Proposed Glanmire Solar Farm, Glanmire, New South Wales

Hydrological and Hydraulic Analysis

Project No.: 2179
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Prepared for: ngh consulting

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (*Footprint*) has been engaged by Elgin Energy through ngh consulting to undertake a hydrological and hydraulic analysis in support of a proposed solar farm located approximately 10km east of Bathurst, NSW.

The purpose of the analysis is to define the flood behaviour, including depth of inundation, flood velocity and flood hazard within the development site. The result of the analysis will be used to guide the design with respect to the extent and elevation of proposed solar array infrastructure and to determine the potential impact of this infrastructure on the existing flood behaviour.

1.1. Scope of Works

The scope of works for the project includes:

1. Review available background information including LiDAR data, topographic maps, proposed development plans.
2. Undertake hydrologic calculations to determine critical storm durations for the 5% AEP, 1% AEP and PMF events to apply to the two-dimensional rainfall on grid hydraulic model.
3. Undertake two-dimensional rainfall on grid hydraulic modelling (using HEC-RAS) to determine the depth and extent of flooding over the proposal area for each of the above rainfall events for pre-development scenario.
4. Undertake two-dimensional hydraulic modelling (using HEC-RAS) to determine the impact of the proposed development for the 1% AEP post development scenario.
5. Preparation of a hydrological and hydraulic report, including flood mapping, defining the methodology and results of the above investigations, and providing any recommendations with respect to floodplain management.

2.0 PROPOSAL AREA

The proposed Glanmire Solar Farm is located approximately 10km east of Bathurst, NSW and is located immediately south of the Great Western Highway in the locality of Glanmire.

The proposal area is described as Lot 141, DP1144786 and comprises a total land area of approximately 186 hectares, of which approximately 158 hectares would comprise the development footprint.

The location and extent of the proposal area in relation to Bathurst is shown in Figure 1.

