

SUNNYSIDE ESTATE MODEL UPDATE, FLOOD CONSTRAINTS ASSESSMENT AND STORMWATER

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now OEH)
DNR	Department of Natural Resources (now OEH)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP	ARI
			(1 in x)	
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
	0.0002	0.02	5000	4999.5
Extreme			↓	
			PMP/ PMP Flood	

1. INTRODUCTION

A subdivision is planned for a 110.17 ha parcel of land located at 474 and 456 Plumpton Road, Rowan NSW 2650 (the Site). The Site sits at the boundary of the southern development area in Wagga Wagga, providing a key link to the broader region. The subdivision will provide over 700 homes, and land set aside for a small commercial lot, a restored riparian corridor and outdoor recreation purposes. The Site is currently zoned RU1 Primary Production and requires rezoning. The rezoning Planning Proposal was developed in 2020 and 2021 and has received Gateway Determination. The Sunnyside Estate site is being progressed through the planning process in parallel to the adjacent Rowan Village site. Since the Gateway Determination small refinements have been made to the proposed masterplan.

The 2020 and 2021 Planning Proposal was supported by a Site Stormwater Management Strategy (SSMP) which included an assessment of broader flooding constraints. The Wagga Wagga Major Overland Flow Floodplain Risk Management Study (MOFFRMS; WMAwater, 2021) (Reference 8), defines existing design overland flood behaviour at the site. The information derived from that study is the most up to date representation of the broad catchment flood behaviour available (based on around 2018/2019 conditions). The modelling is based on a 5 m resolution grid and is considered suitable as a starting base for the assessment of flood behaviour. The models established as part of Reference 1 were refined for a site specific assessment as part of the 2020 and 2021 work.

Given the refinements to the proposed masterplan and the time since the original flood models in Reference 8 were developed, there is an opportunity to develop a further refined localised site based assessment. As such Wagga Wagga City Council has requested that the underlying topographic information be updated and refined, and to consider current guidance in relation to the assessment of climate change (as documented in Australian Rainfall and Runoff 2019 Version 4.2). The outcomes of this update are documented in this report and the resulting flood constraints considered in the context of the updated proposed masterplan.

A refined SSMP has also been prepared.

2. BACKGROUND

The land parcels, known as Sunnyside Estate, with a total area of 110 hectares, are being investigated for rezoning and development options with average lot sizes of 250 m² and 850 m², and an indicative dwelling yield in excess of 700, including land set aside for a small commercial lot, a restored riparian corridor and outdoor recreation purposes.

The site is currently vacant cropping and grazing land, and is legally described as:

- Lot 23 and 25 in DP 757246

2.1. Planning Proposal

The Planning Proposal seeks to rezone the site from RU1 Primary Production to the following mix of land use zones:

- R1 General Residential
- R3 Medium Density Residential
- C2 Environmental Conservation
- RE1 Public Recreation

The Planning Proposal will enable the creation of a new amenity-led neighbourhood providing an opportunity for a variety of housing options through a range of residential lot sizes, supported by the timely delivery of resilient utilities and infrastructure that supports and promotes the future growth of Wagga Wagga in an orderly and sustainable way. The delivery of a mix of low-density housing choices will be crucial to attracting a wide range of demographics to the area.

Future development on the site would be facilitated by a highly connected, and permeable network with convenient access to public transport, public spaces, facilities, and amenities. Cycleways and footpaths will connect across the site to promote a walkable community.

The Planning Proposal will also ensure that the environmental values of the site are preserved through the dedicated retention, and where required rehabilitation, of significant trees and riparian corridors.

2.2. Study Site

The site is located in Rowan off Plumpton Road, on the southern fringe of Wagga Wagga. The site is bounded by existing residential development fronting Lloyd Road (north), Plumpton Road (west), Rowan Road (south) and the proposed Rowan Village (west).

The site and surrounding areas are subject to inundation from overland flow, which is typically shallower than mainstream flooding. The area sits within the Lake Albert catchment, which moves in a generally northerly direction from the site, towards the Murrumbidgee River.

Elevations across the site vary from approximately 230 mAHD at the south western corner of the site, falling to approximately 215 mAHD at the north eastern corner of the site.

This represents an elevation change of 8 m from west to east and 7 m, south to north. The topography creates three (3) distinct sub catchments and points of discharge –

- Stringybark Creek which enters across the southern boundary and discharges across the eastern boundary where it is joined by a tributary.
- A small tributary enters the Site across the western boundary from Rowan Village and joins Stringybark Creek at the eastern boundary.
- Stormwater runoff also moves across the western boundary from Rowan Village and travels across the north west corner of the site, draining towards properties fronting Lloyd Road. A portion of this runoff diverts towards the tributary traveling west to east.

The location of the Site is shown on Figure 1.

2.3. Previous Studies

There have been a number of regional and local flood investigations in this area, including the following recent studies:

- Planning Proposal – Rowan Village, 7066 Holbrook Road Rowan – Stormwater Management Strategy (SSMP) – WMAwater, 2022 (Reference 5)
- Sunnyside Estate Wagga Wagga Precinct Stormwater Drainage Strategy – WMAwater 2021 (Reference 6)
- Sunnyside Estate Wagga Wagga Site Stormwater Management Plan (SSMP) – WMAwater 2020 (Reference 7)
- Wagga Wagga Major Overland Flow Floodplain Risk Management Study (MOFFRMS) – Public Exhibition Version, WMAwater, 2020 (Reference 8)
- Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan, WMAwater, 2018 (Reference 9)
- Wagga Wagga Detailed Flood Model Revisions, WMAwater, 2014 (Reference 10)
- Wagga Wagga LGA Murrumbidgee River Flood Modelling, WMAwater, 2012 (Reference 11)
- Wagga Wagga Major Overland Flow Flood Study (MOFFS), 2011 (Reference 12)

The MOFFRMS defines existing design overland flood behaviour at the site using a hydrologic (WBNM) and hydraulic (TUFLOW) model. The information derived from that study is the most up to date representation of the broad catchment flood behaviour available (based on around 2018/2019 conditions). The modelling is based on a 5 m resolution grid and is considered suitable as a starting base for the assessment of flood behaviour. The 2020/2021 Sunnyside Estate SSMP refined the models from MOFFRMS to develop a site specific assessment. This work did not update the topographic information or grid resolution.

3. HYDROLOGIC AND HYDRAULIC MODEL UPDATE

3.1. Overview

The Wagga Wagga Major Overland Flow Floodplain Risk Management Study (MOFFRMS; WMAwater, 2021), provides the most up to date definition of the broad catchment design flood behaviour at the site.

MOFFRMS utilised a TUFLOW hydraulic model coupled with a WBNM hydrologic model to define overland flooding within the model domain. The study does not consider flooding impacts resulting from the Murrumbidgee River; however, the Murrumbidgee River inundation does not extend to the Lake Albert model domain.

The topography within the MOFFRMS TUFLOW model generally represents catchment conditions around 2018/2019, however was derived from a base LiDAR dataset captured in 2009. The model topography was represented by a 5m grid resolution, this was considered appropriate for the representation of catchment scale overland flow inundation.

MOFFRMS applied the data and methodologies outlined in Australian Rainfall and Runoff 2019 (ARR 2019), this included the selection of representative storms, which were considered appropriate at a catchment scale.

As the current investigation is a localised site based assessment, Wagga Wagga City Council has requested that the underlying topographic information be refined and updated to more recent data and that the catchment wide assumptions, around representative storm events are reviewed in relation to the localised flood behaviour at the site.

The following sections outline the model refinement and its associated outcomes. All other modelling assumptions remain unchanged from those documented in MOFFRMS; WMAwater, 2021.

3.2. Available Data

3.2.1. LiDAR

Light Detection and Ranging (LiDAR) topographic survey of the study area and its immediate surroundings was provided for the impact assessment by NSW Government Spatial Services, freely available from Geosciences Australia (ELVIS). LiDAR is aerial survey data that provides a detailed topographic representation of the ground with a survey mark approximately every square metre. The LiDAR data used in this study across the Site was collected in 2020 with a resolution of 1 m.

The accuracy of the ground information obtained from LiDAR survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water. The accuracy is typically ± 0.15 m for clear terrain.

The horizontal accuracy of the data is 0.8 m at 95% confidence interval (CI), while the vertical accuracy is 0.3 m at 95% CI.

A comparison of the 2020 LiDAR to the 2009 LiDAR across the Site is provided in Figure 3. Broadly, in the vicinity of the site the 2020 LiDAR is slightly (<0.2m) higher than the 2009 LiDAR.

3.3. Model Updates

3.3.1. Refinements Undertaken in 2022 SSMP Assessment

The 2020/2021 Sunnyside Estate SSMP refined the hydrologic and hydraulic models from MOFFRMS (Lake Albert Sub-model) to develop a site specific assessment. These refinements included:

- Sub-catchment delineation around the Site was refined according to the boundaries of the Site, refined sub-catchments are shown on Figure 2;
- Areas were recalculated for those adjusted/new sub-catchments with fraction impervious retained as 0% as per the MOFFRMS;
- The IFD for each AEP was averaged for the study catchment rather than the whole MOFFRMS catchment;
- The ARFs were updated to the catchment area draining to Stringybark Creek, which were previously based on the entire catchment area;
- Hydraulic model was updated with new inflow locations (2d_sa) for the new/refined sub-catchments;
- Additional reporting locations/cross-sections (2d_po) were added to extract flow information within/around the Site.

These aspects have been applied to the current assessment.

Further details of the original model development are available in Reference 8.

3.3.2. TUFLOW Model Version

The TUFLOW model version was updated from 2018-03-AC-iSP-W64 to 2020-10-AF-iSP-w64 to allow the implementation of a refined model grid across a portion of the model domain via the Quadtree function.

3.3.3. DEM and Grid Resolution

The TUFLOW model grid across the Site was established by sampling from a triangulation of filtered ground points from the 2020 LiDAR dataset.

MOFFRMS implemented a TUFLOW model with a grid cell size of 5 m by 5 m, a portion of the model domain has been refined to 2m by 2m as part of this site specific impact assessment. This resolution provides sufficient detail for roads, localised features and overland flow paths. The remainder of the model domain is represented by that developed as part of MOFFRMS.

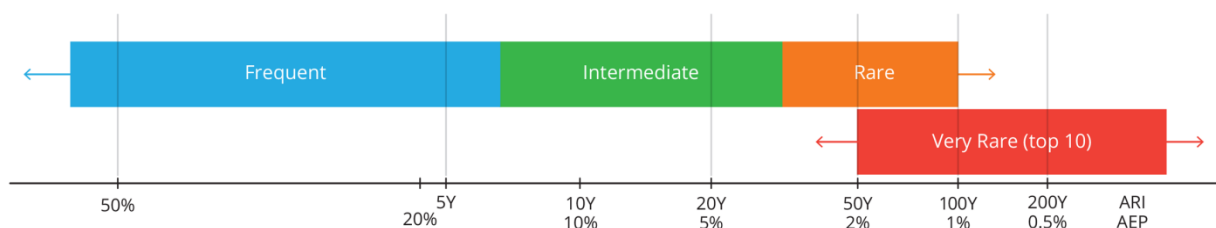
3.3.4. Representative Storm

The representative storm is a combination of temporal pattern and storm duration which best represents the flood behaviour (e.g. flow, level) for a specific design magnitude at the location of interest. MOFFRMS selected temporal patterns and durations based on an overall balance across the model domain, for this localised assessment a review of the selected representative storms for the site and immediate vicinity has been undertaken.

Temporal patterns are a hydrologic tool that describe how rainfall falls over time (storm duration) and are often used in hydrograph estimation. Given the variability in flood producing storms, ARR 2019 recommends an approach where an ensemble of different temporal patterns are investigated.

Temporal patterns for this assessment were obtained from ARR 2019 and accessed from the ARR Data Hub. The ARR 2019 method divides Australia into 12 temporal pattern regions, with the study catchment falling within the Murray-Darling Basin region. ARR 2019 provides 30 patterns for each duration, which are sub-divided into three temporal pattern bins based on the frequency of the events. Diagram 1 shows the three categories of bins (frequent, intermediate and rare) and corresponding AEP groups.

Diagram 1: Temporal Pattern Bins



The critical storm duration is the storm duration that produces the highest mean flow or level at a point of interest (where the mean is calculated from the ensemble of ten temporal patterns for that duration). Where there are multiple locations of interest with different contributing catchment sizes or flood mechanisms, there can be multiple critical durations that need to be considered.

Once the critical duration is established, it is usually desirable to select a single representative design storm temporal pattern that reproduces this behaviour for all points of interest. This representative storm can then be used for determining design flood behaviour. Peak flow is often used as an indicator to determine the representative temporal pattern. This approach was applied to the study area.

A range of storm durations (30 min to 12 hr) with an ensemble of ten temporal patterns per duration were run to produce peak flow estimates.

A summary of the adopted durations and temporal patterns for this assessment are shown in Table 1.

Table 1: Adopted durations and temporal patterns for design flood events

Event	Duration (min)	TP#
20% AEP	180	3983
10% AEP and 5% AEP	120	3947
2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP	90 120	3890 3936

3.3.5. Results

Across the site flood levels are increased by less than 0.3m during the 1% AEP event (Figure 4). Some localised reductions of less than 0.2m also occur. Within Stringybark Creek, closer to the southern boundary of the site the flood levels change by up to 0.5m. Due to the model refinement, additional areas of inundation are shown to occur from two flow paths, one generating close to the western boundary of the site and moving towards the north and the other moving from west to east along the gully lying north of Stringybark Creek. The refined grid resolution has also slightly reduced the flood extent for Stringybark Creek.

The refined base case provides a suitable base against which the proposed development can be considered.

3.3.6. Future Climate Scenario

The Flood Risk Management Manual places an emphasis on the importance of developing floodplain risk management plans that address existing, future, and continuing flood risk for flood prone land on a strategic, rather than an ad hoc or individual, proposal basis. As well as considering the current flood risk, consideration must be given to the potential future conditions. It is important to also understand how the masterplan will perform under future flood conditions.

Consideration of future conditions assists in ensuring that the management of flood prone land is consistent with flood risk and that such development does not cause undue future distress to individuals, nor unduly increase potential flood liability to them or the community.

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities into the future. Intensive scientific investigation is ongoing to estimate the effects that increasing amounts of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone) may be having on the average earth surface temperature. Changes to surface and atmospheric temperatures may affect climate and sea levels. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades.

Both increases in sea levels and rainfall intensities have the potential to impact on flood behaviour. Considering and understanding the sensitivity of the current catchment flood behaviour to these influences is crucial in the management of future flood risk. Potential increases in rainfall intensity are more likely to impact the flood behaviour within the Site.

As such increases to rainfall intensity only due to climate change, have been considered for the 1% AEP event, assuming current catchment conditions.

Any change in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. The primary driver for this change is under a warmer climate, the atmosphere can hold more water, and hence more rainfall can occur in any given storm event. ARR 2019 provides some guidance about consideration of the impacts of climate change on design rainfall intensities. It suggests assuming that rainfall intensities can be assumed to scale up by 7 - 8% per degree of average surface warming. Projected increases to evaporation are also an important consideration because increased evaporation would lead to generally dryer catchment conditions, resulting in lower runoff from rainfall in dry years. The combination of uncertainty about projected changes in rainfall and evaporation makes it difficult to predict with confidence the exact changes to peak flows for large flood events within the catchments under warmer climate scenarios.

Australia Rainfall and Runoff 2019 Version 4.2 states:

There is unequivocal evidence that greenhouse gas emissions have caused global warming. The Intergovernmental Panel on Climate Change's sixth assessment report concluded that global surface temperatures have significantly increased above pre-industrial levels, with significant further warming expected (IPCC, 2023).

This warming is causing an increase in many drivers of flood risk, including an intensification of extreme rainfall events and the elevation of average and extreme sea levels (IPCC, 2023).

Traditionally, design flood estimation has assumed that historical observations are representative of current and future conditions. This is no longer the case. Records on historical flooding or flood drivers (such as extreme rainfall or sea level) can no longer be assumed to provide a direct analogue of current or future flood risk.

To account for significant observed and projected changes to the drivers of flooding, it is necessary to account for the non-stationarity of flooding in the assessment of current and future flood risks.

The research used in developing the guidance in ARR2019 Version 4.2 has been applied to existing conditions in the catchment. To consider the potential consequences of a changing climate into the future, a range of scenarios have been developed, including SSP 2 – 4.5 2050 (14 – 27%) and SSP 3 – 7.0 2090 (29 – 59%). SSP 2 – 4.5 is considered the middle of the road scenario and SSP3 – 7.0 is considered a high-emission scenario.

4. FLOOD CONSTRAINTS

4.1. Overview

The Site is subject to overland flow flooding as initially defined by the Major Overland Flow Floodplain Risk Management Study undertaken by Wagga Wagga City Council. The hydraulic model established as part of the MOFFRMS was based on catchment conditions around 2018/2019, built from an initial base topography from 2009. As the current assessment is a localised site based assessment, the existing hydrologic and hydraulic models have been updated and refined. The outcomes of this update are documented in Section 3 and the results presented in the following sections are based on the updated hydraulic model.

The site and surrounding area slopes down from the southwest to the northeast and north, towards Lake Albert and then ultimately the Murrumbidgee River. Three (3) distinct sub catchments impact the Site:

- Flow generates in the west of the site (within the Rowan Village Site) and moves in a northeast direction, impacting properties on Lloyd Road to the north of the site.
- The stormwater from the upstream catchments moves through the middle of the site from west to east through the naturally formed gully.
- Stringybark Creek enters the site from the south and then moves northeast towards Plumpton Road and then moves along the eastern boundary of the site. This is joined by the gully that flows through the middle of the site, just downstream of Plumpton Road. Flood water is banked up against Plumpton Road which seems to result in backwatering within the site.

