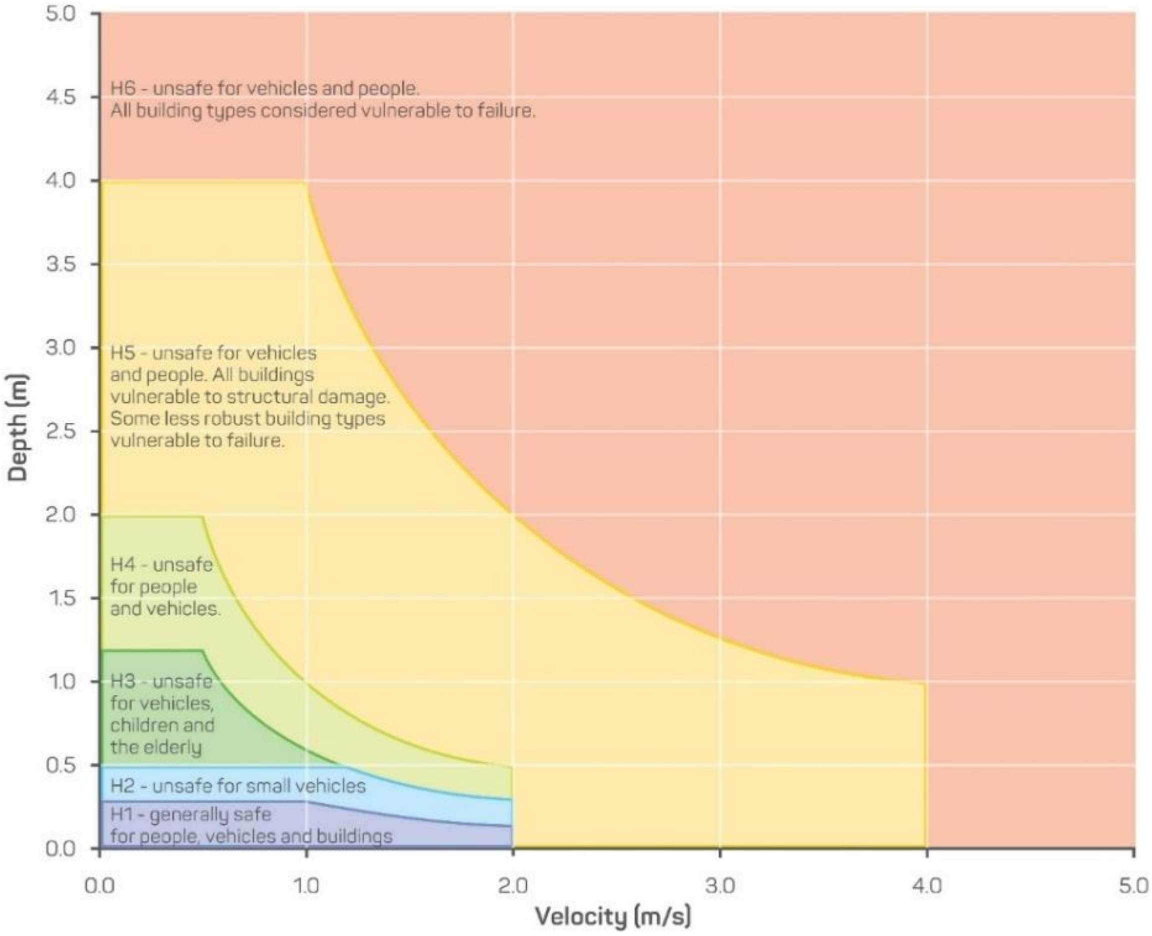
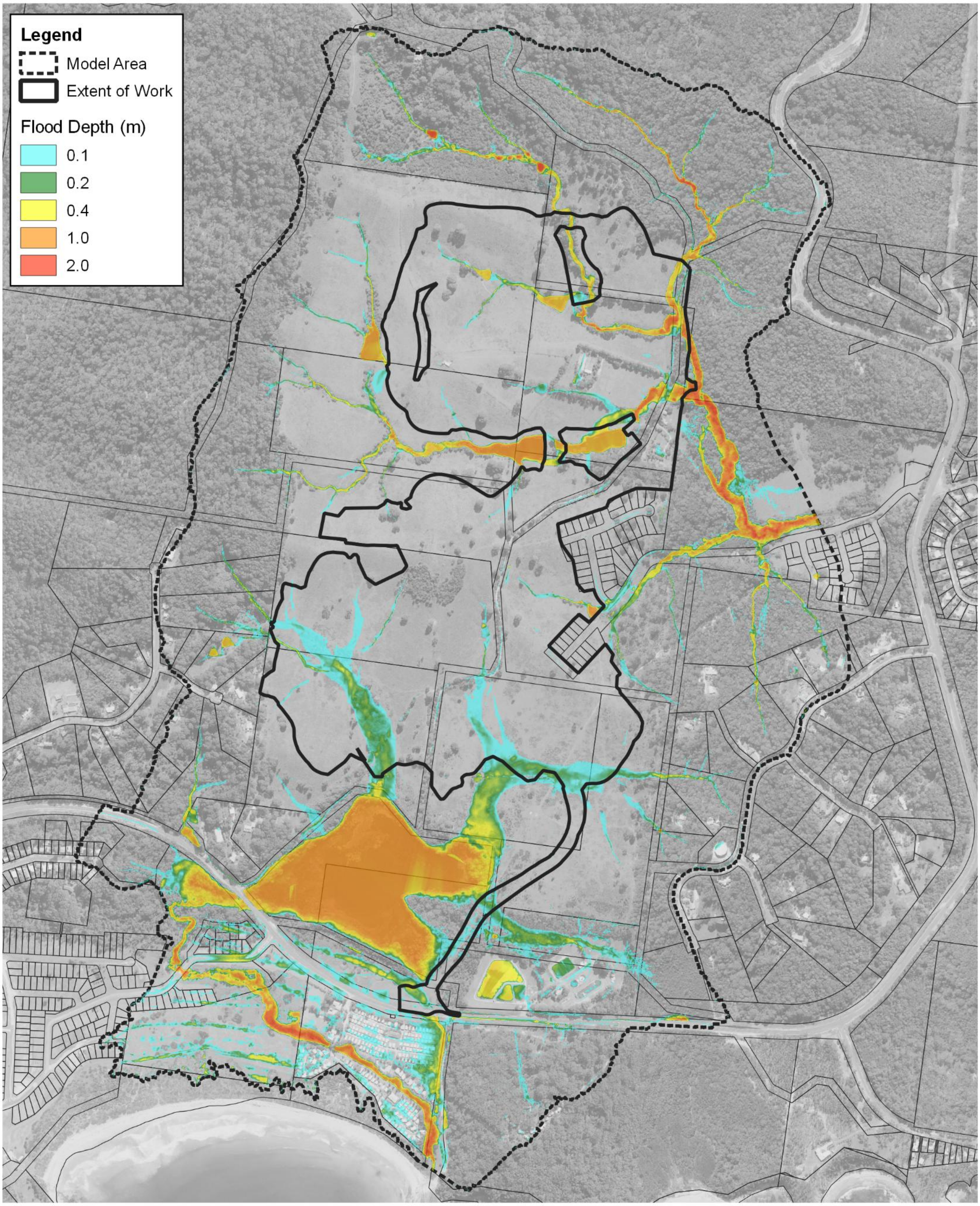



**Figure 4-2 General Flood Hazard Vulnerability Curves (AIDR, 2017)**

Appendix A contains the design flood mapping for existing conditions for the full range of simulated events. The simulated peak 1% AEP and PMF flood inundation extents and flood depth distribution for existing conditions are shown in Figure 4-3 and Figure 4-4 respectively. The extent of works for the proposed modification is shown for reference. The general inundation extents are similar to those presented in PBP (2007) (as per Figure 3-2), with additional modelled detail particularly in the Bevian Wetland catchment.