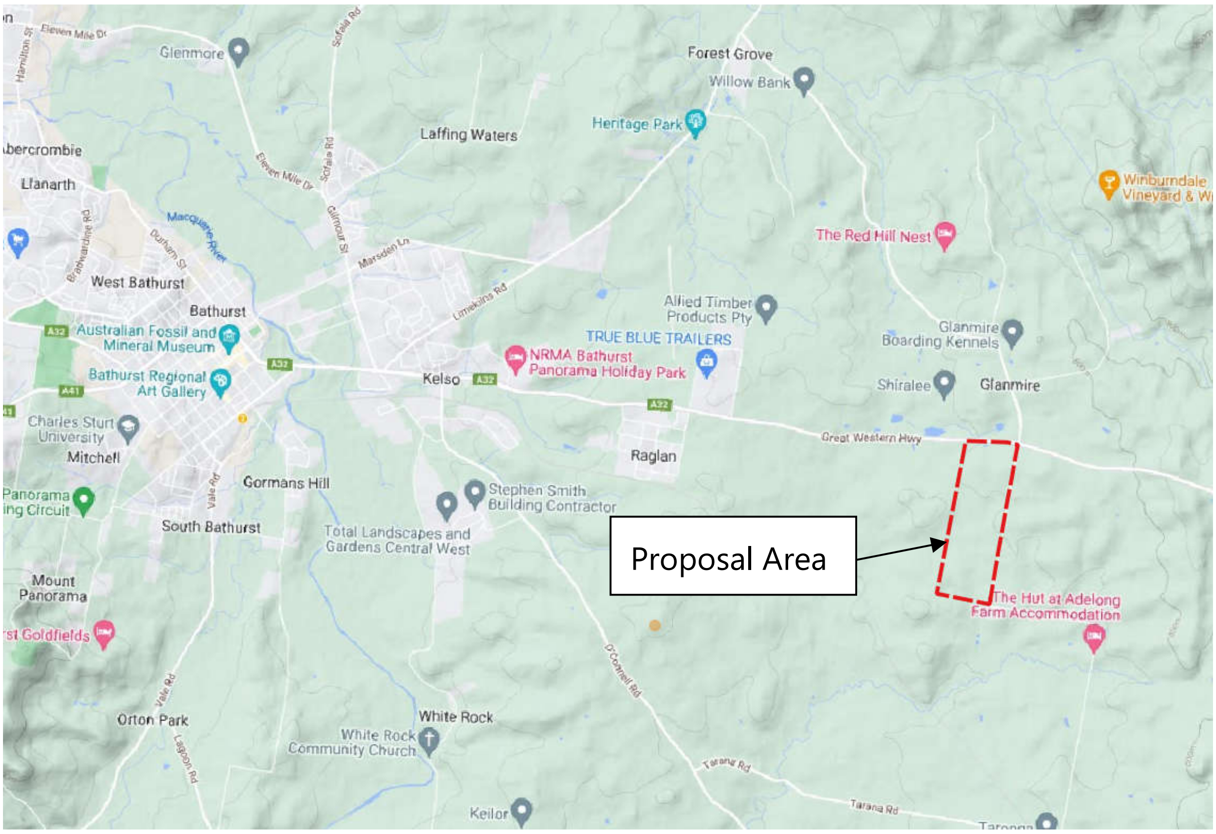


Figure 1: Location and Extent of Proposal Area

The proposal area is traversed by several first and second order streams which are tributaries of Salt Water Creek which at it closest point is located approximately 1.5km south of the proposal area.

All watercourses within the proposal area would be described as ephemeral and would only contain flowing water during and shortly after rainfall events.

There are also 9 small farm dams within the proposal area, mostly located on the existing watercourses.

It is understood that the proposal area has been used for agricultural cultivations, including grazing and cropping, and is almost entirely cleared of understorey vegetation (refer to Figure 2).

Figure 2: View of Proposal Area (outlined in red)

Except for a small northern portion of the site (approximately 380m) which drains to the north towards the Great Western Highway, the proposal area typically falls from north-east to south and south-west with elevations ranging from about 780m AHD to 735m AHD.

