Princes Highway Upgrade Program

JERVIS BAY ROAD INTERSECTION UPGRADE

Flood and Surface Water Assessment

26 MAY 2021

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TRANSPORT FOR NSW PRINCES HIGHWAY UPGRADE PROGRAM JERVIS BAY ROAD INTERSECTION UPGRADE

Flood and Surface Water Assessment

Authors	Ian Rath / Bruce Withnall
Checker	Bruce Withnall
Approver	Yvonne Almandinger

Report No	PHUPJB-ADAP-NWW-EN-RPT-000006
Date	26/05/2021
Revision Text	C

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REVISIONS

Revision	Date	Description	Prepared by	Approved by
A	17/11/2020	Draft issue to Transport for NSW	IR	YA
B	19/02/2021	Draft issue to Transport for NSW	IR	YA
C	26/05/2021	Final report	IR	YA

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APPENDICES

GLOSSARY

Definitions	
AEP	Annual Exceedance Probability. The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of a 500 cubic metres per second or larger events occurring in any one year (see ARI).
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval. The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DEM	Digital Elevation Model. A digital surface of ground elevation points, typically at a regular interval. The base terrain for a flood model typically consists of a DEM derived from Airborne Laser Scanning with LiDAR surveying equipment.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second. Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second.
Flood liable land	Synonymous with flood prone land, ie land susceptible to flooding by the Probable Maximum Flood (PMF) event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (PMF) event (that is, flood prone land).
Floodplain risk management plan	Aa management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, 2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Flood planning area	The area of land below the FPL and thus subject to flood related development controls.
FPL	Flood Planning Level. The combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
Flood prone land	Land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
Flood storage areas	Parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Freeboard	It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. that Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. Freeboard is included in the flood planning level.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (2005) the hazard is flooding which has the potential to cause damage to the community.

Definitions	
Hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Mathematical / computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and environmental planning instruments. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and environmental planning instruments.
Minor, moderate and major flooding	Both the State Emergency Services and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: *minor flooding:* causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. *moderate flooding:* low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. *major flooding:* appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
NSW	New South Wales
PMF	Probable Maximum Flood. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the NSW Floodplain Development Manual (2005) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.

EXECUTIVE SUMMARY

Transport for NSW proposes to upgrade the intersection of Jervis Bay Road and the Princes Highway in the vicinity of Falls Creek, NSW, located about 12 kilometres south of Nowra within the City of Shoalhaven local government area. The proposal would provide a grade separated through alignment for the Princes Highway with network access to Jervis Bay Road and Old Princes Highway provided via dual at grade roundabouts serviced by on and off ramps.

Arcadis were appointed by Transport for New South Wales to undertake the Concept Design and Review of Environmental Factors for the proposal.

Flooding

The investigation area is within the Parma Creek catchment (a tributary sub-catchment of Currambene Creek) and is exposed to flooding from tributaries to Parma Creek and its downstream backwater as well as overland flow from small local catchments.

A full-catchment flood model was created to model the catchment upstream of the Princes Highway to provide information on creek flows and backwater flooding in the Parma Creek network. Results from this model aligned with results from the flood model used by Shoalhaven City Council for areas downstream of the Princes Highway, and with anecdotal evidence of backwater flooding near the proposal.

A high resolution TUFLOW flood model was used to represent the local catchments within the site investigation area to determine flood levels, depths, velocities, and to estimate potential flood level impacts associated with the design proposal configuration. The model used Australian Rainfall and Runoff 2019 data and methods with location-specific adjustments to maximise the resilience and safety of this link in the transport network.

The flood model results indicate that backwater flooding from Parma Creek can have an influence on the proposal. Under existing conditions, the backwater extent affects up to a 400-metre length of Princes Highway embankment. Similar flooding has been experienced in the past and is reflected in the *Shoalhaven Local Environment Plan 2014* flood maps. The results have also shown that the existing triple cell box culvert located beneath the Princes Highway carriageways near the southern limit of the site investigation area is potentially undersized and could lead to overtopping of both the Princes Highway and Jervis Bay Road in the one per cent Annual Exceedance Probability (AEP) flood (equivalent to a 100 Year Average Recurrence Interval).

The proposal aims to prevent overtopping of the Princes Highway and Jervis Bay Road, providing a one per cent AEP flood immunity. To achieve this, an upgrade of the existing box culvert to four cells is required. Modelling indicates that this would largely resolve the potential for overtopping. Design development has identified and resolved localised areas of inundation affecting the southbound on ramp and a section of the adjoining main carriageway.

As a result of the culvert upgrade, the modelling indicates there would be a reduction in upstream flood levels where there are several dwellings that may be flood affected under existing conditions. Upgrading of the culvert would increase the flow capacity and result in an increase in flood levels over a relatively small, localised area immediately downstream. This area is not developed, and the magnitude and extent of impacts should not have any adverse impacts for surrounding properties.

Other areas immediately upstream of the proposed embankments to the north of Jervis Bay Road also show some increases in flood levels. These impacts are mostly contained within the road corridor but there is a relatively small area extending into an adjoining property that largely comprises undeveloped bushland.

Water quality

The existing intersection does not appear to have any water quality treatment measures in place. Stormwater runoff and any spills from the roadway are not currently treated prior to discharge into the receiving environment.

Water quality considerations and measures will be required during the construction and operation of the proposal. With due consideration of the proposal site conditions and constraints, it is proposed that the operational water quality treatment requirements would be achieved using vegetated swales, bioretention swales and bioretention basins across the drainage layout. Temporary sediment control basins will be provided during construction.

The intersection of Jervis Bay Road and Princes Highway is generally situated well away from any perennial stream or other environmentally sensitive creek or waterway. Additionally, one of the main objectives of the proposal is to improve the overall road safety for the area and minimise the risk of accidents occurring. Therefore, in the unlikely event of an emergency spill situation during operation, there would be sufficient opportunity to provide temporary bunding within the adjacent swales to prevent or minimise the spread of contaminants and pollutants to downstream areas and sensitive receivers. Potential impacts would be managed via the existing Princes Highway emergency response procedures using Transport for NSW emergency response teams located at Nowra and Berry (17 and 30 kilometres away from the proposal, respectively).

1 INTRODUCTION

1.1 The Proposal

Transport for NSW proposes to upgrade the intersection of Jervis Bay Road and the Princes Highway in the vicinity of Falls Creek, NSW, located about 12 kilometres south of Nowra within the City of Shoalhaven local government area. The proposal would provide a grade separated through alignment for the Princes Highway with network access to Jervis Bay Road and Old Princes Highway provided via dual at grade roundabouts serviced by on and off ramps.

Key features of the proposal are shown in Figure 1Figure 1 and would include:

- A new intersection between Jervis Bay Road and the Princes Highway, incorporating:
  - Realignment of the existing Princes Highway, including widening from two lanes to a four-lane divided highway (two lanes in each direction), with median separation using flexible safety barriers, providing an uninterrupted through alignment for the Princes Highway
  - An overpass bridge over Jervis Bay Road
  - An unsignalised single-lane at-grade double roundabout interchange providing:
    - Direct access from Jervis Bay Road and Old Princes Highway to the Princes Highway
    - Direct access from the Princes Highway to Jervis Bay Road and Old Princes Highway
  - Direct connection to existing properties and businesses at the Old Princes Highway
  - A connection from Willowgreen Road to Old Princes Highway
  - Tie-ins with the Old Princes Highway and with Jervis Bay Road
- Access road to service Princes Highway properties south east of the intersection
- Shared user paths along Jervis Bay Road, connecting to the new bus bay and Jervis Bay Road and Old Princes Highway road shoulders
- Adjustments of drainage infrastructure and provision of new drainage infrastructure such as pit and pipe networks, culverts, open channels and retention basins
- Permanent water quality measures such as vegetated swales, bioretention swales and bioretention basins
- Adjustment, protection, and relocation of existing utilities
- Other roadside furniture including safety barriers, signage, line marking, lighting and fencing
- A bus bay adjacent to the interchange, including kiss and ride car spots
- Establishment and use of temporary ancillary facilities during construction
- Property works including acquisition, demolition, and adjustments to accesses, and at-property noise treatments
- Rehabilitation of disturbed areas and landscaping.

1.2 Purpose of this Report

This purpose of this report is to:

- Provide a summary of hydrologic and hydraulic models established for the flood assessment
- Define existing flood behaviour in the vicinity of the proposal
- Detail design flood information used to inform development of the proposal design
- Present a summary proposed flooding conditions
- Identify potential hydraulic impacts associated with the proposal

- Assess surface water quality conditions for existing and proposed conditions
- Identify water quality treatment measures where required.

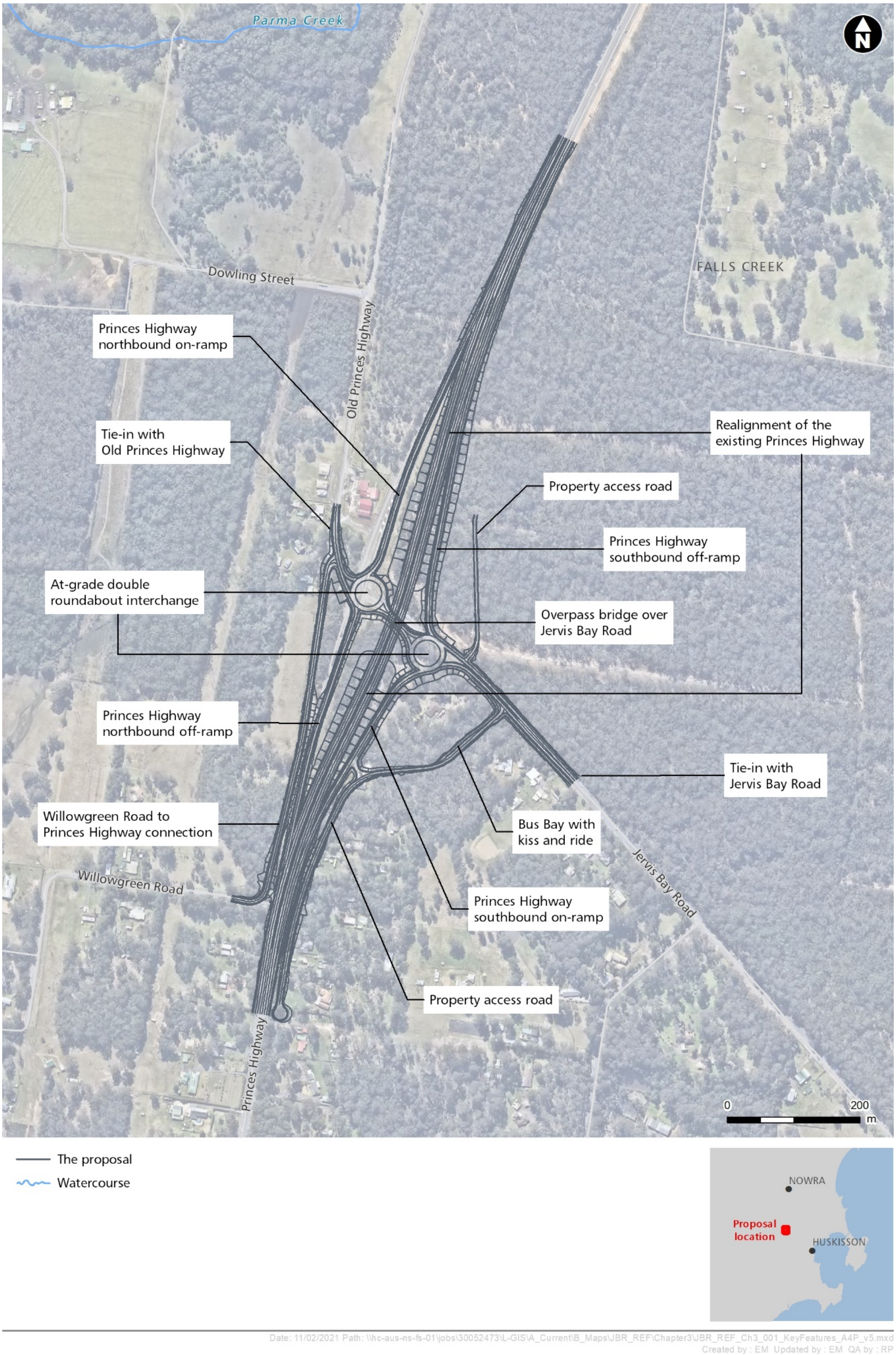

Figure 1 Key features of the proposal

2 ASSESSMENT REQUIREMENTS

2.1 Relevant Guidelines

The relevant guidelines for this flood assessment include:

- *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Ball *et al*., 2019) (ARR2019)
- *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources, 2005)
- *Practical Consideration of Climate Change* (Department of Environment and Climate Change, 2007)
- *Technical Guide – Climate Change Adaptation for the Road Network* (Transport for NSW, Draft Issue No 1, undated)
- *Managing Urban Stormwater: Soils and construction – Volume 1* ('the blue book') (Landcom, 2004)
- *Policy and Guidelines for Fish Friendly Waterway Crossings* (Department of Primary Industries, 2004)
- *Policy and Guidelines for Fish Habitat Conservation and Management* (Department of Primary Industries, 2013)
- NSW Water Quality Objectives (NSW Department of Environment, Climate Change and Water, 2006)
- *Water sensitive urban design guideline* (Roads and Maritime Services, 2017).

2.2 Regulatory Framework

2.2.1 NSW Government Flood Prone Land Policy

The NSW Government's Flood Prone Land Policy (the Policy) (Department of Infrastructure, Planning and Natural Resources, 2005) provides a framework for managing development on the floodplain with the aim of reducing the impact of flooding on occupiers and users of the floodplain. The primary objective of the policy is to develop sustainable strategies for managing human occupation and use of the floodplain using risk management principles. An outline of the policy framework is shown in Figure 2.

For the purposes of Section 733 of the *Local Government Act 1993*, the NSW *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources, 2005) (the Manual) has been prepared to incorporate the principles of the NSW Flood Prone Land Policy as it relates to the development of flood liable land. Under the Policy, the management of the floodplain remains the responsibility of local government, but the State government provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The main principles of the Manual outline a merit-based approach to floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological, and flooding issues to determine strategies for the management of flood risk. The Manual recognises that there are differences between urban and rural floodplain issues and therefore a different emphasis may be required for each type of floodplain. However, it maintains that the same overall floodplain management approach should still apply to both situations.

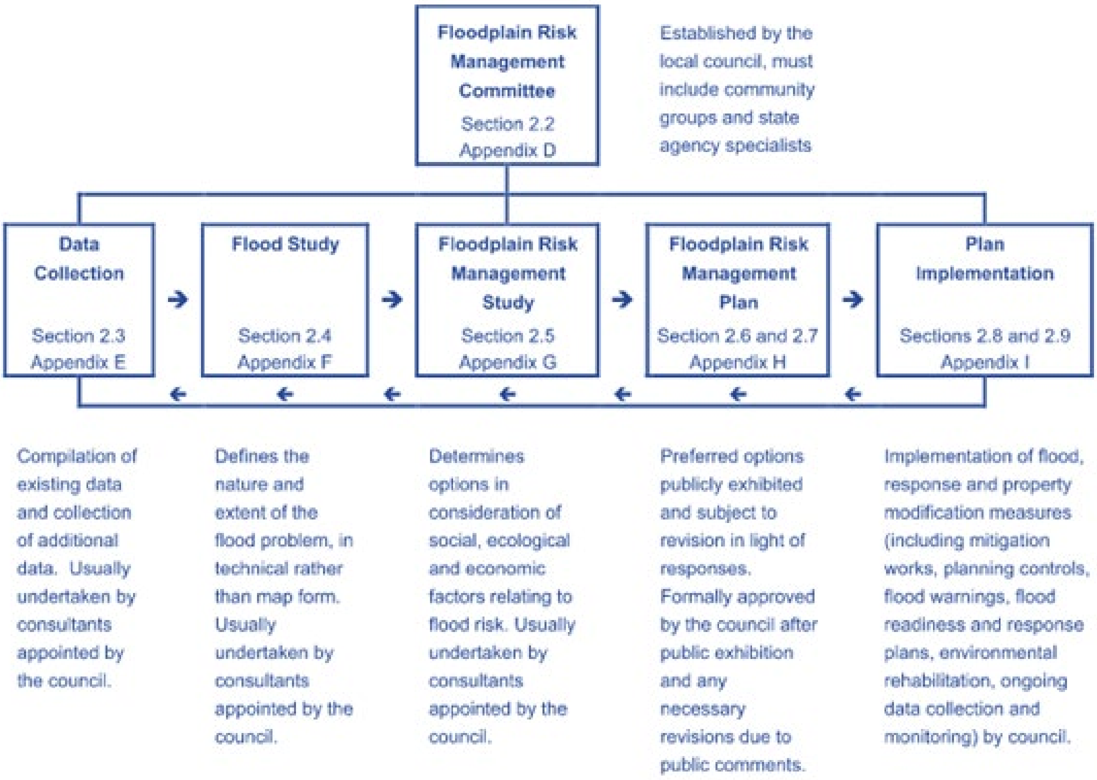

Figure 2 NSW government floodplain risk management process

2.2.2 Shoalhaven Local Environment Plan 2014

The *Shoalhaven Local Environmental Plan 2014* is used as the basis for guiding planning decisions for the entire Shoalhaven City local government area through zoning and development controls which provide the framework for the way in which land in different areas can be used or developed. This includes the Jervis Bay Road Intersection Upgrade site investigation area.

The *Shoalhaven Local Environmental Plan 2014* also contains additional local provisions with respect to flood planning and development of flood prone lands (Clause 7.3). The applicable building and development controls are defined separately within the associated *Shoalhaven Development Control Plan 2014*.

2.2.2.1 Flood Planning Levels

Consistent with recommendations of the Manual, Shoalhaven City Council have adopted the one per cent Annual Exceedance Probability (AEP) flood event plus 0.5 metre freeboard for Flood Planning Levels (FPL) applicable to the Shoalhaven area.

Since the preparation of the *Shoalhaven Local Environmental Plan 2014*, Shoalhaven City Council has updated the background flood investigations and prepared a floodplain risk management plan for the lower reaches of Currambene Creek (WMA Water, 2016). The extent of the flood planning area in vicinity of the proposal based on the FPL derived by the most recent Currambene Creek flood modelling (WMA Water, 2016) is shown in Figure 3.

Note that the study area for the Currambene modelling only covered the reaches downstream of the Princes Highway and as such there is no definable Flood Planning Area or FPL applicable to the upstream floodplain areas. There is, however, an indicative flood extent for the tributary floodplain area immediately downstream of the Jervis Bay Road Intersection which is based on historical flood event data.

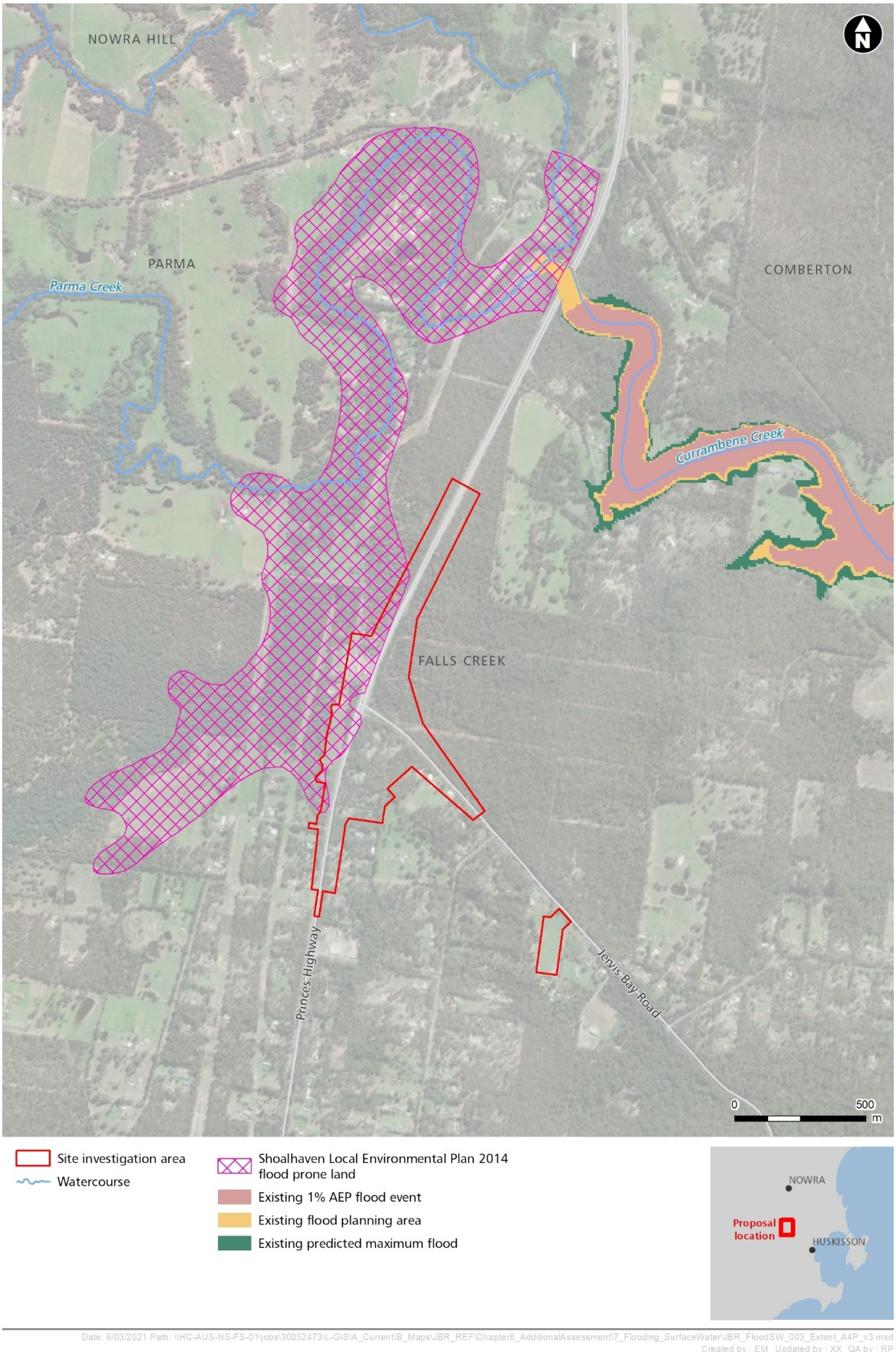

Figure 3 Extent of flood planning area in the vicinity of the proposal (WMA Water, 2016)

2.2.3 Shoalhaven Development Control Plan 2014

A Development Control Plan is the primary instrument supporting the Local Environmental Plan that is used by councils in managing development on the floodplain to ensure it is compatible with the local flood conditions and situation. Flood related building and development controls for flood prone lands in the Shoalhaven area have been identified and developed in accordance with the ongoing floodplain management process and are defined in the *Shoalhaven Development Control Plan 2014*.