The inundation extents in the northern tributary catchments of Saltwater Creek are typically limited to well-defined corridors along the main waterway alignments, including the existing on-line water storages (farm dams). The catchment inflows to Bevian Wetland show a broader and shallower inundation in comparison, driven by the local topography. There is a broad expanse of floodwater associated with the Bevian Wetland which also provides for extensive overtopping of George Bass Drive. The combined creek flows and overtopping of George Bass Drive provides for extensive inundation in the lower catchment to the coastal outlet at Barlings Beach. It is noted that under the PMF condition extensive scouring of the outlet channel may occur, as such the simulated condition assuming a fixed outlet channel may represent a conservative condition with respect to flood levels upstream to George Bass Drive.

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**Simulated 1%AEP Flood Depth**
**Existing Conditions**

Figure: **4-3**

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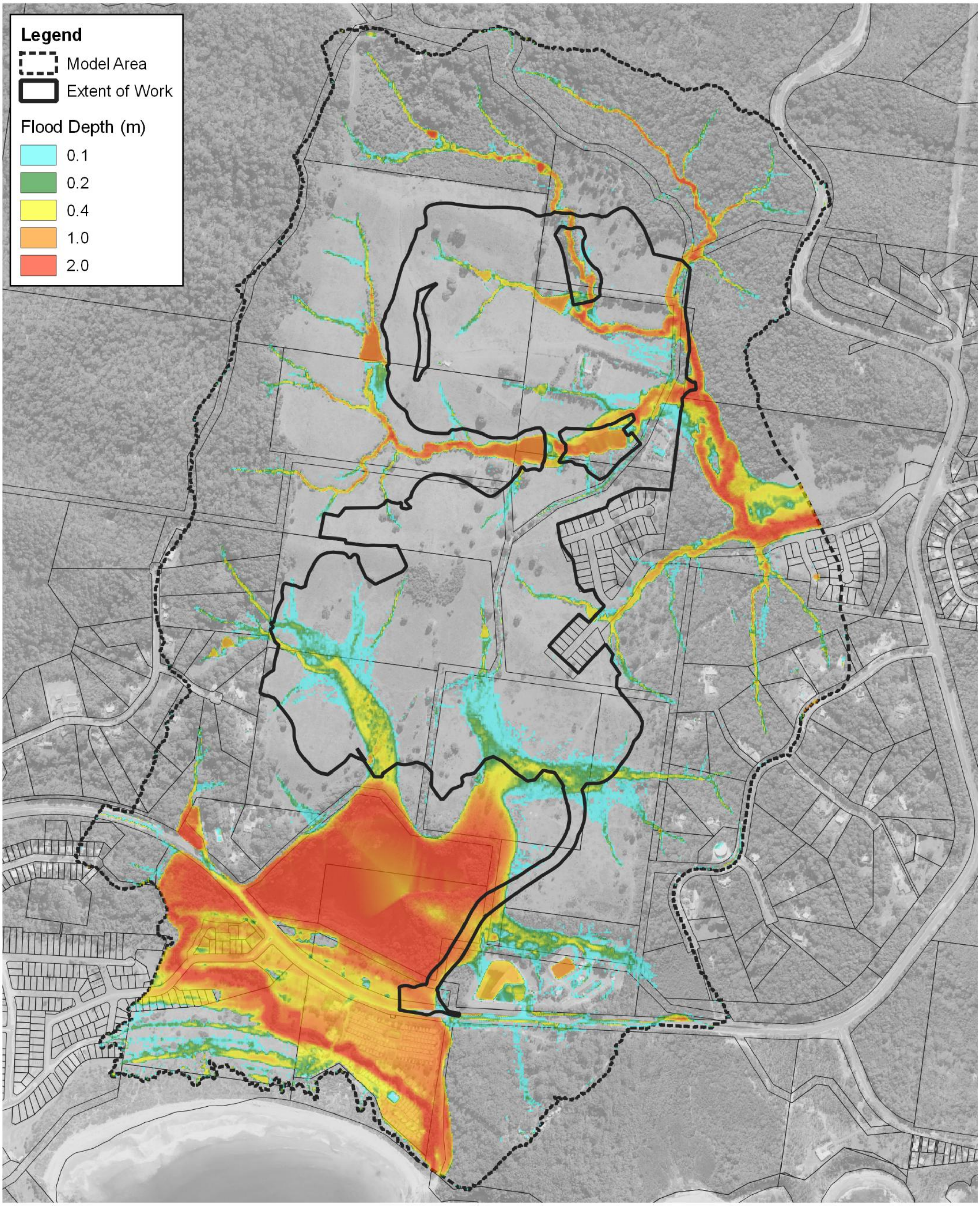


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**Simulated PMF Flood Depth**
**Existing Conditions**

Figure: **4-4**

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# 5 Proposed Development

## 5.1 Design Layout and Model Representation

The proposed modification layout and finished surface levels is shown in Figure 5-1. Changes to the TUFLOW model to represent the post-development condition and assessment of potential flood impacts are summarised below.

- The proposed modification design surface has been directly imported into the TUFLOW to overlay the base topography. The design DEM inherently incorporates:
  - the elevated residential lot areas
  - internal road and local connection road profiles
  - water management basins located online and offline within the existing waterway corridors
  - full fill batter profiles merging to existing natural surface.
- Surface roughness (Manning's 'n') values updated for proposed modification footprint including specification of urban lots and roadways in accordance with Table 4-1.
- Initial and continuing losses for simulating rainfall runoff response modified for proposed modification impervious surfaces (urban lots and road corridors) in accordance with adopted values summarised in Section 4.1.4.
- Incorporation of cross drainage culverts at roadway crossings of the waterways and detention basin outlets.