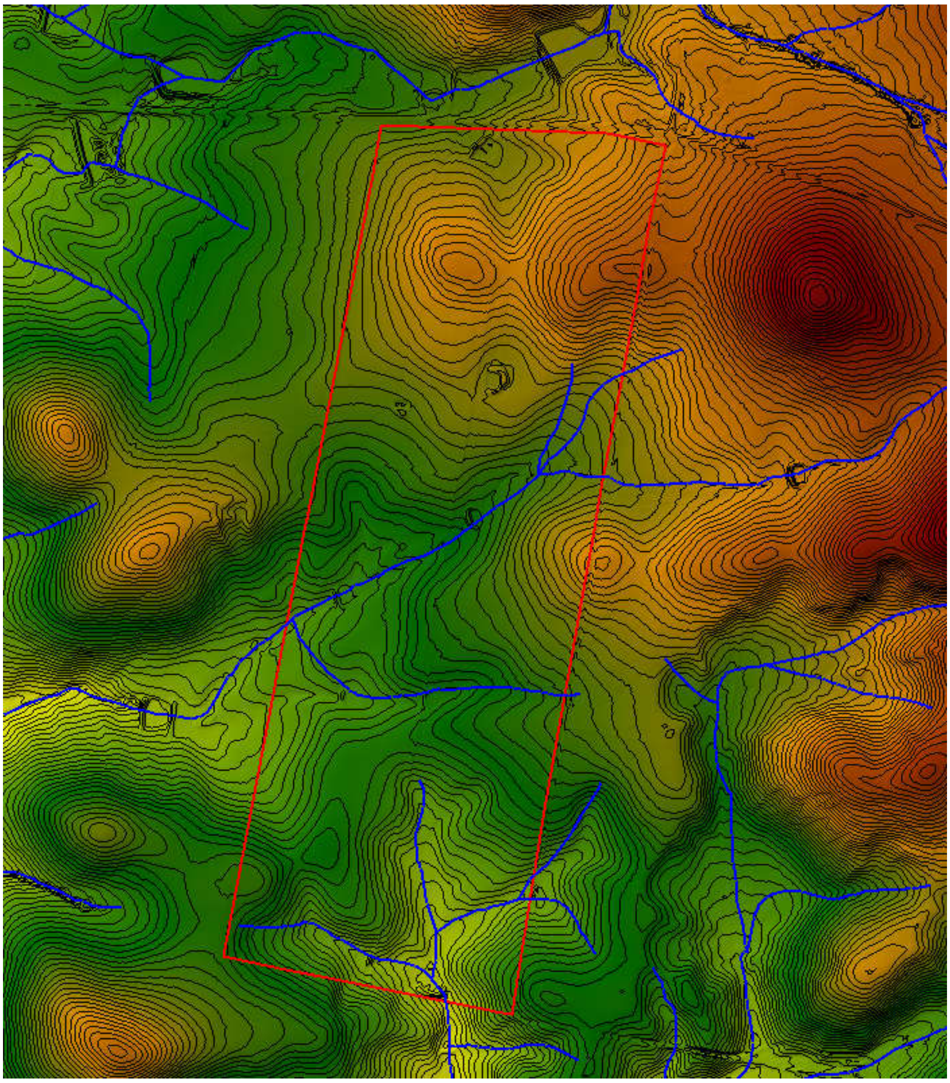


Figure 3: Terrain Analysis over Proposal Area (1m contour interval)

3.0 HYDROLOGICAL MODELLING

3.1. Purpose

Hydrological modelling was conducted to inform the HEC-RAS two-dimensional direct rainfall hydraulic model. The primary purposes of the hydrological model were to:

i. determine the critical storm duration for the subject site, and
ii. determine the median storm within the ensemble of modelled storms such that the hydraulic modelling could be limited to only one storm for each storm event.

3.2. Model Adoption

Hydrological modelling was conducted in DRAINS using a RAFTS storage routing model.

Storage routing models can model larger catchments using a lumped approach by assuming heterogeneity within the sub-catchment to account for the storage and retardence of flows that occurs within the sub-catchment. Such models account for slope and roughness and use a loss model to produce a hydrograph at the sub-catchment outlet.

The RAFTS hydrological model was chosen because it is widely used and accepted across Australia within the industry and has been shown to be insensitive to initial conditions.

3.3. Catchment Areas

Catchments draining to the proposal area were defined using hydrologic analysis software package Catchment SIM and were derived from the 2m Digital Elevation Models (DEM) covering the area which were obtained through the Australian Foundation Spatial Data web portal.

In total three separate catchment areas were defined covering the proposal area as defined in Figure 1.1 in Appendix A.

Sub-catchment slopes were derived by CatchmentSIM using the above terrain data.

Percentage imperviousness was estimated based off aerial photography.

3.4. Modelling Input Parameters

The parameters adopted for hydrological modelling are shown in Table 1.

Table 1: Hydrological Parameters Adopted

Parameter	Value Adopted	Justification/Source
Pervious Area Initial Loss (mm)	33	Value for Central Slopes obtained through ARR data hub (refer Appendix B)
Pervious Area Continuing Loss (mm/h)	2.36	40% of the value for East Coast (NSW) obtained through ARR data hub (refer Appendix B) in accordance with recommended NSW loss hierarchy (level 5)
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 1.1 in Appendix A
Impervious Area (%)	Varies	Based on aerial photography
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	0.035	Typical value for pasture land

3.5. Rainfall Data

3.5.1. Design Rainfall

IFD design rainfall depth data and temporal patterns were derived in accordance with Australian Rainfall and Runoff (2019) using the Bureau of Meteorology's 2019 Rainfall IFD on-line Data System.

The temporal patterns for the Central Slopes (CS) region was used as these cover the subject site (latitude -33.436, longitude 149.701).

A copy of the rainfall depths for the range of storm durations used can be found in Appendix C.

Storm probabilities in ARR2019 are now classified in two ways: Very Frequent storms, quantified as 'Exceedances per Year' (EY), and both Frequent and Infrequent storms given as Annual Exceedance Probability (AEP). The 'very frequent' storms have only been used for the 1EY, 0.5EY and the 0.2EY as these are equivalent to the former classifications of 1 in 1 year, 1 in 2 year and 1 in 5 year storms respectively (ARR 2016 state that the 50% AEP and the 20% AEP do not correspond statistically to the 1 in 2 year and 1 in 5 year storms, but rather are equivalent to the 1 in 1.44 year and 1 in 4.48 year storms respectively).

3.5.2. Pre-Burst Rainfall

NSW transformation pre-burst rainfall depths derived from ARR 2019 data hub (refer Appendix B) were adopted in the model.

3.5.3. Probable Maximum Precipitation

The PMF is the response of the catchment to the probable maximum precipitation (PMP) and is the largest flood event that can reasonably be expected to occur at a location.

Estimates of PMP were made using the Generalised Short Duration Method (GSDM) presented in Bureau of Meteorology (2003) and are provided in Table 2. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000km^2 in area and storm durations up to 6 hours and is therefore considered appropriate for the subject catchment. For the subject catchment PMP rainfall depths were limited to a maximum 3 hour duration.