The most relevant flooding component of the *Shoalhaven Development Control Plan 2014* is Chapter G9 Development on Flood Prone Lands which provides the information and development controls required for development applications associated with flood prone lands. The requirements of this chapter apply to all development on flood prone land within the Shoalhaven local government area whether the land has been identified and mapped by specific flood studies. Additional or special controls applicable to certain areas identified and mapped within specific flood studies or floodplain risk management plans are also included.

Chapter G2 Sustainable Stormwater Management and Erosion Sediment Control sets out controls for water quality, waterway stability, detention, erosion, and sediment control. The main objectives of this chapter seek to manage stormwater flow paths and systems to mitigate impacts of development and ensure the safety of human life and assets as well as protecting environmental values. Chapter 2.2 prescribes assessment and mitigation measures to be undertaken and considered for water sensitive urban design.

The controls and requirements of the *Shoalhaven Development Control Plan 2014* were developed based on due consideration of the flood related information, issues, and outcomes available from various Flood and Floodplain Risk Management Studies and Plans undertaken across the Shoalhaven local government area. For areas where potential flood prone lands have not been subject to a detailed flood study, a flood assessment report may be required to be undertaken.

2.3 Design Criteria

The flooding design criteria for the proposal are outlined in the Transport for New South Wales specification PS271.

The proposal design aimed to minimise flood impacts through appropriate design of stormwater management features. The general flooding and flood immunity requirement for the drainage design is the one per cent AEP.

The proposal design also aimed to provide improved flooding conditions upstream of the Princes Highway as there are dwellings that are susceptible to flooding.

Water quality criteria are outlined in the Transport for NSW *Water sensitive urban design guideline* (Roads and Maritime Services, 2017). The proposal design aimed to meet or exceed the pollution retention targets outlined in this guideline (refer to Section 4.2).

3 AVAILABLE DATA

3.1 Previous Studies

3.1.1 Currambene Creek and Moona Moona Creek Flood Studies, Lyall & Associates 2006

The Currambene Creek and Moona Moona Creek Flood Studies (combined report) were undertaken by Lyall & Associates in 2006. The study objective was to update flood information for the lower reaches of Currambene Creek and define flood behaviour for the Moona Moona Creek catchment in terms of flows, levels and flooding behaviour for floods ranging between five and 200 years Average Recurrence Interval (ARI), as well as for the Probable Maximum Flood (PMF).

Flood behaviour was defined using hydrologic models (RORB) of the catchments and hydraulic models (HECRAS) of the two main streams and their tributaries. The hydrologic models were based on a runoff routing approach and in the case of Currambene Creek, calibrated against recorded rainfall and stream flow data. Parameters derived from calibrating the Currambene Creek model gave guidance for the parameters selected for design flood estimation on that catchment and Moona Moona Creek.

Design storms were applied to the models to generate discharge hydrographs within the study area. These hydrographs constituted the upstream boundaries and tributary inflow inputs to the hydraulic models. A flood envelope approach was adopted for defining design water surface profiles for design events. This procedure involved selection of the upper limit of expected flooding for each frequency resulting from two alternative scenarios:

- Catchment runoff derived from design storm events of the relevant frequency in conjunction with a Normal Semi-Diurnal Tide
- Storm tide hydrographs of the relevant frequency in conjunction with a minor five year ARI catchment flood.

Elevated ocean levels due to storm tides and wave action controlled design flood levels in the lower reaches of both creeks, whereas catchment flooding controlled further upstream.

3.1.2 Currambene and Moona Moona Creeks Floodplain Risk Management Study and Plan, WMA Water 2016

This study was undertaken to update the floodplain management process using the latest flood information, technologies and approach order to define and address the existing, future and continuing flood problems. The objectives of the study were to:

- Review available data and the previous 2006 flood study, and update the modelling and mapping in accordance with the latest techniques and requirements
- Prepare a Floodplain Risk Management Study to quantify the extent of the flood problem including an assessment of flood damages and emergency response. The results of the assessment were then used to help identify potential mitigation options and make recommendations on management measures and strategies for consideration and/or implementation
- Based on the outcomes from the Floodplain Risk Management Study, prepare a draft Floodplain Risk Management Plan that details how flood prone land within the study area should be managed.

3.2 Historical Events

The Currambene Creek catchment has experienced several storm events over the years with the five of the largest events occurring in February 1971, March 1975, October 1976, August 1990 and June 2013. Of these events the February 1971 event produced the highest level on record at a stream gauge that was established downstream of the Princes Highway in 1969.

In terms of relative magnitude, and based on frequency analysis for the estimated time of concentration for the overall catchment (WMA Water 2016), the 1971 rainfall event was estimated to be in the order of approximately 0.33 per cent AEP (300 year ARI) while events in 1974, 1975 and 1976 were in the range of four to 7.1 per cent AEP (19 to 25 year ARI). The more recent 2013 event was much smaller and estimated to have an approximate 30 per cent AEP (3.5 year ARI). However, the catchment did experience rainfall intensities approaching a 10 per cent AEP (10 year ARI) for durations of up to 48 hours.

A relatively small event by comparison was experienced in July 2020. The storm resulted in local flooding within the site investigation area as depicted in the photographs presented as Figure 4, Figure 5 and Figure 6.

Figure 4 Looking north from Stock Feeds property

Figure 5 Looking north along the Old Princes Highway

Figure 6 Looking north west across Parma Creek tributary floodplain opposite Stock Feeds property

3.3 Survey Information

Terrain survey consisted of two sources: LiDAR from NSW Government's Land and Property Information (2010), and Transport for NSW ground survey derived specifically for this proposal (July 2020).

As the flood modelling tasks progressed it became evident that backwater flooding from the unnamed creek, immediately south and west of the intersection, could be a significant flooding characteristic that would potentially influence the design configuration for the proposal. This backwater flooding was evident during the July 2020 flood event outlined in Section 3.24.2.

To model this backwater flooding behaviour, a full catchment flood model was required that included the unnamed creek west of the site investigation area as well as Parma Creek and Currambene Creek downstream of the junction with the unnamed creek. This full catchment flood model required supplementary LiDAR data (ICSM, 2020) (shown in Figure 7) which consisted of one metre and two metre resolution Digital Elevation Models (DEMs).

LiDAR data, the stormwater catchment boundary and the site investigation area are shown in Figure 7.

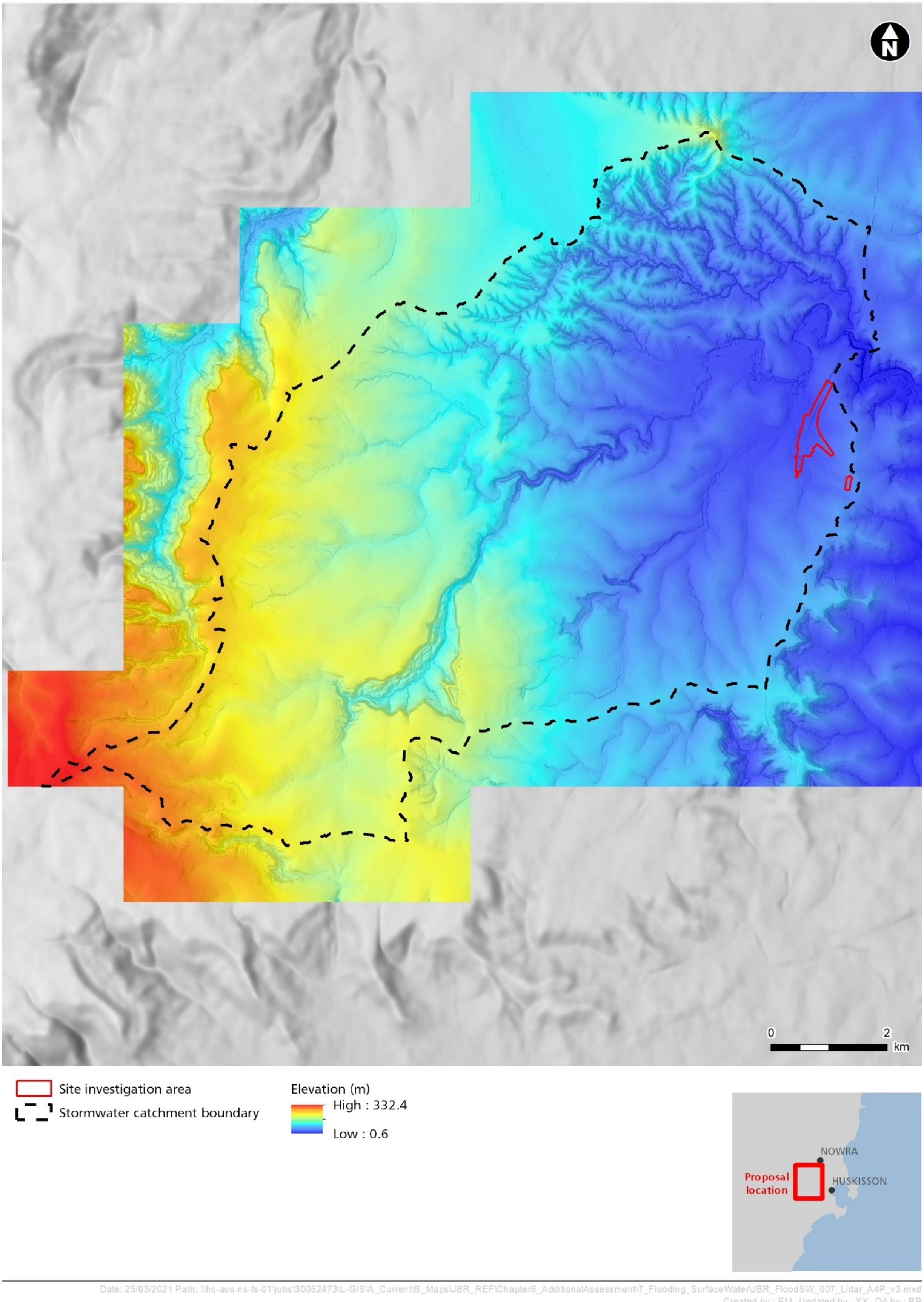

Figure 7 LiDAR used for the overall stormwater catchment flood model

4 ASSESSMENT METHODOLOGY

Desktop assessment and consideration of anecdotal reports on recent flooding indicated that further information was required to inform the flood assessment and to inform the design of the proposal. Backwater flooding of the unnamed creek west of the site investigation area has potential to significantly influence the proposal, and modelling was required.

A rain on grid TUFLOW model was created for hydrologic response of the full catchment, and the same model adapted for high resolution hydraulic modelling of the local catchment.

4.1 Flooding

The method of assessment for flooding included:

- A review of available data and existing flood studies within the catchments associated with the proposal
- Development of a full-catchment rainfall-runoff mode to generate design discharge hydrographs and backwater flooding levels for input to the hydraulic models. Flooding patterns in the vicinity of the proposal were defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software
- Running the flood models and preparing exhibits showing flood behaviour under present day conditions for design floods with a range of AEPs to the data and methods of Australian Rainfall and Runoff 2019 (with modifications as outlined in Appendix A), as well as the PMF
- Assessment of the impact the proposal would have on flood behaviour and flood hazards for the design flood events
- Assessment of the impact future climate change would have on flood behaviour under operational conditions
- Assessment of potential measures which are aimed at mitigating the risk of flooding to the proposal and its impact on existing flood behaviour and flood hazards.

4.1.1 Hydrologic Modelling

4.1.1.1 Hydrologic Modelling Approach

A full catchment hydrologic model was required to represent the generation of runoff volumes associated with modelling of backwater influences on the unnamed tributary creek west of the site investigation area. This creek has a network of tributaries connecting west of the Jervis Bay Road and Princes Highway intersection before joining with Parma Creek approximately 700 metres downstream, and then Currambene Creek a further two kilometres on as it passes under the Princes Highway. The Currambene Creek Flood Study (WMA Water, 2016) reports that Currambene Creek conveys about 720 cubic metres per second at the highway in the one per cent AEP event. The complexity of the creek junctions near the site investigation area are shown in Figure 8.

Due to the interaction of flood routing and flood storage potentially affecting the site investigation area, a flood model was constructed to model both the hydrology and hydraulics of all waterways influencing backwater within the site investigation area. A full catchment TUFLOW rainfall-on-grid model was created and nominally calibrated to the one per cent AEP flood frequency value outlined in the Currambene Creek Flood Study. An overview of the model extent is shown in Figure 9.

The established TUFLOW models used the latest software version available at the time of modelling (2020-01-AB) with the HPC solver (64 bit Single Precision). The hydrology model adopted a 20 metre grid cell size.

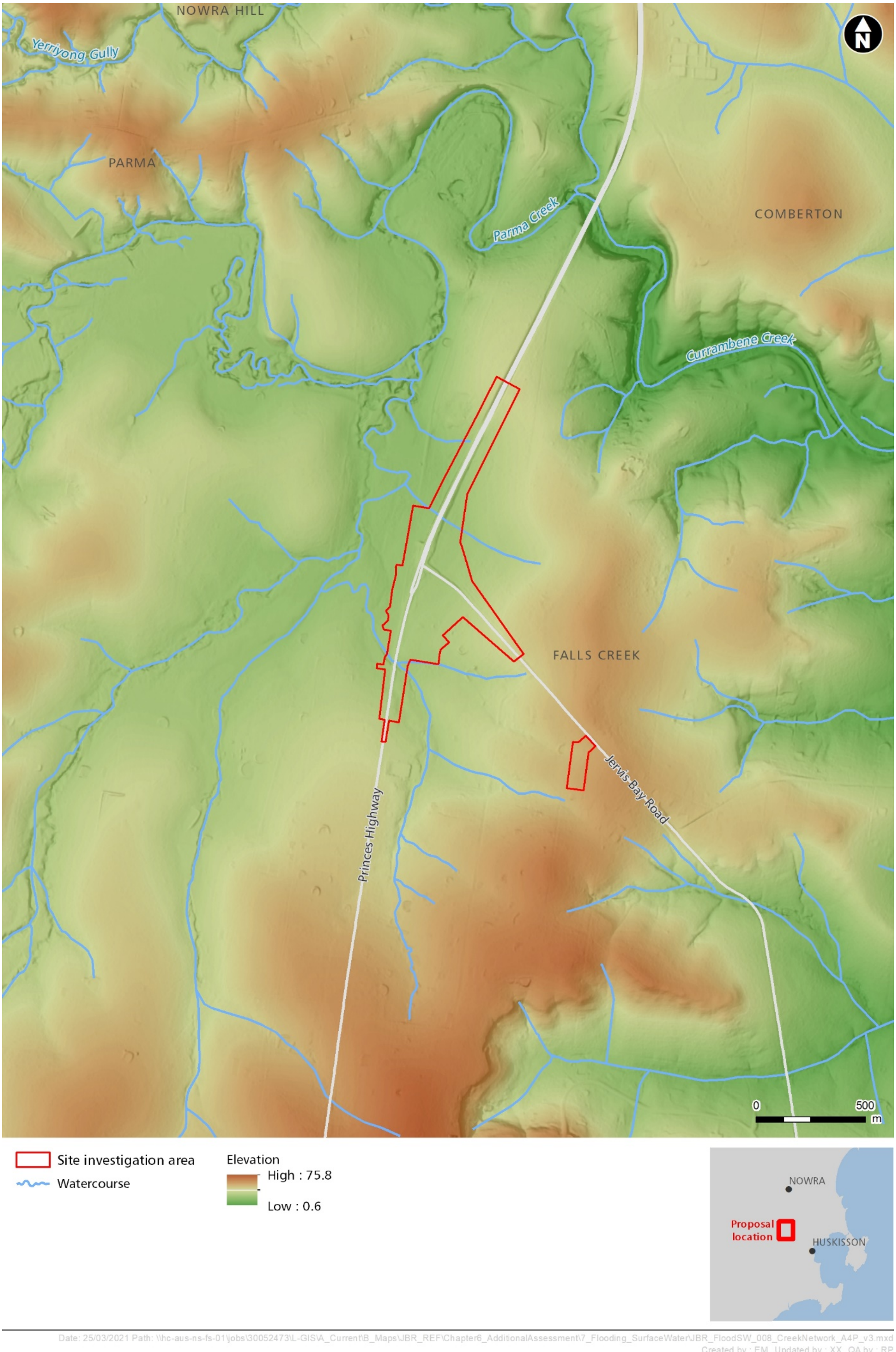

Figure 8 Creek network within and surrounding the site investigation area

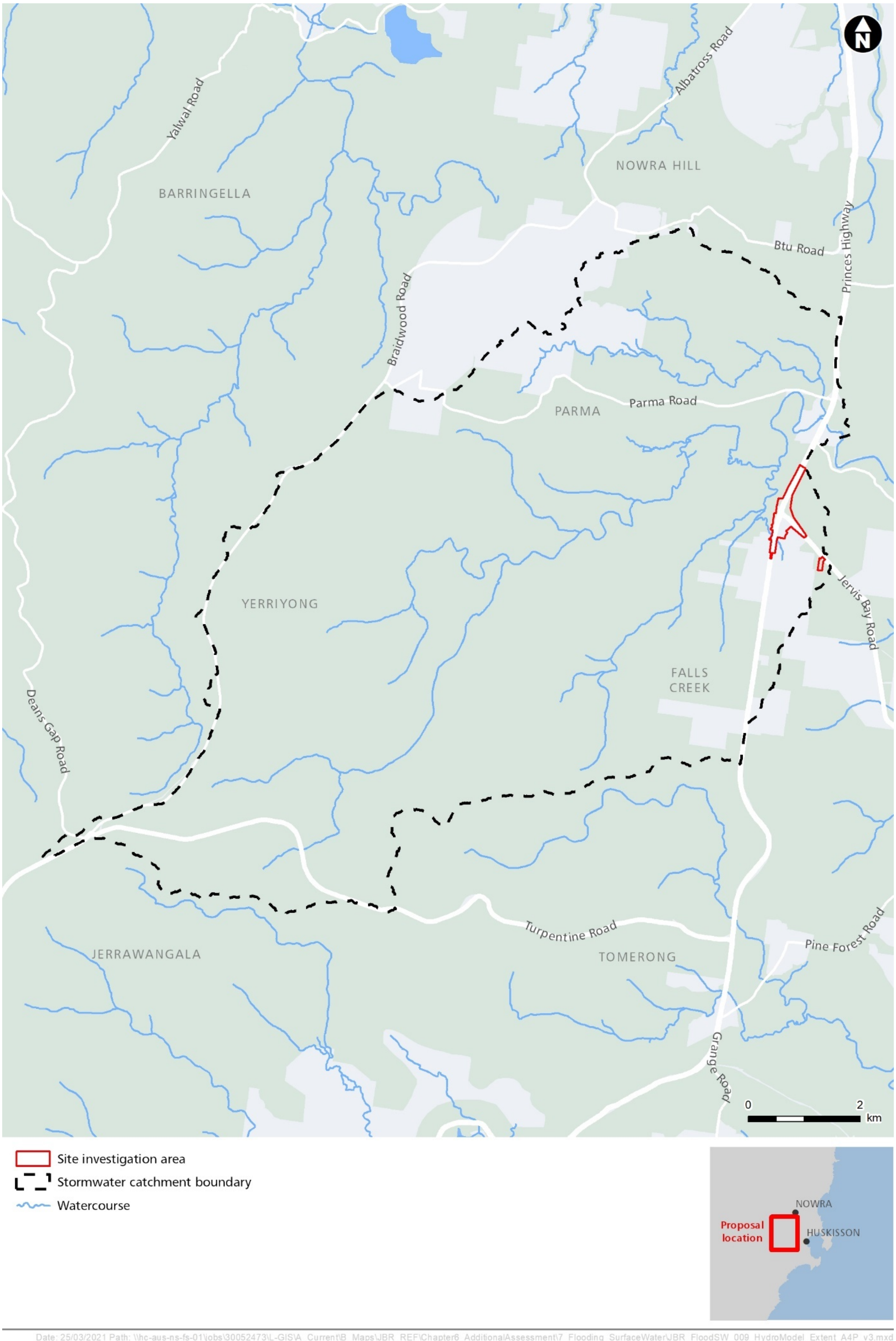

Figure 9 Extent of the full catchment hydrologic model

4.1.1.2 Design Rainfall Intensities and Temporal Patterns

The full-catchment model created to calculate flooding conditions downstream of the site was developed using ARR87 data and methods, then calibrated to the upstream flow value in the Currambene Creek Flood Study (WMA Water, 2016).

Design rainfall intensity values issued by the Bureau of Meteorology on a 2.5-kilometre grid for ARR87 methods were used to derive rainfall intensity contours for 20 rainfall event durations ranging from five minutes to three days. Each of the twenty storm durations had a unique spatial distribution of rainfall.

Design rainfall temporal patterns (ie the distribution of rainfall over time) were taken from the ARR87 guideline. The temporal patterns are unique for each storm duration but are categorised into two sets, with the one set applicable for storms more frequent than the 30 year ARI, the other set for rarer storms.

4.1.1.3 Validation with Previous Studies

The full catchment TUFLOW model was nominally calibrated to the Currambene Creek Flood Study (WMA Water, 2016) by using the shape and timing of the inflow hydrograph for that flood model and the flood frequency analysis estimated flow value of 720 cubic metres per second. A form of validation was made by firstly calibrating the TUFLOW model to the Currambene Creek Flood Study (WMA Water, 2016) then checking if the calibration storm was indeed the critical storm (ie the storm duration producing the highest flow).

Table 1 provides an overview of the various trials and the configuration chosen to progress with the modelling. For these calibration runs, the storm duration chosen was the same as that reported for the flood frequency analysis (ie the nine hour storm). A graph of the flow hydrograph for each trial is shown in Figure 10 compared to the inflow used for the Currambene Creek Flood Study (WMA Water, 2016). The hydrograph output location is at the flood gauge site on Currambene Creek just downstream of the Princes Highway.

Two main roughness categories were used in the hydrologic modelling of the catchment, with categories defined by woodland and pasture visible in the available aerial photography. Woodland was categorised as dense trees with fallen logs (Manning's n = 0.12), and pasture as pasture (n = 0.04). Roughness values were varied with depth as per Table 1. The high roughness values at shallow depths are necessary to represent the slow runoff behaviour for sheet flow areas where the flow depth is less than the roughness height. Areas of deeper flow have roughness values converging on typical values for the surface types. Roughness values are linearly interpolated for depths in between the two values shown in the table. Roughness values in TUFLOW are calculated based on the depths at every cell at every calculation timestep.