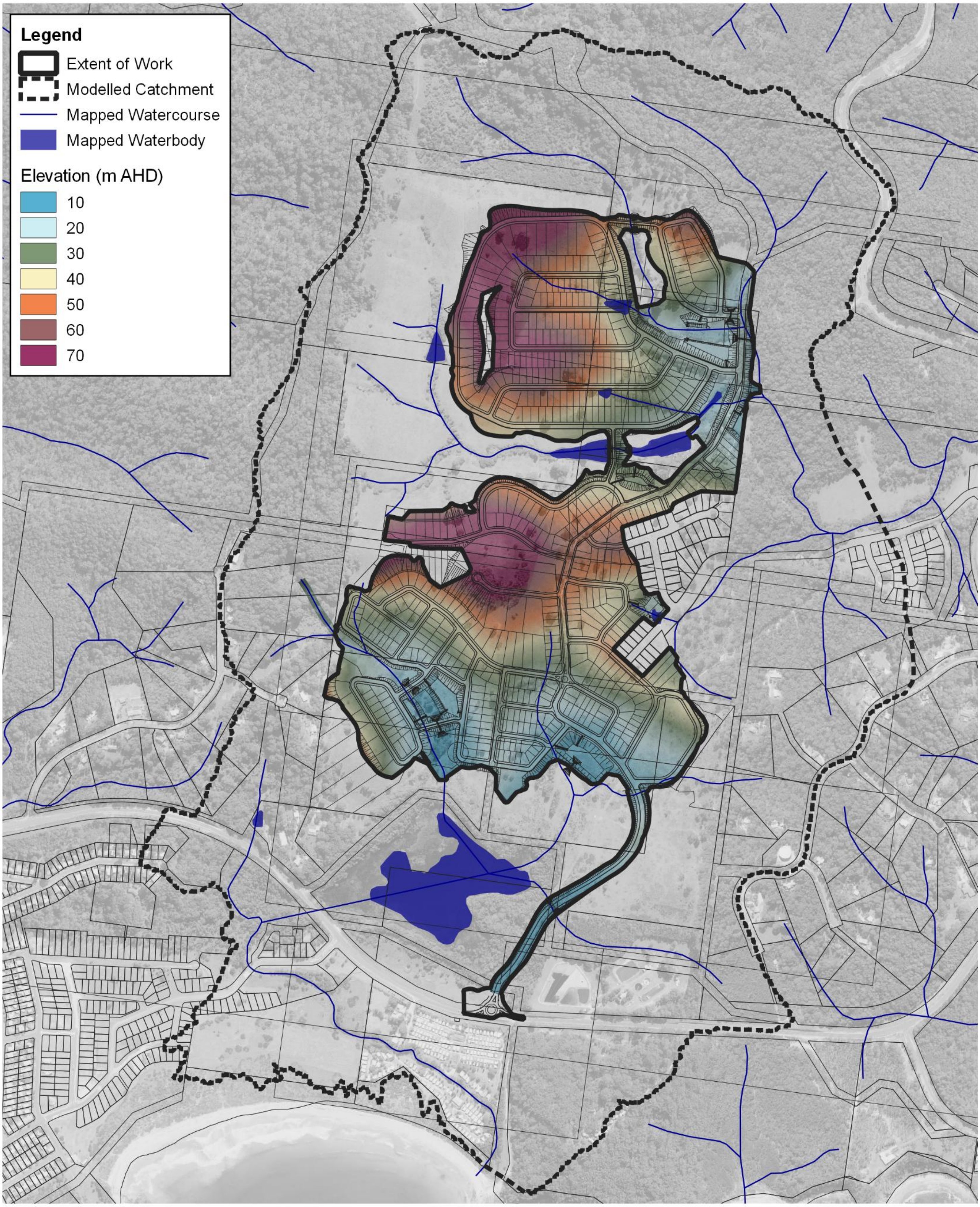
## 5.2 Post-Development Flooding Conditions

The models developed to establish existing flood conditions have been modified to represent post-development floodplain conditions as described above. The full suite of design flood mapping for post-development conditions is provided in Appendix B.

The simulated post-development peak flood depths and inundation extents for the 1% AEP and PMF event is shown in Figure 5-2 and Figure 5-3 respectively. The post-development flood hazard classification for the PMF is shown in Figure 5-4.

As similarly noted for the approved layout, the wide corridors along the main waterway alignments are maintained which provide for the effective conveyance of floodwater, with proposed residential areas occupying existing flood free land with respect to the mainstream flooding. Overland flow paths within the residential development footprint would be managed via internal road and drainage provisions as per normal engineering design.

The velocity and flood hazard classification distributions are included for reference. Whilst peak flood velocities exceed 2m/s principally along the main waterway alignments, they would not pose any significant constraint on the development recognising this being the PMF condition. The corresponding flood hazard classifications providing for up to H5 classification within the waterways represent limited constraint to the proposed development. The flood hazard may be considered further in future design stages of the local road network and proposed bridge/culvert design of the main waterway crossings.




Title:

**Proposed Modification Layout and Topography**

0 300 600 m

approx. scale

Figure: **5-1**

Revision: **A**

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Title:

**Simulated 1% AEP Flood Depth**
**Post-Development Conditions**

0 300 600 m

approx. scale

Figure: **5-2**

Revision: **A**

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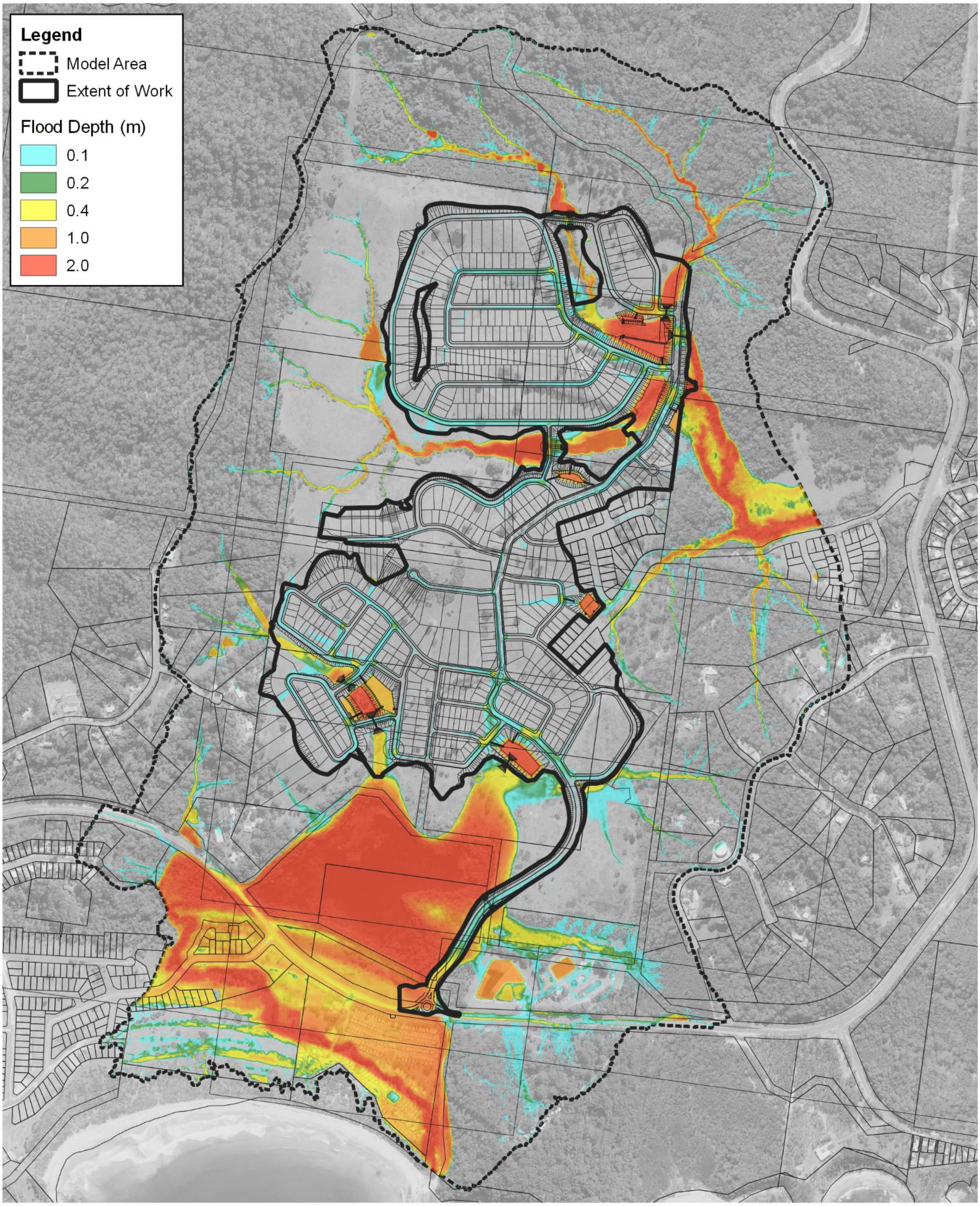
Filepath: Z:\Projects\T2535_Rosedale_FRA\GIS\T2535_010_2400404_1%_depth_modification.qgz