4.2. Peak Flood Depth

Peak design flood depths and levels are provided on Figure 5 to **Error! Reference source not found.** for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events.

For the 20% AEP, flow from the upstream catchments enters the site at the Rowan Road culvert, through Stringybark Creek (through existing Lot 23 DP757246). Inundation is generally contained to the creek line as it conveys the upstream flow through the site until it is joined by flow moving towards the intersection of Rowan Road and Plumpton Road which then moves north along the eastern boundary of the site. Flood depths up to 1.2m occur within the creek and up to 0.2m within the flow path. A flow path generates close to the western boundary of the site and moves along the natural gully within the site with flood depths typically less than 0.5m. This converges with Stringybark Creek just downstream of the site, near the boundary between existing Lot 23 and Lot 25 (DP757246). Flood depths up to 1m occur close to the confluence.

Another flow path generates just upstream of the western boundary of the site (within the Rowan Village site) and moves in northeast direction (through existing Lot 23 DP757246), resulting in flooding over the properties on Lloyd Road and Plumpton Road although the flood depths remain less than 0.05m within the site with a maximum of 0.15m in small pockets.

There is a slight increase in the flood extent in the 10%, 5% and 2% AEP events, however the overall flood behaviour is very similar to the smaller 20% AEP event. Flood depths are also similar with only the main creek line increasing to a maximum of 1.1m, 1.2m and 1.5m deep, in the 10%, 5% and 2% AEP event, respectively.

In the 1% AEP event, the flood extent increases further with the same areas flooded as the 20% AEP event. Flood depths up to 1.5m occur within Stringybark Creek and up to 0.7m within the flow path through the middle of the site. For the northern flow path, the flood depths remain generally less than 0.05m with slightly larger areas impacted by depths up to 0.15m compared to the 20% AEP event. A similar flood behaviour is observed in the 0.5% and 0.2% AEP event with depths up 1.7m and 1.8m respectively within the creek channel and up to 0.71m and 0.75m within the central creek. Depths pond up to 0.3m at the site boundary.

4.3. Hydraulic Hazard

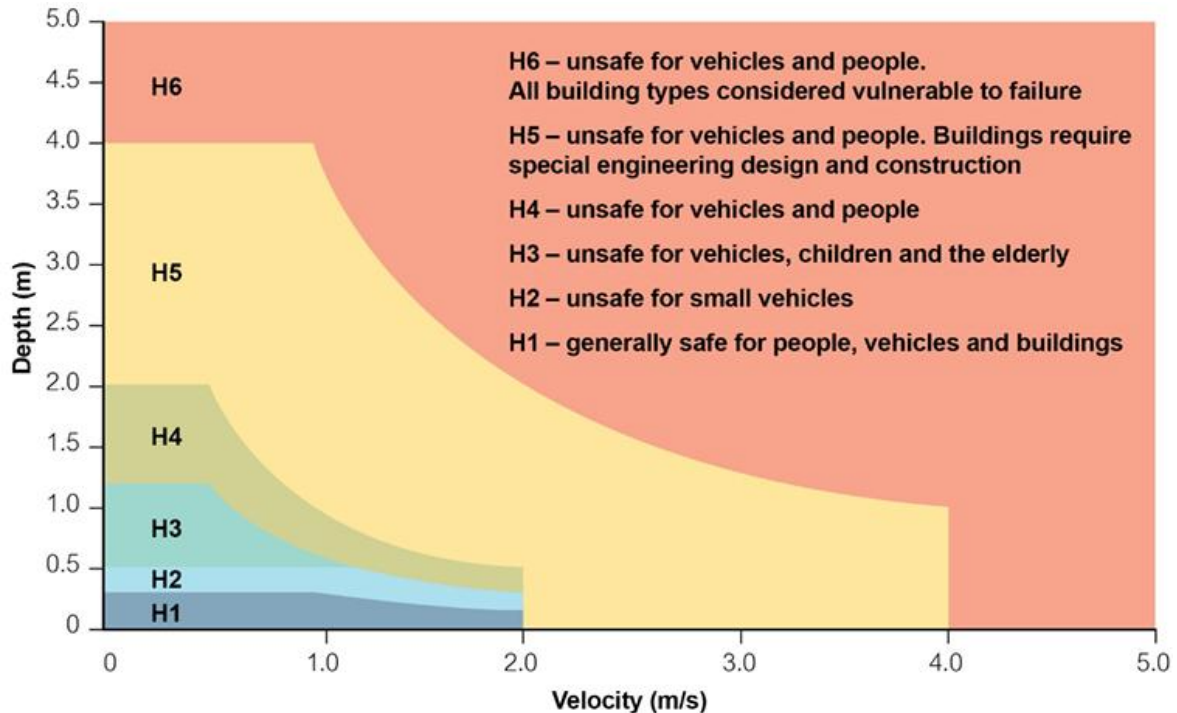
Hazard classification plays an important role in informing floodplain risk management in an area, as it reflects the likely impact of flooding on development and people providing a measure of potential risk to life and property damage from flooding. Hydraulic hazard is typically determined by considering the depth and velocity of floodwaters.

Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth, velocity and velocity depth product.

Hydraulic hazard categories have been determined for the study area in accordance with the NSW Government Flood Risk Management Manual and its accompanying guideline FB03 – Flood Hazard. FB03 provides a best practice approach for understanding of the potential vulnerabilities as a result of hydraulic hazard of flood water.

The accompanying guideline FB03 contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 1.

Diagram 1: General flood hazard vulnerability curves



This classification provides a more detailed distinction and practical application of hazard categories, identifying the following 6 classes of hazard:

- H1 – No constraints, generally safe for vehicles, people and buildings.
- H2 – Unsafe for small vehicles.
- H3 – Unsafe for vehicles, children and the elderly.
- H4 – Unsafe for people and all vehicles.
- H5 – Unsafe for people and all vehicles. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure. Buildings require special engineering design and construction; and
- H6 – Unsafe for people and vehicles. All building types considered vulnerable to failure.

It should be noted that these classifications are based on the physical flood behaviour in design flood events and do not account for other hazards that may exist (such as, road surface failure, loss of access) or the variability in real storm events

The majority of the Site is classified as H1 - No constraints, generally safe for vehicles, people and buildings, in the 20% AEP event. Areas with higher Hydraulic Hazard occur through the main creek line (up to H5 - Unsafe for people and all vehicles) and the natural depressions within the site (H2 - Unsafe for small vehicles).

Increasing event size from the 20% AEP through the 10%, 5%, and 2% AEP events, shows a similar distribution of Hydraulic Hazard across the Site. Larger areas of category H5 - Unsafe for people and all vehicles occur through the creek line and through natural depression areas, H3 hazard category (Unsafe for vehicles, children and the elderly) is observed.

At the 1% AEP event, majority of the site remains classified as category H1 - No constraints, generally safe for vehicles, people and buildings. H5 Hazard Category is prominent within Stringybark Creek. These areas increase in the 0.5% and 0.2% AEP events.

4.4. Future Climate Scenario Flood Behaviour

The 1% AEP event under the SSP2 – 4.5 2050 scenario, shows that flood levels are expected to increase by up to 0.12m. In the SSP3 - 7.0 2090 scenario (1% AEP event), larger increases in flood depth of up to 0.4m are shown to occur. Flood levels within majority of the site increase by less than 0.05m with a negligible change in the flood extent for both the scenarios.

4.5. Access Constraints

The site is accessible from Rowan Road, Plumpton Road and Lloyd Road. Understanding the flood constraints on these roads helps to inform the emergency management of the development.

Inundation is shown to occur in events as frequent as the 20% AEP, Lloyd Road, Plumpton Road and close to Stringybark Creek on Rowan Road. Depths are generally less than 0.05m, except near Stringybark Creek crossing on Rowan Road (depth up to 0.35m) and Plumpton Road (depths up to 0.2m). These depths translate to Hydraulic Hazard of H1 - No constraints, generally safe for vehicles, people and buildings.

In the 1% AEP event, additional areas of the impacted road surfaces are inundated, although the majority remains at a shallow depth, deeper flows run adjacent to the road. In addition, the depth near Stringybark creek crossings at Rowan and Plumpton Road increase to up to 0.4m. Again, these depths translate to Hydraulic Hazard of H1 - No constraints, generally safe for vehicles, people and buildings.

4.6. Flood Constraints for the Proposed Development Layout

The existing flood constraints have helped to guide the broad layout of the proposed development. It has been designed with a riparian corridor which allows for the creeks to move through the Site. The majority of the proposed residential lots remain flood free or impacted with flood depths less than 0.2m.

The open space conveys the primary Stringybark Creek channel and the gully to the north except for the small gully that flows into the creek just upstream of the eastern boundary of the site, which impacts some proposed lots. The flow path moving to the north of the site is impacted with flood depths less than 0.15m and impacts the lots in that region.

Deeper areas of inundation through the Site under existing conditions is not expected to occur in proposed conditions as topographic depressions would likely be removed in this area in the development process. Filling of these areas will likely resolve this inundation; however localised flood levels will likely increase within the riparian corridor.

A series of basins are proposed to manage the stormwater runoff through the site. Additional drainage considerations will also be needed for the lots proposed in the northern portion of the site (existing Lot 25 DP 757246). Similar considerations will be required for the flow approaching Stringybark Creek just before it flows out of the site. In all modelled events, the existing conditions flood extent is shown to encroach into the proposed road.

5. SITE STORMWATER MANAGEMENT PLAN

The objective of the SSMP is to demonstrate that the site can be developed using best practice stormwater management principles and techniques. This will enable the subdivision to meet the stormwater management requirements set in WWCC Development Control Plan (DCP) (Reference 16) and WWCC Engineering Guidelines for Subdivision and Development Standards (Reference 17). The objectives will inform stormwater designs and ensure that stormwater quality and quantity targets are achieved and maintained.

Specific objectives are detailed below.

Existing Flooding Objectives:

- Prepare existing flood mapping for designated range of storm events;
- Establish the existing flood characteristics for the site;
- Quantify flows into and out of the Site under existing conditions.

Site Stormwater Quality Objectives:

- 60% reduction in Suspended solids (SS);
- 40% reduction in total nitrogen (TN);
- 45% reduction in total phosphorus (TP);
- 90% reduction in gross pollutants (GP).

Site Stormwater Quantity Objectives:

- No-worsening stormwater peak discharges after development.

The objective of the Site Stormwater Management Plan (SSMP) is to mitigate adverse impacts on stormwater discharges resulting from the development of the Site. Site stormwater discharge will meet the conditions and requirements for stormwater management. These requirements ensure that appropriate design and stormwater mitigation is applied to ensure that stormwater quality and quantity targets are achieved and maintained. To undertake this assessment the following models have been established:

- a local hydrological (DRAINS with RAFTS module) model of the Site for the design of detention facilities to manage site stormwater discharges;
- and a local water quality model (MUSIC) of the Site to design treatment facilities and predict the efficiency of the proposed treatment system in the reduction of contaminants and pollutants.

5.1. Site Delineation

The aim of this study is to develop a stormwater management plan to inform the permit application process. A plan of subdivision layout is provided in Diagram 2.



As concluded in Section 3, the Site was delineated into three sub-sites, i.e., S1 (northern sub-site), S2 (middle sub-site), and S3 (southern sub-site), based on the existing topography. Under developed conditions, the subcatchments are expected to be slightly different as shown in Diagram 3.

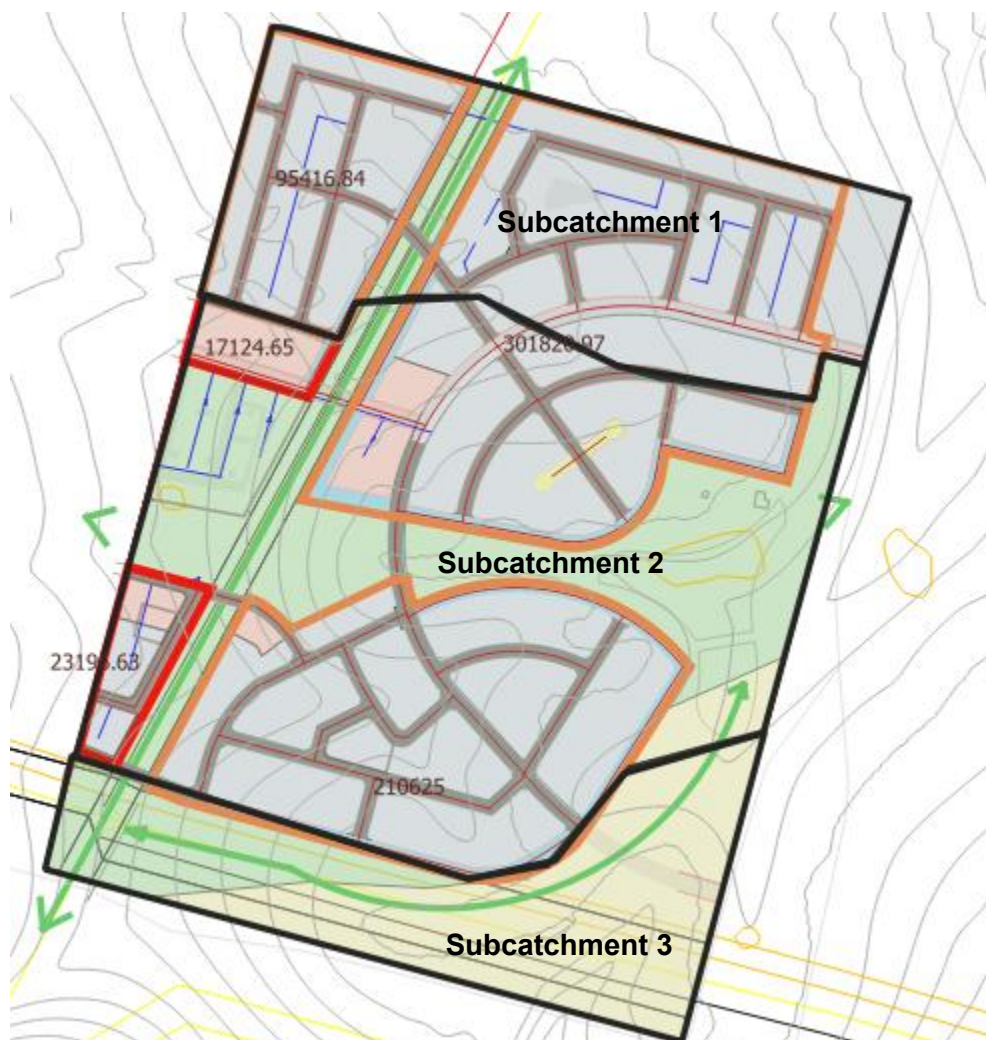


Diagram 3: Developed Subcatchments

Based on the existing flood characteristics, it is suggested to design “offline” stormwater management facilities to mitigate/treat stormwater locally generated by the Site while conveying the external flow through the Site by appropriate civil conveyance design. Specifically, the sheet flow across the northwest corner of the Site can be captured by a perimeter swale along the western boundary and conveyed around the Site to the northern point of discharge. Stormwater runoff can also be conveyed within the proposed road reserves via kerb and channel, and proposed drainage system. The existing waterways delineating the middle and southern sub-sites are suggested to be retained with minor modification to allow the conveyances of the external flows.

The benefit of implementing offline management facilities is that the sizes of facilities, such as detention basins and wetlands, can be minimised to account for Site discharge only by avoiding conveyance of all external flows through the proposed mitigation/treatment train. Inflow from significant waterways, such as Stringybark Creek, can be difficult to detain through on-site detention facilities due to volume requirements.

In this case, an end-of-line combined wetland (for water quality) and detention basin (for water quantity) was conceptually designed for each of the three sub-sites, as detailed in below sections.

The sub-site area and further breakdown are summarised in Table 2, based on the following assumptions:

- 1% AEP flood extent (depth > 50 mm) within the site are reserved area for floodway (non-developable) to convey external flood. The rest area of each sub-site will be conveyed to detention basin/wetland (Contributing Area);
- Powerline reserve area in S3 is considered as non-developable but needs to contain the detention basin/wetland;
- Zones have percentage impervious as outlined in Table 3.

Table 2: Site Breakdown

Zones	Total Development Area (ha)	Subcatchment 1 Area (ha)	Subcatchment 2 Area (ha)	Subcatchment 3 Area (ha)
R1 - General Res	63.5	28.2	35.3	0.0
R3 - Medium Density	4.6	0.0	4.6	0.0
RE1 - Public Rec	22.2	0.0	16.8	5.4
C2 - Enviro Conservation	13.5	0.0	0.0	13.5
Electrical easement	6.5	1.9	4.6	0.0
Total	110.4	30.1	61.3	18.9

Table 3: Impervious Areas

Zones	Total Impervious Area	Effective Impervious Area (ha)				
		Area factor	Development	Sub-catchment 1	Sub-catchment 2	Sub-catchment 3
R1 - General Res	55%	0.6TIA	21.0	9.3	11.7	0.0
R3 -Medium Density	60%	0.6TIA	1.7	0.0	1.7	0.0
RE1 - Public Rec	20%	0.6TIA	2.7	0.0	2.0	0.6
C2 - Enviro Conserv	0%	-	0.0	0.0	0.0	0.0
Electrical easement	0%	-	0.0	0.0	0.0	0.0
Total			25.3	9.3	15.3	0.6

5.2. Stormwater Quality

Assessment of the quality of stormwater discharge from the developed Site was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) by eWater. It allows the analysis of stormwater quality and the assessment of the efficiency of the treatment facilities. The operation of MUSIC requires climatic forcing, i.e., rainfall and potential evapotranspiration (PET), and geological parameters.

MUSIC source node types have been assumed based on NSW MUSIC Modelling Guidelines (Aug 2015) as specified in Table 4.