The parameters for Trial 7 were adopted for the hydrologic model. The hydrograph shape matched reasonably well with the Currambene Creek Flood Study (WMA Water, 2016) hydrograph (particularly the timing of the peak and tail) and the peak flow value of 733 cubic metres per second was slightly more conservative than the flood frequency analysis value of 720 cubic metres per second.

The Trial 7 parameters were carried forward to produce design flow results for twenty storm durations ranging from five minutes to three days.

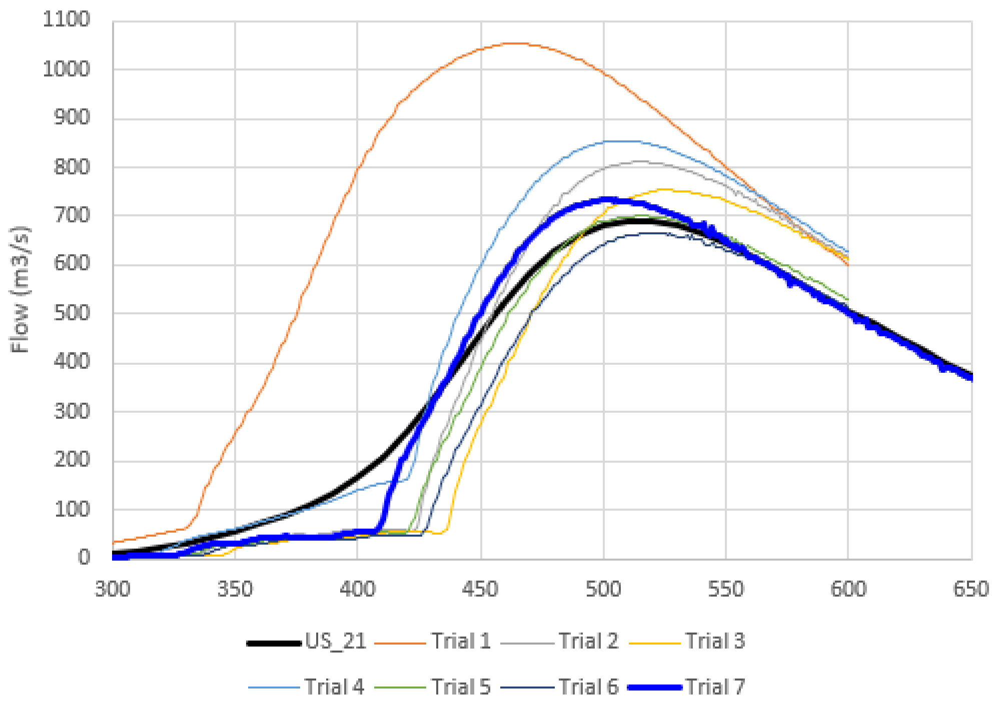

Figure 10 Comparison of TUFLOW hydrograph trials with Currambene Creek Flood Study (WMA Water, 2016) inflow (black)

Table 1 – Hydrologic model calibration trials (one per cent AEP nine hour ARR87 design storm)

Simulation	Initial / Continuing Rainfall Loss (millimetres)	TUFLOW Cell Size (metres)	Material 1 Roughness with Depth	Material 2 Roughness with Depth	Peak Flow (cubic metres per second)
CCFS Inflow ('US_21')	-	-	-	-	720
Trial 1	10 / 2.5	20	All depths, n = 0.12	-	1054
Trial 2	60 / 2.5	20	d <= 50mm, n = 0.5 d > 100mm, n = 0.12	-	811
Trial 3	60 / 2.5	10	d <= 50mm, n = 1.0 d > 100mm, n = 0.12	-	755
Trial 4	60 / 2.5	20	d <= 50mm, n = 1.0 d > 100mm, n = 0.12	-	855
Trial 5	2.5 / 10	20	d <= 50mm, n = 1.0 d > 100mm, n = 0.12	-	701
Trial 6	2.5 / 11	20	d <= 50mm, n = 1.0 d > 100mm, n = 0.12	-	665
Trial 7	2.5 / 10	20	d <= 50mm, n = 1.0 d > 100mm, n = 0.12	d <= 50mm, n = 1.00 d > 100mm, n = 0.04	733

4.1.1.4 Design Flow Results

Estimated peak flow values for Currambene Creek at the Princes Highway are shown in Table 2. Flood Frequency Analysis results from the Currambene Creek Flood Study (WMA Water, 2016) are also indicated next to their respective durations in parentheses. The Currambene Creek Flood Study (WMA Water, 2016) adopted the nine-hour storm as the critical duration for all ARI's (except the PMF which was four hours).

The results in Table 2 indicate that the nine hour storm was critical for the one per cent AEP and similar for the five per cent AEP. The critical duration for the ten per cent AEP was slightly longer at 12 hours. This set of results provides a measure of confidence that the model is representing the runoff routing behaviour expected for the Currambene Creek catchment.

The results also reflect the adoption of a relatively high continuing rainfall loss value of 10 millimetres per hour, with the shorter duration storms in low AEP storms producing little runoff.

The full catchment TUFLOW model was used for generating hydrographs for the tributaries downstream of the site investigation area to assess the backwater influence only. Runoff across the site investigation area was generated within the higher resolution hydraulic model which used ARR2019 data and methods. The short duration peak flows from the full catchment model are not a sensitive consideration for the proposal because there would be less likelihood of backwater influencing the site in these short events. It is most likely that several hours of rainfall are required to generate enough flooding in the downstream creeks for backwater to occur near the site investigation area.

For example, a storm duration of one hour would not be expected to generate enough backwater flooding to affect the site unless the rainfall intensity was very large, which would be a very rare rainfall event, much rarer than a one per cent AEP. The Currambene Creek Flood Study (WMA Water, 2016) stated that the PMF (ie the largest probable flood) had a four hour critical duration.

The full-catchment model and the hydraulic model are therefore independent in their hydraulic behaviour for the relatively short duration storms that are critical for design and flood impact mapping. The backwater flooding which reaches the site is associated with much longer duration storms where local flows through the Jervis Bay Road stormwater structures would be significantly less than their peak flows from shorter duration events.

The hydraulic model was arranged to accept the downstream flood data from the full-catchment model so that a combined local and backwater flooding envelope could be mapped. However, the interaction of backwater flooding and peak local flooding is unlikely to occur due to the storm duration differences between the local catchment and the full Currambene Creek catchment.

Table 2 –Peak flow values for Currambene Creek at the Princes Highway

Storm Duration			Annual Exceedance Probability (AEP)		
Minutes	**Hours**	**Days**	**1%**	**5%**	**10%**
5			0.03	0.01	0.01
10			0.10	0.05	0.03
15			0.21	0.10	0.06
20			26.1	0.2	0.1
25			47.5	0.2	0.1
30	0.5		66.5	0.3	0.2
45	0.75		122	0.4	0.3
60	1		174	47.6	0.3
90	1.5		258	108	29.0
120	2		326	142	60.4

Storm Duration			Annual Exceedance Probability (AEP)		
180	3		431	196	107
270	4.5		515	239	141
360	6		575	270	162
540	9		**733** (720)	**321** (370)	183 (250)
720	12	0.5	686	**322**	**201**
1080	18	0.75	621	304	183
1440	24	1	587	258	140
2160	36	1.5	705	354	218
2880	48	2	696	375	224
4320	72	3	320	153	77.6

4.1.1.5 Climate Change

The effects of climate change on this proposal relate to the potential for increases in rainfall intensity only. Sea level rise values typically adopted for coastal studies would not affect this site as the ground elevations are above 20 metres Australian Height Datum (AHD).

The Transport for NSW Technical Guide *Climate Change Adaptation for the Road Network* (Roads and Maritime Services [no date]) was used to test the proposal for one climate change scenario. Table 3 of that document suggests using a 0.5 per cent or 0.2 per cent AEP to predict what a one per cent AEP flood may be escalated towards under a changed climate. For this study, the 0.2 per cent AEP was modelled to test the upper bound of the suggested range.

4.1.2 Hydraulic modelling

4.1.2.1 Hydraulic Modelling Approach

The hydraulic model was established to provide relevant information on flood behaviour for runoff interacting with the design elements. This included flood levels, velocities, and changes in flood levels between pre- and post-construction conditions. The flood model also serves as a design tool to optimise transverse drainage infrastructure such as culverts.

The TUFLOW model established for the full catchment analysis was adapted to suit this purpose. The modelling domain was reduced to incorporate the complete local catchments associated with the proposal. Flow hydrographs from the full catchment TUFLOW model were used as inflows to the tributary creeks adjoining the site investigation area and for Parma Creek. Rainfall was also directly applied within the model extent, and data and methods of ARR2019 were used with the modifications described in Appendix A (Section 11.6).

Figure 11 shows the hydraulic model extent.

4.1.2.2 TUFLOW Version and Cell Size

The hydraulic model used the latest software version available at time of modelling (2020-10-AA) with the HPC solver (64 bit Single Precision). The local hydraulic model used a five metre cell size. TUFLOW's Sub-Grid-Sampling feature was invoked to increase the resolution to one metre (the resolution of the LiDAR terrain grids).

4.1.2.3 Roughness Values

The base roughness values adopted in the hydrology model were supplemented with local roughness polygons for major roads.

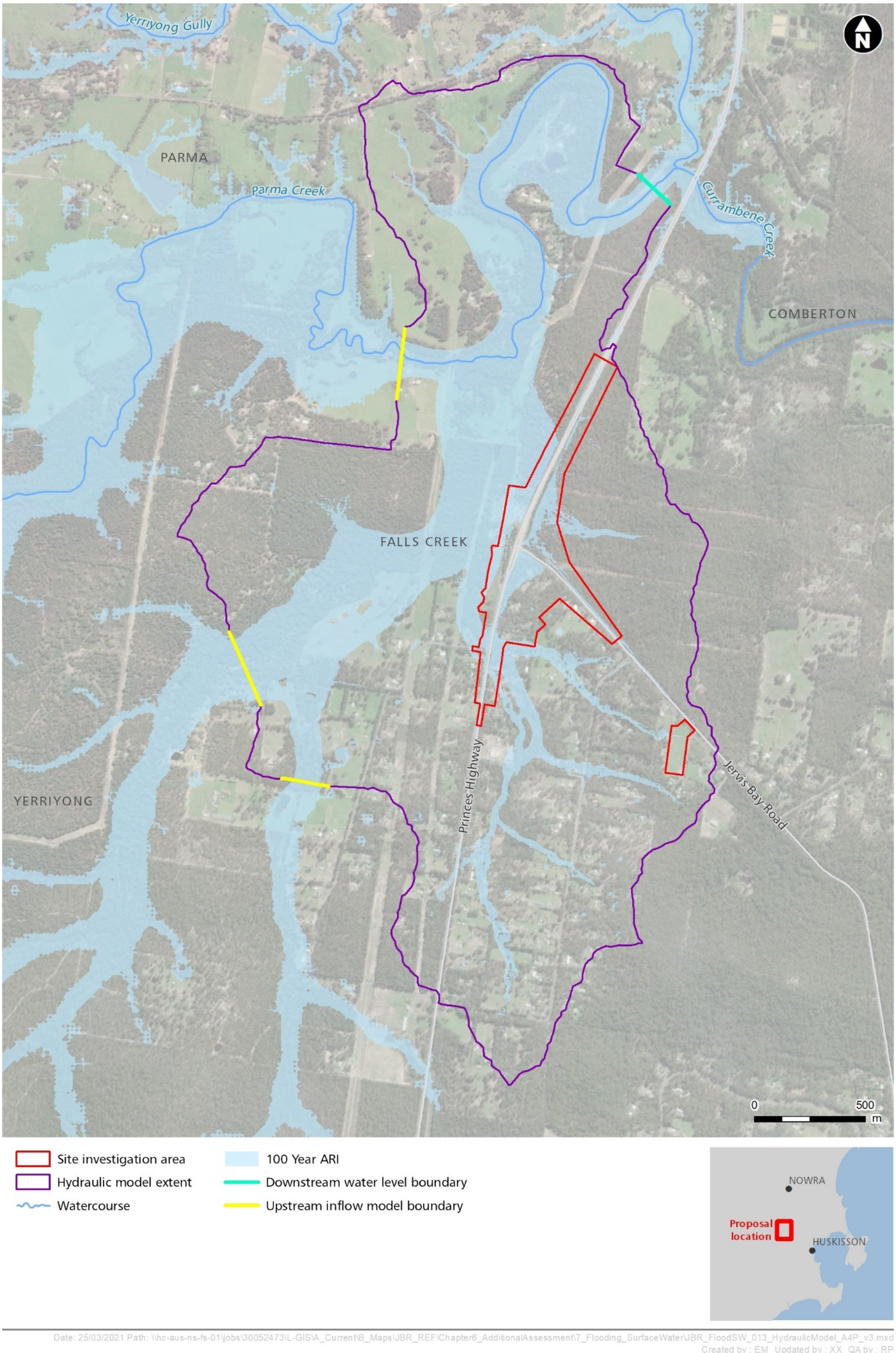

Figure 11 Hydraulic model extent

4.1.2.4 Hydraulic Structures

All transverse drainage structures of the proposal are culverts. These were modelled as 1D elements connected with TUFLOW 'SX' connections that linked TUFLOW's 1D and 2D domains. Culvert data was taken from ground survey. The location of the culverts is shown in Figure 12.

4.1.2.5 Terrain Modifiers

To supplement the survey DEM, survey break lines along crests and gullies were incorporated into the TUFLOW model to ensure that hydraulically significant features were enforced within the terrain definition irrespective of the TUFLOW cell size and orientation. The survey DEM is shown in Figure 13. Note that both Jervis Bay Road and the Princes Highway have crest lines. This ensures that any overtopping of these roads that may be visible in the results has ground survey levels underpinning the results.

4.1.2.6 Rainfall Losses

Rainfall losses for the ARR2019 method were taken from the NSW-specific webpage of the ARR data Hub. The Currambene Creek catchment has a flow gauge just downstream of the Princes Highway. On the NSW-specific map link this gauge is called 'Falls Ck' and is classed as a 'poor quality gauge' as opposed to the other option ('good quality gauge').

Initial Storm Loss values were taken from the Data Hub's 'Probability Neutral Burst Initial Losses' published on the Data Hub. These Initial Losses vary for both AEP and duration.

The Continuing Storm Loss value was taken to be constant for all storms based on the Flood Frequency Reconciled Losses for the 'Falls Ck' gauge.

Figure 12 Existing culvert structures

Figure 13 Terrain modifiers (existing conditions)

4.1.3 Proposed conditions flood modelling

4.1.3.1 Proposed Terrain and Culverts

The flood model representing the proposed conditions was built with the base terrain from existing conditions, with overrides of design surface DEMs for the proposed earthworks layout.

The southbound access road and adjacent (eastern) table drain have been designed for one per cent AEP flood immunity as part of the drainage design package. The table drain is graded towards the box culverts near the southern end of the works rather than beneath the access road and through the works. This design guides the stormwater through open drains along the perimeter of the works and avoids the use of small culverts beneath the access road which are susceptible to blockage and would require a minimum level of earth cover, raising the access road for little benefit.

To achieve a positive gradient along its length, the access road table drain is required to be against-the-grade of the natural surface for about 100 metres so that local runoff is directed freely to the box culverts. The flood model incorporated a levee and gully line along the eastern side of this access road to simulate the result of this design. Figure 14 shows the location of culverts for the proposal.

The proposed culvert works mainly consist of extensions to the existing culverts at the same grade. A new twin 1.05 metre diameter culvert was modelled at the eastern roundabout, and a box culvert upgrade incorporating one additional cell was modelled at the southern watercourse.

4.1.3.2 Proposed Rainfall Application

The rainfall-on-grid approach leads to every part of the model appearing flooded. An important aspect of the flood modelling was to understand if any runoff from the catchment overtopped any proposed road surface, triggering a potential non-compliance with the flood immunity criterion.

This issue was addressed in the proposed conditions modelling by excluding rainfall over the works area via a TUFLOW material type which absorbed all rainfall with an artificially large Initial Loss, and by adding the lost rainfall at the perimeter of the works rather than directly onto the proposed road surfaces. The result of this process is that any flooding appearing within the results on the proposed road surface has originated from an external catchment, which highlights areas of concern for the road design.

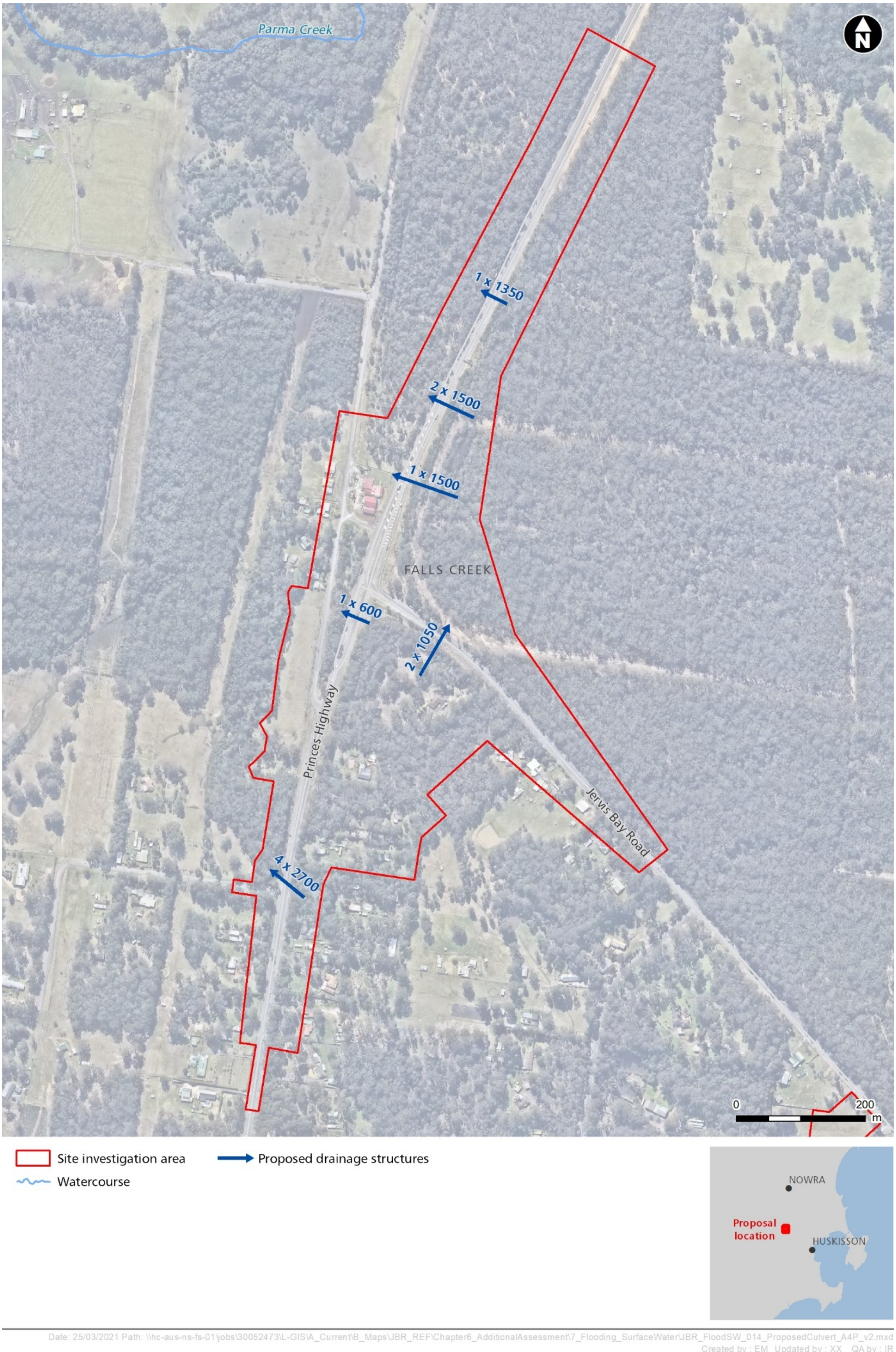

Figure 14 Overview of proposed drainage features for the design proposal

4.2 Surface water quality

The method of assessment for surface water included:

- A desktop review and analysis of existing information to determine potential receptors, characterising the existing environment and identify potential issues.
- Assessment of potential construction and operational impacts related to hydrology, geomorphology, water quality and water quantity, including:
  - Qualitative assessment of how construction may impact the receiving environment and the effects of physical disturbance to waterways during construction.
  - Obtaining climatic data for inclusion in modelling.
  - Modelling of the proposed conditions using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC).
- Development of a treatment train to meet the water quality objectives as per the Transport for NSW *Water sensitive urban design guideline* (Roads and Maritime Services, 2017) (Table 3).

Table 3 Water quality objectives as per Transport for NSW Water sensitive urban design guideline (Roads and Maritime Services, 2017)

Objective	Parameter
Suspended solids	85 per cent retention of the average annual load
Total phosphorus	65 per cent retention of the average annual load
Total nitrogen	45 per cent retention of the average annual load
Flow management	Maintain the 1.5year ARI (average recurrence interval) peak discharge to pre-development magnitude

5 EXISTING ENVIRONMENT

5.1 Catchment and Waterways

The Jervis Bay Road and the Princes Highway intersection is situated within the overall catchment of Currambene Creek. Currambene Creek is one of a series of short streams which drain the coastal strip of the South Coast of NSW. It rises in the plateau area occupied by the Royal Australian Navy Air Station, HMAS Albatross, at an elevation of 100 metres and falls through 90 metres along a stream length of seven kilometres to the Princes Highway crossing. Another major tributary sub-catchment, known as Parma Creek, joins Currambene Creek just upstream of the highway. Currambene Creek and Parma Creek are shown in Figure 8.

A series of small waterfalls are situated near the Princes Highway on Currambene Creek. Immediately upstream of the Princes Highway, the stream bed drops up to eight metres at a location known as The Falls. There is also a smaller waterfall located approximately 300 metres downstream of the highway and this marks the tidal barrier on Currambene Creek. The stream is tidal from this point to its outlet at Jervis Bay at Huskisson where the total contributing catchment area to the outlet is 160 square kilometres.

The Parma Creek tributary sub-catchment rises to the southwest at an elevation of 300 metres and has a stream length of 20 kilometres before joining Currambene Creek just upstream of the Princes Highway. The combined catchment area at the Princes Highway is 95 square kilometres, of which Parma Creek is the major arm and contributes 75 square kilometres.