Title:

**Simulated PMF Flood Depth**
**Post-Development Conditions**

0 300 600 m

approx. scale

Figure: **5-3**

Revision: **A**

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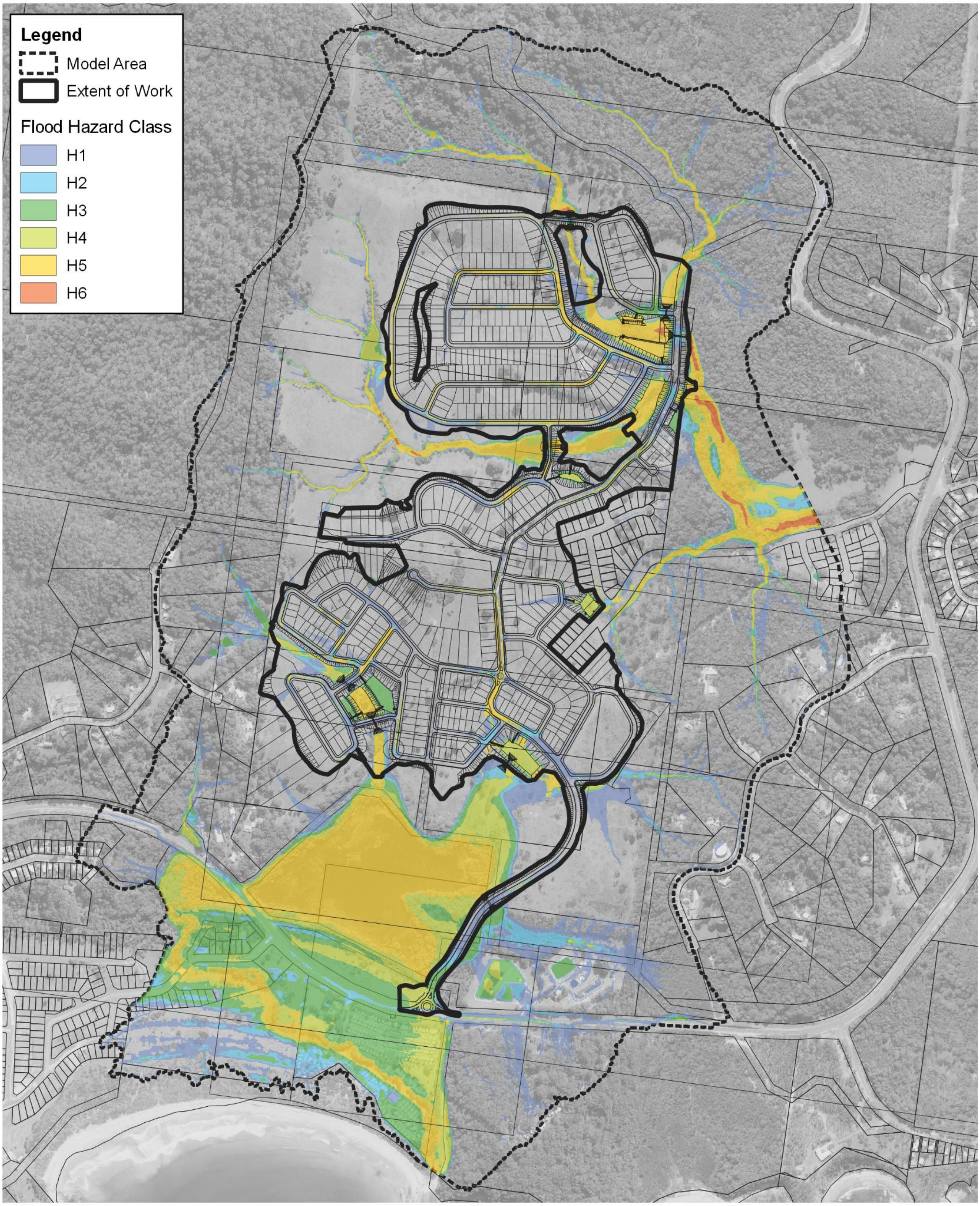


Title:

**Simulated PMF Flood Hazard Classification Post-Development Conditions**

0 300 600 m

approx. scale

Figure: **5-4**

Revision: **A**

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The following key observations are noted with respect to modelled peak flood conditions and proposed development modification:

- The proposed residential areas are effectively flood free at PMF level for the mainstream flooding conditions noting that the minor overland flow paths simulated within the residential footprint areas would be accommodated via appropriate road and drainage design.
- There is some minor encroachment of the proposed modification footprint into the Bevian Wetland PMF extent at the southern edge of the development. The encroachment would be less for lower order events such the 1% AEP event (principal flood planning event) and accordingly, provides for limited potential impact particularly given the existing hydraulic control afforded by the overtopping of George Bass Drive.
- There is adequate space within the retained waterway and green space corridors to accommodate water management infrastructure including retention of some of the existing on-line water storages. It is assumed that this infrastructure or other water management measures provide the appropriate treatment to not increase existing design flows discharging to downstream receiving areas.