Table 2: Estimate of PMP

Duration (Hours)	PMP Estimate (mm)
0.25	170
0.50	240
0.75	300
1.0	350
1.5	450
2.0	530
3.0	640

Due to the small size of the catchment no adjustment to the point values above were made to account for spatial variation of the rainfall.

The PMP Calculation spreadsheet is included in Appendix D

3.6. Results

Due to catchment 3 being largely external to the proposal area only catchments 1 and 2 were included in the DRAINS model. The catchments were represented in the model by a single node.

The DRAINS model was run in 'standard' mode for storm durations ranging from 10 minutes to 6 hours for the 5% and 1% AEP events and 15 minutes to 3 hours for the PMF event.

The critical duration and median storm from the ensemble, where applicable, for the range of events modelled across both modelled catchments are shown in Table 3.

Table 3: Summary of Critical Durations and Storms

Event	Critical Duration	Median Storm from Ensemble
5% AEP	3 hours	Storm 8
1% AEP	2 hour	Storm 5
PMF	1.5 hours	N/A

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady direct rainfall two-dimensional HEC-RAS model (Version 6.2) which covered the entire catchment draining to the proposal area.

4.1. Two-Dimensional Domain

A digital elevation model (DEM) of the entire catchment areas draining to the subject site was established using a series of 2m gridded digital elevation models (Bathurst2015.asc) sourced from www.elevation.fsdf.org.au.

A two-dimensional flow area (i.e. active cells) was defined over the entire catchment to simulate the rainfall-runoff process. The extent of the two-dimensional flow area is shown in Figure 4.

The 2m DEM grid was imported into HEC-RAS and used as the basis for development of a 5m x 5m terrain model. The DEM grid was further refined where required by applying breaklines to enforce abrupt changes in geometry, such as along existing roadways and dam embankments.