The local catchment areas contributing to the site investigation area are primarily drained by two relatively small ephemeral watercourses (Figure 15). These watercourses are conveyed under the existing Princes Highway via transverse culverts before discharging to the floodplain associated with a larger tributary watercourse of Parma Creek. Within the worksite investigation area, there are three smaller transverse culverts that also provide drainage relief for local sub-catchment depressions

5.2 Existing Design Flood Levels and Extent

Flood mapping of existing flood levels and depths for the 10 per cent, five per cent, and one per cent AEP flood events are included in Appendix B. The flood extents shown in the mapping have been defined as follows:

- Areas where flood depth is greater than or equal to 0.15 metres, OR
- Areas where the Velocity x Depth product is greater than or equal to 0.05 square metres per second.

This combination eliminates areas of ponding where the water is not actively flowing but includes areas of shallow inundation that is flowing with less depth than the nominated threshold.

There are several features to note in the Existing Conditions flood maps in Appendix B regarding the flood behaviour. There is a large area of backwater from Parma Creek and its tributaries adjoining the western side of the highway embankment in the larger flood events. Even the 10 per cent AEP event has a significant backwater area, but it does not reach the highway embankment. The backwater flood surface is flat, denoted by the lack of flood level contours within it.

There is also a large area of ponding adjoining the southern side of the Jervis Bay Road and the Princes Highway intersection. This ponding originated from the main waterway south of the intersection where a surcharging box culvert passes under the Princes Highway. The results indicate this culvert is undersized for the estimated flows and consequently floodwater ponds at shallow depth into the southbound lane of the Princes Highway, as well as flowing north towards the Jervis Bay Road intersection. The ponding at the intersection is high enough to spill into the westbound lane of Jervis Bay Road in the one per cent AEP flood where the maximum depth adjacent to the road is about 1.5 metres.

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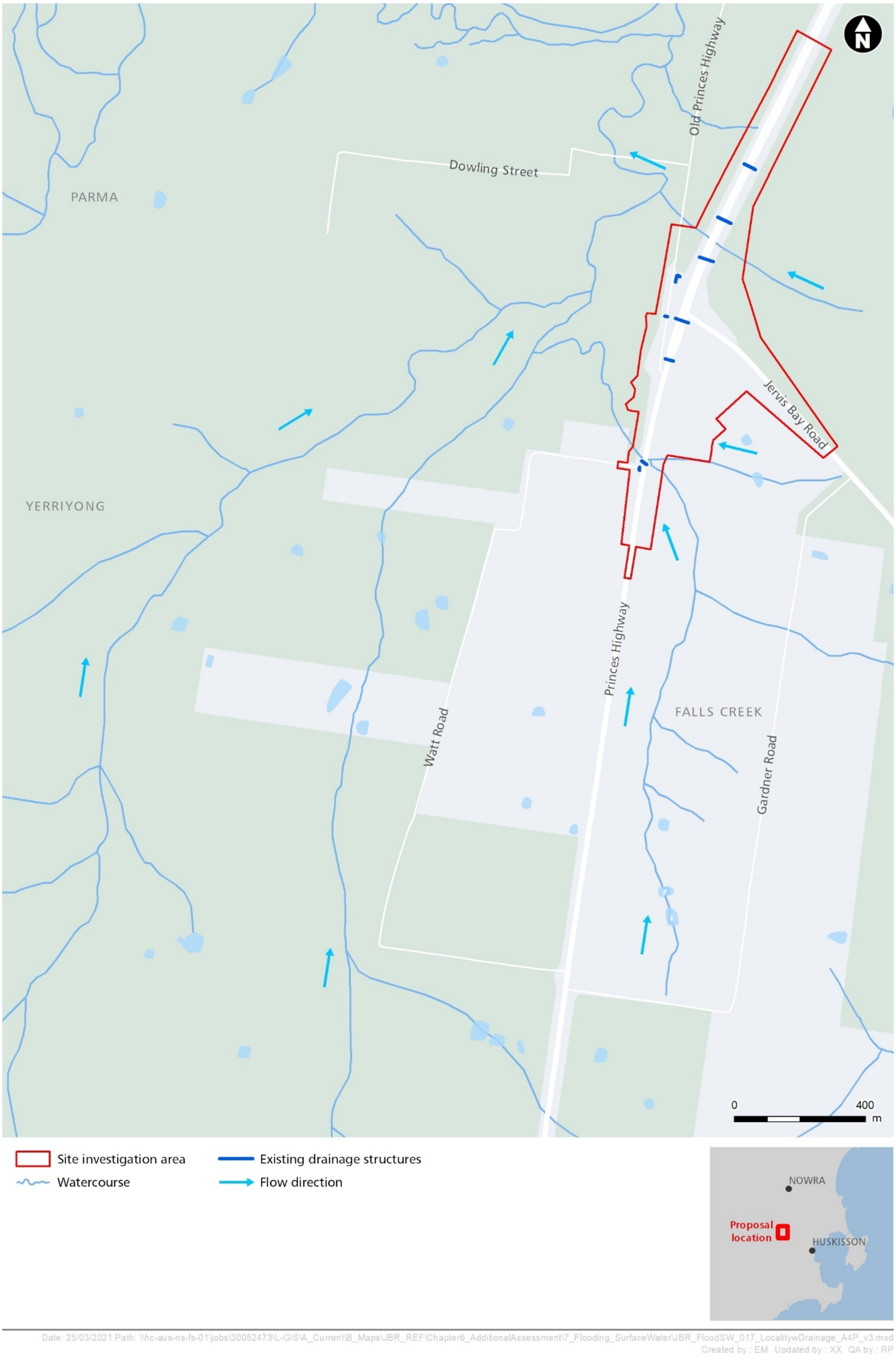

Figure 15 Locality plan with drainage features

5.3 Existing Velocities

Flood mapping of existing velocities for the 10 per cent, five per cent, and one per cent AEP flood events are included in Appendix B.

The Existing Conditions velocity maps in Appendix B show areas of faster moving floodwater compared to areas mainly subjected to ponding. In the one per cent AEP, a small amount of floodwater can be seen overtopping the Princes Highway just north of the triple box culverts.

The ponded area at the Jervis Bay Road intersection can be seen to be of low velocity.

5.4 Existing Surface Water Quality

5.4.1 Existing water quality infrastructure

Site investigation and aerial imagery indicates that there is no existing water quality monitoring or infrastructure within the site investigation area.

5.4.2 Sensitivity of Receiving Environments

The site investigation area does not cross any major creeks, rivers or streams. Most of the existing aquatic habitats within the site investigation area are minor and/or ephemeral (eg drainage lines and small, constructed farm dams) however three unnamed tributaries of Parma Creek lie within the site investigation area.

The unnamed tributaries within the site investigation area are considered streams/ ephemeral streams. No important substrates, habitat features, or vegetation was recorded within any of the tributaries during site investigations undertaken by Arcadis ecologists in August and October 2020. Water quality, based on visual observation, appeared poor (ie signs of pollutants, excess sediments and nutrients) and contained a high density of weeds. In addition, these waterways are adjacent to the Princes Highway and are subject to edge effects and regular disturbance (ie vegetation trimming for powerlines, road works).

No threatened aquatic species were recorded within the site investigation area, and none are expected to occur. While Parma Creek is mapped as key fish habitat for the Shoalhaven area (Department of Primary Industries, n.d.), the three unnamed tributaries located within the site investigation area do not meet the definition of key fish habitat in accordance with the *Policy and guidelines for fish habitat conservation and management* (Department of Primary Industries, 2013) as they are all classified as first order streams. Similarly, any drainage lines and/or dams within the site investigation area are not considered key fish habitat.

6 ASSESSMENT OF CONSTRUCTION IMPACTS

6.1 Key construction activities

Key construction activities would include:

- Pre-construction and early works
  - Demarcation of construction footprint with construction fencing and temporary safety barriers where required
  - Installation of erosion and sediment controls
  - Set up of temporary traffic management arrangements
- Site establishment
  - Site survey, geotechnical and other investigations
  - Pre-clearing biodiversity surveys
  - Vegetation clearing and grubbing
  - Mobilisation and establishment of ancillary facilities
- Intersection construction
  - Utilities relocation/protection including overhead power lines
  - Construct temporary Jervis Bay Road alignment
  - Construct access road for south eastern properties
  - Construct Old Princes Highway connection
  - Construct eastern and western ramps and associated fill embankment
  - Construct bridge, bridge abutments and retaining walls
  - Construct roundabouts and connecting roads
  - Tie-in works
  - Construction of new drainage structures and extension or replacements of existing drainage structures
  - Construction of pavement layers including selected material, sub-surface drainage, subbase and base layers and surfacing
  - Construction of vegetated swales, bioretention swales and bioretention basins
  - Installation of lighting, safety barriers, traffic signs and bus shelters
  - Line marking and raised pavement markers
  - Fencing
  - Property accesses adjustments
- Finishing work
  - Rehabilitation of disturbed areas and landscaping in accordance with the urban design and landscape plan
  - Installation of safety barriers, street lighting, fencing and roadside furniture
  - Decommission and rehabilitation of ancillary facilities.

Subject to the proposal obtaining planning approval, construction is anticipated to commence in 2022 and is expected to take around two years to complete.

6.2 Construction footprint and ancillary facilities

The area required for construction of the proposal is presented in Figure 16.

Temporary ancillary facilities, such as site compounds and stockpile areas, would be required to enable construction of the proposal. These facilities would be located within the proposal construction footprint outside the five per cent AEP flood extent where possible and practical. To provide the construction contractor with the necessary flexibility in the location of such facilities, several ancillary facilities have been identified as summarised in Table 4 and shown in Figure 16.

Table 4 Construction facilities

Facility	Location (refer to Figure 16)	Approximate size (hectares)	Purpose
Ancillary Facility 1	• 24 Jervis Bay Rd, Lot 7 DP1093336 • 921 Princes Highway, Lot 59 DP15507	1.0	• Offices • Amenities • Workshops • Stockpile and laydown areas • Car park • Storage areas.
Ancillary Facility 2	• 24 Willowgreen Rd, Lot 1 DP871596	1.5	• Stockpile and laydown area • Car park.
Ancillary Facility 3	• 132 Jervis Bay Rd, Lot 4 DP773881	1.9	• Stockpile and laydown area.

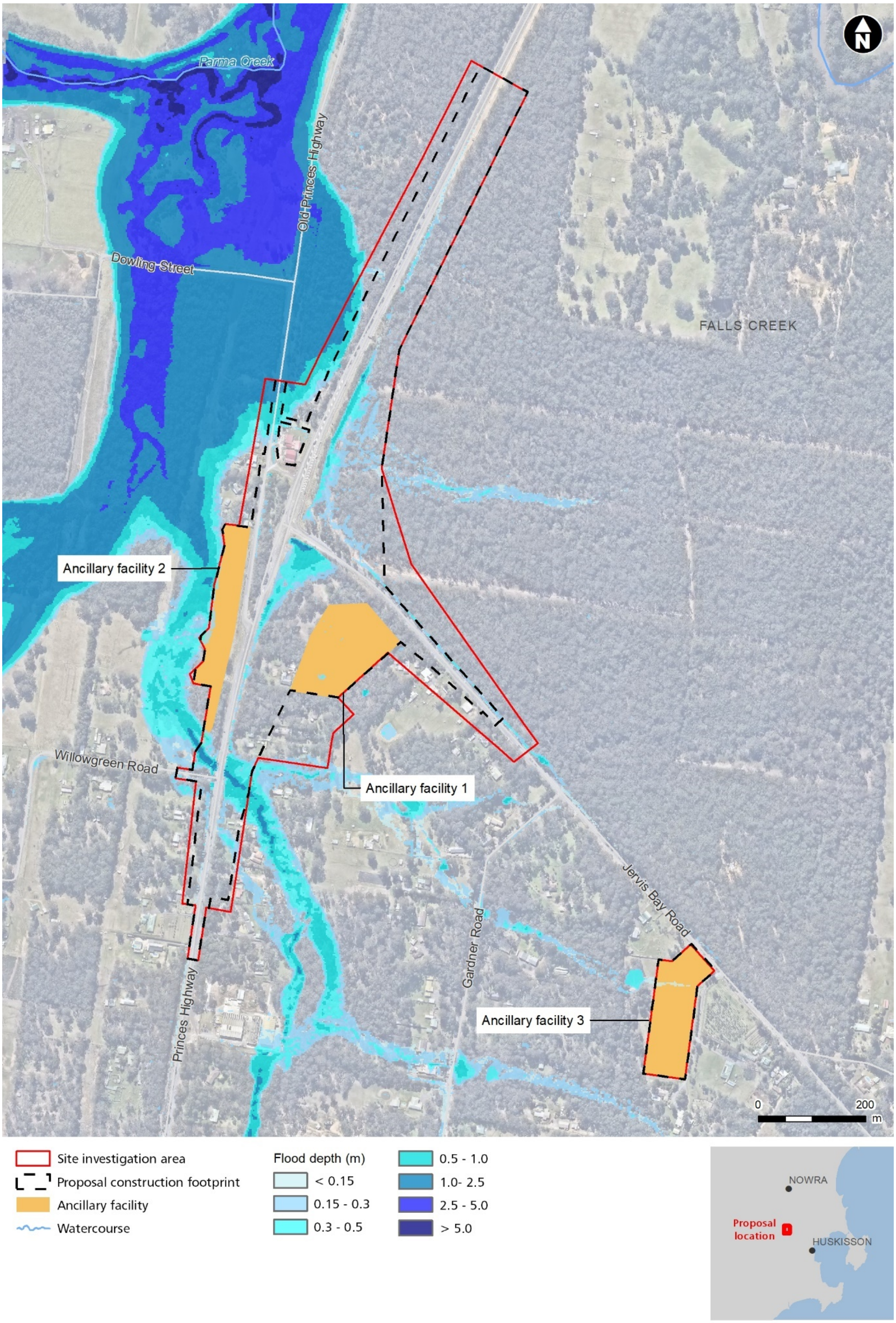

Figure 16 Proposal construction footprint and facilities with five per cent AEP flood extent

6.3 Construction Related Impacts

6.3.1 Flooding

Several construction activities have the potential to impact flooding for the proposal. The inclusion of any temporary fill within the floodplain (eg embankment earthworks, preloading, stockpiles etc.) would reduce floodplain storage, which can result in increased flood levels. Temporary crossings of the watercourses may be required during the construction and would have the potential to impact on flooding. Construction impacts on flood behaviour have not been modelled as part of this assessment of proposed operational conditions. It is generally considered that the proposal construction footprint does not differ significantly from the final operational footprint.

Additional earthworks for temporary traffic diversions or preloading within soft soil areas for bridge abutments may result in extents and levels of fill within the floodplain that are temporarily greater than the final operational requirements. Should this difference in fill extent be much greater, this could result in localised changes in flood behaviour with increased flood impacts during construction. Construction of proposed culverts or culvert extensions, including preloading at these locations, could also temporarily result in the obstruction of flow paths and risk of increased localised short term flood impacts.

The proposed location of stockpiles indicated on Figure 16 are all generally outside the five per cent AEP flood extent but may slightly encroach around the fringes in some localised areas (eg small section within Ancillary Facility 2). However, if stockpiles were to be located within the floodplain, the obstruction of flow paths and loss of floodplain storage has the potential to cause flood impacts. In the event of inundation of an ancillary facility, there is potential for:

- Erosion of exposed soils or stockpiles, and subsequent sedimentation of watercourses
- Inundation of temporary sediment basins, resulting in sedimentation
- Mobilisation of contaminants from any chemical storage areas, re-fuelling stations, generators, plant or machinery that may be subject to inundation
- Transport of litter and other loose materials stored on site into watercourses
- Mobilisation of plant or machinery by floodwater, with associated negative impacts on the environment
- Moving debris to become a substantial hazard during a flood, and downstream deposition could contribute to obstruction or blockage of watercourses and/or hydraulic structures.

Where watercourses are traversed by the proposal construction footprint, temporary construction pads or crossings may be required to facilitate construction activities particularly where larger waterway structures (i.e., box culverts or bridges) are proposed. If required, these pads or causeway crossings would comprise low level fills with temporary culverts to maintain the low flows while allowing larger flows to overtop during construction. These works may result in the following potential impacts:

- Disturbance of the watercourse bed and banks causing in erosion and sedimentation
- Partial obstruction of low flows resulting in minor modification of downstream flows
- Scour of the bed near the culvert inlets and outlets.

6.3.2 Impacts to Surface Water Quality

A summary of potential impacts to surface water quality as a result of the proposal construction is provided in Table 5. Identified surface water quality impacts would likely be managed via installation of temporary sedimentation basins (indicative location shown in Figure 17) as well as standard erosion and sediment control management and mitigation measures for all ancillary facilities and surface works areas.

Water extraction from surface water is not proposed during construction of the proposal.

Table 5 Summary of potential construction impacts on surface water quality

Activity	Potential impact
Vegetation clearing and grubbing	If unmanaged, the removal of vegetation has the potential to increase the risk of erosion and sedimentation within the surrounding waterways due to instability and mobilisation of soils and sediment. The majority of vegetation that would be removed would be located away from watercourses.
Utilities relocation	The relocation of utilities would involve soil disturbance as a result of trench excavation and/or under-boring. The disturbance of soil by machinery would increase the potential for soil erosion which has the potential to impact downstream water quality if not appropriately managed.
Demolition of structures	Demolition works have the potential to disturb and/or spread sources of pollutants that could affect water quality if not appropriately managed. Demolition can also generate dust and airborne pollutants. These pollutants once mobilised can be picked up by stormwater runoff and distributed downstream waterways via the drainage network.
Operation of ancillary facilities	Establishment and operation of ancillary facilities may result in erosion and mobilisation of exposed soils and open cuts by stormwater runoff and wind leading to sedimentation of waterways. The operation of ancillary facilities may include storage of chemicals, vehicle wash down areas, vehicle refuelling areas and other activities that have the potential to impact downstream water quality, if unmitigated, through spills of pollutants flowing to downstream watercourses. Further, the movement of construction vehicles may transfer soil and pollutants to adjacent roads, which may then be conveyed via stormwater runoff into waterways.
Stockpiling	Storage of earthwork materials, crushed rock, mulch and vegetation in stockpiles on construction support sites has the potential to impact water quality and impact the aquatic environment if not appropriately managed.
Earthworks	Exposure of soils during earthworks, including stripping of topsoil, excavation, removal of existing paved areas, stockpiling and transport of materials, if unmanaged, has the potential to result in soil erosion and off-site movement of eroded sediments by wind and/or stormwater into waterways. Once sediments enter waterways, they can directly and indirectly impact on the aquatic environment.

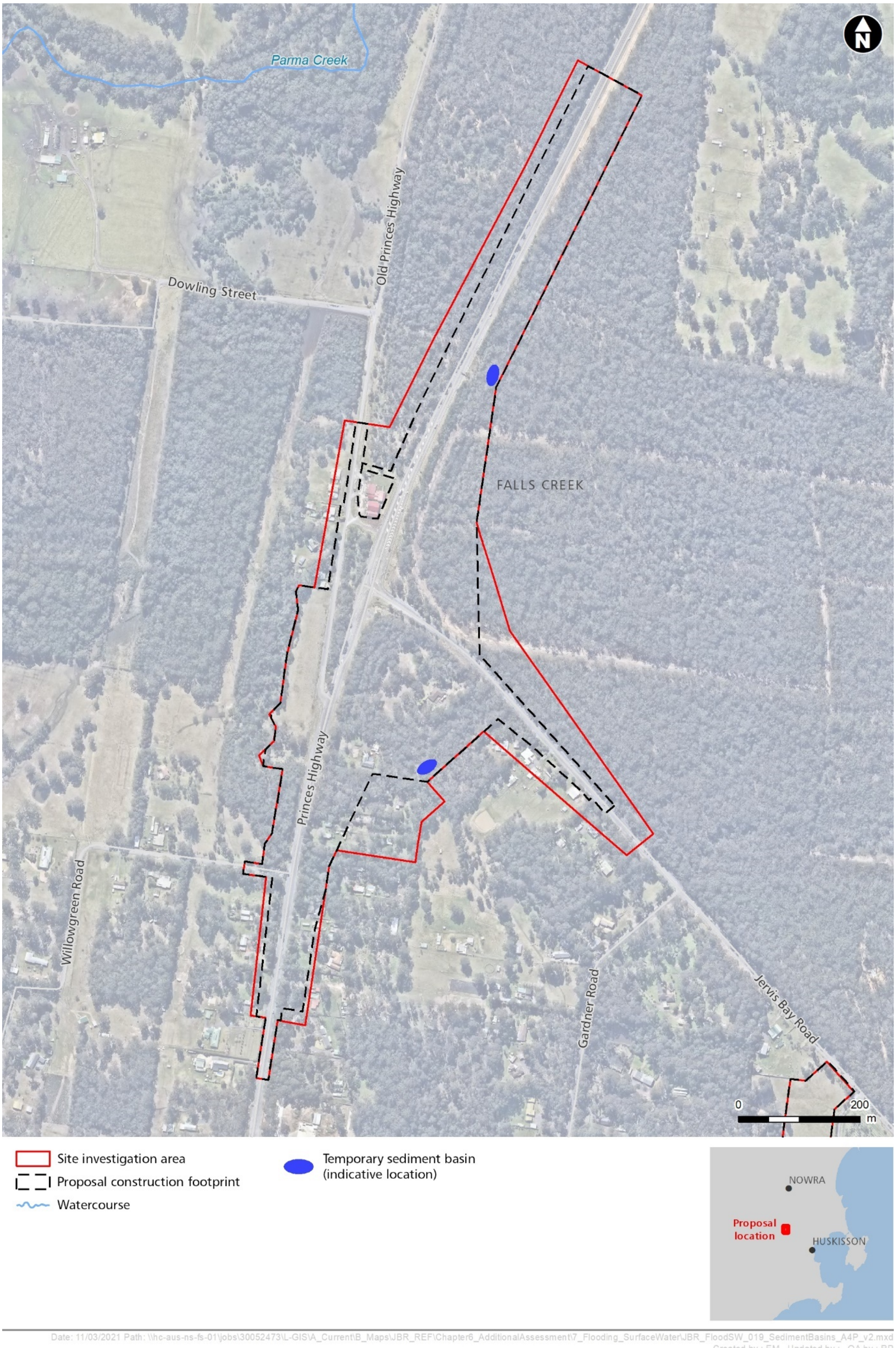

Figure 17 Indicative location of temporary sediment basins

7 ASSESSMENT OF OPERATIONAL IMPACTS

7.1 Flooding

7.1.1 Design Flood Levels and Extent

Flood mapping of flood levels and depths under proposed conditions for the 10 per cent, five per cent and one per cent AEP flood events are included in Appendix B. Flood maps of the Climate Change scenario (0.2 per cent AEP, refer to Section 4.1.1.55.1.1.5) and the PMF for Proposed Conditions are also included in Appendix A.