## 5.3 Impact Assessment

The relative impact of the proposed development has been considered in terms of potential changes to existing flood behaviour.

The impact of the proposed development on existing design flood conditions can be better understood in a spatial context through comparison of the change in modelled peak flood levels and velocities.

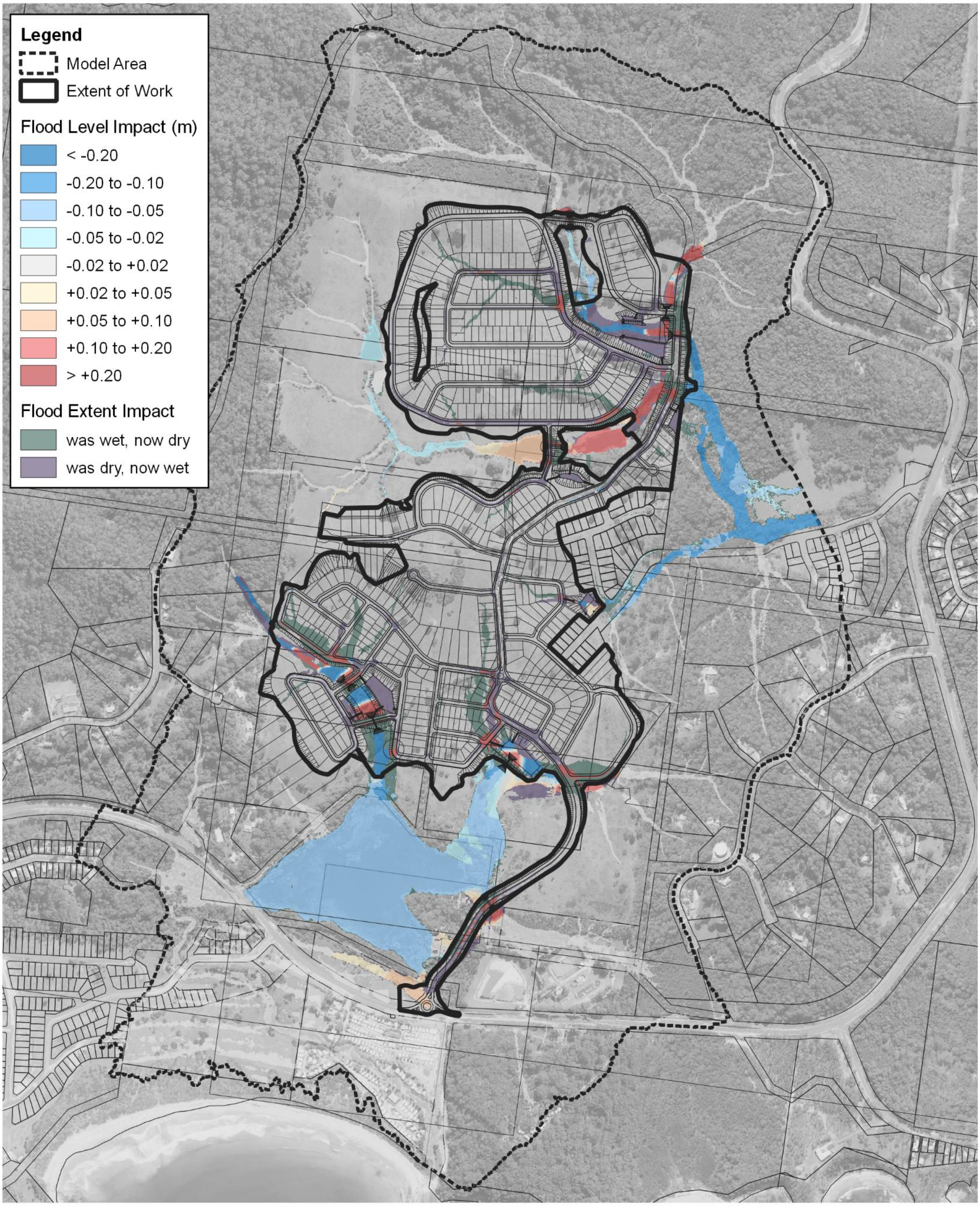
Simulated changes in peak flood level for the 1% AEP and PMF event are presented in Figure 5-5 and Figure 5-6 respectively.

Changes in peak flood level within the development footprint are largely driven by the modified topography. There are multiple areas noted as being previously wet now made dry, and conversely previously dry now made wet. Within the residential lot areas, this largely represents changes to the natural overland flow distribution in accordance with modified surface and road layout. The changes in the waterway corridors are largely representing the incorporation of water management infrastructure (both online and offline basins).

Increases in peak flood levels within the waterway corridors in the development area are associated with higher retained water levels within the water management structures and upstream of internal road embankments. These increased water levels are retained in waterway corridors providing the detention function as designed.

Outside of the proposed modification footprint in the downstream receiving environments (i.e. Saltwater Creek and Bevian wetland) there is typically negligible changes to flood levels including some minor reductions. The peak flood level reductions are driven by the detention function within the modification footprint providing slightly lower peak discharges to the downstream environment.

This demonstrates the effectiveness of the water management strategy to manage downstream flood impacts. It is envisaged that future detailed design of the water management and cross drainage infrastructure will further optimise this detention function. This would also include refined cross drainage design to address any minor afflux upstream of road crossings.




Title:

**Simulated 1% AEP Flood Level Impact**
**Post-Development Conditions**

0 300 600 m

approx. scale

Figure: **5-5**

Revision: **A**

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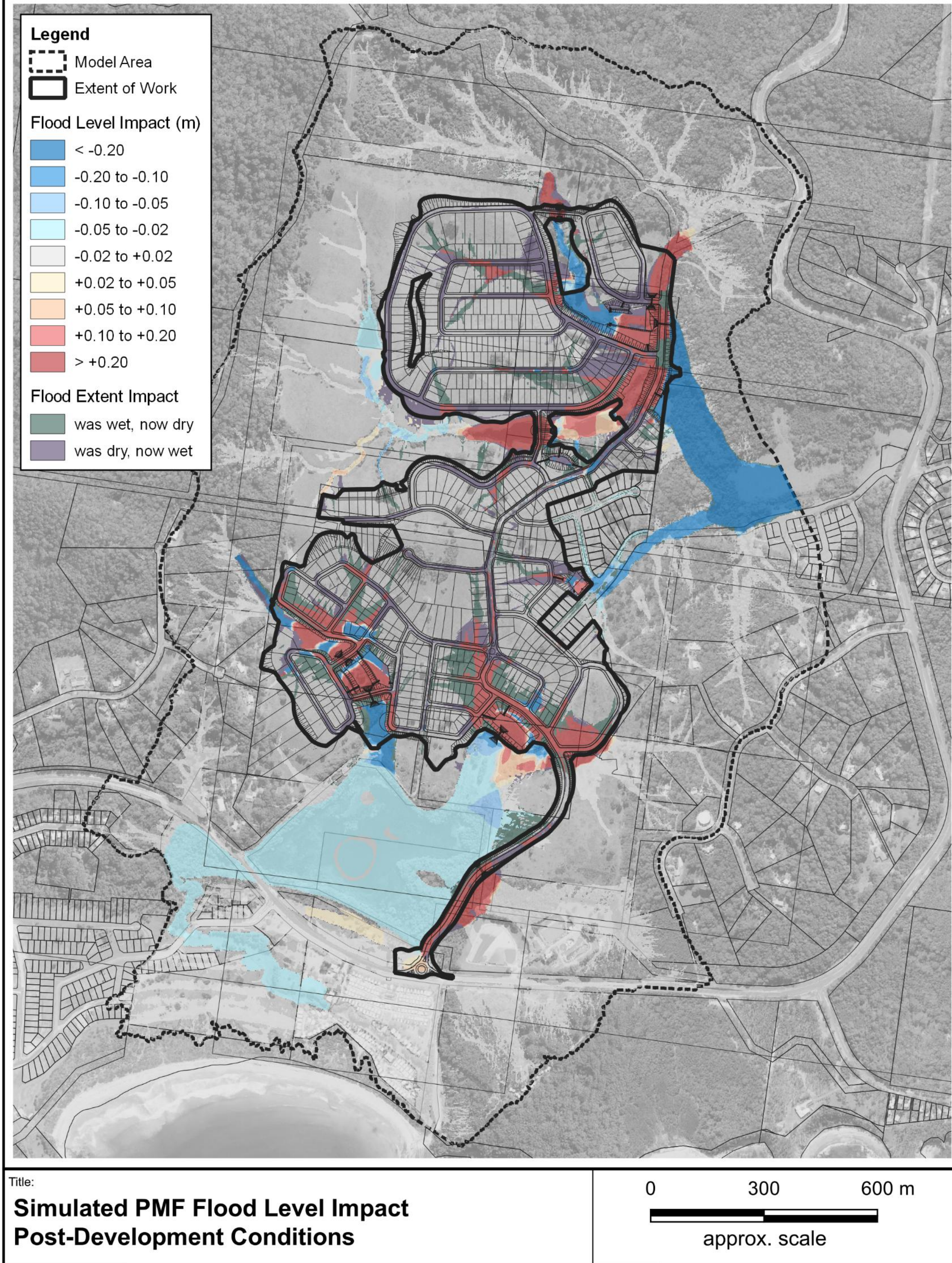


Title:

**Simulated PMF Flood Level Impact**
**Post-Development Conditions**

Figure: **5-6**

Revision: **A**

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Simulated changes in peak flood velocity for the 1% AEP and PMF event are presented in Figure 5-7 and Figure 5-8 respectively.

Similar to the changes in peak flood levels, the change in velocity within the proposed modification footprint is driven by the modified topography and particular changes within the waterway corridors incorporating the water management works and road embankment crossings. Reductions in peak flood velocities are typically associated within water storages areas, with increases associated with modified channel and floodplain cross section. Notwithstanding these changes, the resulting peak velocities do not represent any significant risks.

Peak velocities in the downstream receiving environments are also largely unchanged, or slightly reduced associated with the detention function in the proposed modification area.

The impact mapping across the full suite of design events included in Appendix C provides for similar results as described. Whilst the degree of attenuation of the flood hydrographs through the watercourse alignments depending on flow magnitude, a similar net impact is realised with no increase in peak levels or velocities external to the Site.


Title:

**Simulated 1% AEP Flood Velocity Impact Post-Development Conditions**

Figure: **5-7**

Revision: **A**

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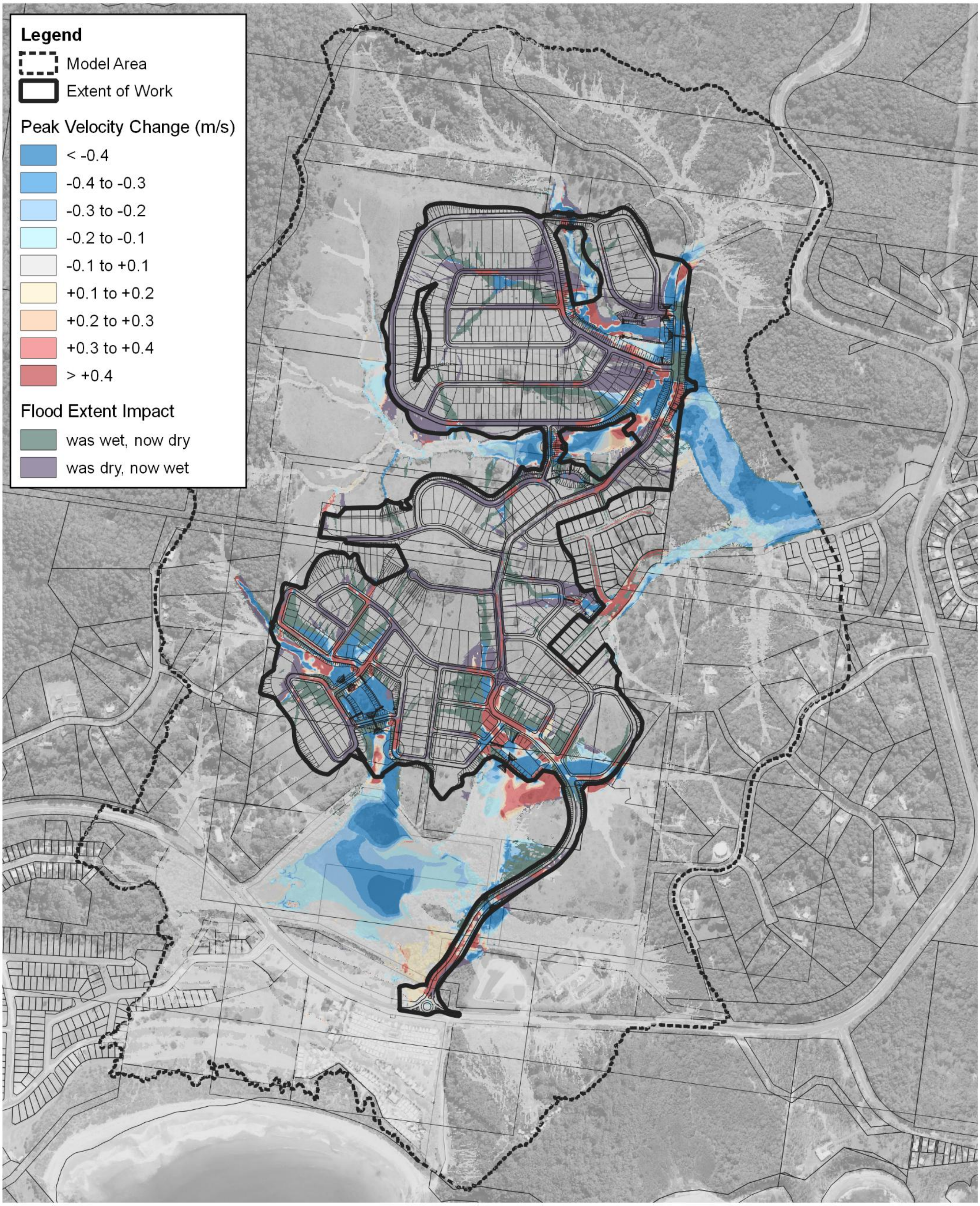


Title:

**Simulated PMF Flood Velocity Impact**
**Post-Development Conditions**

0 300 600 m

approx. scale

Figure: **5-8**

Revision: **A**

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# 6 Flood Emergency Management

The proposed residential development footprint is located on land above the mainstream PMF flood extents. Accordingly, there is no direct inundation risk for the future properties up to the PMF event. This provides for no requirement for specific flood evacuation and emergency response considerations.