Table 4: Source Node Types

Zones	MUSIC
R1 - General Res	Residential
R3 - Medium Density	Residential
RE1 - Public Rec	Residential
C2 - Environ Conserv	Forest
Electrical easement	RuralResidential

5.2.1. Climatic Inputs

Wagga Wagga AMO is one of the closest rain gauges to the Site with high quality pluviograph records. Ten (10) years of pluviograph data from 01/01/1990 to 01/01/2000 recorded by Wagga Wagga AMO station were used together with the monthly average PET data at the same location.

5.2.2. Geology

The default soil parameters from MUSIC were adopted as shown in Table 5.

Table 5: Soil Characteristics for the Study Site

Parameter	Urban Residential
Rainfall Threshold (mm/day)	1
Soil Capacity (mm)	120
Initial Storage (%)	25
Field Capacity	80
Infiltration Capacity coefficient a	200
Infiltration Capacity coefficient b	1
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Base flow Rate (%)	5
Daily Deep Seepage Rate (%)	0

5.2.3. Model Structure

A water quality model was set up in MUSIC, as shown in Diagram 4. Each zone within each sub-catchment in the development area was defined as a source node and connected to an end-of-line wetland. Total Area and Effective impervious areas for each source node were implemented as shown in Table 2 and Table 3 with node types as specified in Table 4.

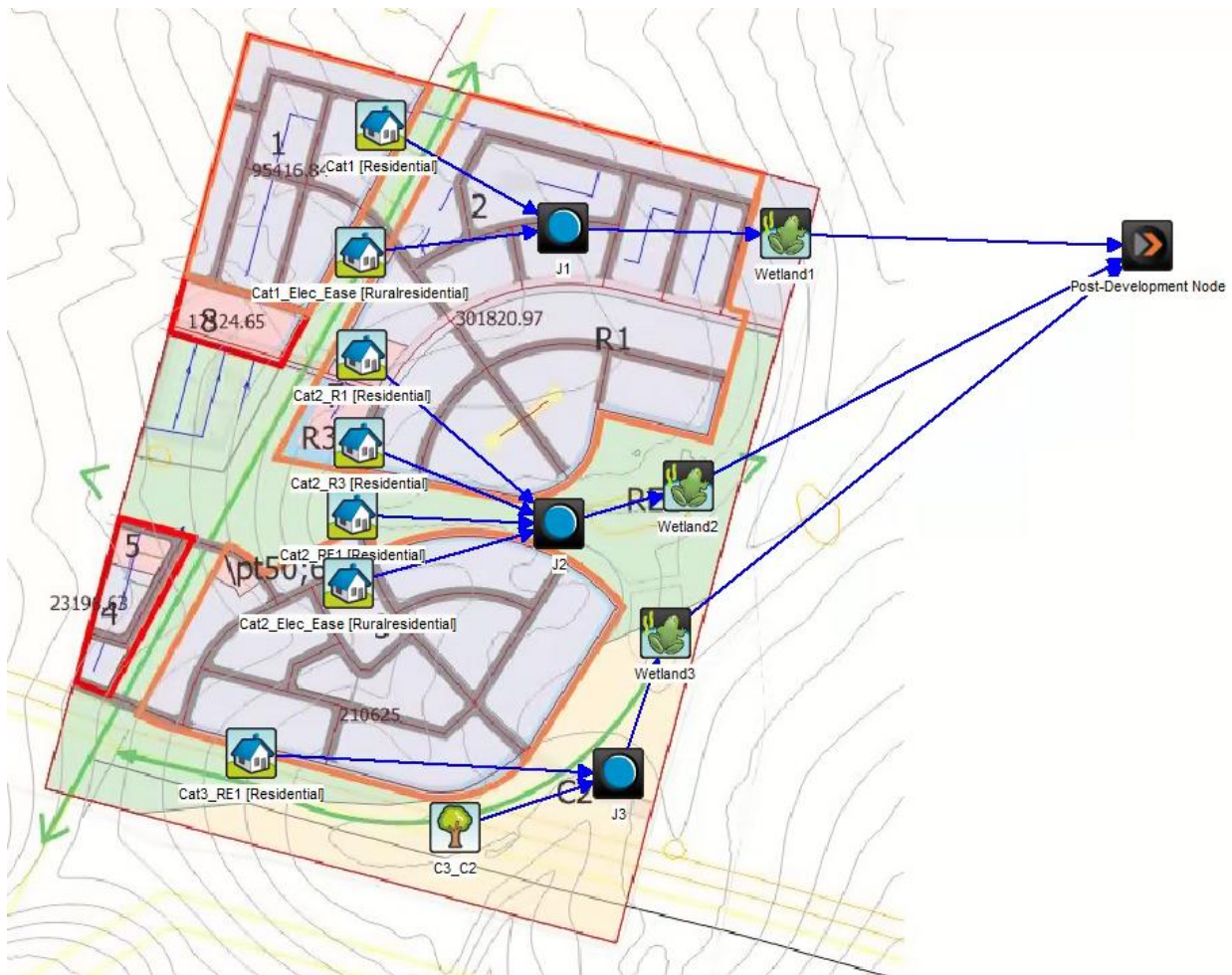


Diagram 4: MUSIC Network Schematic

5.2.4. Modelling Results

Each wetland was optimised to ensure that water quality from the developed Site meets stormwater quality objectives. The following rules as suggested by WaterNSW were applied while optimising the wetlands:

- The constructed wetland should then be modelled with an inlet pond with a volume more than 10% of the wetland's permanent pool volume.
- Extended detention should not exceed 0.5 m unless it can be shown that a higher depth is achievable without flooding impacts.
- The permanent pool volume in the constructed wetland should not exceed the surface area (at permanent pool level) multiplied by one metre unless more detailed information is provided of the wetland configuration.
- Exfiltration shall be 0 mm per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).
- The evaporative loss shall be the default value of 125% of the relevant potential evapotranspiration (PET) value.
- The notional detention time of the wetland should typically be between 48 to 72 hr to ensure optimal treatment of nutrients.

The proposed wetland configurations and the stormwater quality treatment efficiencies are summarised in Table 6 and Table 7, respectively.

Table 6: Wetland Requirements

Parameter	Wetland 1 (Site 1)	Wetland 2 (Site 2)	Wetland 3 (Site 3)
Low Flow By-pass (m ³ /s)	0	0	0
High Flow By-pass (m ³ /s)	100	100	100
Inlet Pond Volume (m ³)	350	350	250
Surface Area (m ²)	6,200	6,200	4,300
Extended Detention Depth (m)	0.5	0.5	0.5
Permanent Pool Volume (m ³)	2,480	2,480	1,720
Initial Volume (m ³)	1,240	1,240	860
Exfiltration Rate (mm/hr)	0	0	0
Evaporative Loss as % of PET	125	125	125
Equivalent Diameter (mm)	90	90	80
Overflow Weir Width (m)	3	3	3
Notional Detention Time (hr)	64.5	64.5	56.6

Table 7: Stormwater Quality Treatment Efficiency

Parameter	Reduction (%)				Objective (%)
	Wetland 1	Wetland 2	Wetland 3	Total	
Total Suspended Solids (kg/yr)	94.5	78.8	96.2	84.4	60
Total Phosphorus (kg/yr)	79.8	64.2	80.8	69.8	45
Total Nitrogen (kg/yr)	56	40.7	64.7	46.4	40
Gross Pollutants (kg/yr)	100	100	100	100	90

5.3. Stormwater Quantity

Assessment of the quantity of stormwater discharge from the developed Site was undertaken by establishing a local hydrological model in XPRAFTS. It allows the quantification of Permissible Site Discharges (PSD) and the optimisation of the detention basins. The following sections summarises the model establishment, PSD estimation, detention basin optimization and mitigation results.

5.3.1. XPRAFTS Parameter Identification

As the Lake Albert WBNM was calibrated and validated through MOFFRMS (Reference 8), most of the parameters adopted in the WBNM were directly implemented for the XPRAFTS. This includes the implementation of:

- Probability Neutral Burst Initial Losses (PNBIL) from ARR Data Hub by applying Storm Initial Losses from ARR Data Hub and back-calculated Pre-burst (Storm IL - PNBIL);
- Continuous Losses adjusted by the multiplier 0.4;
- The ARFs updated to the catchment area draining to Stringybark Creek;

The catchment (hillslope) and river routing are modelled through different methods in WBNM and XPRAFTS, therefore, the calibrated routing parameters from WBNM cannot be directly applied to XPRAFTS. To identify the routing parameters, a local calibration model was set up in XPRAFTS with exactly the same sub-catchments as in WBNM as shown in Diagram 5, and the XPRAFTS model was calibrated to the WBNM model at the same location (total outflow from sub-catchment LA_101g).

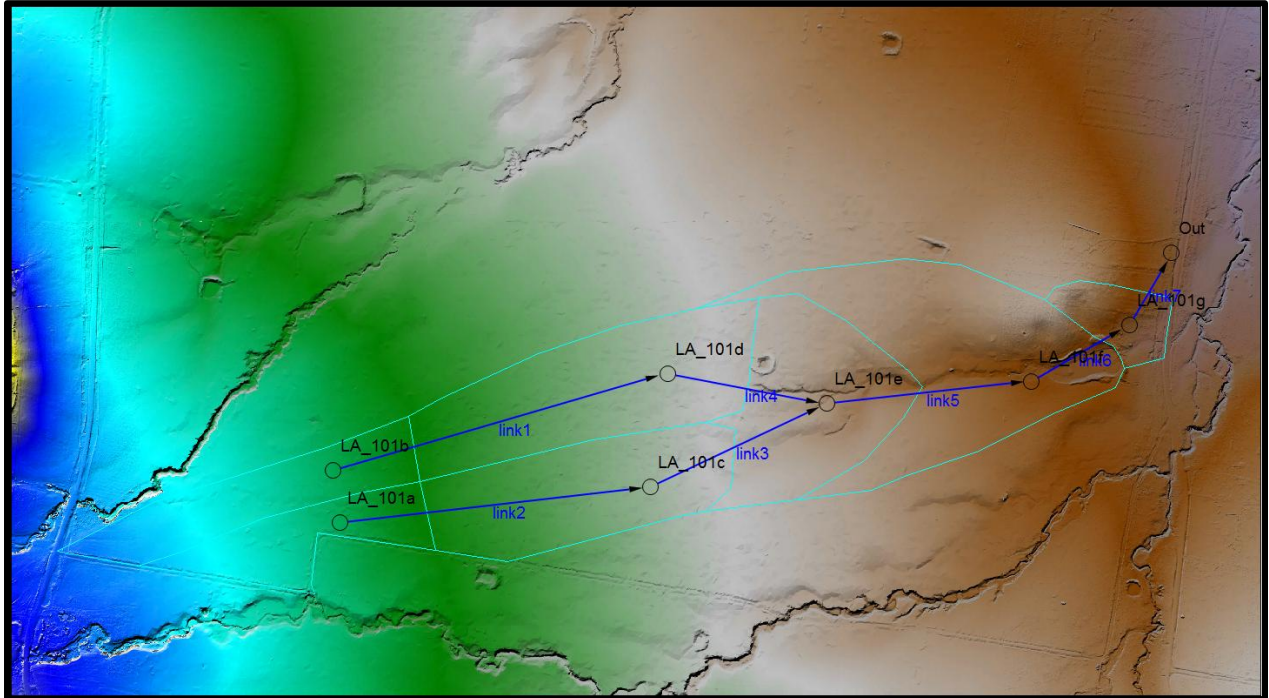


Diagram 5: The Local Calibration XPRAFTS Model Schematic

5.3.1. Existing Site Conditions

A site-based local DRAINS model was established, as shown in Diagram 6. The fraction impervious for each sub-site was set to 0% as shown in Table 2 to represent the existing conditions.

An ensemble of storm events was used to simulate 20% to 1% AEP events and evaluate the stormwater peak discharges generated by the contributing catchment areas.

The critical duration for each design event probability and each sub-catchment may vary depending on a number of conditions. Therefore, to ascertain the critical storm duration impacting the site, the consideration of a number of storm durations is important. For this study, the temporal patterns from 30 min to 12 hr duration for each AEP were analysed. The median temporal patterns were selected and the critical peak discharge rates (i.e., the duration producing the highest peak flow) for all AEPs were simulated and used as PSDs for detention basins design. The PSD for each AEP was determined and tabulated in Table 8.

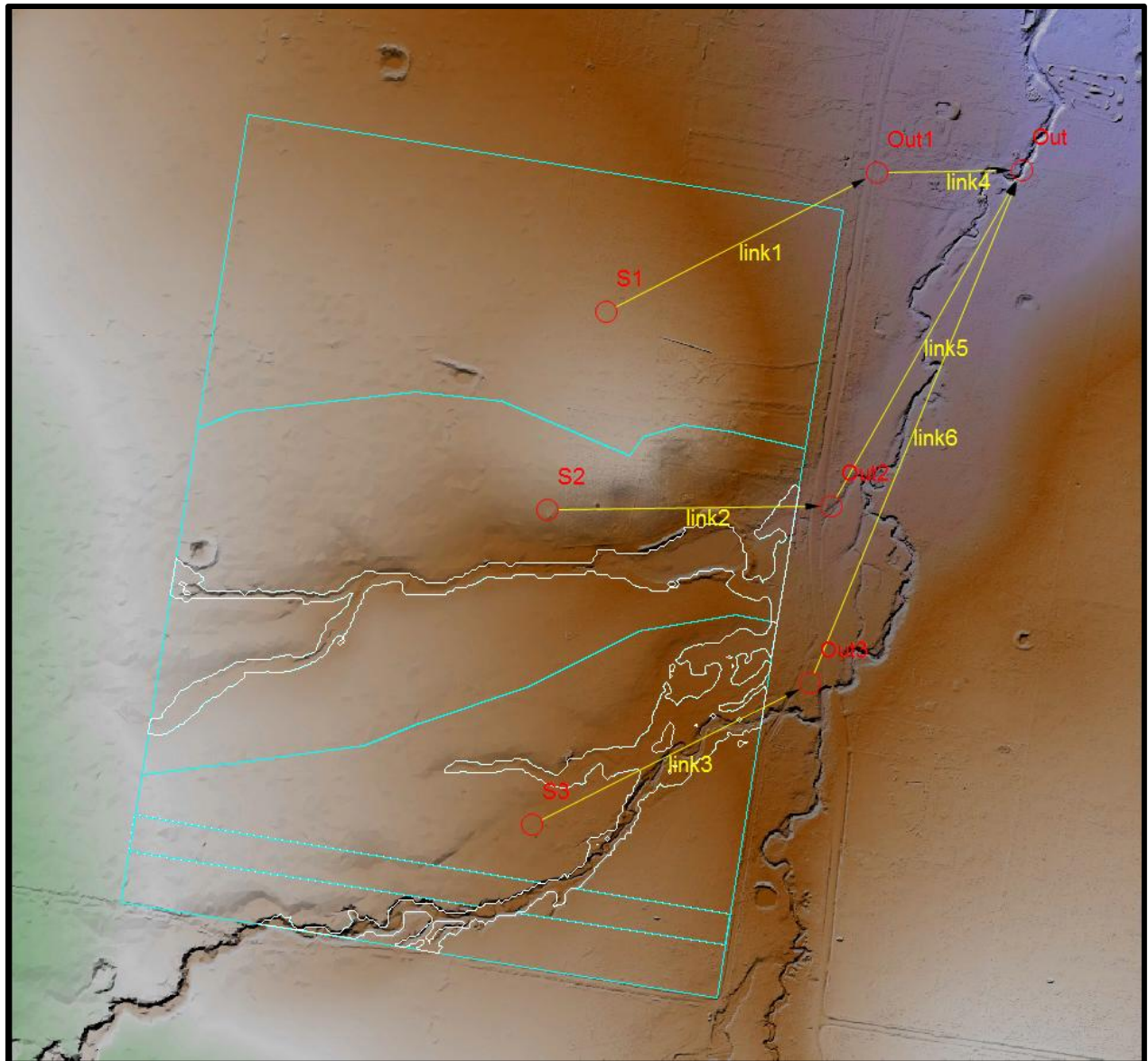


Diagram 6: The Local Site-based DRAINS Model Schematic for Existing Conditions

Permissible Site Discharge has been calculated for two climate scenarios for the year 2041 – 2060.

Table 8: 2041-2060 Permissible Site Discharges (SSP2-4.5)

	S1			S2			S3		
AEP	Critical Peak Discharge (m³/s)	Event Duration		Critical Peak Discharge (m³/s)	Event Duration		Critical Peak Discharge (m³/s)	Event Duration	
1%	4.58	1hr		4.63	1hr		3.90	1hr	
2%	3.64	1hr		3.67	1hr		3.10	1hr	
5%	2.75	1.5hr		2.78	1.5hr		2.34	1.5hr	
10%	2.20	2hr		2.23	2hr		1.87	2hr	
20%	1.57	2hr		1.59	2hr		1.33	2hr	

Table 9: 2041-2060 Permissible Site Discharges (SSP3-7.0)

	S1		S2		S3	
AEP	Critical Peak Discharge (m ³ /s)	Event Duration	Critical Peak Discharge (m ³ /s)	Event Duration	Critical Peak Discharge (m ³ /s)	Event Duration
1%	4.69	1hr	4.73	1hr	3.99	1hr
2%	3.73	1hr	3.75	1hr	3.17	1hr
5%	2.81	1.5hr	2.84	1.5hr	2.39	1.5hr
10%	2.24	1.5hr	2.26	1.5hr	1.90	1.5hr
20%	1.60	1.5hr	1.61	1.5hr	1.36	1.5hr

5.3.2. Developed Site Conditions

The site-based local DRAINS model (RAFTS hydrology) was revised by incorporating three (3) on-site detention basins and adjusting the catchments based on the site layout, as shown in Diagram 7. However, due to the change in catchment area, the third basin was not required to limit flows and has been removed from modelling. The pervious and impervious areas for each sub-site were set according to the values in Table 2 to represent the developed conditions. The median temporal pattern was selected for each duration and each AEP under developed (unmitigated) conditions, which were then used for basin design.