For the one per cent AEP flood event, the large area of backwater from Parma Creek and its tributaries has not changed in flood level or extent compared to the existing situation. However, the large area of ponding that was previously evident adjoining the southern side of the Jervis Bay Road and the Princes Highway intersection is no longer present as the local runoff has been directed towards the box culverts. The upgraded box culverts at the southern watercourse are shown to have adequate capacity to prevent overtopping of the Princes Highway and bypass flow towards the Jervis Bay Road intersection.

7.1.2 Velocities

Flood mapping of velocities under proposed conditions for the 10 per cent, five per cent, one per cent and 0.2 per cent AEP flood events and PMF are included in Appendix B.

The distribution of velocities under proposed conditions is indiscernible from existing conditions. Minor changes in the immediate vicinity of culverts dissipate within a short distance. Any required energy dissipation structures at culvert outlets to manage localised changes in velocities due to culvert upgrades would be investigated during detailed design.

7.1.3 Flood level impacts

Mapping of flood level changes (ie impacts) are included in Appendix B.

The one per cent AEP flood impact results have been presented such that an increase in flood depth is seen as a positive number, and a decrease is negative. The results are based on the maximum ARR2019 results (refer to Section 1).

The results indicate that the greatest areas of changes in flood level outside the proposal construction footprint are associated with the box culvert upgrade at the southern end of the proposal. There is a slight reduction in flood level upstream of the culvert, including at the residence referred to in Section 3.34.3 (Lot 62 DP15507) which has a 20 millimetre to 40 millimetre flood level reduction at the dwelling.

Downstream of the culvert upgrade has dissipating flood level increases within the watercourse ranging from about 20 millimetres to 60 millimetres. Areas affected are within the existing flood zone as the increase in flood extent is minimal due to the relatively steep creek banks. Affected properties include Lot 1 DP871596 and Lot 1 DP587300.

The stormwater flow through the culvert upgrade would be more aligned with the natural flow-paths than in existing conditions, where the undersized culvert diverts some excess runoff northwards towards Jervis Bay Road.

The proposed culvert extensions north of Jervis Bay Road are associated with some flood level increase, mainly within the proposal construction footprint. The main cause of this increase is that the Princes Highway southbound off-ramp to Jervis Bay Road is positioned east of the existing highway where natural surface levels are higher. The culvert extensions reduce the culvert capacity marginally, but not enough to warrant additional culvert capacity. The affected terrain is steep, so the increase in flood extent due to the flood level increase is less than 20 metres at its widest. The affected land is undeveloped.

At each end of the proposed works there are patches of flood level increase and decrease that are not particularly significant. These results are a product of the transition from existing road pavement to proposed pavement where roadside drainage would direct the runoff to controlled outlets.

7.1.4 Climate change considerations

Mapping of the Climate Change scenario (the 0.2 per cent AEP) under proposed conditions is required for state roads and is included in Appendix B.

Under the modelled Climate Change scenario, flood immunity would be maintained on the Princes Highway and Jervis Bay Road with implementation of the proposal.

7.2 Impacts to Surface Water Quality

During operation, stormwater runoff from the proposal has the potential to impact on the water quality of receiving watercourses. Typical pollutants associated with stormwater runoff from roads include heavy metals and hydrocarbons, as well as potential for atmospheric deposition of material on the road, which would contribute to stormwater pollution.

As a result of the proposed works, there would be an increase in the overall-pollutant loads if stormwater treatment measures are not provided. The potential permanent water quality treatment measures could include vegetated swales, bioretention swales and/or a bioretention basins as indicated in (Figure 18). The proposed location of these measures is based on the available space and the discharge location to the receiving environment.

MUSIC modelling (Table 6) indicates that the proposed treatment measures would exceed the pollution retention objectives outlined in Table 3. As such, the operational water quality treatment system would produce a future net benefit to water quality.

Further refinement and optimisation of proposed stormwater treatment measures would be carried out during detailed design, including confirmation of the practicality, constructability, maintainability and effectiveness of the proposed measures.

Table 6 MUSIC modelling results

Parameter	Target retention	Retention through proposed design	Comment
Suspended solids	85 per cent	91 per cent	Target exceeded
Total phosphorus	65 per cent	75 per cent	Target exceeded
Total nitrogen	45 per cent	55 per cent	Target exceeded

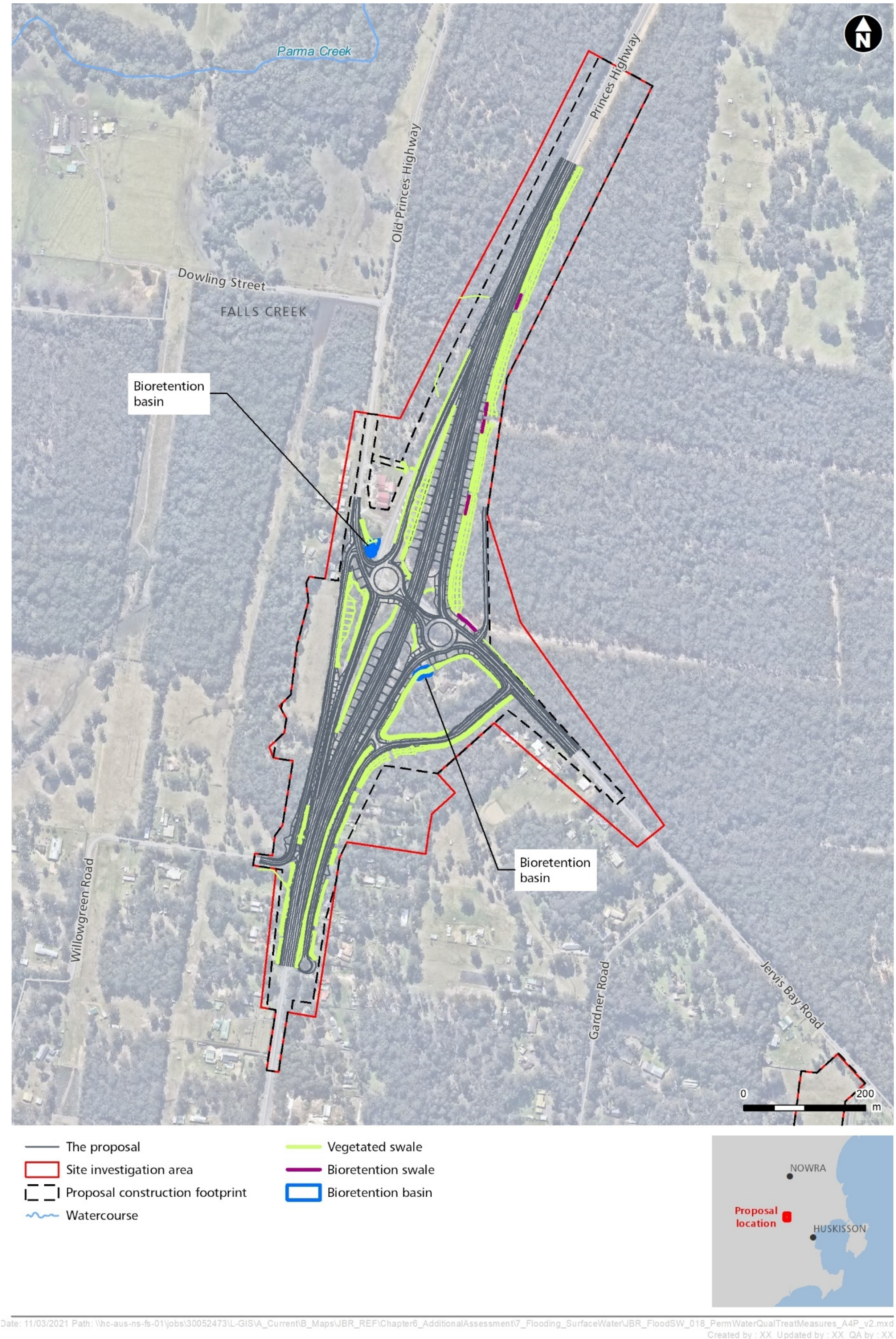

Figure 18 Indicative location of permanent water quality treatment measures

8 Environmental management measures

It is important to manage construction and operational activities in a way which mitigates the potential to impact flooding and water quality in the vicinity of the proposal and within the broader catchment. Environmental management measures to minimise potential flood and water quality impacts are described in Table 7.

Table 7 Environmental management measures

Impact	Environmental management measure	Responsibility	Timing
	A Soil and Water Management Plan (SWMP) will be prepared and implemented as part of the CEMP in accordance with Section 2.1 of QA *G38 Soil and Water Management*. The SWMP will identify all reasonably foreseeable risks relating to soil erosion and water pollution and describe how these risks will be addressed during construction. The SWMP will provide: • Measures to minimise/ manage erosion and sediment transport both within the proposal construction footprint and offsite, including requirements for the preparation of an Erosion and Sediment Control Plan (ESCP) in accordance with Section 2.1 of QA *G38 Soil and Water Management* • Arrangements for managing erosion and sediment transport during wet weather events, including monitoring of potential high risk events (such as storms) and specific controls and follow-up measures to be applied in the event of wet weather • Measures to manage stockpiles including locations, separation of waste types, sediment controls and stabilisation • Measures to manage groundwater de-watering and impacts including mitigation required • Processes for de-watering of water that has accumulated on site, including relevant discharge criteria • Emergency spill procedures, including spill management measures in accordance with the *Code of Practice for Water Management* (Road and Traffic Authority, 1999) and relevant EPA guidelines, and requirement to maintain materials such as spill kits on site • Details of surface water quality monitoring to be carried out before, throughout, and following construction, as required	Contractor	Pre-construction
Erosion and sediment control	A site specific Erosion and Sediment Control Plan will be prepared and implemented as part of the SWMP. The Plan will include arrangements for managing wet weather events, including monitoring of potential high risk events (such as storms) and specific controls and follow-up measures to be applied in the event of wet weather.	Contractor	Pre-construction

Impact	Environmental management measure	Responsibility	Timing
Flooding	A flood contingency plan will be prepared where stockpiles are proposed within areas with flood immunity of less than five per cent AEP. This plan should consider the likelihood of flooding, evacuation routes, warning times, and potential impacts of the ancillary facility flooding. The plan will: • Identify a designated “Site Flood Controller”. The Site Flood Controller will familiarise with the Local Flood Plans and advice from the SES to ensure the plan can be executed. • Include relevant emergency contact details including the SES • Include instruction on monitoring of the Bureau of Meteorology website and/or the nearby Currambene Creek water level gauge in relation to flooding, if required • Include procedures to be followed in preparation for, during and after a flood event for the proposal construction footprint. A copy of these procedures will be retained on site at all times • Include details of flood behaviour for the site, including extent and duration of inundation during events • Include information on flooding and training in what to do to prepare, during and after a flood event • Ensure that copies of the SES’s “Local Flood Plan” for Currambene Creek area are kept on site at all times.	Contractor	Pre-construction Construction
Flooding	Drainage construction works will avoid or minimise afflux on private dwellings.	Contractor	Construction
Flooding	Ancillary facility layout and stockpile locations would be planned to minimise any potential flood impacts.	Contractor	Pre-construction Construction

9 CONCLUSIONS

Flood modelling to assess the proposal has been conducted with the software package TUFLOW using Australian Rainfall and Runoff 20109 data and methods. A full catchment rainfall-on-grid TUFLOW model was created to quantify the backwater in Parma Creek affecting the site investigation area, and to provide hydrograph inflows into a more detailed TUFLOW hydraulic model used to assess the local runoff affecting the proposal.

The one per cent AEP flood modelling results for existing conditions indicate two locations of road inundation: one on the Princes Highway near the southern limit of the site investigation area, the other on the westbound lane of Jervis Bay Road at its intersection with the Princes Highway. Both inundations are caused by surcharging of the triple cell box culverts at the waterway near the southern limit of the site investigation area.

Flood modelling results for the proposed conditions, which includes an additional box culvert cell upgrade, indicate that the culvert upgrade would be effective in eliminating overtopping of the Princes Highway and preventing surcharge flows from heading northwards towards Jervis Bay Road. The culvert upgrade would also help protect dwellings on the eastern side of the highway of which at least one is susceptible to over-floor flooding in large flood events.

During construction there would be an impact on the water quality and receiving environment as a result of vegetation clearance, sedimentation and erosion, and stockpiling of soil material near waterways and overland flowpaths.

Vegetated swales, bioretention swales and bioretention basins have been proposed to mitigate operational water quality impacts. Proposed measures would exceed the pollution retention objectives and provide an overall future net benefit to water quality. Refinement and optimisation of water quality treatment measures would be carried out during detailed design.

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Appendix A AUSTRALIAN RAINFALL & RUNOFF 2019

Overview

This section provides a brief overview of Australian Rainfall and Runoff, the main guideline used in Australia for developing flood model output, including the output of this study. This provides context for the flood study results and design decisions for the Jervis Bay Road Intersection Upgrade proposal.

In simple terms, Australian Rainfall and Runoff is a guideline used by engineers to convert rainfall data into flood data, such as flow, depth, velocity, and flood extent. Rainfall data is provided by the Bureau of Meteorology, and the guideline provides additional data and methods for use with specialist flood modelling software to estimate flooding information for floods ranging from common to rare.

The guideline is periodically updated. The 2019 update is currently superseding the previous edition from 1987. The new version is commonly referred to as ARR2019.

The data and methods in ARR2019 are more comprehensive and complex than the 1987 version. There is about 30 years of additional rainfall data, most of it at higher resolution than the 1987 data, and the methods of processing the rainfall data have become more comprehensive.

Frequency Terminology

ARR2019 has adopted a new approach in describing the likelihood of rainfall and flood events. The new terminology relates each event in terms of likelihood for a single year; 'Annual Exceedance Probability' (AEP). The event formally known as the 100 Year 'Average Recurrence Interval' (ARI) is now termed the one per cent AEP as it has a one percent chance of being exceeded in any one year.

The AEP terminology was adopted to dissuade the misconception that rainfall and flooding events occur at regular intervals as may be implied by the ARI terminology.

The one per cent AEP may appear rare because it is a small percentage for any particular year. However, for infrastructure that is exposed to this likelihood year upon year (such as the Jervis Bay Road stormwater culverts), the chances increase exponentially the longer the exposure time. In a 100-year period of exposure, the one per cent AEP has a 63 per cent chance of occurring. In the ARI terminology, 63 per cent chance was the definition of 'average'.

For the Jervis Bay Road Intersection Upgrade proposal, the following AEP's were analysed. 'PMF' represents the Probably Maximum Flood. The AEP's are listed with their ARI equivalents for reference:

AEP (per cent)	ARI (years)
10	10
five	20
one	100
0.2	500
PMF	N/A

Rainfall Patterns

The main difference between the ARR versions relates to the way the Bureau of Meteorology's rainfall data is distributed within the duration of a simulated storm. In the 1987 version, each storm had a single rainfall pattern which gave a simplified version of complex storm rainfall patterns. ARR2019 attempts to model the natural variability in storm behaviour via several different rainfall ‘temporal’ patterns.

ARR2019 provides ten temporal patterns for each duration storm based on recorded rainfall data from storm events of comparable rarity and geographic location. ARR87 provided a single temporal pattern which was largely synthetic and not particularly representative of real rainfall.

ARR2019 also looks beyond the main rainfall burst which was largely the focus of ARR87. ARR2019 considers that the main rainfall burst may come after a significant amount of rainfall which wets the catchment leading to more runoff.

The NSW Department of Planning, Industry and Environment commissioned a study into the rainfall loss values, and the revised loss values published on the ARR2019 Data Hub were adopted for the hydraulic modelling of the Jervis Bay Road Intersection Upgrade flood study.

Rainfall Intensity

The Bureau of Meteorology provide rainfall data in the format of Intensity-Frequency-Duration (IFD). Rainfall of a high intensity (such as a thunderstorm) lasting five minutes is relatively common, but if that same level of high intensity rainfall lasted for over two hours this would be quite rare. The IFD data outlines this type of rainfall data for storm durations ranging from one minute up to seven days, and for rarity one month up to 2000 years.

The Bureau of Meteorology have updated their rainfall IFD data to incorporate about 30 years more data, mainly from rainfall gauges that measure rainfall in six minute intervals. These 30 years happened to include a relatively dry rainfall period. The Bureau of Meteorology have also used updated data aggregating and averaging methods compared to the ARR87 data.

The combination of the new rainfall data and processing techniques has affected the rainfall data in the Jervis Bay area significantly. The updated data shows significantly lower rainfall intensities compared with the data it is superseding, in the order of 30 per cent. In a design context, particularly regarding a major transport route such as the Princes Highway, this reduction is significant and cannot be used on face value.

Median versus Maximum Results

The ARR2019 method produces 10 times the results compared to ARR87 due to the 10 temporal patterns per storm duration. ARR2019 recommends using the median result for each storm duration to bring the ten results to one for each duration, then to extract the maximum result of these medians which effectively gives a ‘critical duration’ for each point of interest. This is effectively the same as ruling a line of best fit through the results with several results that exceed the medians being discarded.

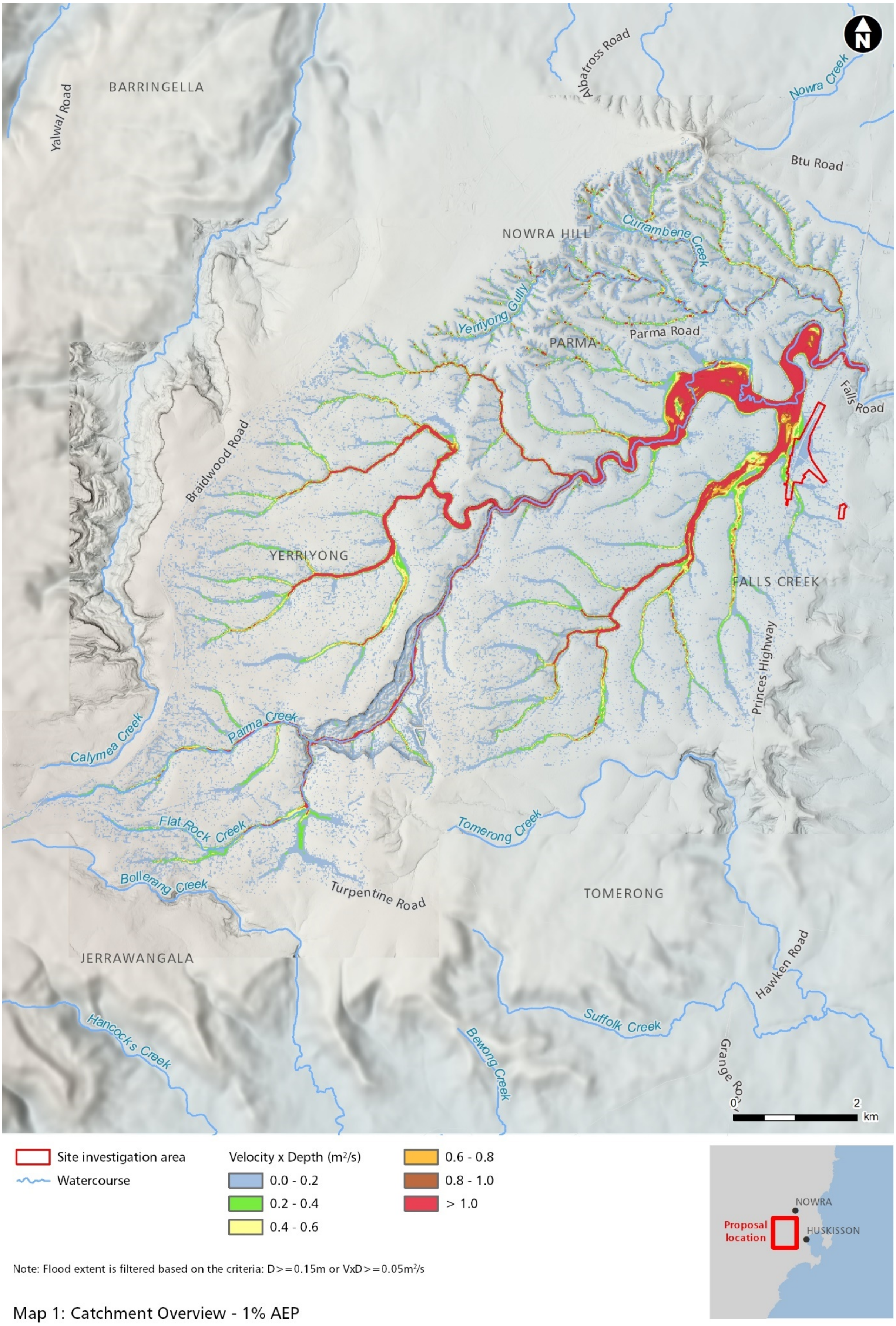
In a design context, using a median result is arguably unconservative. This method disregards results that may be within reasonable bounds of probable outcomes. A line of best fit approach may be appropriate for general floodplain mapping, but for design it has been recommended to TfNSW to use this approach with caution.

Agreed ARR2019 Methods for Design and Mapping

During design development, the issue of the relatively large Bureau of Meteorology rainfall IFD data differences were discussed with Transport for NSW, Shoalhaven City Council and the Department of Planning, Industry and Environment. Discussion was in the context of the Jervis Bay Road Intersection Upgrade being a link in a transport network which has been designed to ARR87 which produces higher flows than ARR2019. The flow difference at Jervis Bay Road is about 30 per cent.

It was agreed to continue to use ARR2019 in preference to ARR87, and to use maximum instead of median flows. The ARR2019 maximum flows are about the same as the ARR87 flows which provides consistency of design along the transport link and aids the resilience of the road network. Flood mapping in this report should be viewed in this context.