Depending on the flood immunity of the local and regional road network, there may be some expected road closures to limit flood access to the Site. Given the relatively small local catchments, the duration of flooding is likely to be relatively short, thereby limiting any issues associated with potential isolation up to the PMF event.

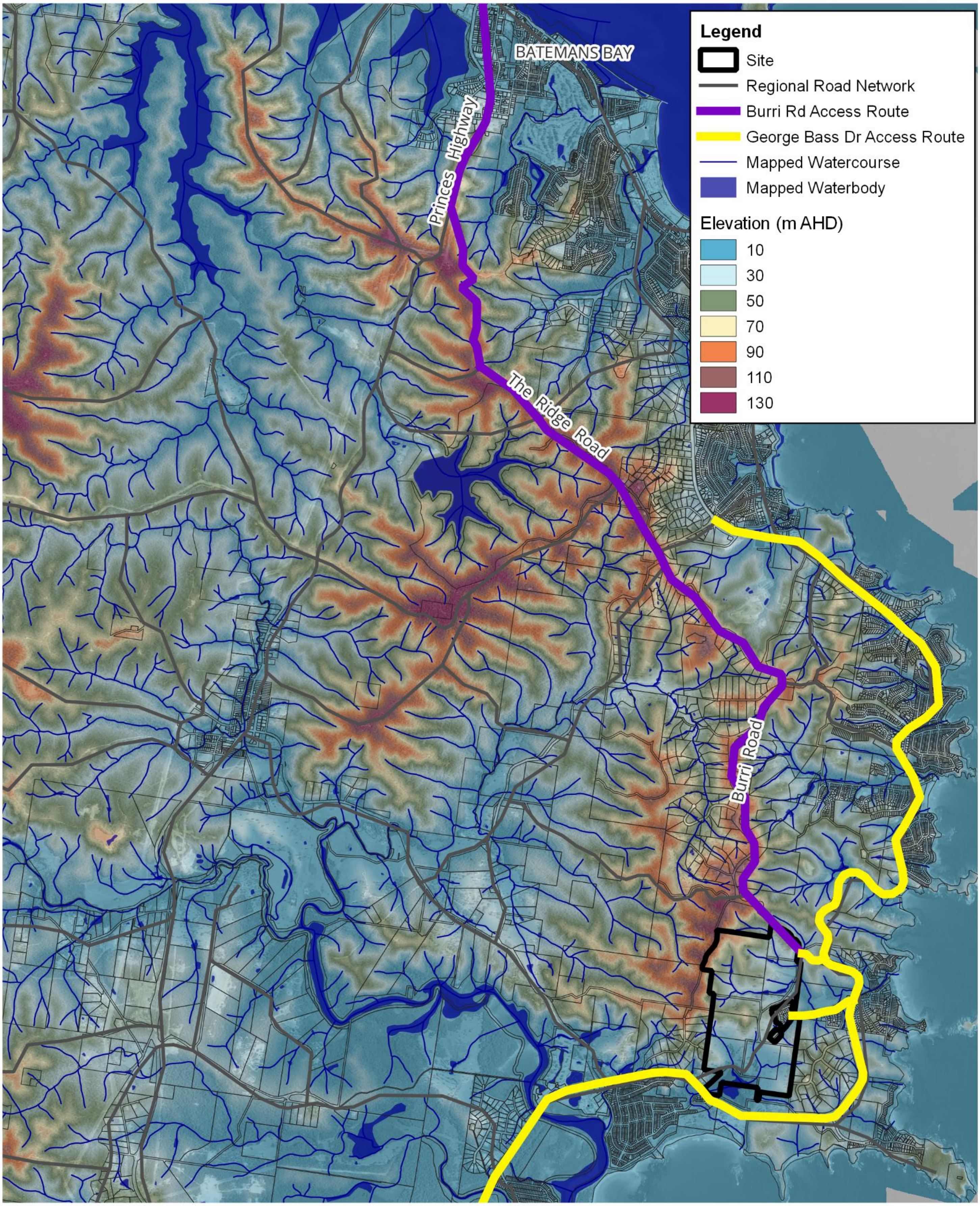
The internal road system within the proposed development has effective flood immunity up to the 1% AEP design magnitude in general. Some of the access roads have a limited higher immunity, however, all would subject to overtopping at the PMF event. As noted, the catchments draining to these watercourse crossing locations are small, with the largest less than 0.6 square kilometres in area. Accordingly, the catchments rise and fall relatively quickly in response to local rainfall. The short duration events (less than 60 minutes design duration) provide for the highest peak flows and subsequent road overtopping for the large events. The duration of overtopping and potential loss of flood access is substantially shorter. Notwithstanding, short periods of isolation (less than one hour) for events in excess of the 1% AEP does not represent a significant risk.

Further consideration is given to the flood emergency access in broader regional road network beyond the proposed development internal road network. The regional access routes are George Bass Drive (northbound and southbound from the Site) and Burri Road (northbound from the Site). These access routes are shown in Figure 6-1 in the context of the regional topography and watercourse locations. It is noted George Bass Drive has multiple access points from the Site via Bevian Road and Saltwood Drive as shown.

Travel south of the Site via George Bass Drive may be compromised for more extended periods of time given the watercourse crossing locations downstream of Bevian Wetland and Tomaga River.

Northwards of the Site George Bass Drive traverses a number of local watercourse catchments draining towards the coastline. Flooding details in these catchments has not been considered in the current study, nor is existing Council flood information available for these catchments. Accordingly, the regional flood road immunity along this route is unknown.

An alternative flood access route via Burri Road is available from the Site to Batemans Bay which effectively runs along a ridgeline with no major watercourse crossings. The route from the Site is shown in Figure 6-1 along Burri Road, The Ridge Road and Princes through to Batemans Bay. This route is expected to provide essentially flood free access providing for flood emergency access to the Site.




Title:

**Flood Access Route**

0 1,000 2,000 m

approx. scale

Figure: **6-1**

Revision: **A**

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# 7 Conclusions

The FIRA requirements for the current assessment appear to be the standard wording for inclusion with the SEARs, and do not indicate any specific consideration of the context of the proposal as a modification to the existing approval. The existing approved layout was considered to be compatible with the established flooding conditions up to the PMF event. The proposed modification layout has similar limited interaction with flooding conditions up to the PMF. Accordingly, the approach to the FIRA has been a reduced to scope to initially confirm the PMF extents via additional modelling and confirm the suitability of the modification layout with the established flood risk. With consideration of this approach, some further responses to the main SEARS requirements are provided below.