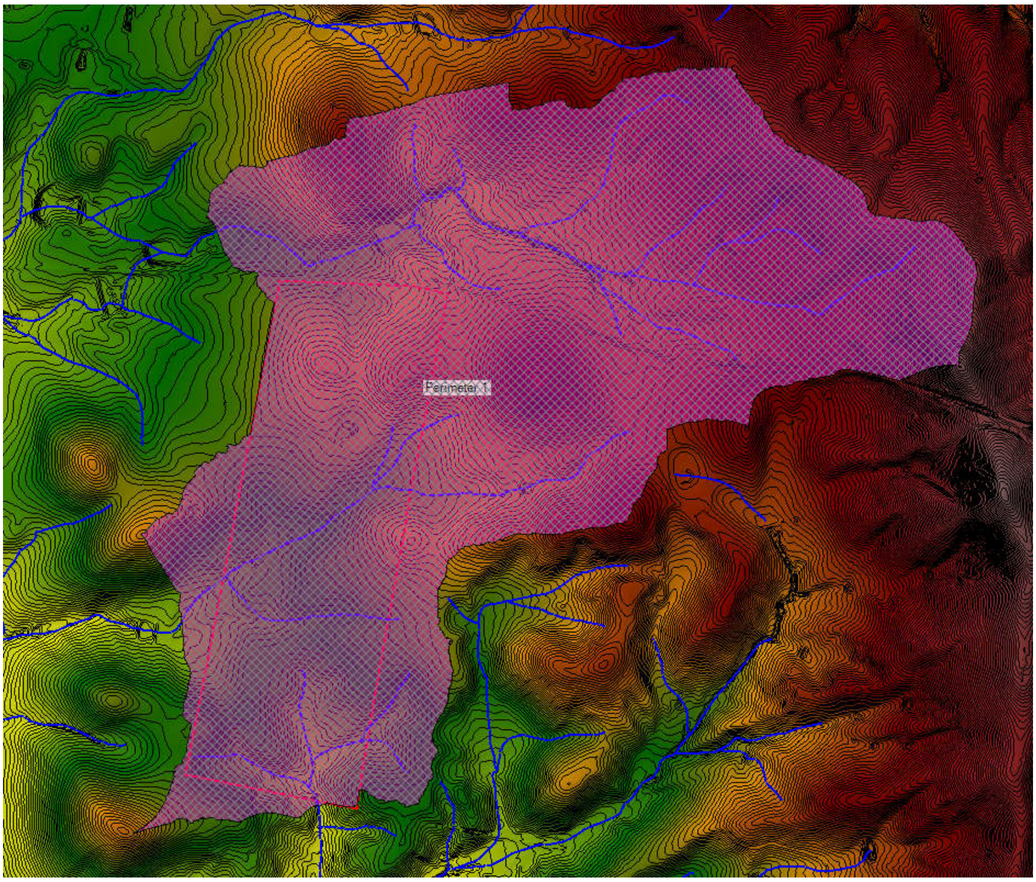


Figure 4: Two-Dimensional Flow Area

4.2. Manning's Roughness

The entire active area was assigned a default Manning's n value of 0.035 which is considered representative of pasture lands lacking any significant vegetation.

The default Manning's n was adjusted in certain area to account for heavier vegetation (0.05), sealed roads (0.015) and structures (3.0) as defined in Figure 1.2 in Appendix E.

4.3. Boundary Conditions

4.3.1. Direct Rainfall Boundary Condition

The direct rainfall boundary condition applies precipitation directly to the surface of the grid to perform two-dimensional hydraulic calculations.

HEC-RAS version 6.2 provides for initial and continuing losses to be applied spatially over the rainfall area to simulate the rainfall-runoff process.

To account for pre-burst rainfall the initial loss specified in Table 1 were adjusted downwards to account for the respective pre-burst rainfall depths for each storm event as defined in Table 4. For the PMF event the catchment was assumed to be saturated and therefore an initial loss of zero was adopted.

Table 4: Hydrological Parameters Adopted

Event	Initial Loss (mm)	Pre-Brust Rainfall Depth (mm)	Adopted Initial Loss in Direct Rainfall Model (mm)
5% AEP	33	23.6	9.4
1% AEP	33	20.7	12.3
PMF	33	-	0

4.3.2. Downstream Boundary Condition

Flows leaving the two-dimensional area were defined with a normal depth downstream boundary condition with a friction slope approximating the gradient of the land at the location of the boundary. The friction slope method uses the Manning's equation to compute a normal depth for each given flow, based on the cross section underneath the two-dimensional boundary condition line and is computed on a per cell basis.

4.4. Results

The HEC-RAS model was run in unsteady mode with variable timestep controlled by Courant conditions using the diffusion wave computational method. The results are provided in Appendix F and include the pre-development mapping shown in Table 5.

The results include the mapping of flood hazard vulnerability in accordance with Book 6, Chapter 7 of Australian Rainfall and Runoff (2019).

Table 5: Summary of Results

Figure	Description
Figure 3.1	Pre-Development Maximum Flood Levels and Depths – 5% AEP
Figure 3.2	Pre-Development Maximum Flood Velocities – 5% AEP
Figure 3.3	Pre-Development Maximum Flood Hazard – 5% AEP
Figure 4.1	Pre-Development Maximum Flood Levels and Depths – 1% AEP
Figure 4.2	Pre-Development Maximum Flood Velocities – 1% AEP
Figure 4.3	Pre-Development Maximum Flood Hazard – 1% AEP
Figure 5.1	Pre-Development Maximum Flood Levels and Depths – PMF
Figure 5.2	Pre-Development Maximum Flood Velocities – PMF
Figure 5.3	Pre-Development Maximum Flood Hazard – PMF

Flows leaving the two-dimensional domain at the outlet for Catchments 1 and 2 were compared to those of the DRAINS model and were found to be higher although within acceptable range for a direct rainfall model.

4.5. Hazard Vulnerability

The flood hazard vulnerability over the project site was mapped in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2019) and is shown in Figures 2.3, 3.3 and 4.3 in Appendix F for the 5%AEP, 1%AEP and PMF events respectively.

The mapping shows that flooding within the project site is classified as a H1 hazard vulnerability in the 5% AEP and 1% AEP events, except for flooding within existing farm dams which reach moderate hazard levels (H3 and H4). As expected, hazard increases considerably over the project site in the PMF (extreme) event with the high hazard areas (H5 and H6) occurring over the second order watercourse

Table 6.7.3 of Australian Rainfall and Runoff describes the hazard thresholds for community interaction with floodwaters and its' content to repeated in Table 6.