Appendix B FLOOD MAPPING

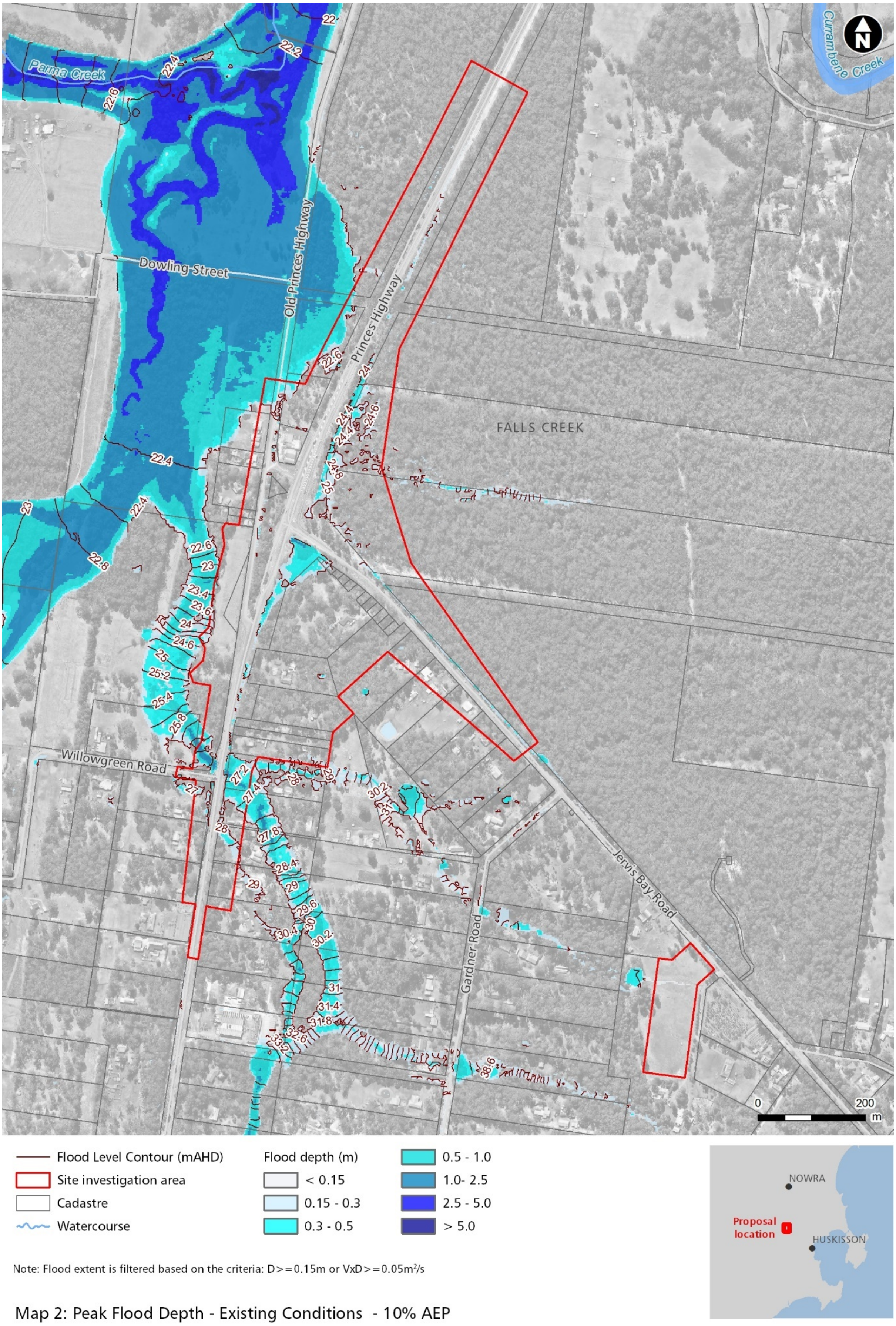


Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 1: Catchment Overview - 1% AEP

Date: 25/03/2021 Path: \\hc-aus-ns-fs-01\jobs\30052473\L-GIS\A_Current\B_Maps\JBR_REF\Chapter6_AdditionalAssessment\7_Flooding_SurfaceWater\Appendix\JBR_1_Overview_A4P_v4.mxd
Created by : NS Updated by : EM QA by : IR

Jervis Bay Road Intersection Upgrade



Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 2: Peak Flood Depth - Existing Conditions - 10% AEP

Date: 25/03/2021 Path: \\hc-aus-ns-fs-01\jobs\30052473\L-GIS\A_Current\B_Maps\JBR_REF\Chapter6_AdditionalAssessment\7_Flooding_SurfaceWater\Appendix\JBR_2_FloodDepth_10AEP_A4P_v4.mxd

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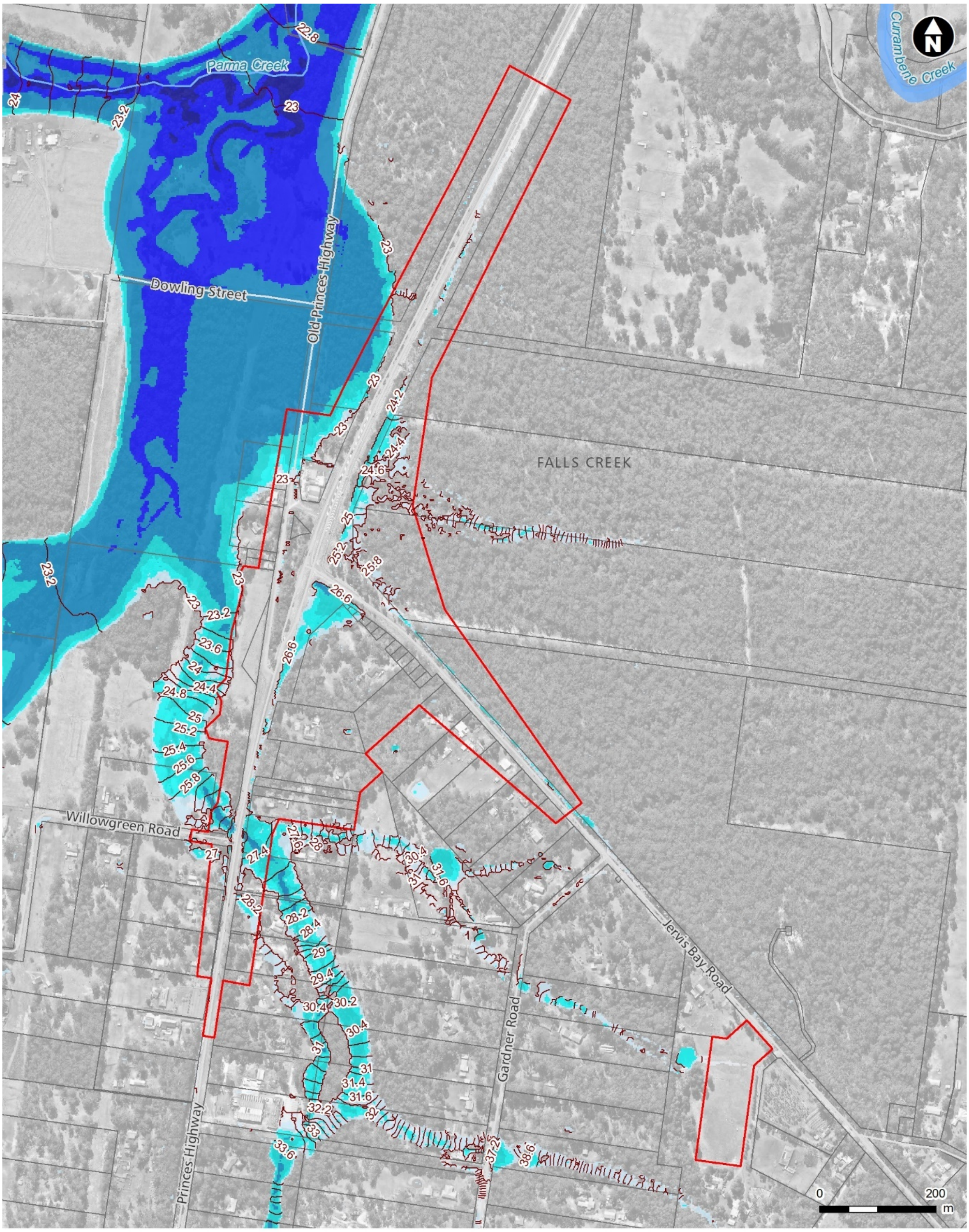
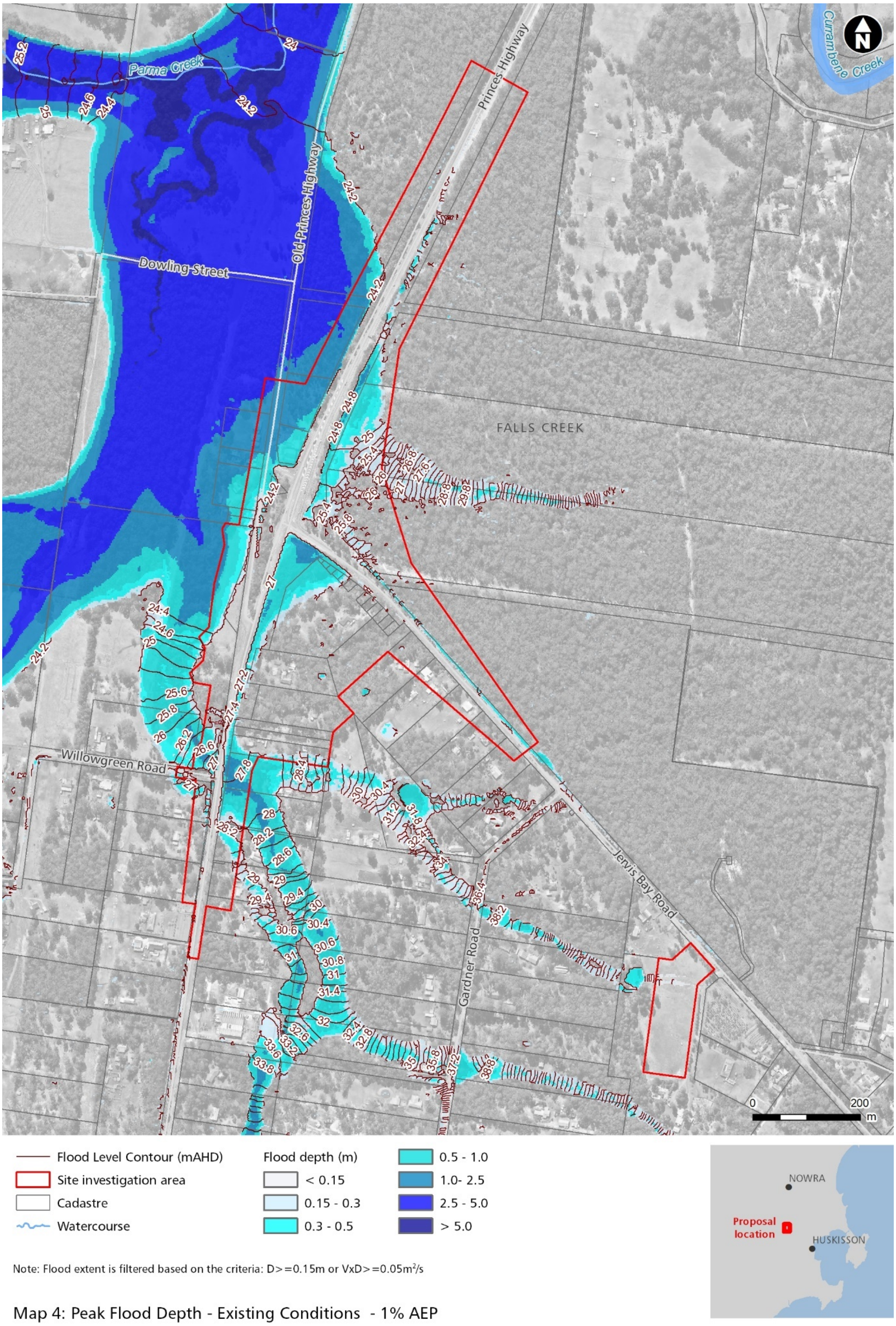


Flood Level Contour (mAHD)	Flood depth (m)	0.5 - 1.0
Site investigation area	< 0.15	1.0- 2.5
Cadastre	0.15 - 0.3	2.5 - 5.0
Watercourse	0.3 - 0.5	> 5.0

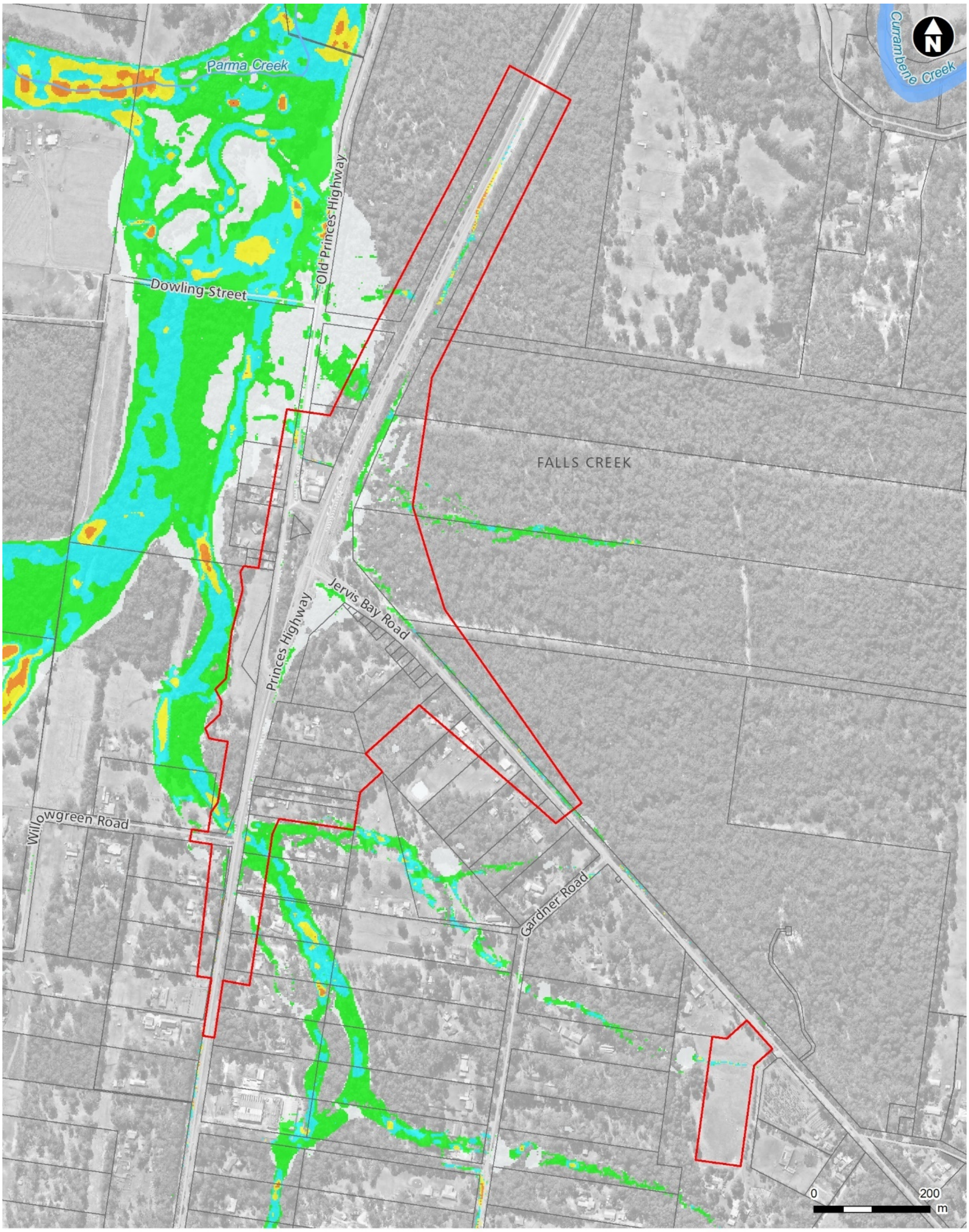
Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 3: Peak Flood Depth - Existing Conditions - 5% AEP



Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 4: Peak Flood Depth - Existing Conditions - 1% AEP



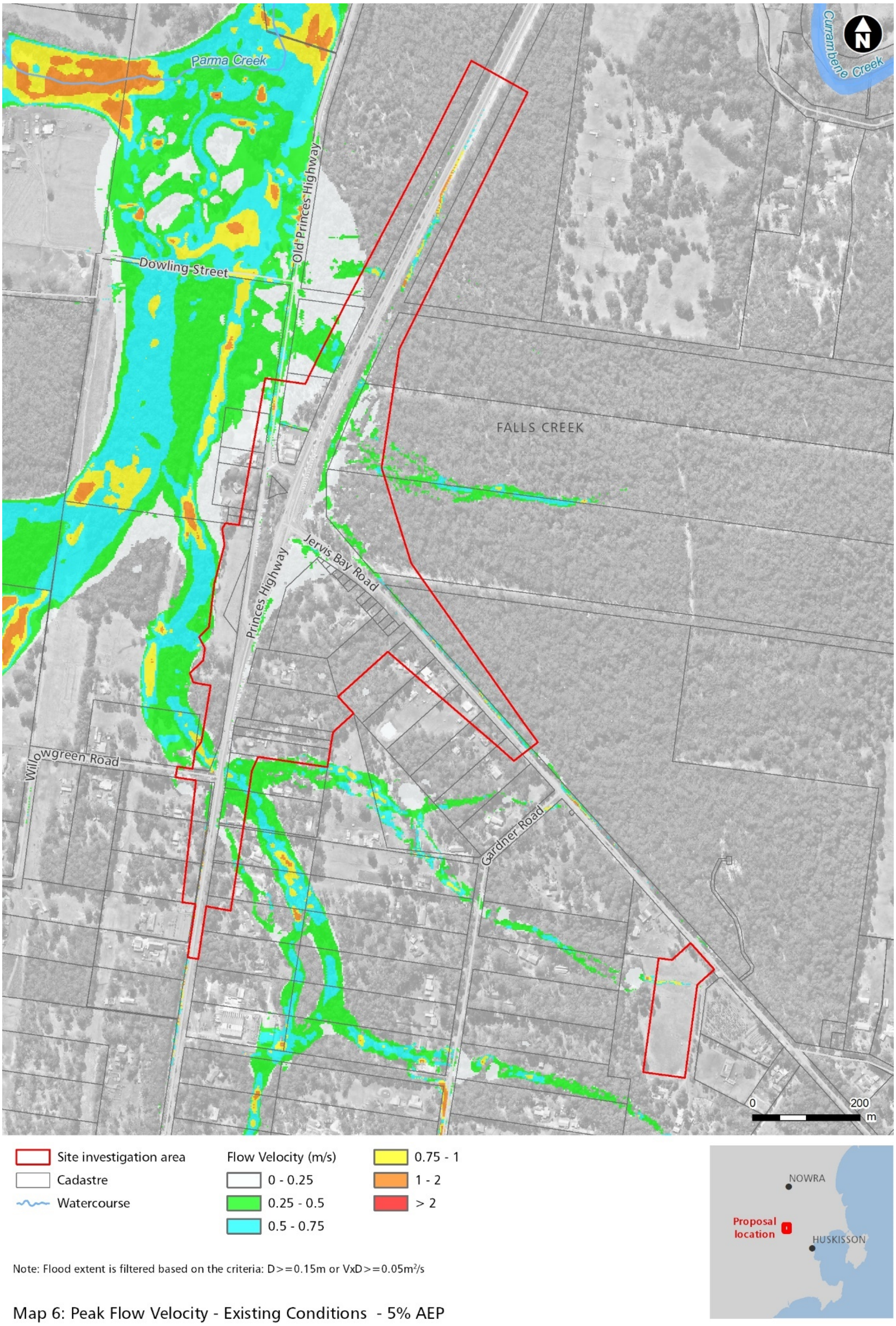
Site investigation area
Cadastre
Watercourse

Flow Velocity (m/s)

0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
> 2

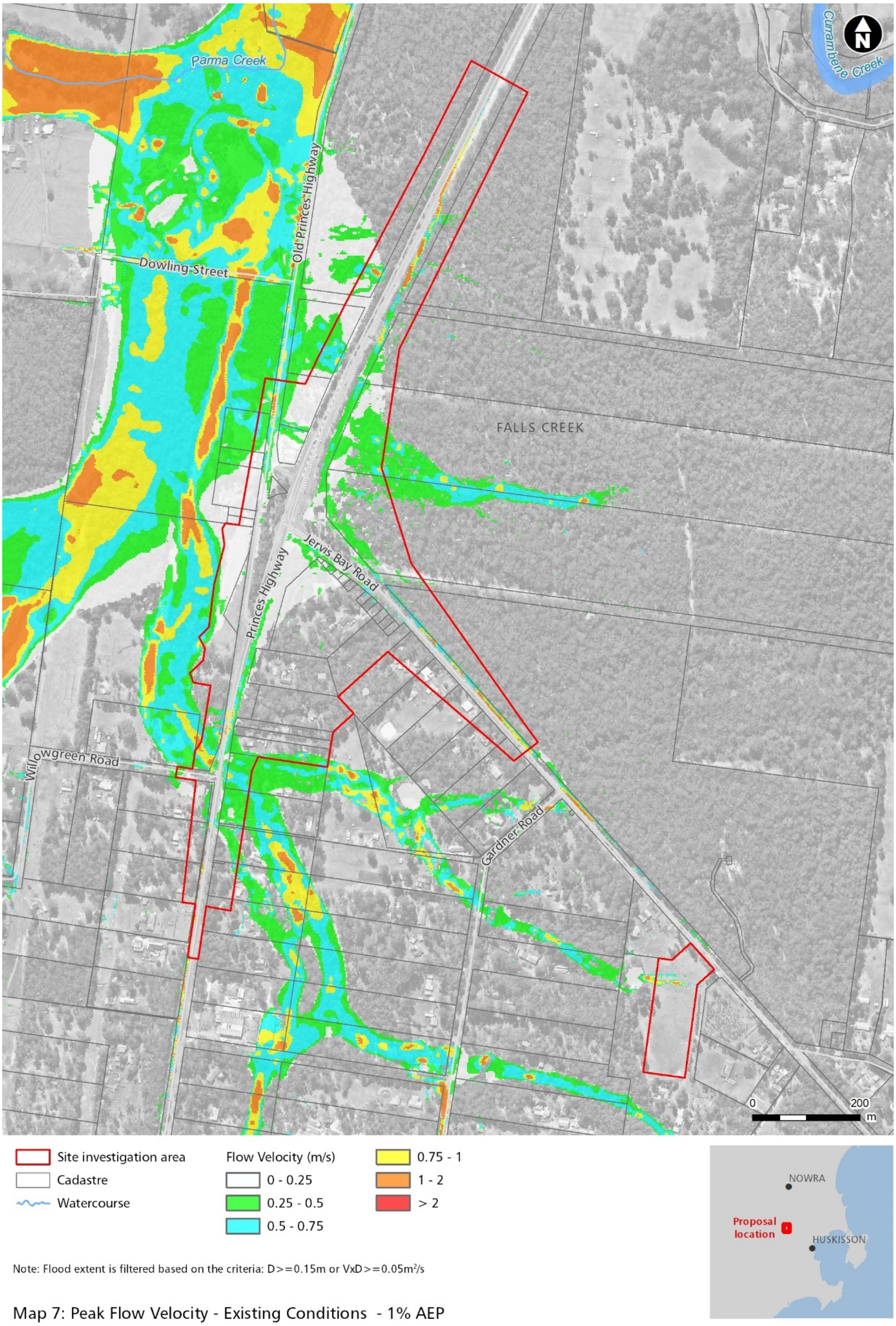
Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 5: Peak Flow Velocity - Existing Conditions - 10% AEP