- *Consider the relevant provisions of the NSW Flood Risk Management Manual (2023) and associated guides, and existing council and government studies, information and requirements.*

There is no existing council and government studies relevant to the catchment, with flood information limited to the PBP (2007) assessment for the existing approval. A review of this assessment has considered it fit for purpose, however, additional modelling applying contemporary analysis techniques has been undertaken to confirm design flood conditions and provide the basis for the flood risk assessment in accordance with contemporary flood risk management guidelines.

- *Identify and describe existing flood behaviour on the site and its surrounding areas for the full range of events, including 5% AEP, 1% AEP, PMF and 0.5% AEP or 0.2% AEP and provide an assessment of the compatibility of the development and its users with flood behaviour. This may require flood modelling where existing flood information is not available.*

The assessment included the development of a TUFLOW software model applying contemporary techniques and industry guidelines to establish the design flood conditions for events between the 5% AEP and PMF magnitudes. The modelling provides for the simulation of the design inundation extents, flood water levels, flood depth, velocity and hazard distributions. The modelled 1% AEP and PMF event confirmed similar flood inundation extents as per PBP (2007) for the existing approval. The proposed modification layout has limited interaction with the PMF extent, with broad corridors maintained along the main waterway alignments to accommodate the PMF design flows. The simulation of the other lower order flood events is considered to not be required in this instance given they will also be readily accommodated within the mapped PMF extent and further reduced interaction with the proposed modification layout. It is noted however, these events would be expected to be simulated in future design stages to consider design flood immunity for proposed infrastructure within the mapped extents (e.g. road crossings, water management infrastructure etc.).

- *Determine and describe changes in post development flood behaviour, impacts of flooding on existing community and on the development and its future community for full range of events, 5% AEP, 1% AEP, PMF and 0.5% AEP or 0.2% AEP. This will typically require flood modelling.*

As noted, the proposed modification footprint has limited interaction with the PMF flood extent. There is some minor encroachment at the southern limit of the development at the edge of the flooded extent of Bevian Wetland, and on the northern floodplain edge of the nominal “Tributary 2”. These minor encroachments don’t represent a significant flow impedance or loss of temporary flood storage at the PMF level. Any minor change in flow conditions are localised and contained within the Project boundary, noting this would be further reduced for the lower order flood events. Other infrastructure to be located within the floodplain are the main waterway road crossings and potential some water management infrastructure. Whilst the detail of these works would be established at future design stages, given the wide waterway corridors, including significant additional capacity over and above the PMF level, the design of these infrastructure is expected to be readily accommodated in the floodplain with no adverse impact.

- *Consider impacts of climate change due to both sea level rise and increase in rainfall intensities considering relevant Council and government advice. The 0.5% AEP or 0.2% AEP events can be used to provide an understanding of the scale of change of flood behaviour relative to the 1% AEP event.*

As per the updated ARR 2019 climate change guidance, an adjustment was made to the adopted design rainfall to account for potential increases in rainfall intensity. The rainfall adjustment is determined through a combination of an expected increase in global mean temperature and an associated percentage increase in design rainfall intensity per degree of warming.

- Propose and assess the effectiveness of management measures required to minimise the impacts and risks of flooding to the development and its users and existing community.

The proposed residential development footprint is located on land above the mainstream PMF flood extents. Accordingly, there is no direct inundation risk for the future properties up to the PMF event. This provides for no requirement for specific flood evacuation and emergency response considerations. All local roads have 1% AEP design flood immunity, however, some local flood access restriction may be possible for larger flood events up to the PMF. Given the size of the local catchments draining to road crossing locations within the Site, potential overtopping duration of local access roads is limited to a short period of time and does not pose any significant risk of isolation. Regional flood access to Batemans Bay is available via Burri Road, The Ridge Road and Princes Highway which effectively runs along ta continuous topographic ridgeline with no significant watercourse crossings.

On the basis of the assessment, it is considered the proposed modification is compatible with the flood risk environment noting:

- Compatibility of the proposed modification with the existing approval and associated flood assessment.
- Design flood risk up to the PMF established through additional modelling in accordance with contemporary industry standards.
- No identifiable constraints for future detailed design of infrastructure to address flood risk management requirements.

# 8 References

AIDR (2017) Guideline 7-3, Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia), 2019.

NSW Department of Planning and Environment (2023). *Flood Risk Management Manual.*

Patterson Britton and Partners (2007). *Bevian Road Concept Application - Flood Impact Assessment.*

# Appendix A Existing Conditions Flood Mapping

- 5% AEP Flood Depth and Inundation Extent
- 2% AEP Flood Depth and Inundation Extent
- 1% AEP Flood Depth and Inundation Extent
- 0.5% AEP Flood Depth and Inundation Extent
- 0.2% AEP Flood Depth and Inundation Extent
- PMF Flood Depth and Inundation Extent

- 5% AEP Flood Velocity
- 2% AEP Flood Velocity
- 1% AEP Flood Velocity
- 0.5% AEP Flood Velocity
- 0.2% AEP Flood Velocity
- PMF Flood Velocity

- 5% AEP Flood Hazard
- 2% AEP Flood Hazard
- 1% AEP Flood Hazard
- 0.5% AEP Flood Hazard
- 0.2% AEP Flood Hazard
- PMF Flood Hazard

# Appendix B Post-Development Flood Mapping

- 5% AEP Flood Depth and Inundation Extent
- 2% AEP Flood Depth and Inundation Extent
- 1% AEP Flood Depth and Inundation Extent
- 0.5% AEP Flood Depth and Inundation Extent
- 0.2% AEP Flood Depth and Inundation Extent
- PMF Flood Depth and Inundation Extent

- 5% AEP Flood Velocity
- 2% AEP Flood Velocity
- 1% AEP Flood Velocity
- 0.5% AEP Flood Velocity
- 0.2% AEP Flood Velocity
- PMF Flood Velocity

- 5% AEP Flood Hazard
- 2% AEP Flood Hazard
- 1% AEP Flood Hazard
- 0.5% AEP Flood Hazard
- 0.2% AEP Flood Hazard
- PMF Flood Hazard

# Appendix C Flood Impact Mapping

- 5% AEP Change in Peak Flood Level
- 2% AEP Change in Peak Flood Level
- 1% AEP Change in Peak Flood Level
- 0.5% AEP Change in Peak Flood Level
- 0.2% AEP Change in Peak Flood Level
- PMF Change in Peak Flood Level

- 5% AEP Change in Peak Velocity
- 2% AEP Change in Peak Velocity
- 1% AEP Change in Peak Velocity
- 0.5% AEP Change in Peak Velocity
- 0.2% AEP Change in Peak Velocity
- PMF Change in Peak Velocity