A detention basin was designed on top of each wetland for each sub-site. The conceptual footprint (assumed to be the surface area plus inlet pond area) of each wetland was used as the bottom area for the detention basin. Basin stage-storage relationships were conceptually designed based on the assumed bottom footprints and 1:6 side slope. The basin outlet configurations were adjusted to minimize the requirement for the total footprint of each basin and to ensure that a 'no worsening' of discharge from the developed Site is achieved.

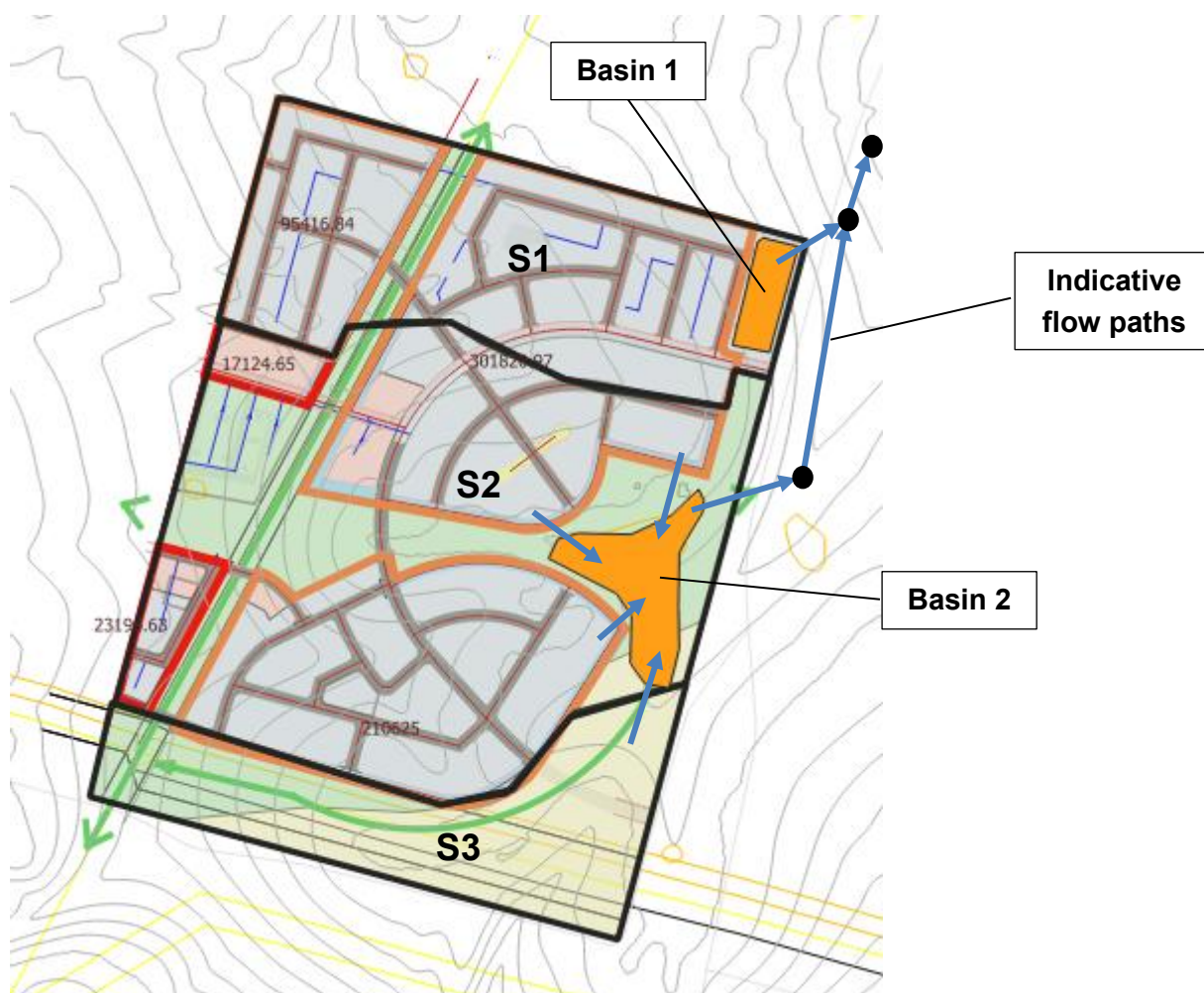


Diagram 7: The Local Site-based Model Schematic for Developed Conditions

The peak discharges from sub-sites under the existing, unmitigated (developed), and mitigated (developed) conditions and the final modelled configurations of the three detention basins are summarised in Table 10 to Table 13. The modelled stage-storage-discharge relationships for the two detention basins are illustrated in Diagram 8.

Table 10: Basin Requirements and Peak Discharges from Basin1 (S1) SSP2-4.5

AEP	Elevation (m AHD)	Area (m ²)	Volume (m ³)	Outlet Configuration		Mitigated Flow (m ³ /s)	Unmitigated Flow (m ³ /s)	PSD (m ³ /s)
				IL (m AHD)	Dimension			
Bottom	215.50	5,000						
20%	216.22		5,030	215.50	1.35 m W × 0.5 m H (culvert)	1.28	4.16	1.57
10%	216.37		6,506				5.49	2.20
5%	216.55		7,769		3.5 m W (spillway)	1.95	6.69	2.75
2%	216.69		9,103			2.66	8.15	3.64
1%	216.83		10,349			3.43	9.62	4.58
Crest	217.50	11,346						

Table 11: Basin Requirements and Peak Discharges from Basin1 (S1) SSP3-7.0

AEP	Elevation (m AHD)	Area (m ²)	Volume (m ³)	Outlet Configuration		Mitigated Flow (m ³ /s)	Unmitigated Flow (m ³ /s)	PSD (m ³ /s)
				IL (m AHD)	Dimension			
Bottom	215.50	5,000						
20%	216.23		5,151	215.50	1.35 m W × 0.5 m H (culvert)	1.29	4.24	1.62
10%	216.42		6,658			1.53	5.6	2.24
5%	216.56		7,923	216.22	3.5 m W (spillway)	2.02	6.82	2.81
2%	216.71		9,260			2.75	8.31	3.76
1%	216.85		10,514			3.54	9.8	4.71
Crest	217.50	11,346						

Table 12: Basin Requirements and Peak Discharges from Basin2 (S2) SSP2-4.5

AEP	Elevation (m AHD)	Area (m ²)	Volume (m ³)	Outlet Configuration		Mitigated Flow (m ³ /s)	Unmitigated Flow (m ³ /s)	PSD (m ³ /s)
				IL (m AHD)	Dimension			
Bottom	216.50	8500						
20%	217.64		14,090	216.50	1.35 m W × 0.5 m H (culvert)	1.74	6.81	2.9
10%	218.00		19,658			2.06	9.16	4.08
5%	218.25		23,803	218.1	3.5 m W (spillway)	2.59	11.2	5.07
2%	218.48		27,849			3.73	14.0	6.71
1%	218.69		31,581			5.39	17.1	8.42
Crest	219.00	20,263						

Table 13: Basin Requirements and Peak Discharges from Basin2 (S2) SSP3-7.0

AEP	Elevation (m AHD)	Surface Area (m ²)	Volume (m ³)	Outlet Configuration		Mitigated Flow (m ³ /s)	Unmitigated Flow (m ³ /s)	PSD (m ³ /s)
				IL (m AHD)	Dimension			
Bottom	216.50	2500						
20%	217.66		14,327	216.50	1.35 m W × 0.5 m H (culvert)	1.75	6.99	2.99
10%	218.02		19,950			2.07	9.38	4.15
5%	218.27		24,101	217.35	3.5 m W (spillway)	2.66	11.5	5.22
2%	218.50		28,113			3.82	14.4	6.91
1%	218.81		32,064			5.21	17.5	8.65
Crest	219.00	20,263						

MODELLED STAGE-STORAGE-DISCHARGE RELATIONSHIPS FOR DETENTION BASINS

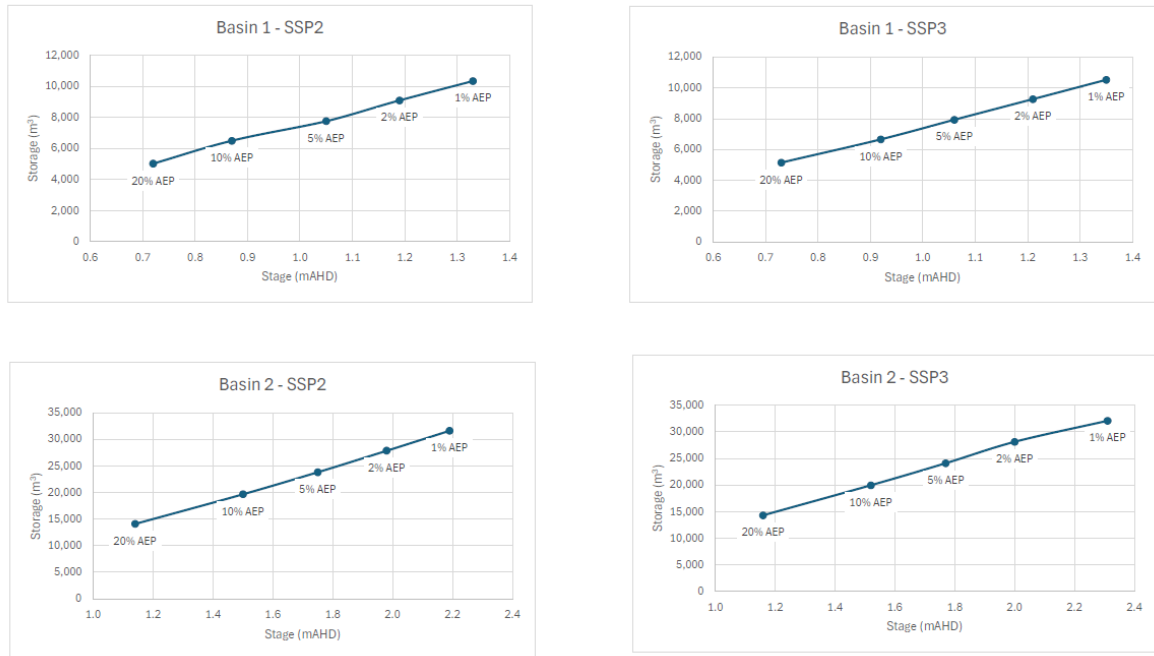


Diagram 8: Modelled Stage-Storage-Discharge Relationships for Detention Basins

5.4. Conceptual Plan for Stormwater Management

The conceptual plan for stormwater management for proposed development is shown on Diagram 7. The indicative locations and footprints of the three combined wetland and detention basins are illustrated.

The existing external sheet flow across the northwest corner of the Site (S1) is proposed to be captured by swale / kerb and channel and conveyed directly towards north. The existing waterways are proposed to be retained to convey external flows through S2 and S3. The last section of each waterway is to be piped and discharged directly to the legal point of discharge (LPOD).

The stormwater generated within the Site will be conveyed to the three combined wetlands and detention basins through internal stormwater drainage systems, and treated / mitigated flows, which meet the SSMP objectives, will be discharged to LPODs.

6. CONCLUSIONS

A review of the existing flooding constraints against the proposed development layout has been undertaken for the 110ha site in Rowan located at the intersection of Rowan Road and Plumpton Road.

The updated flood assessment and Site Stormwater Management Plan demonstrate that the Sunnyside Estate can be developed in a manner that is both resilient and consistent with contemporary floodplain risk management principles.

By refining the underlying hydrologic and hydraulic models with recent 2020 LiDAR, improved grid resolution, and updated representative storm event selection, the study provides a robust and localised understanding of existing, future, and extreme flood behaviour across the site. The study delivers an improved depiction of overland flow patterns and associated flood constraints that inform the development layout and future infrastructure planning. This refinement confirms the key flood pathways associated with Stringybark Creek, the central gully, and upstream overland flows, and shows that while areas of deeper inundation occur along these corridors, the majority of the developable land experiences only shallow flooding or remains flood-free.

The assessment of future climate scenarios further indicates that although climate-driven increases in rainfall intensity may elevate flood levels, these changes are generally modest across most of the site and can be effectively managed through appropriate subdivision design and infrastructure planning. The proposed riparian corridors, open space network, and strategic placement of lots respond directly to these constraints by preserving key flow paths and reducing the exposure of development to unacceptable hydraulic hazards.

The stormwater management strategy, incorporating offline wetlands, detention basins, improved conveyance, and best-practice water quality treatment, demonstrates that site runoff can be mitigated to permissible discharge rates for both current and future climate conditions. The proposed stormwater quality measures exceed the required pollutant reduction targets, supporting positive environmental outcomes and alignment with Council's DCP and engineering guidelines.

Overall, the findings confirm that the Sunnyside Estate can be delivered as a well-planned, flood-resilient neighbourhood. With appropriate implementation of the recommended drainage infrastructure, riparian protection, and development controls, the subdivision can support sustainable growth while maintaining hydraulic performance, managing flood risk, and protecting downstream environments.

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Wagga Wagga City Council, NSW, Australia, 2010
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Wagga Wagga City Council, NSW, Australia, 2017