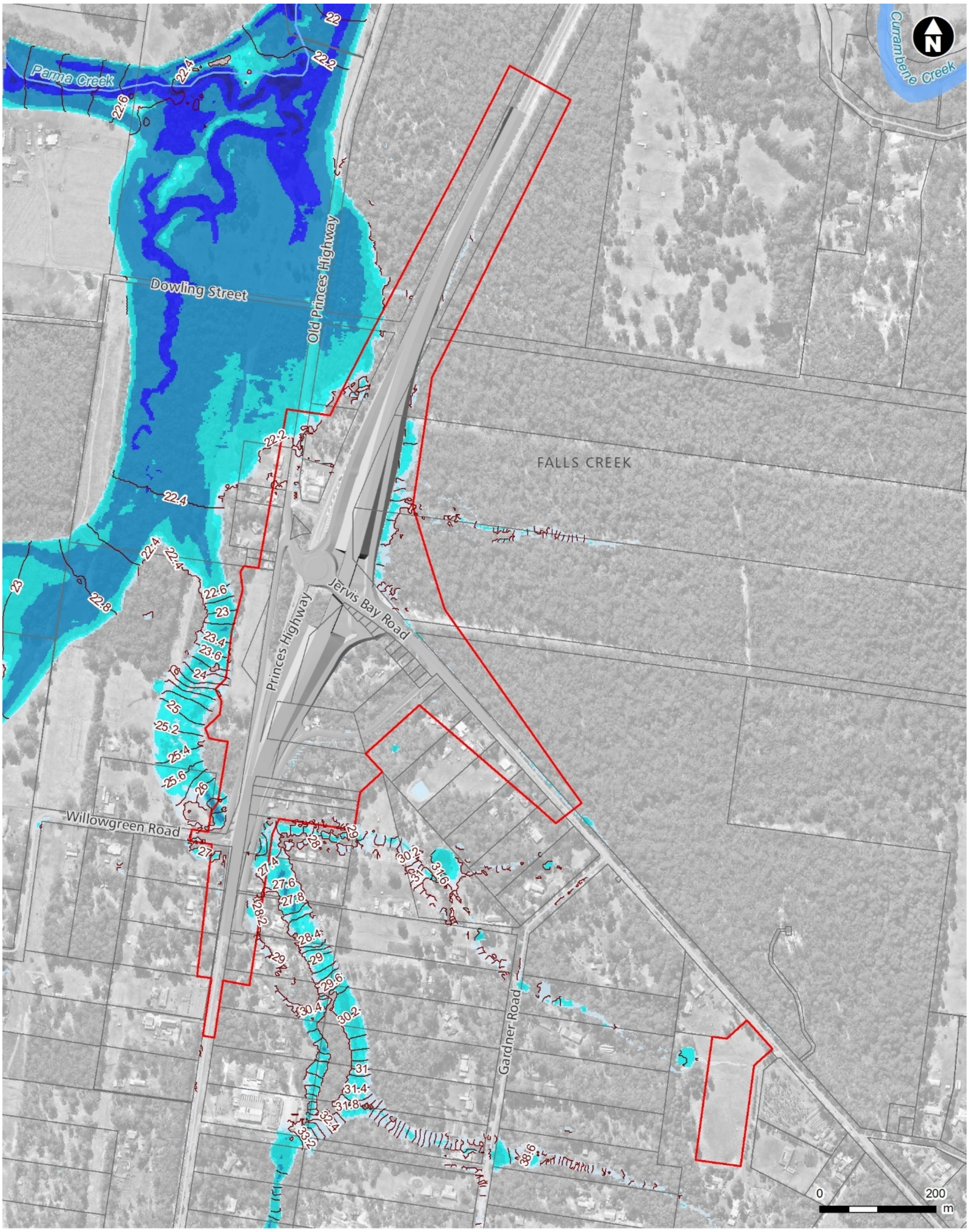
Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 6: Peak Flow Velocity - Existing Conditions - 5% AEP



Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 7: Peak Flow Velocity - Existing Conditions - 1% AEP

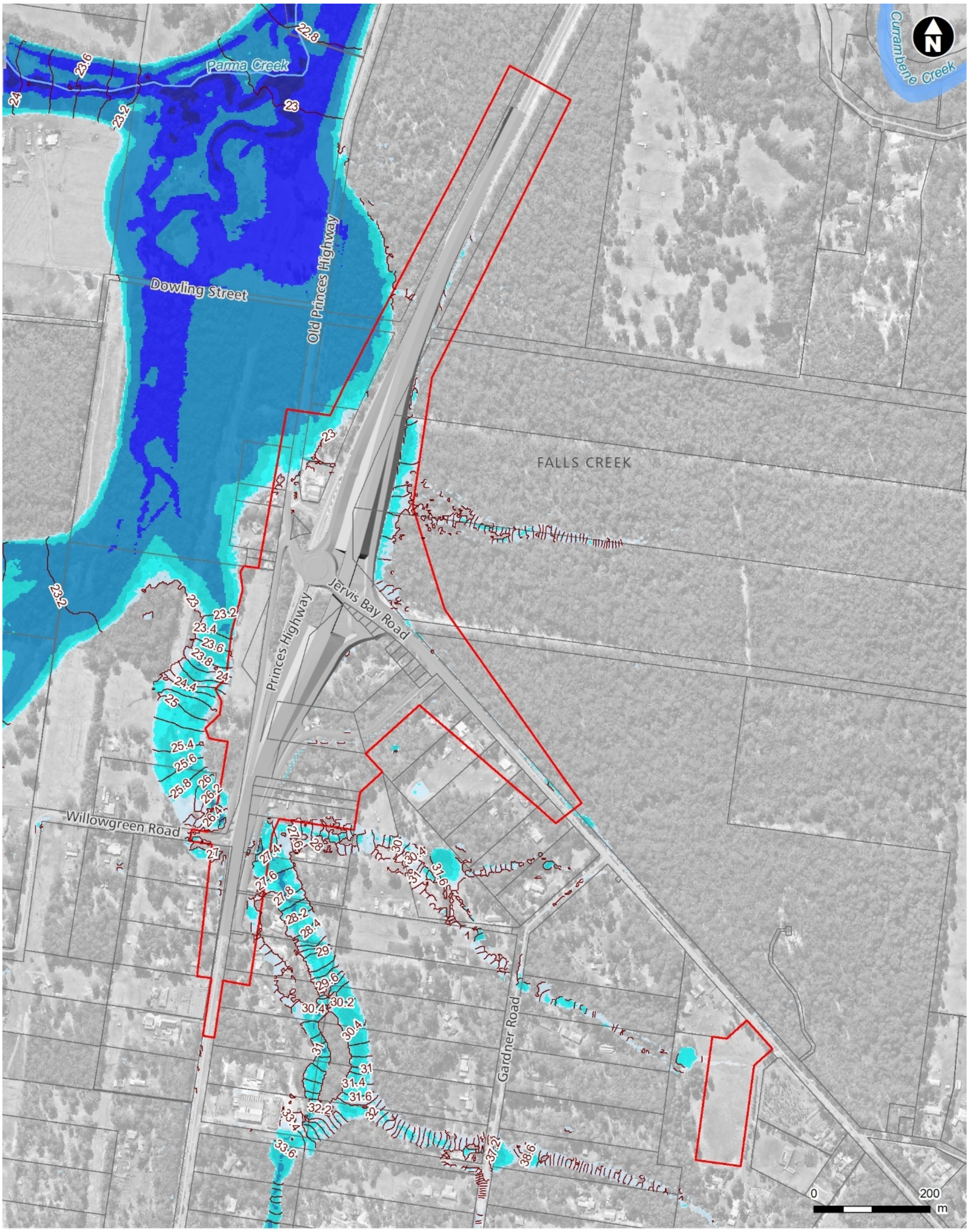


Flood Level Contour (mAHD)	
Site investigation area	
Cadastre	
Watercourse	

Flood depth (m)	
< 0.15	0.5 - 1.0
0.15 - 0.3	1.0- 2.5
0.3 - 0.5	2.5 - 5.0
	> 5.0

Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

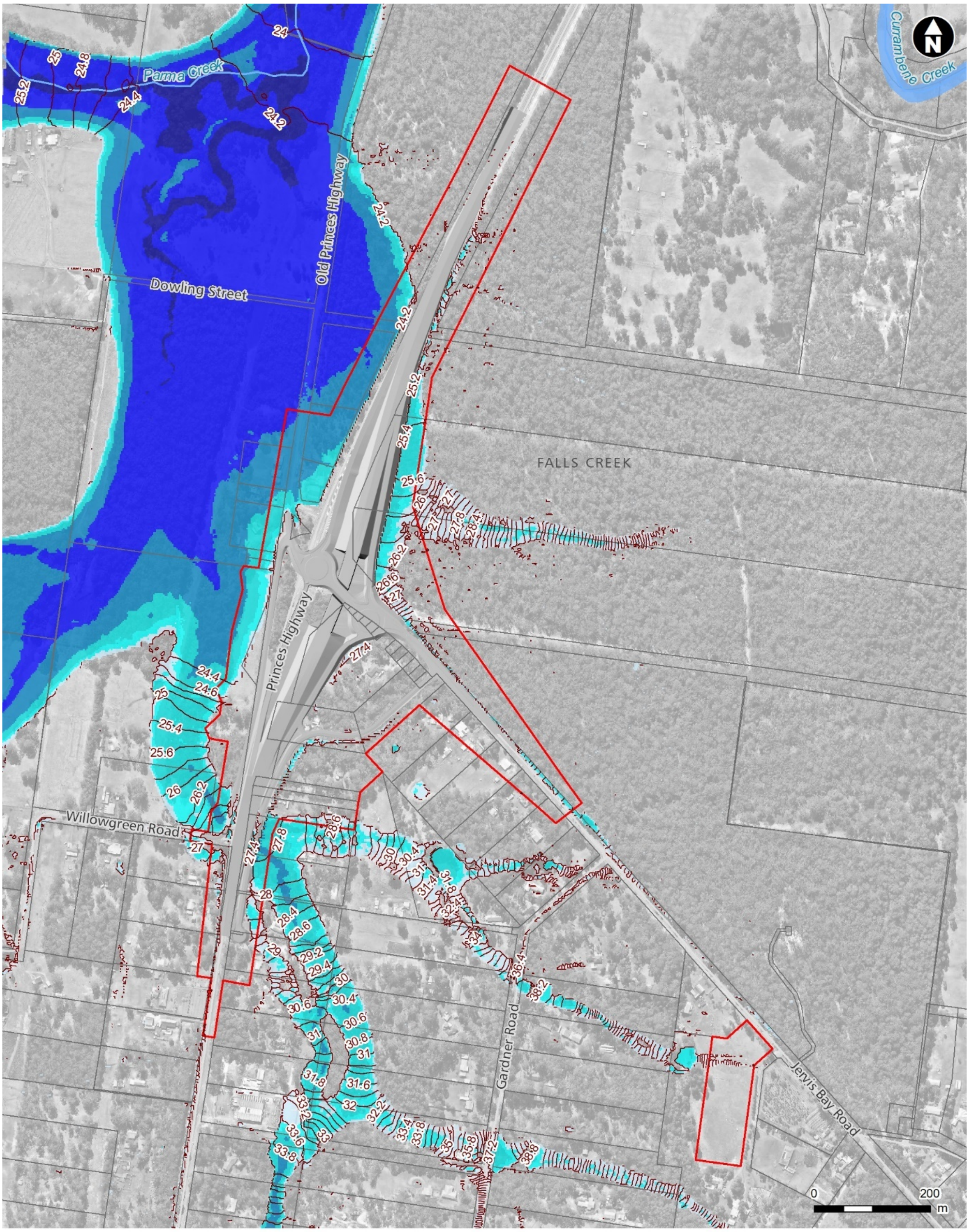
Map 8: Peak Flood Depth - Developed Conditions - 10% AEP



Legend	Flood depth (m)	
Flood Level Contour (mAHD)	< 0.15	0.5 - 1.0
Site investigation area	0.15 - 0.3	1.0- 2.5
Cadastre	0.3 - 0.5	2.5 - 5.0
Watercourse		> 5.0

Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m^2/s

Map 9: Peak Flood Depth - Developed Conditions - 5% AEP



- Flood Level Contour (mAHD)
- Site investigation area
- Cadastre
- Watercourse

Flood depth (m)

- < 0.15
- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0- 2.5
- 2.5 - 5.0
- > 5.0

Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 10: Peak Flood Depth - Developed Conditions - 1% AEP

Date: 10/03/2021 Path: \\hc-aus-ns-fs-01\jobs\30052473\L-GIS\A_Current\B_Maps\JBR_REF\Chapter6_AdditionalAssessment\7_Flooding_SurfaceWater\Appendix\JBR_10_FloodDepth_Dev_1AEP_A4P_v5.mxd
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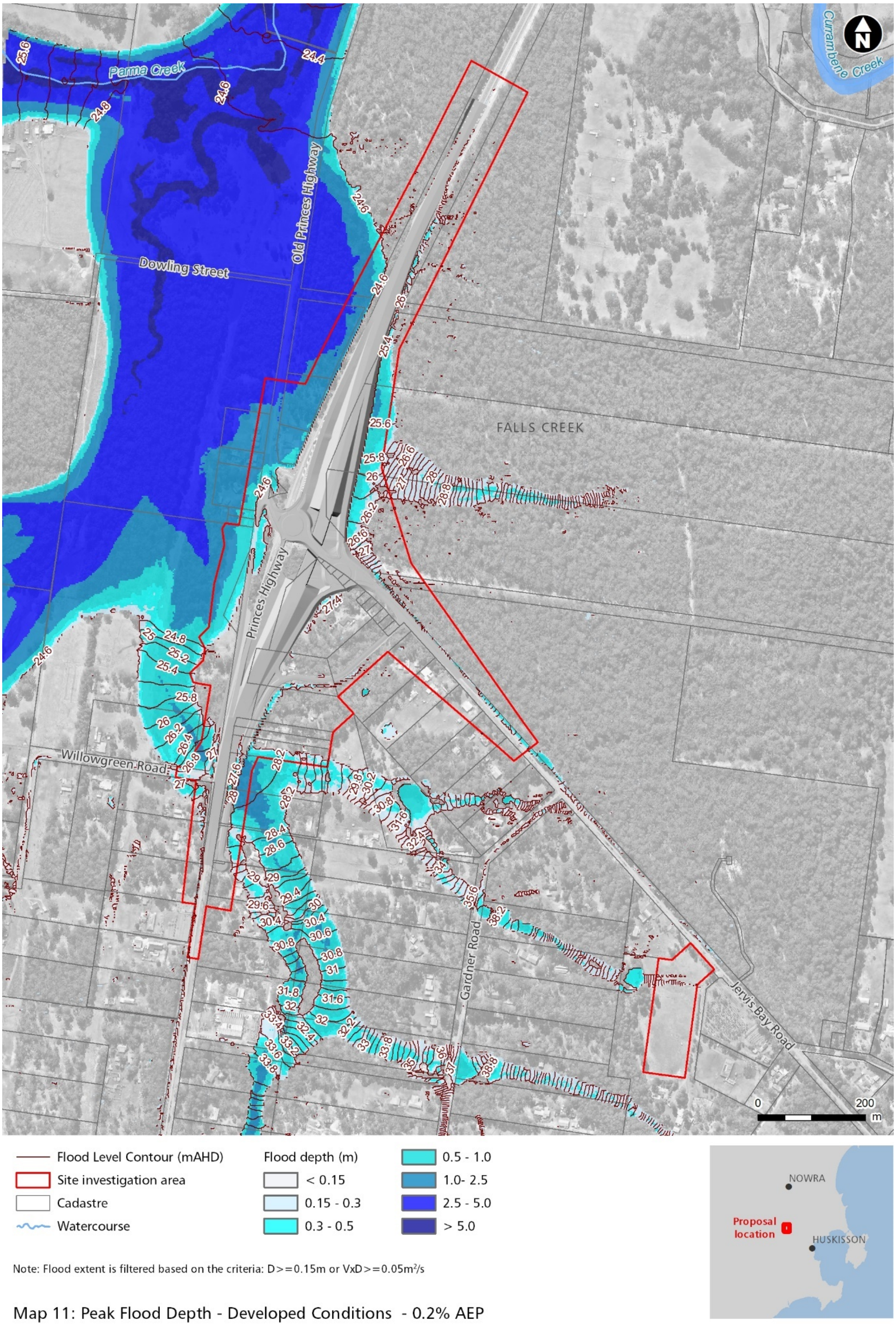
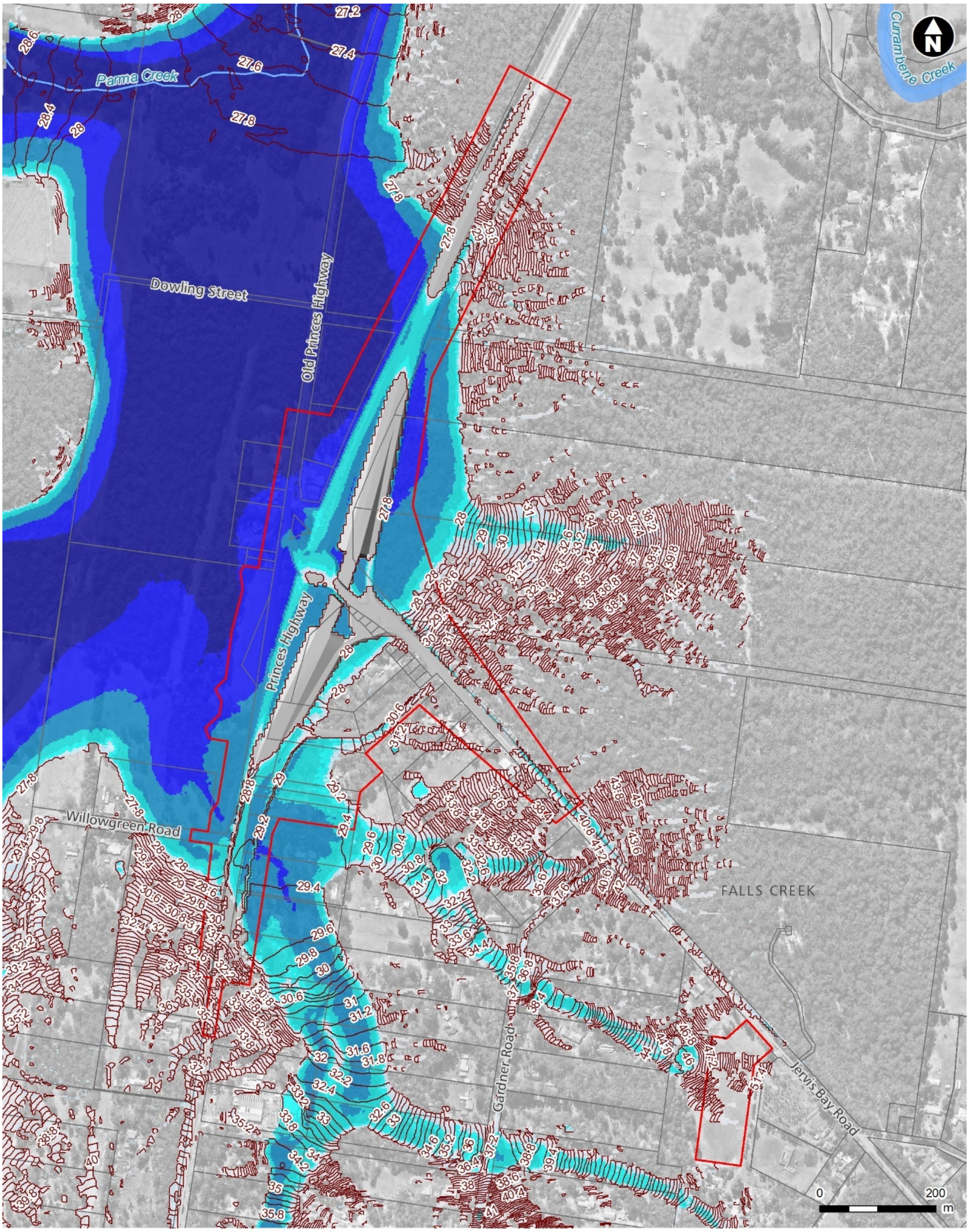


Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 11: Peak Flood Depth - Developed Conditions - 0.2% AEP