Table 6: Combined Hazard Curves – Vulnerability Thresholds (ARR 2019)

Hazard Vulnerability Classification	**Description**
H1	Generally Safe for vehicles, people and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

5.0 IMPACT OF PROPOSED WORKS

5.1. Proposal Description

The proposal involves the construction, operation and decommissioning of a ground-mounted PV solar array which would generate approximately 60 Megawatts (AC) to be supplied directly to the national electricity grid. The proposal site is approximately 180 hectares of which approximately 158 hectares would be developed for the solar farm and associated infrastructure (Development Footprint).

The primary vehicular access point during construction and operation would be off via Brewongle Lane, immediately east of the site, to the Great Western Highway

Key development and infrastructure components would include:

- Installation of approximately 128,000 PV solar modules mounted on a horizontal single-axis tracking system
- Steel mounting frames with pile foundation
- Installation of up to 17 SMA inverters (SC 4220 UP)
- Installation of up to 17 4200 kVA 33/0.66kV transformers
- Underground and above ground cabling to connect the arrays to the inverters/transformers
- A Battery Energy Storage System (BESS) with a power rating up to approximately 60 MW AC/DC coupled (approximately 65MW hours)
- A switchyard and on-site substation
- National Energy Market (NEM) compliant metering
- Internal access track to enable site maintenance
- Security fencing around the perimeter with CCTV
- An operations and maintenance building

In total, the construction phase of the proposal is expected to take 12 months, and the facility would be expected to operate for around 40 years. Up to three fulltime equivalent operations and maintenance staff and service contractors would operate the facility. At the end of its operational life, the facility would be decommissioned. All below ground components to a depth of 500 mm would be removed and returned to its existing agricultural land capability.

5.2. Hydraulic Modelling

An assessment of the impact of the proposed permanent infrastructure on flooding was undertaken by increasing the surface roughness over the proposed development footprint to account for solar array infrastructure and buildings.

Typical solar array modules consist of a frame supported by piers at a typical grid spacing of 5-7m. The addition of the solar arrays and their associated infrastructure will result in an increase in surface roughness over the site, from grazed/cropped pasture to grazed/cropped pasture with a regular grid of steel piers.

The change in floodplain roughness associated with the proposed solar arrays was assessed using the Modified Cowan Method for Floodplain Roughness and is shown in Table 7. It should be noted that only n_3 (effect of obstructions) has been modified to represent the change in roughness associated with the solar array piers, all other variables remain at pre-development values and hence have remained at n_b, n_1 etc.

It demonstrates that the roughness is anticipated to slightly increase because of the proposed development.

Table 7: Modified Cowan Method for Estimation of Floodplain Roughness

Roughness Component	Existing (Grazed Pasture)	Proposed (Solar Array)
Floodplain Material (n_b)	n_b	n_b
Degree of Irregularity (n_1)	n_1	n_1
Variation in Floodplain Cross Section (n_2)	n_2	n_2
Effect of Obstructions (n_3)	0.000	0.003[1]
Amount of Vegetation (n_4)	n_4	n_4
Change in Roughness (n)	0.000	0.003

[1] Based on an obstruction of 2.5% of the available flow area (i.e. 150mm piers at 5-6m intervals)

The increase in roughness was applied to the pre-development roughness value specified in Section 4.2 over the extent of the proposed solar array footprint increasing this roughness to 0.038.

The area nominated for the proposed substation, battery storage and O&M facilities, including parking areas was assigned a Manning's n value of 3 to reflect the impact of the proposed buildings and structures, including possible filling, in these areas.

It should be noted that the proposed development would include a network of access roads and these would be constructed from gravel and within the floodplain itself would be constructed at or near the existing surface level so as not to result in adverse impact on flood behaviour.

In accordance with the Modified Cowan Method of Floodplain Roughness gravel has a similar floodplain roughness to that of the surrounding pre-development floodplain roughness. On this basis and considering the fact these tracks are likely to be less than 10m in width and therefore not well represented by the model, the marginal increase in floodplain roughness associated with the proposed road network has not been included in the post development model.

A low-level crossing is proposed over the central second order watercourse. This proposed crossing is assumed to be a low-level crossing (i.e. ford or causeway) which would have minimal hydraulic impact and therefore has not been included in the model.

The post development hydraulic model is therefore considered to be representative of the development as proposed and therefore reflective of the hydraulic impacts associated with the development.

The hydraulic model was re-run to assess the impact of an increase in surface roughness on flood behaviour for the 1% AEP event and the results in included in Figures 5.1, 5.2 and 5.3 in Appendix F.