Figures

FIGURE 1
SITE LOCATION



FIGURE 2
REFINED WBNM LAYOUT

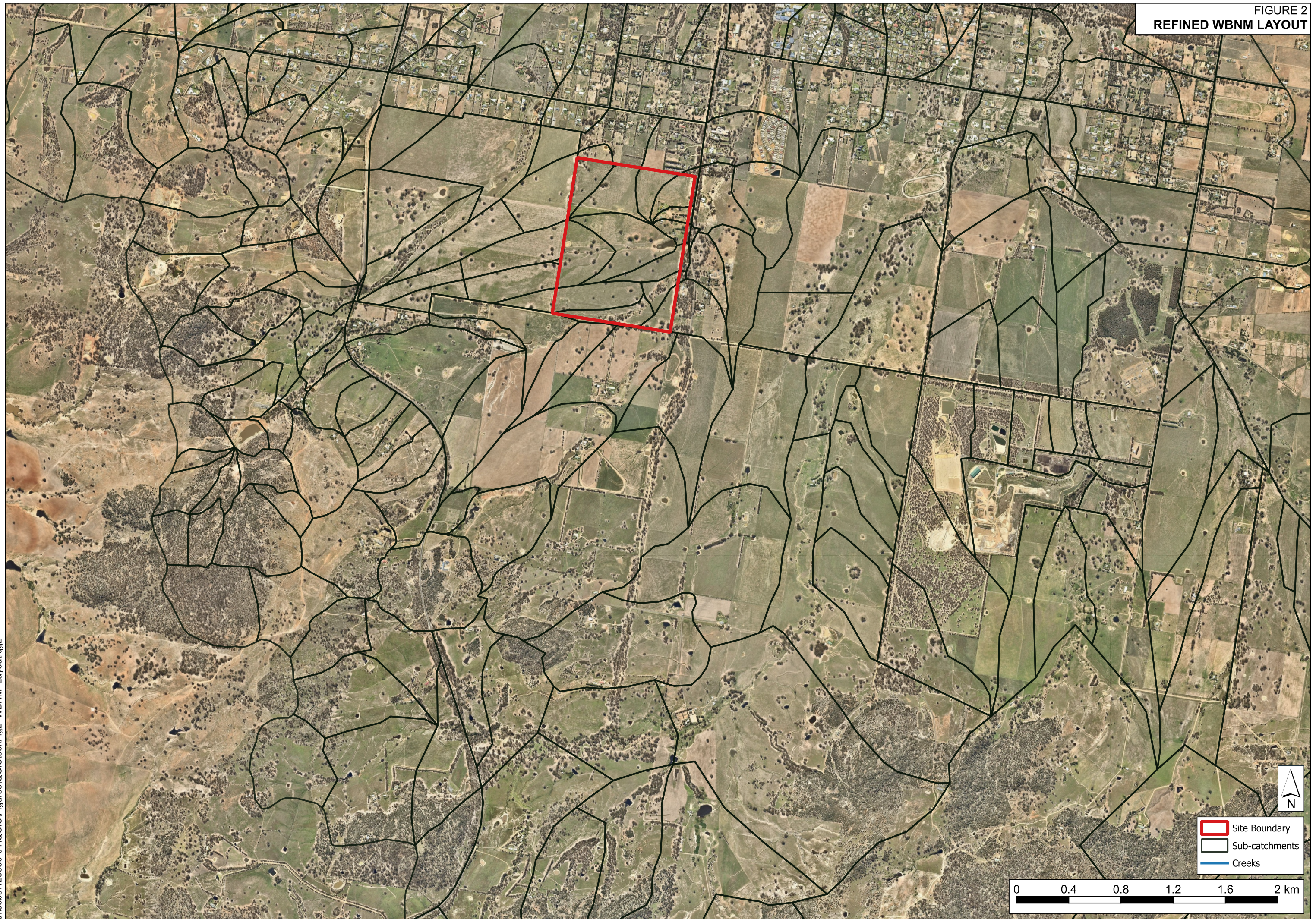


FIGURE 3
DEM COMPARISON
LIDAR 2020 VS 2008

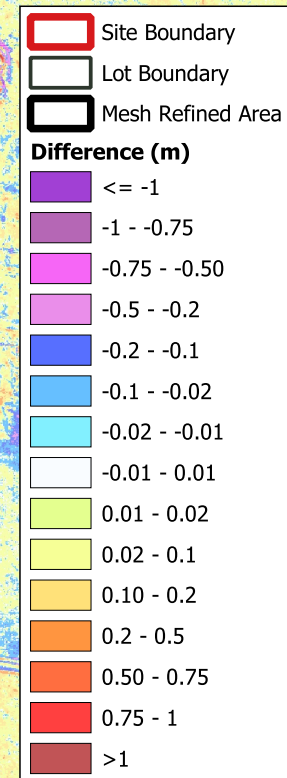
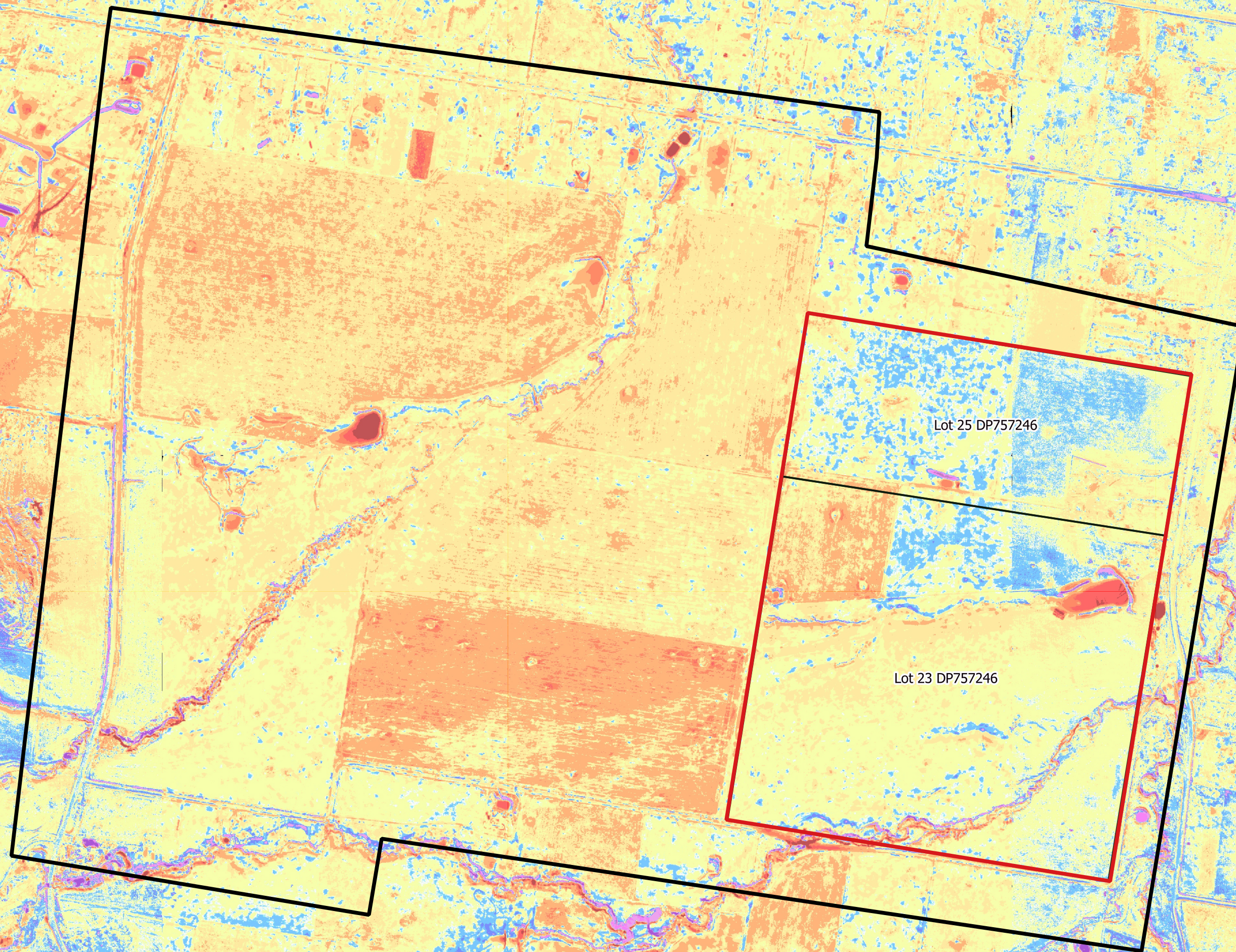
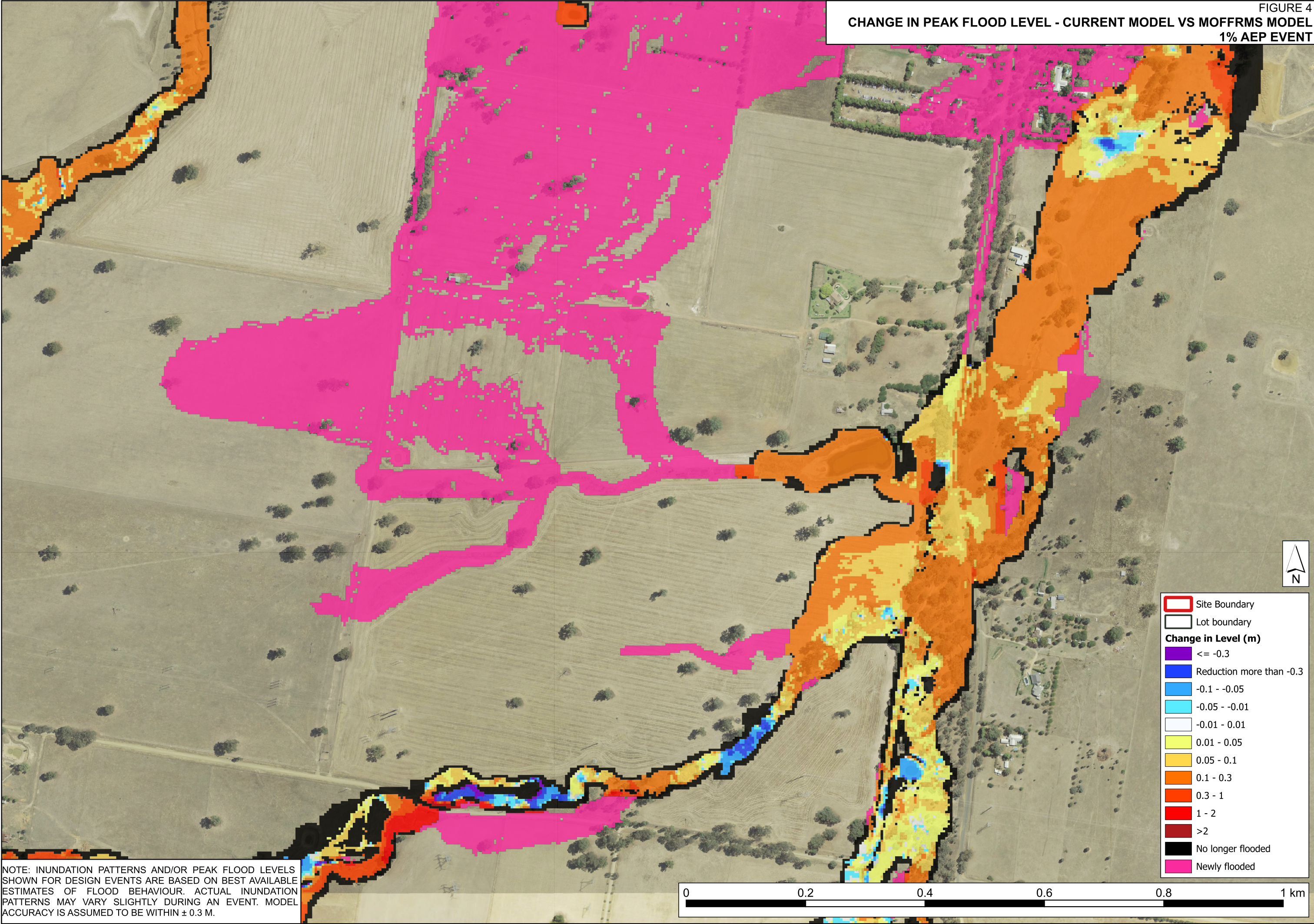


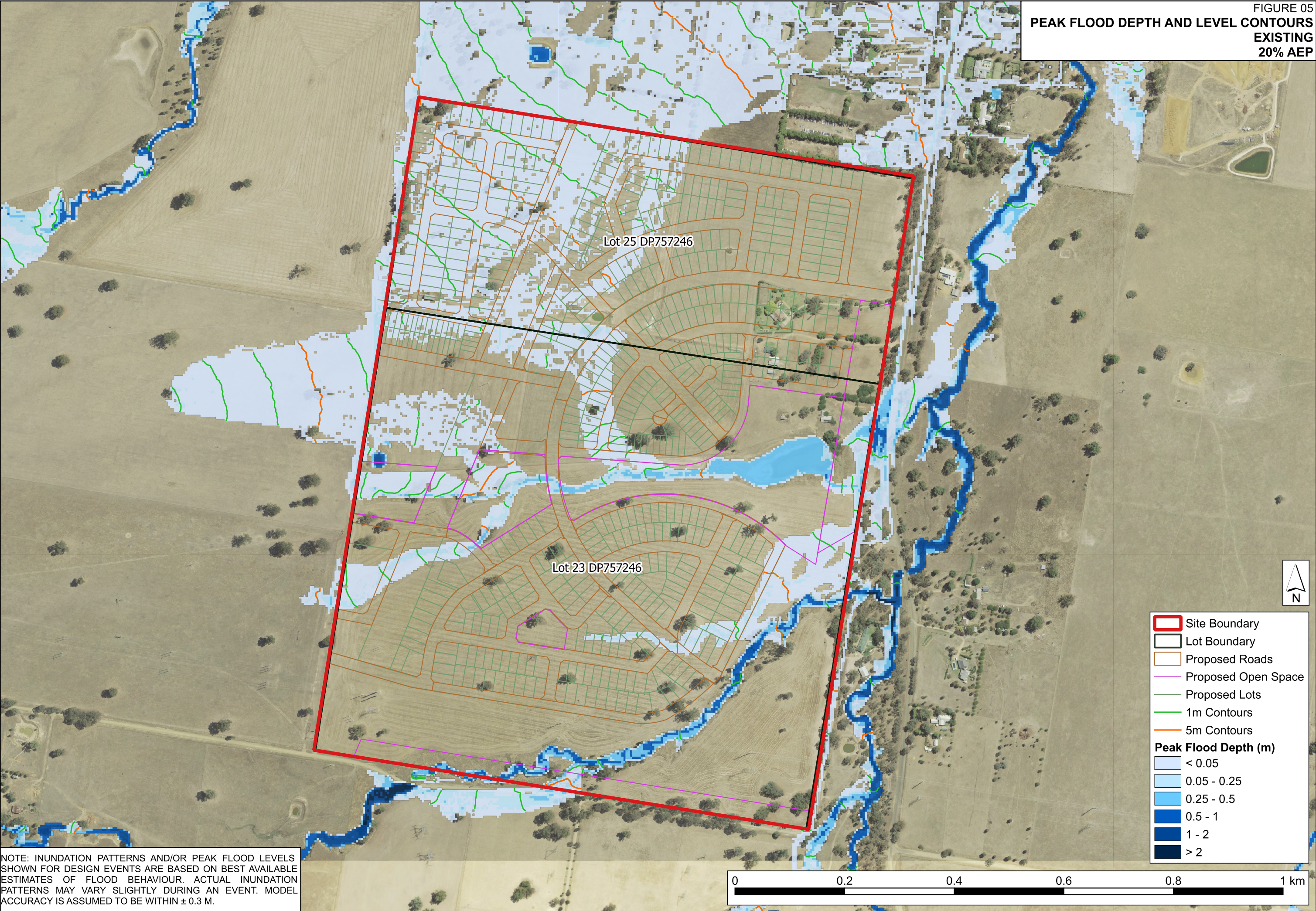
FIGURE 4

CHANGE IN PEAK FLOOD LEVEL - CURRENT MODEL VS MOFFRMS MODEL
1% AEP EVENT



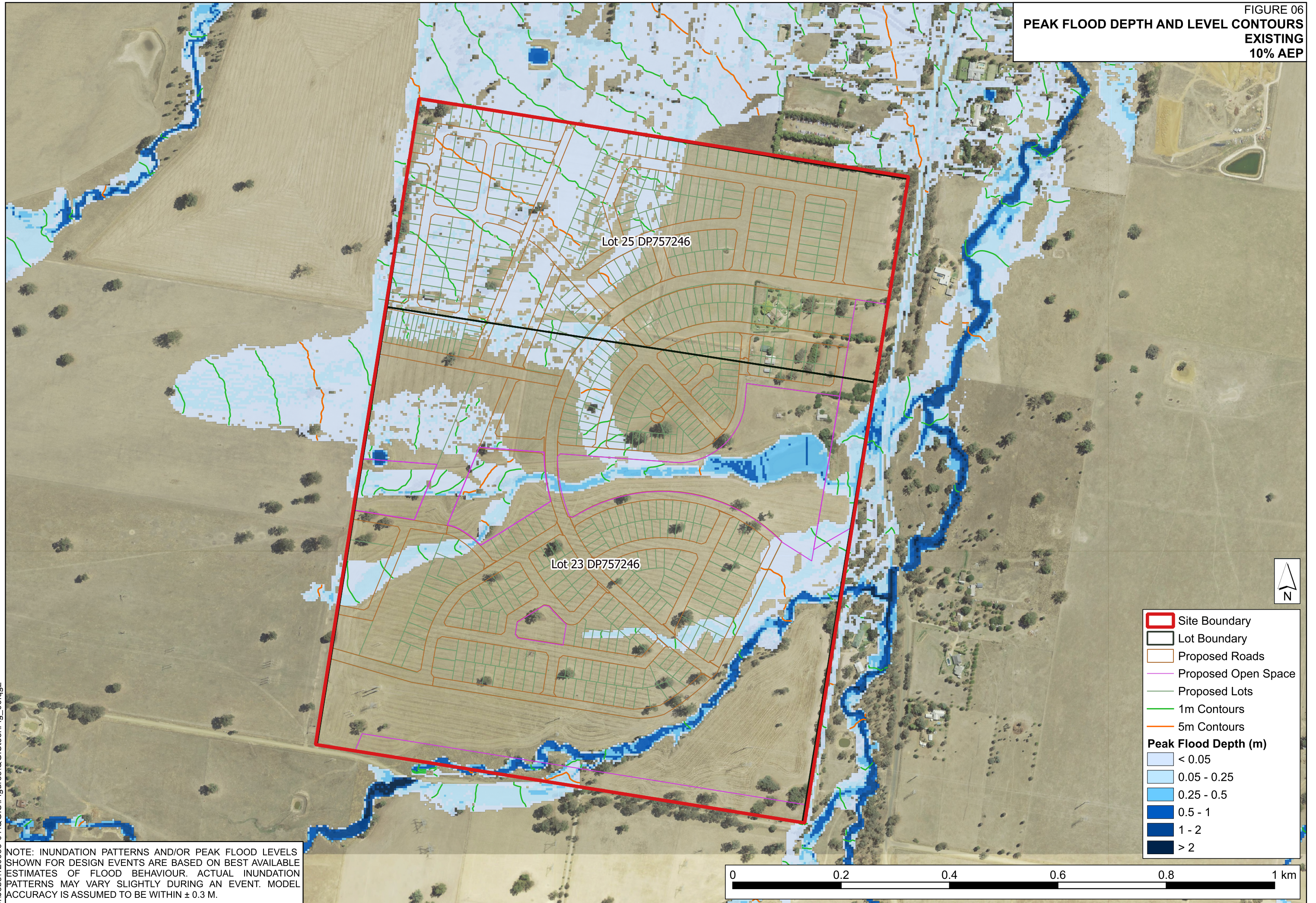
NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 05
PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
20% AEP



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

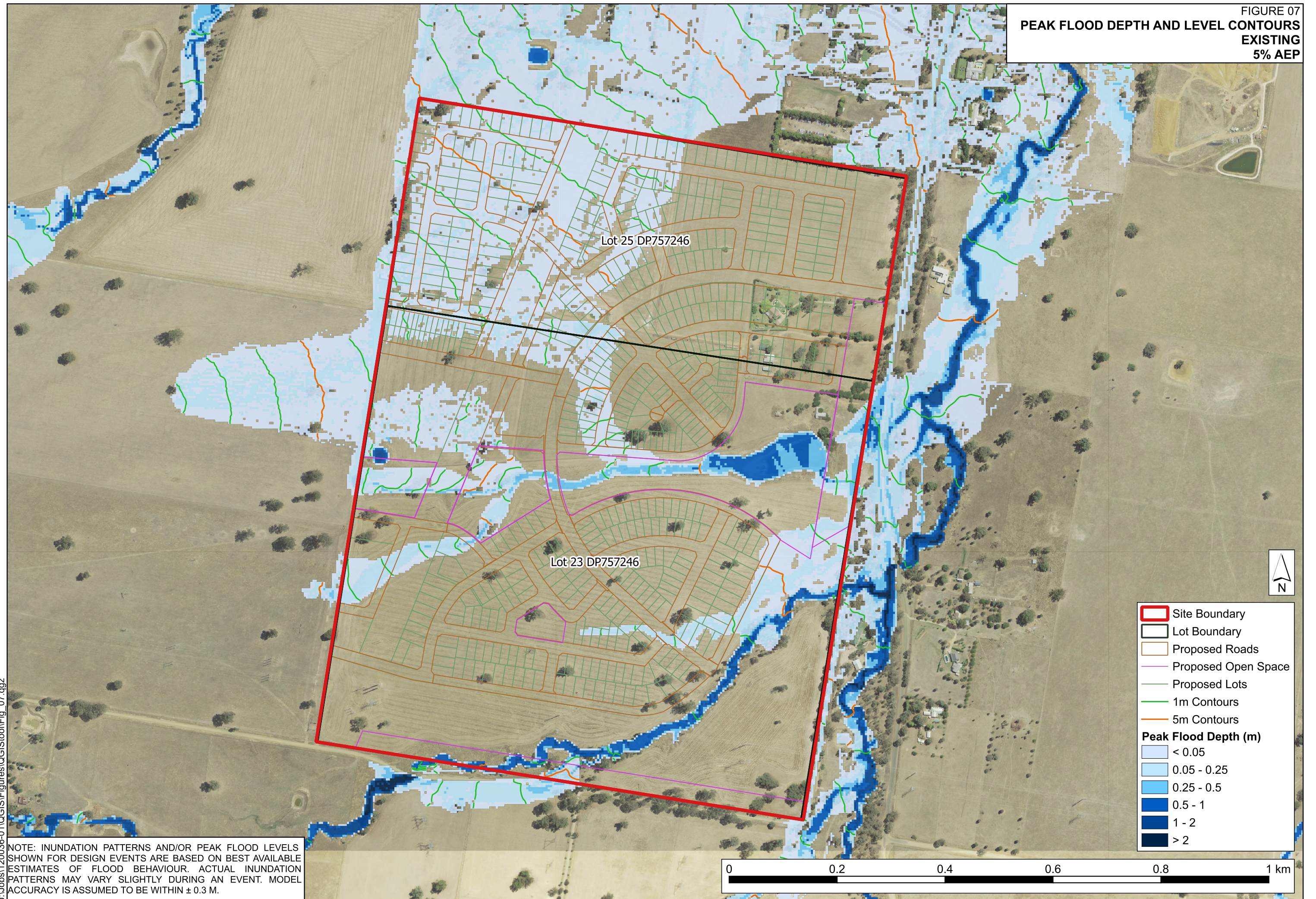
**PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
10% AEP**