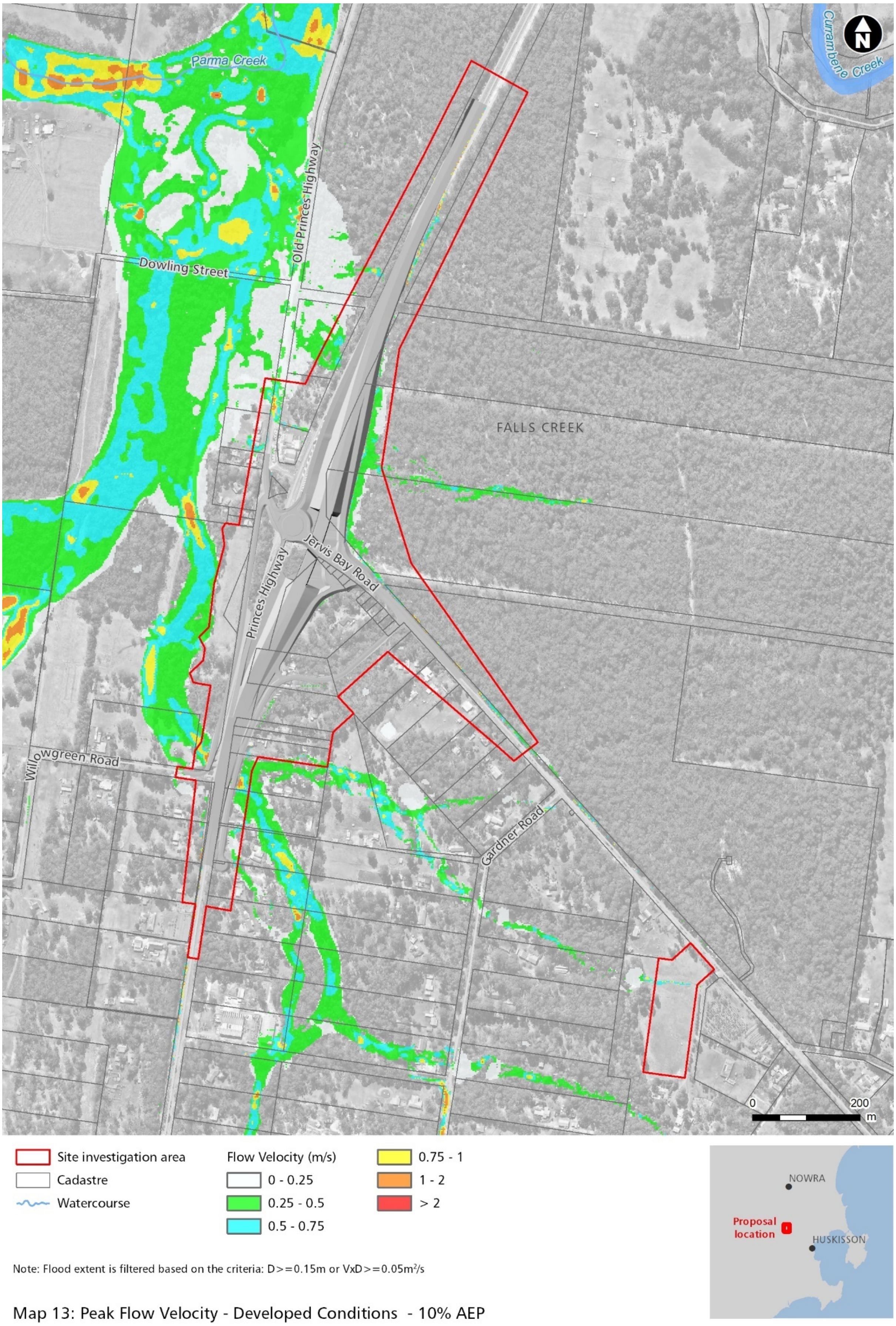


Flood Level Contour (mAHD)
Site investigation area
Cadastre
Watercourse

Flood depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1.0
1.0- 2.5
2.5 - 5.0
> 5.0

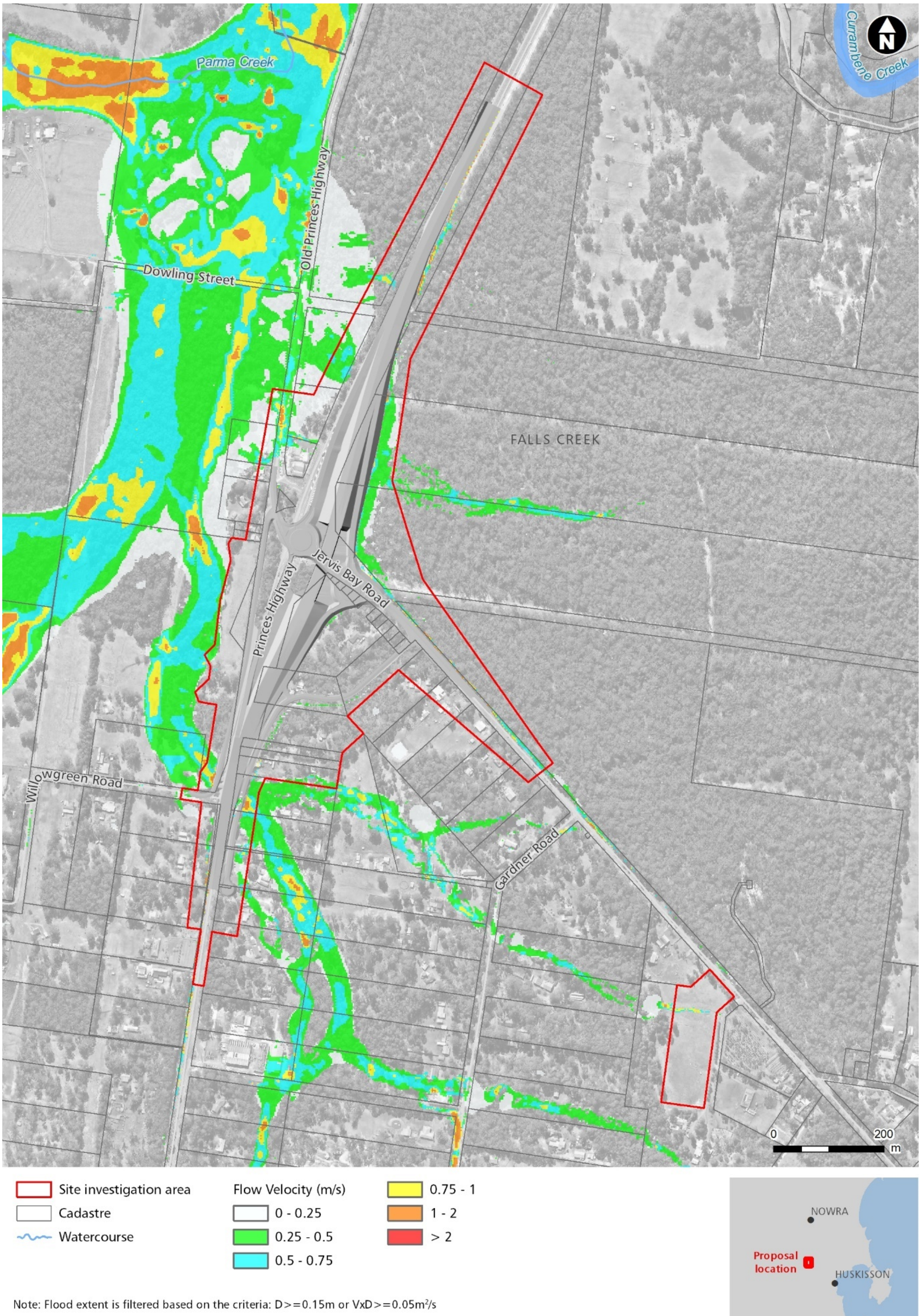
Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 12: Peak Flood Depth - Developed Conditions - PMF



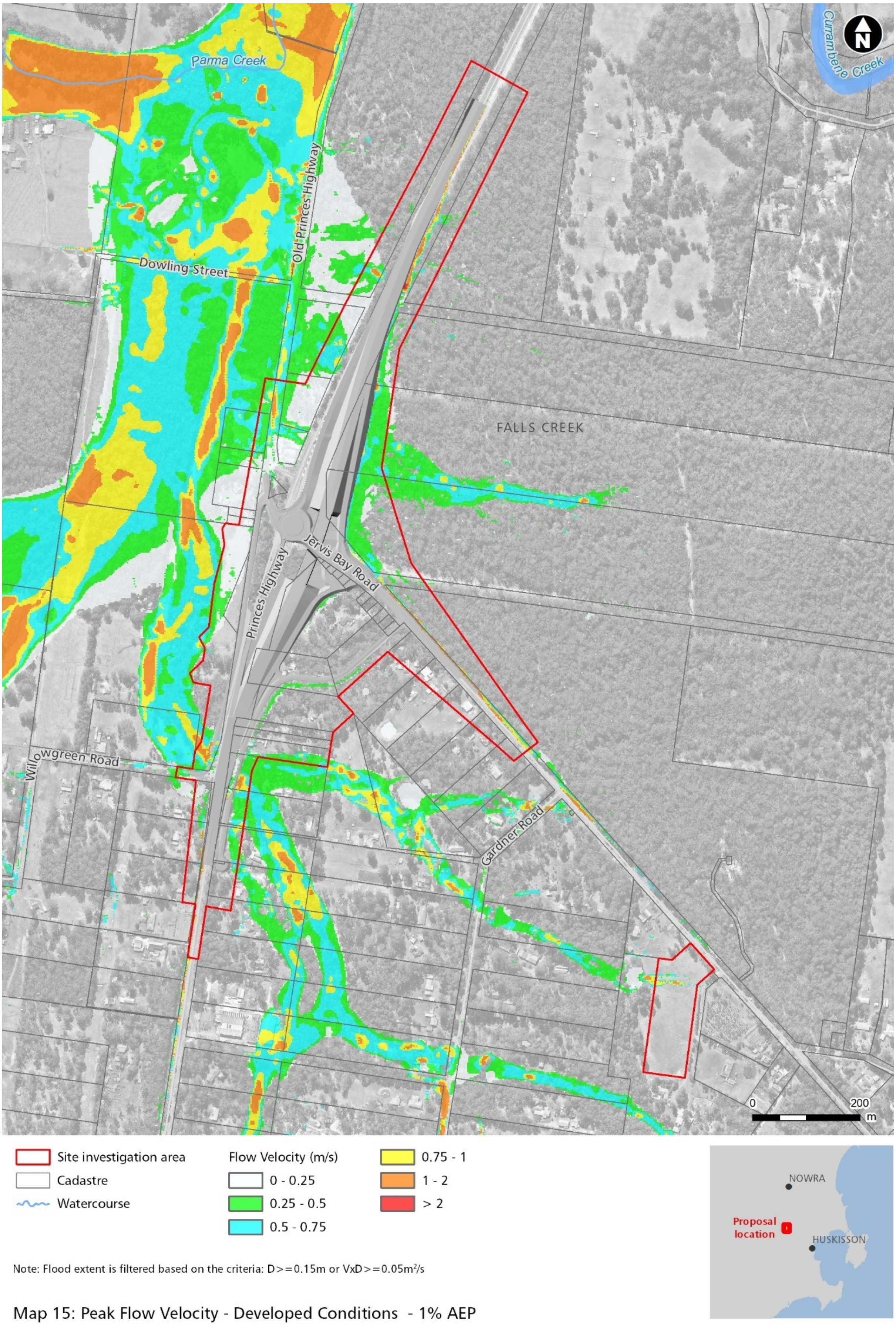
Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 13: Peak Flow Velocity - Developed Conditions - 10% AEP



Map 14: Peak Flow Velocity - Developed Conditions - 5% AEP

Jervis Bay Road Intersection Upgrade



Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 15: Peak Flow Velocity - Developed Conditions - 1% AEP

Date: 25/03/2021 Path: \\hc-aus-ns-fs-01\jobs\30052473\L-GIS\A_Current\B_Maps\JBR_REF\Chapter6_AdditionalAssessment\7_Flooding_SurfaceWater\Appendix\JBR_15_FlowVelocity_Dev_1AEP_A4P_v5.mxd
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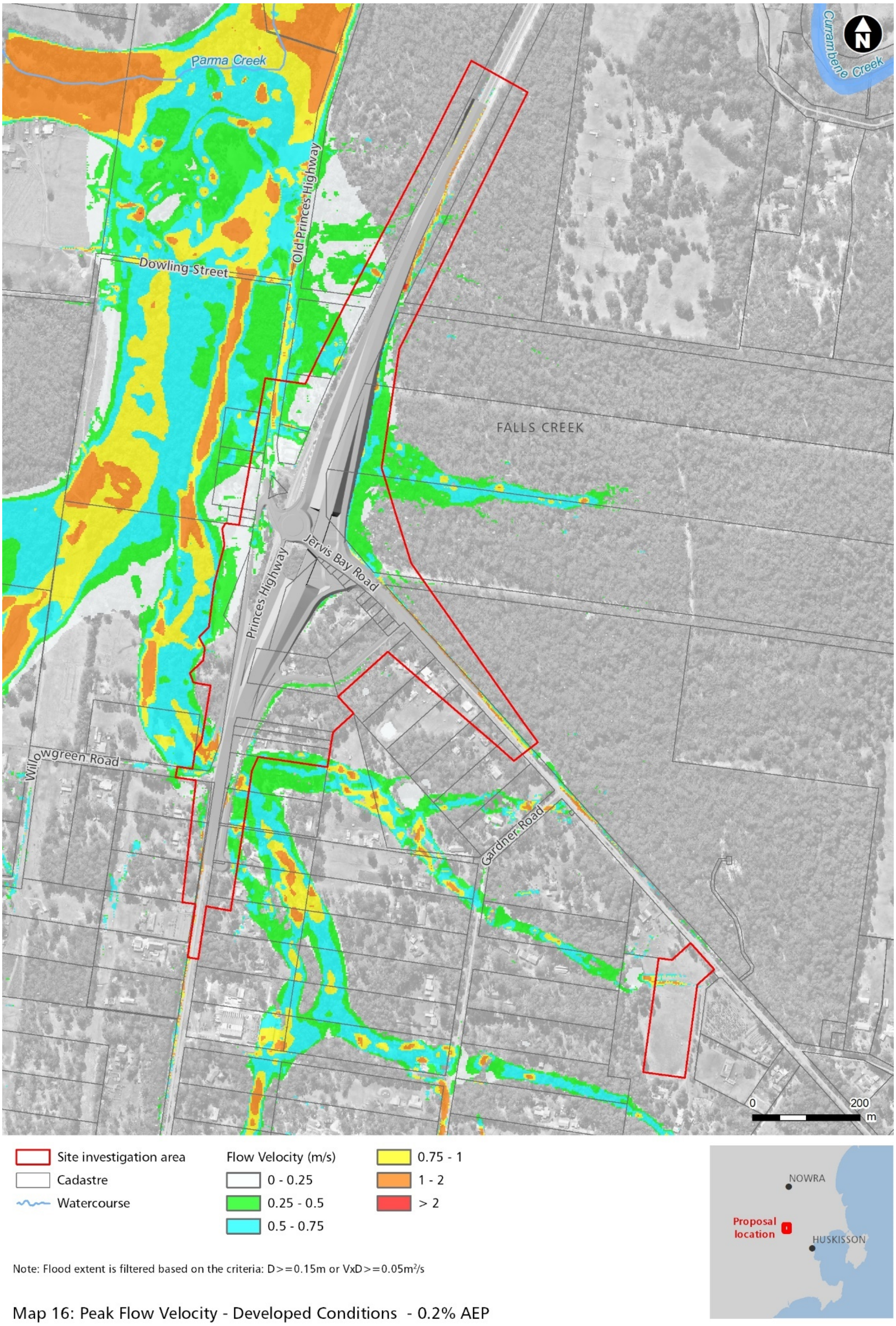
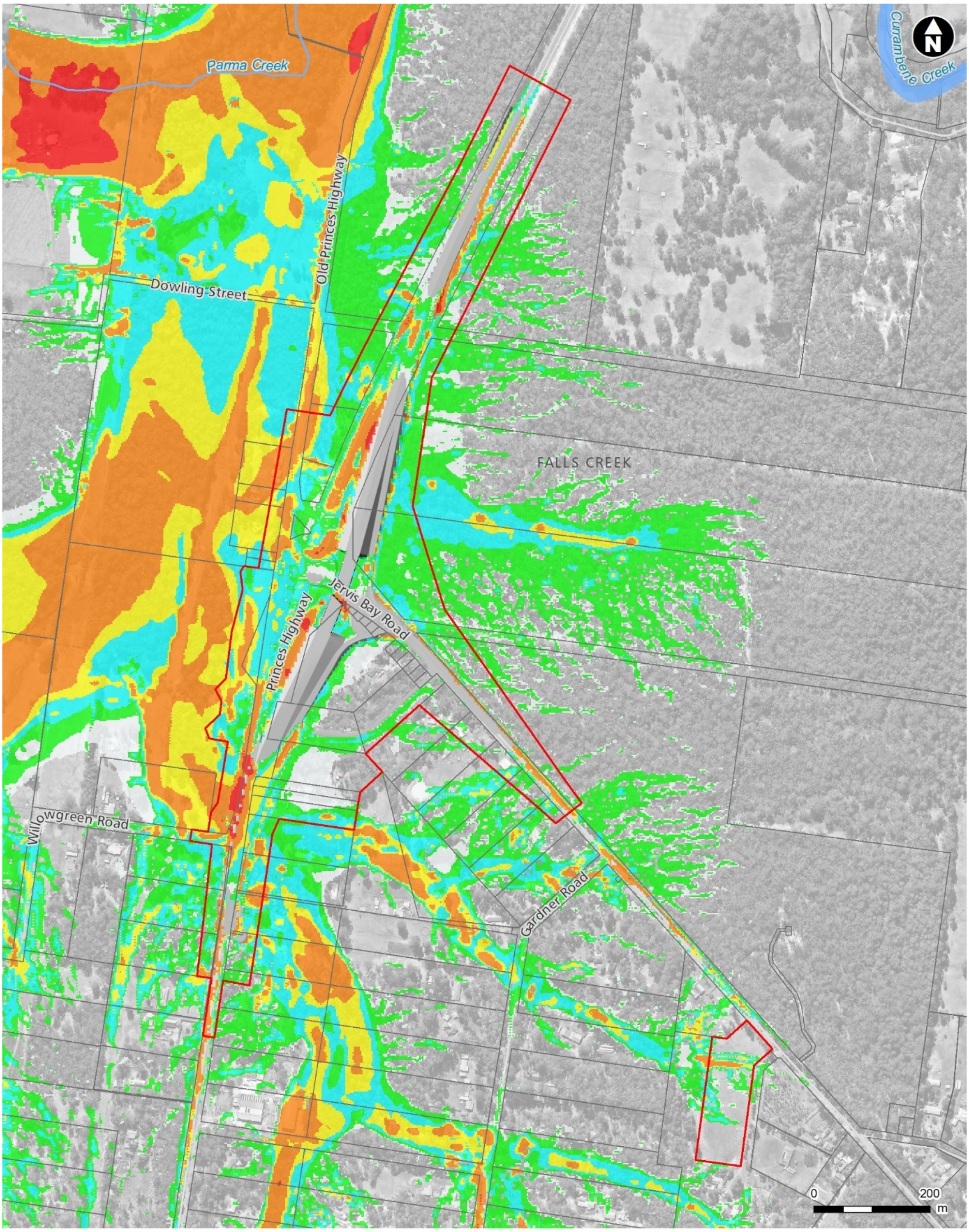


Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 16: Peak Flow Velocity - Developed Conditions - 0.2% AEP



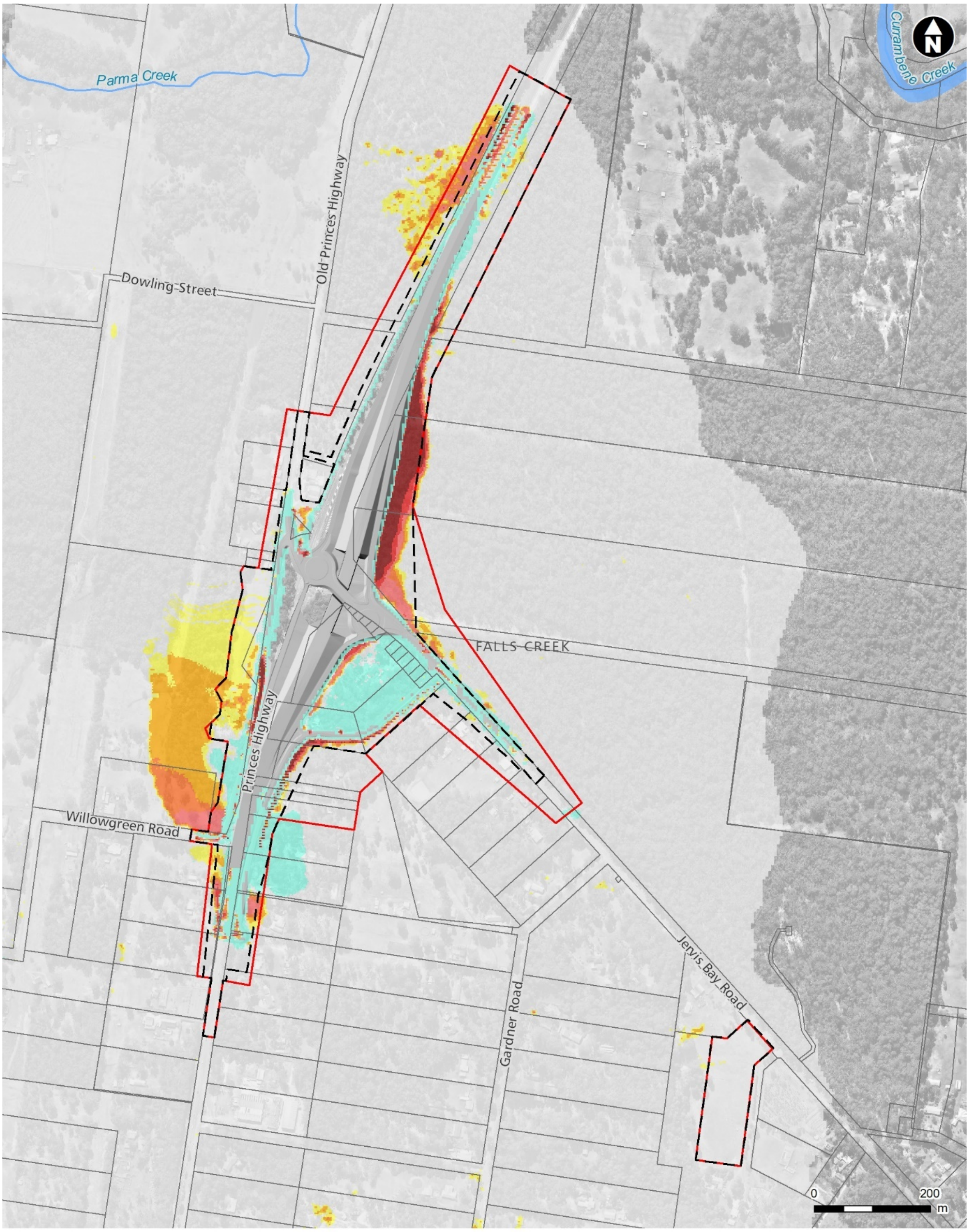
Site investigation area
Cadastre
Watercourse

Flow Velocity (m/s)

0 - 0.25	0.75 - 1
0.25 - 0.5	1 - 2
0.5 - 0.75	> 2

Note: Flood extent is filtered based on the criteria: D>=0.15m or VxD>=0.05m²/s

Map 17: Peak Flow Velocity - Developed Conditions - PMF



Site investigation area
Proposal construction footprint
Cadastre
Watercourse

Water Level Difference (m)
< -0.01
-0.01 - 0.01
0.01 - 0.02
0.02 - 0.035
0.035 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2

Map 18: Flood Level Change - Developed Conditions - 1% AEP

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