- Site Boundary
- Lot Boundary
- Proposed Roads
- Proposed Open Space
- Proposed Lots
- 1m Contours
- 5m Contours
- Peak Flood Depth (m)**
- < 0.05
- 0.05 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 07
**PEAK FLOOD DEPTH AND LEVEL CONTOURS
 EXISTING
 5% AEP**



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 08
PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
2% AEP

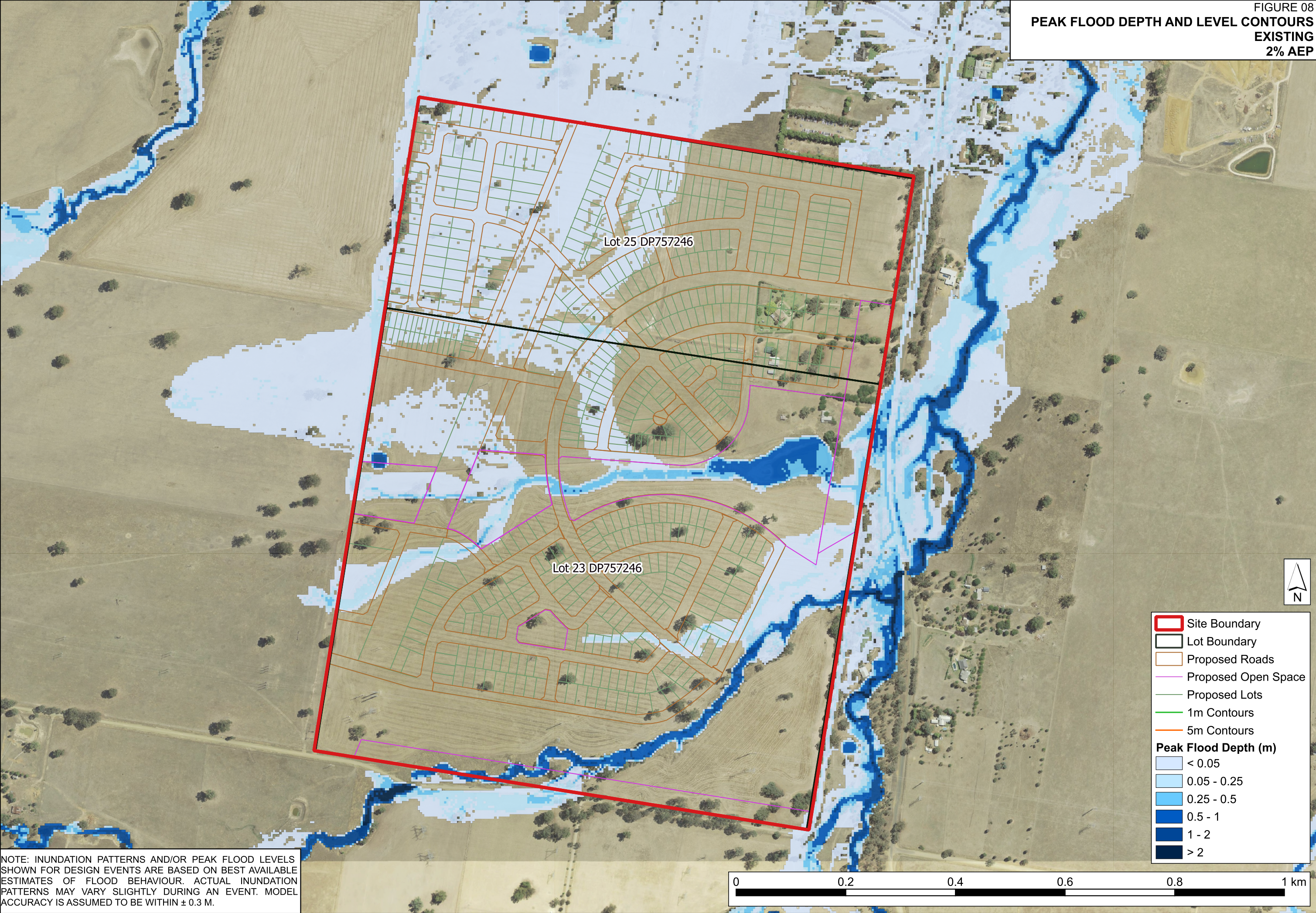


FIGURE 09
PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
1% AEP

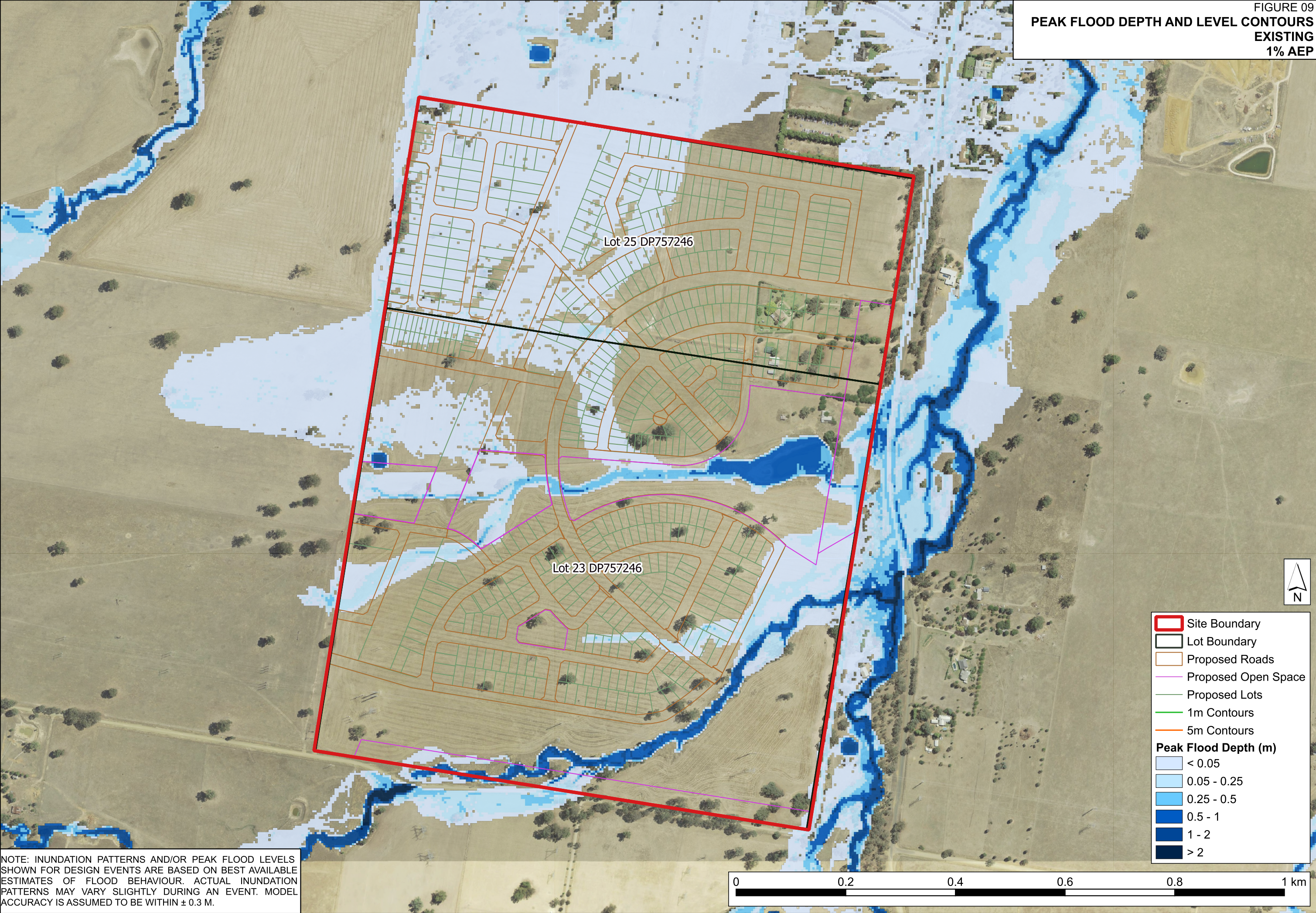
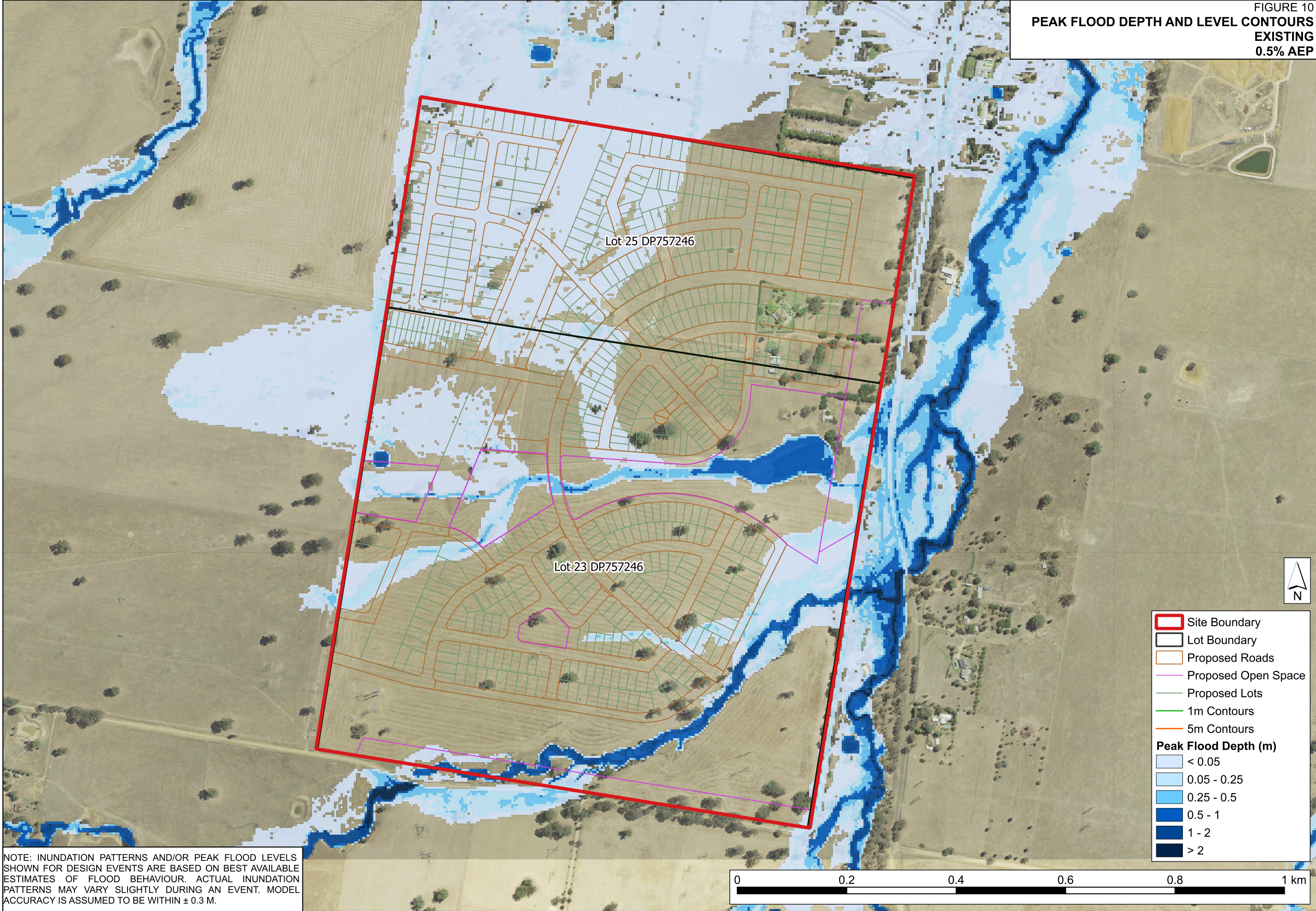
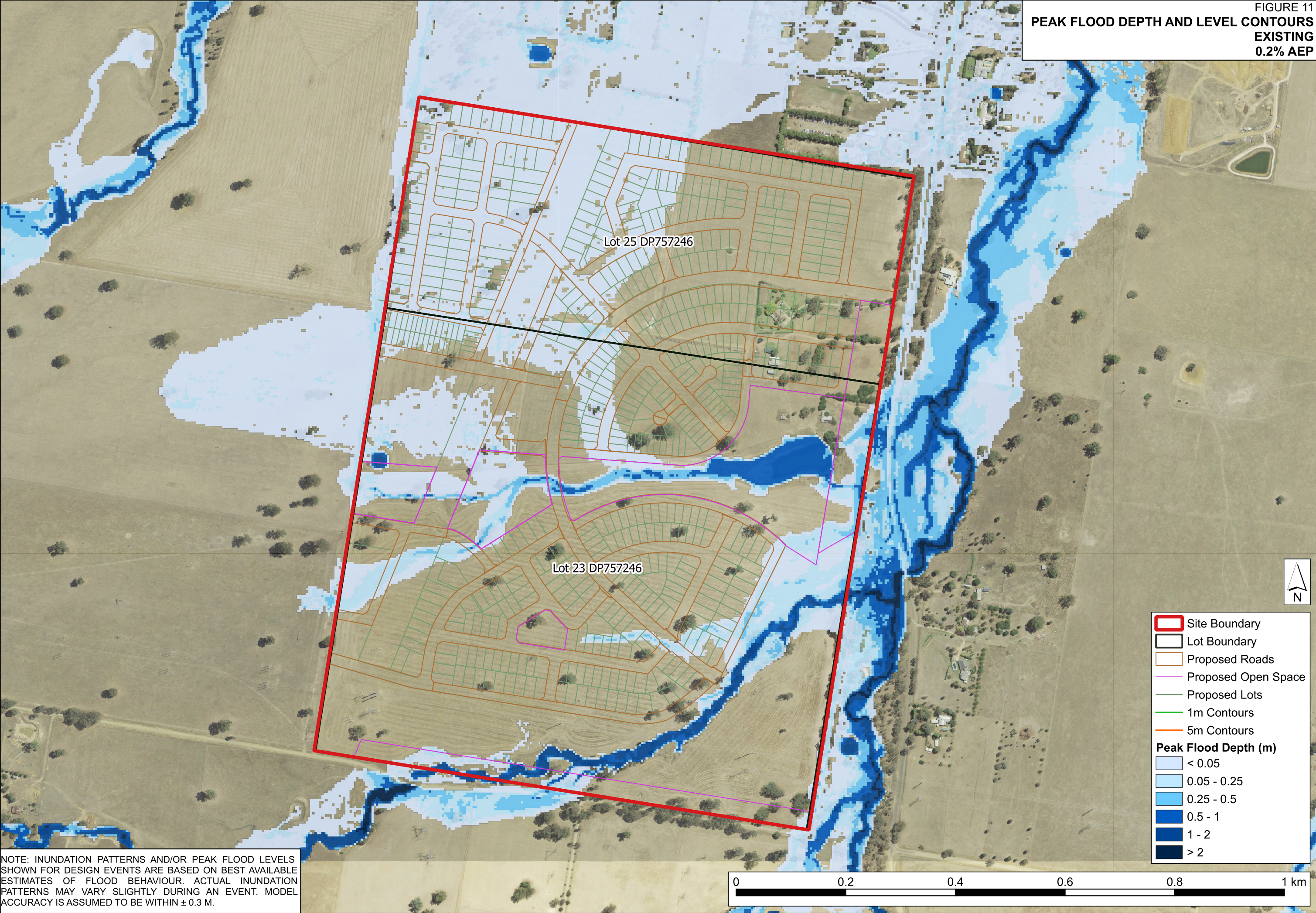


FIGURE 10
PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
0.5% AEP



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 11
PEAK FLOOD DEPTH AND LEVEL CONTOURS
EXISTING
0.2% AEP



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 12
PEAK FLOOD HAZARD
EXISTING
20% AEP

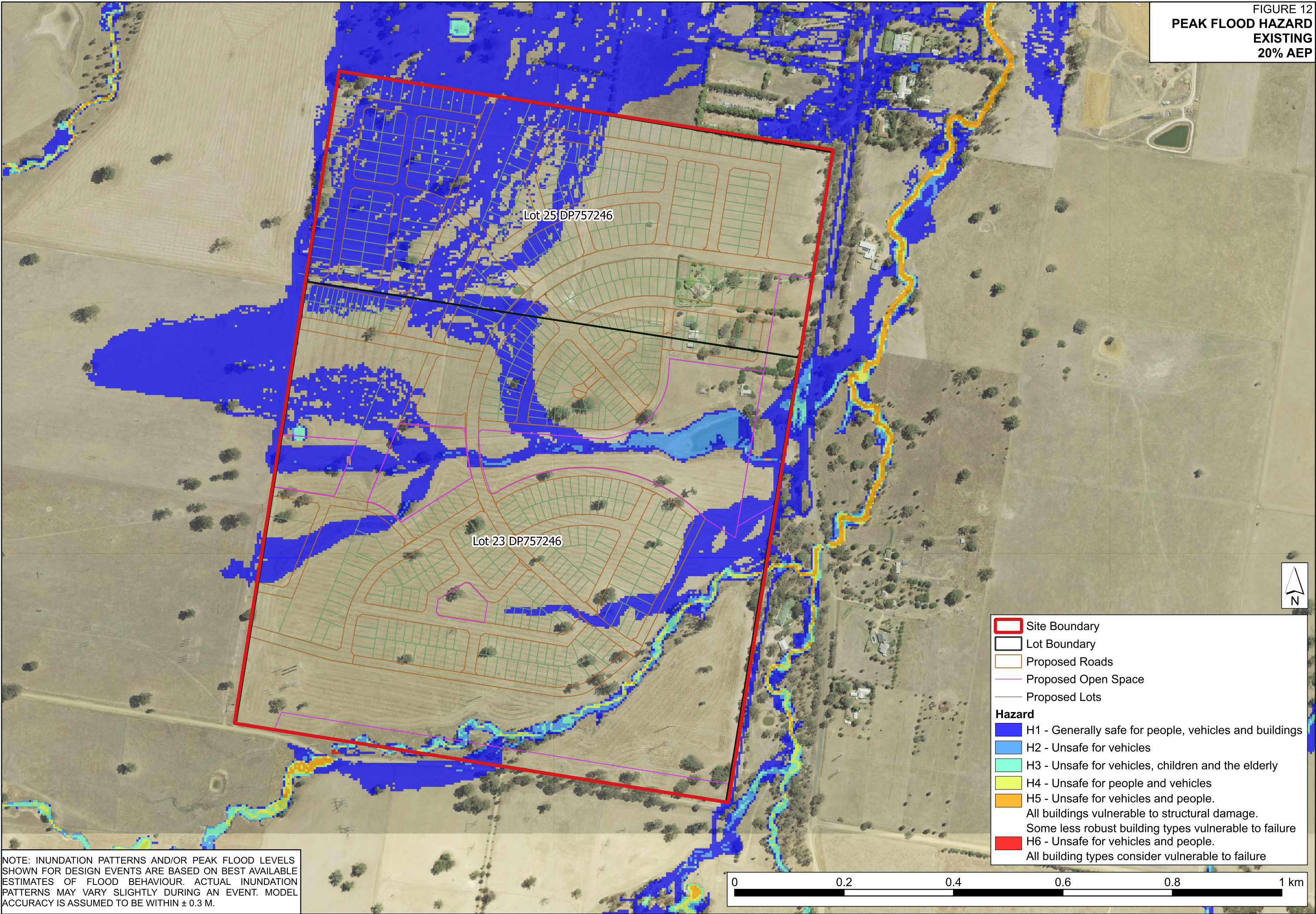


FIGURE 13
PEAK FLOOD HAZARD
EXISTING
10% AEP

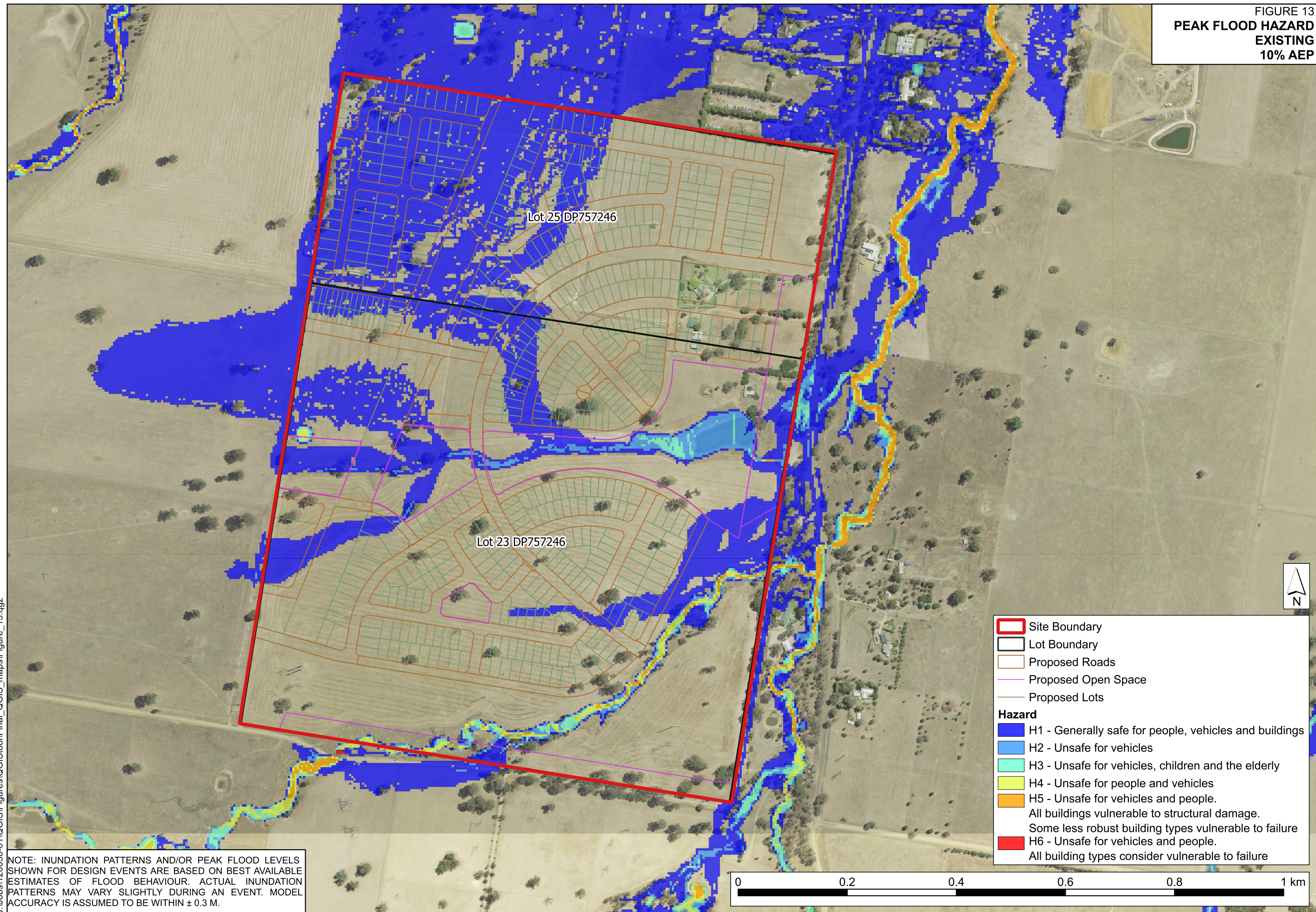
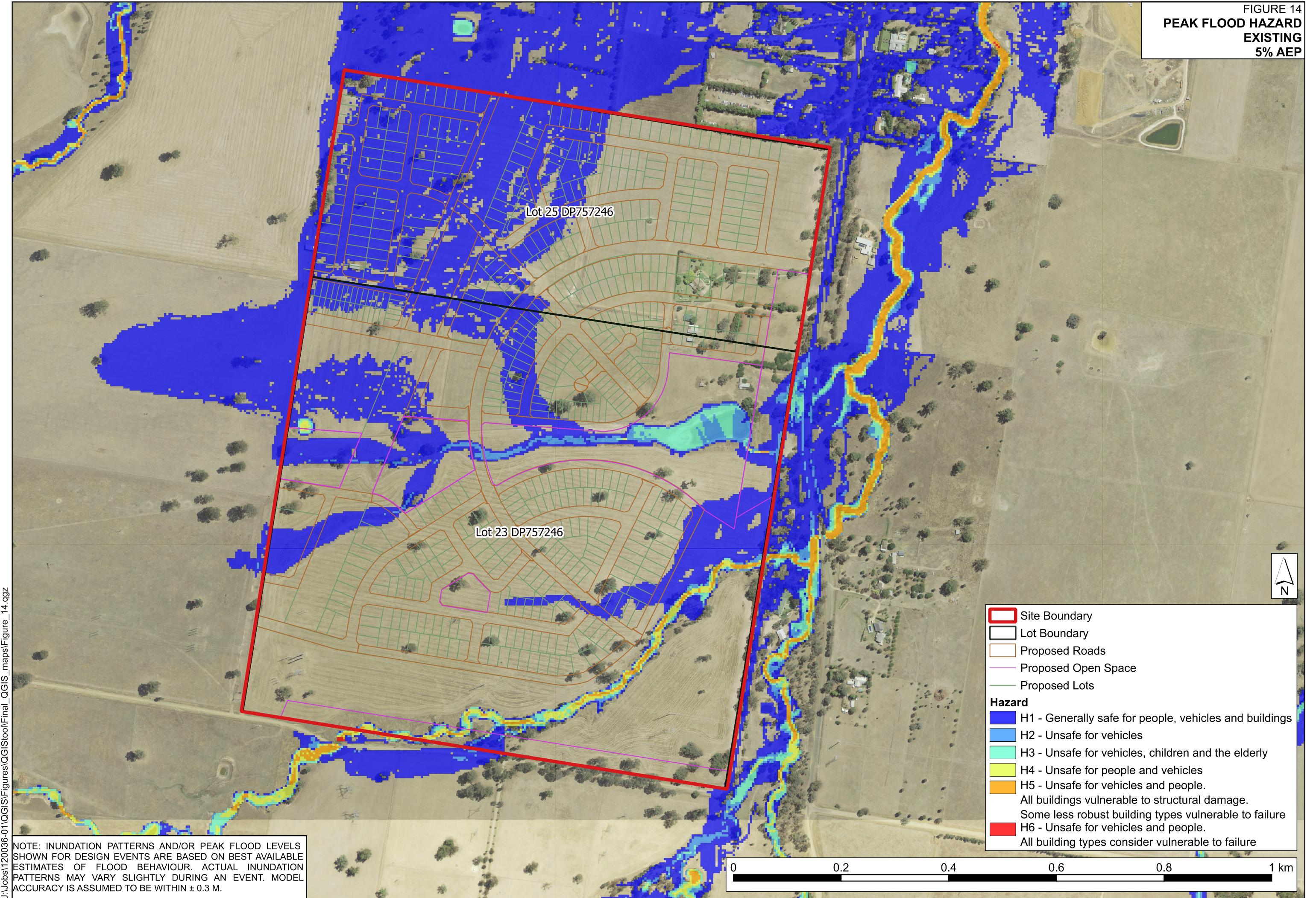


FIGURE 14
PEAK FLOOD HAZARD
EXISTING
5% AEP



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NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 15
PEAK FLOOD HAZARD
EXISTING
5% AEP

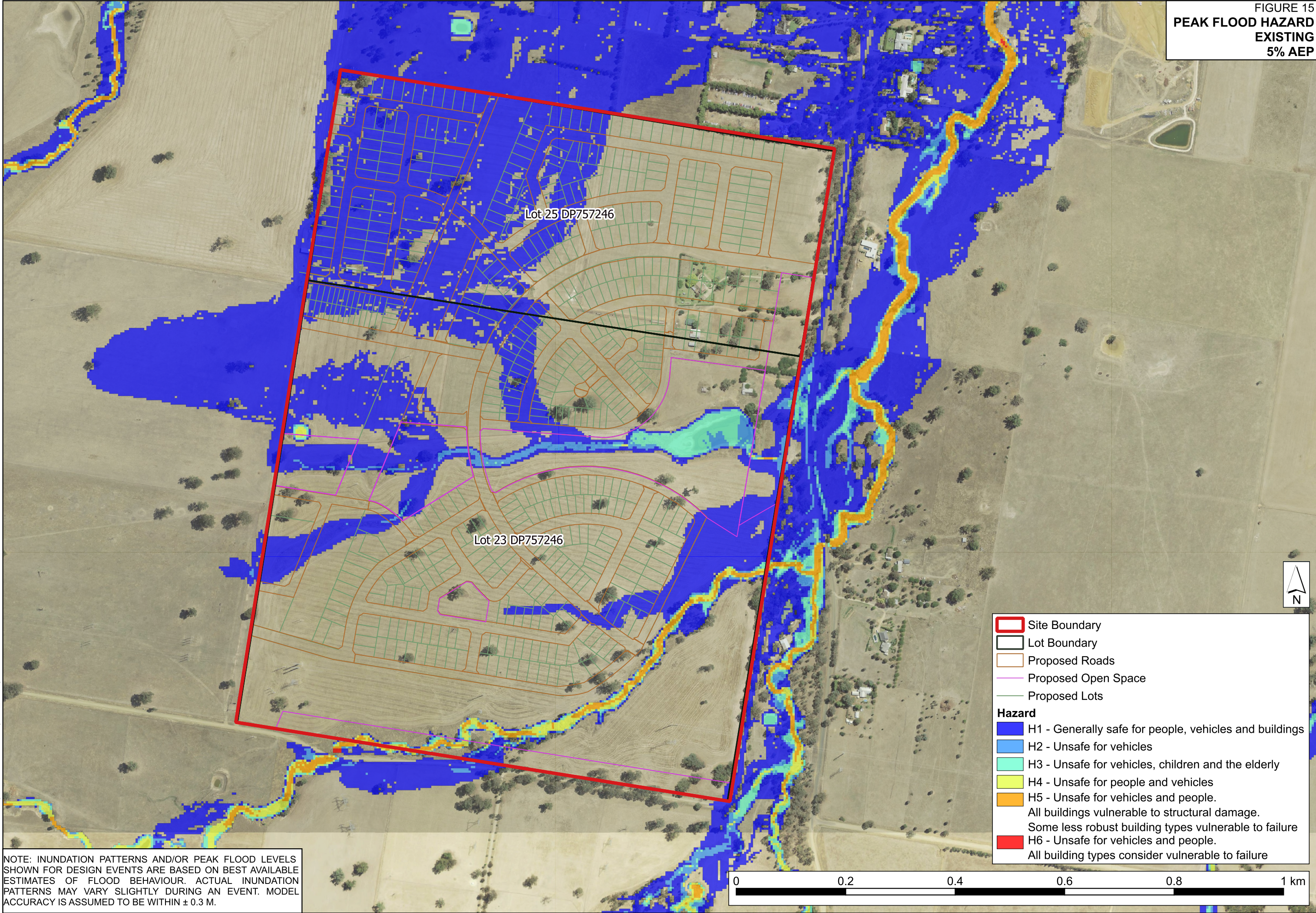


FIGURE 16
PEAK FLOOD HAZARD
EXISTING
1% AEP

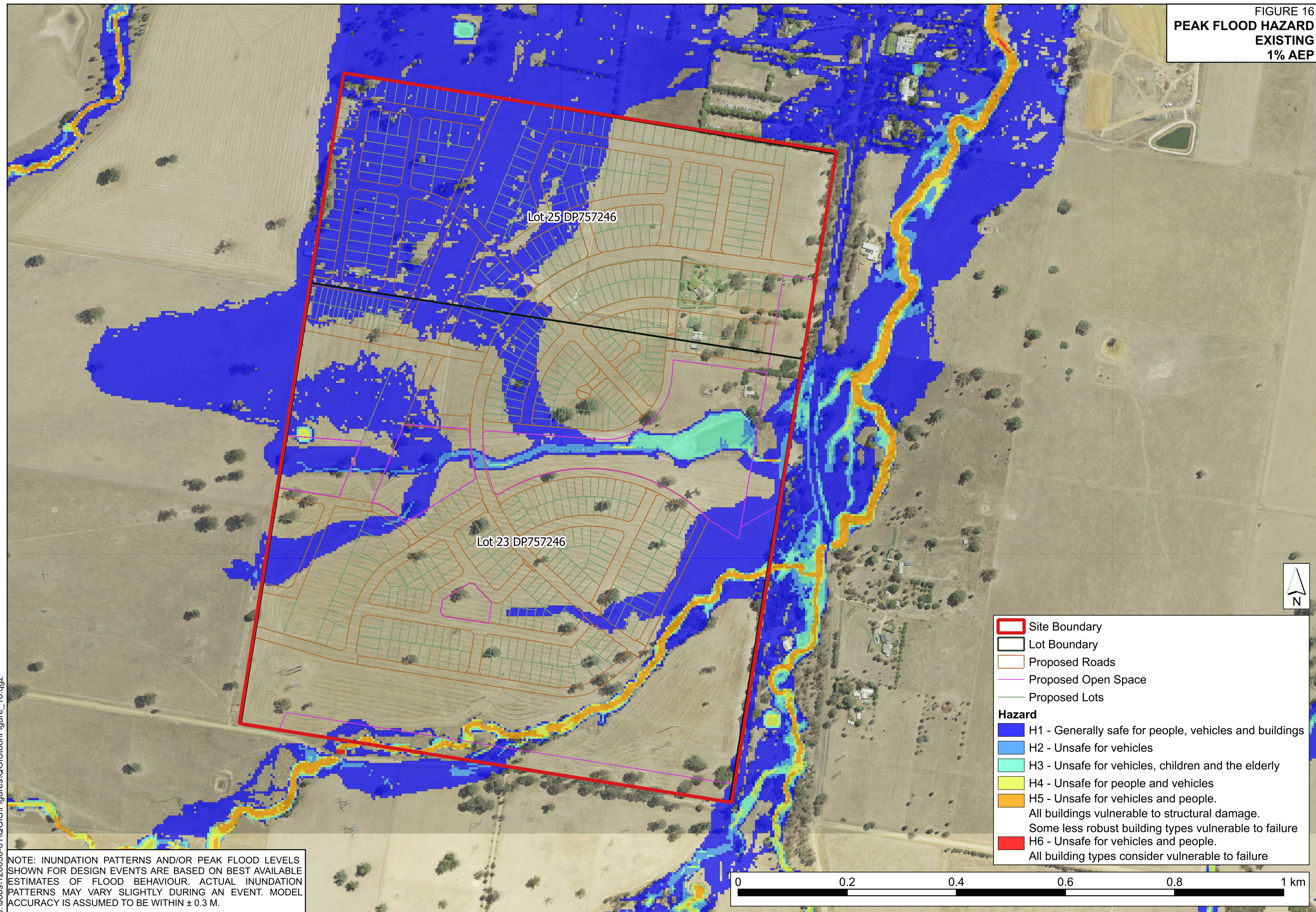
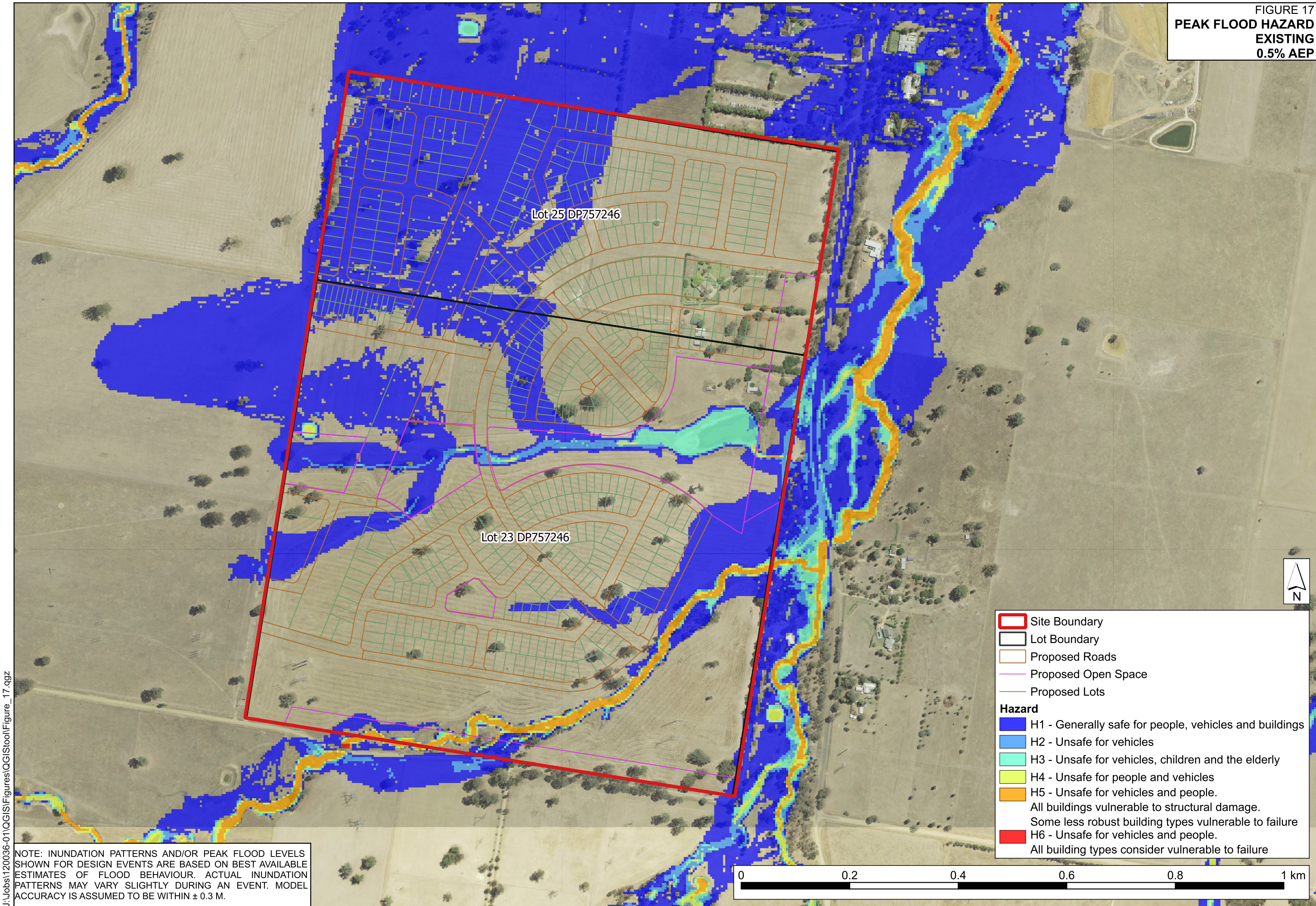


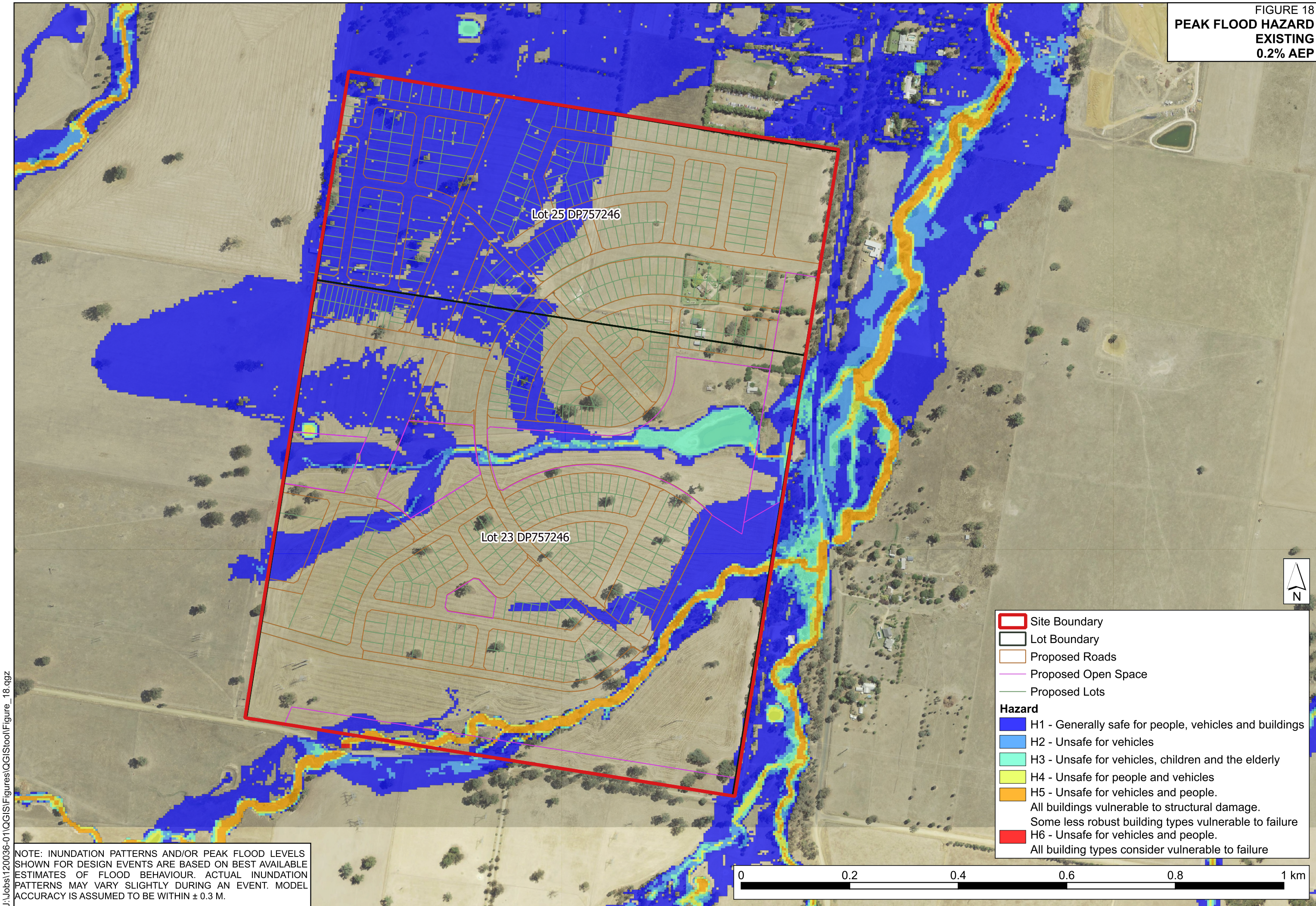
FIGURE 17
PEAK FLOOD HAZARD
EXISTING
0.5% AEP



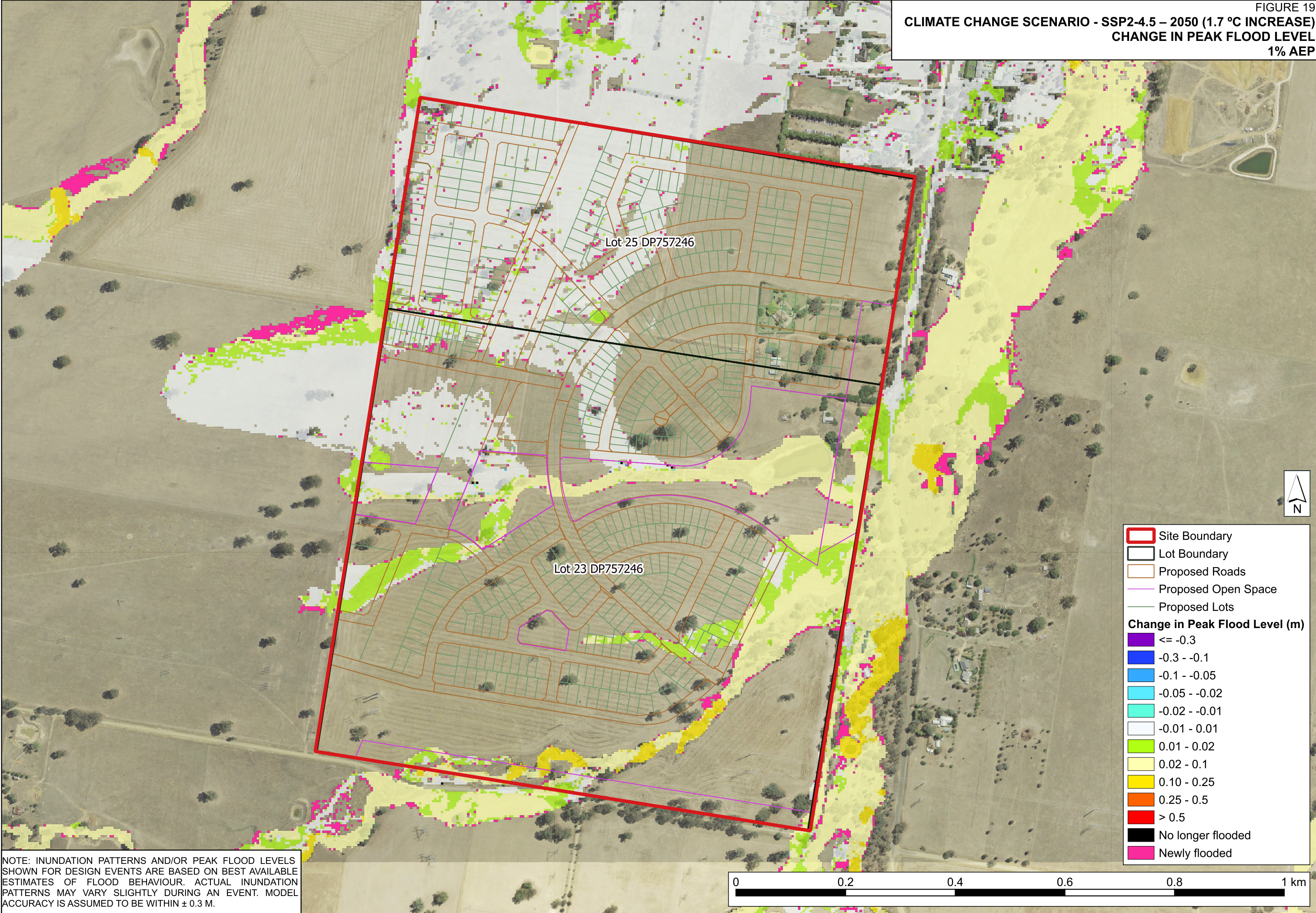
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NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

FIGURE 18
PEAK FLOOD HAZARD
EXISTING
0.2% AEP

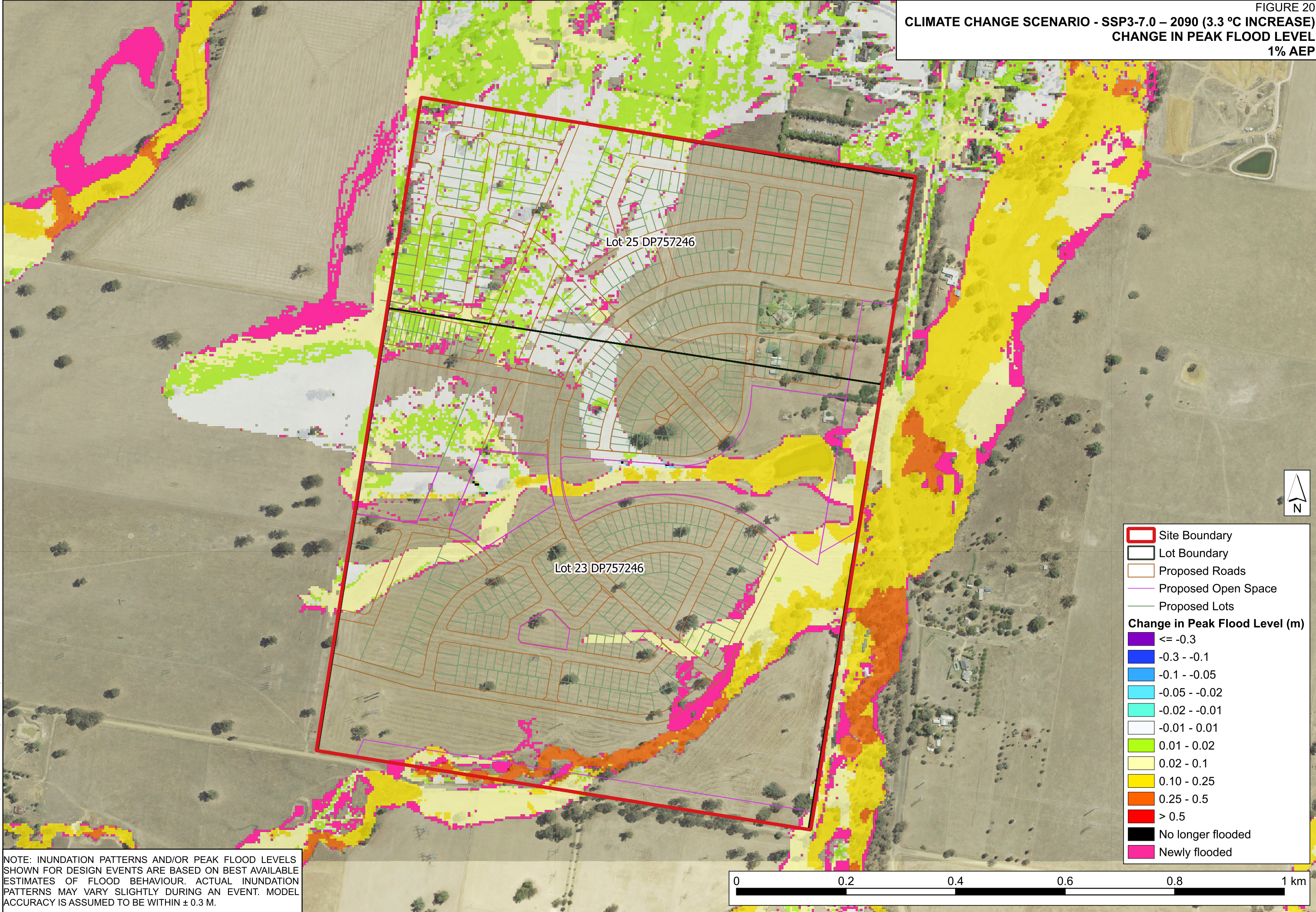


CLIMATE CHANGE SCENARIO - SSP2-4.5 – 2050 (1.7 °C INCREASE)
CHANGE IN PEAK FLOOD LEVEL
1% AEP



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.

CLIMATE CHANGE SCENARIO - SSP3-7.0 – 2090 (3.3 °C INCREASE)
CHANGE IN PEAK FLOOD LEVEL
1% AEP



NOTE: INUNDATION PATTERNS AND/OR PEAK FLOOD LEVELS SHOWN FOR DESIGN EVENTS ARE BASED ON BEST AVAILABLE ESTIMATES OF FLOOD BEHAVIOUR. ACTUAL INUNDATION PATTERNS MAY VARY SLIGHTLY DURING AN EVENT. MODEL ACCURACY IS ASSUMED TO BE WITHIN ± 0.3 M.



APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	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 m ³ /s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m ³ /s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	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.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
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.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

	redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m ³ /s). 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 (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	

	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. 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 plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations 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. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those 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.

floodway areas

Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard

Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room

in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard

A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

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.

local overland flooding

Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage

Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding

Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage

Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

	- major overland flow paths through developed areas outside of defined drainage reserves; and/or - the potential to affect a number of buildings along the major flow path.
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 EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service 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.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	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.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual 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.
stage	Equivalent to Δ water level Δ . Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.