The results in Figures 5.1, 5.2 and 5.3 demonstrate that there is not predicted to be a significant impact on flood behaviour for the 1% AEP event because of the proposed works, with flood level, depths, velocities and hazards remaining largely unchanged.

This is better demonstrated in Figures 6.1 and 6.2 which show the change in maximum flood level and peak velocity resulting from the proposed development. These figures show that the peak flood levels and velocities are anticipated to remain relatively unchanged across most of the proposal area, due primarily to most of the infrastructure being located outside high hazard areas of the floodplain. Some minor increases in flood levels and corresponding decreases in velocity are shown to locally within the development footprint, however these changes are very localised and not anticipated to adversely affect adjoining properties. Some minor reduction in flood levels are observed downstream of Glanmire Lane to the north of the Great Western Highway however these are considered a modelling anomaly as not change to the terrain surface or Manning's n values are proposed in this location. Upon further investigation of this matter, it appears to be associated with a slightly different gridded raster set developed by the software for the pre versus post development land use layer (i.e. Manning's n layer)

Further, velocities over the project site are shown to be contained in the range of plus or minus 0.25m/s when compared to pre-development velocities and therefore should not result in any adverse impact to the stability of the bed and banks of existing waterways or contribute to degradation of the land by erosive flood forces.

6.0 FLOOD MANAGEMENT RECOMMENDATIONS

6.1. Buildings and Structures

All buildings and structures (including solar arrays) associated with the proposal should be located outside high hazard areas (H5 and above) where they may be vulnerable to structural damage and have significant impact on flood behaviour.

The finished floor level of all buildings should be a minimum of 500mm above the 1% AEP flood level.

6.2. Solar Array Field

For fixed solar panel modules, the mounting height of the module frames should be designed such that the lower edge of the frame is clear of the predicted 1% AEP flood level plus 500mm freeboard so as not to impact on existing flood behaviour and to prevent the infrastructure from being damaged from flooding.

For solar tracking modules, the tracking axis should be located above the 1%AEP flood level plus 500mm freeboard, and the modules rotated to the horizontal during significant flood events to provide maximum clearance to the predicted flood level.

Where located in the floodplain the solar array mounting piers should be designed to withstand the forces of floodwater (including any potential debris loading) up to the 1% AEP flood event, giving regard to the depth and velocity of floodwaters. Post development 1% AEP flood levels and velocities are included in Figures 5.1 and 5.2 respectively in Appendix F.

6.3. Electrical Infrastructure

All electrical infrastructure, including power conversions stations and the proposed substation, should be located above the 1% AEP flood level plus appropriate freeboard (min 500mm).

Where electrical cabling is required to be constructed below the 1% AEP flood level it should be capable of continuous submergence in water.

6.4. Perimeter Fencing

Wherever possible security fencing within the floodplain should be avoided or minimised. Where required security fencing should be constructed in a manner which does not adversely affect the flow of floodwater and should be designed to withstand the forces of floodwater or collapse in a controlled manner to prevent impediment to floodwater.

6.5. Watercourse Crossings

Any road crossings on watercourses within the subject site should be of the type defined in Table 2 of Guidelines for Riparian Corridors on Waterfront Land (DPI Water, 2012) (see extract below).

Table 2. Riparian corridor matrix

Stream order	Vegetated Riparian Zone (VRZ)	RC off-setting for non RC uses	Cycleways and paths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10m	•	•	•	•	•	•	•		
2nd	20m	•	•	•	•	•		•		
3rd	30m	•	•	•		•			•	•
4th +	40m	•	•	•		•			•	•

Any proposed crossings (vehicular or service) of existing watercourses on the subject site should be designed in accordance with the following guidelines, and, in the case of vehicular crossings should preferably consist of bed level crossings constructed flush with the bed of the watercourse on first and second order watercourses to minimise any hydraulic impact:

i. Guidelines for Watercourse Crossings on Waterfront land (NSW DPI, 2012)
ii. Guidelines for Laying Pipes and Cable in Watercourses on Waterfront Land (NSW DPI, 2012)

6.6. Access Roads

Within the floodplain access roads should be constructed as close to natural ground levels as possible so as not to form an obstruction to floodwaters.

The surface treatment of roads should be designed giving regard to the velocity of floodwaters to minimise potential for scouring during flood events.

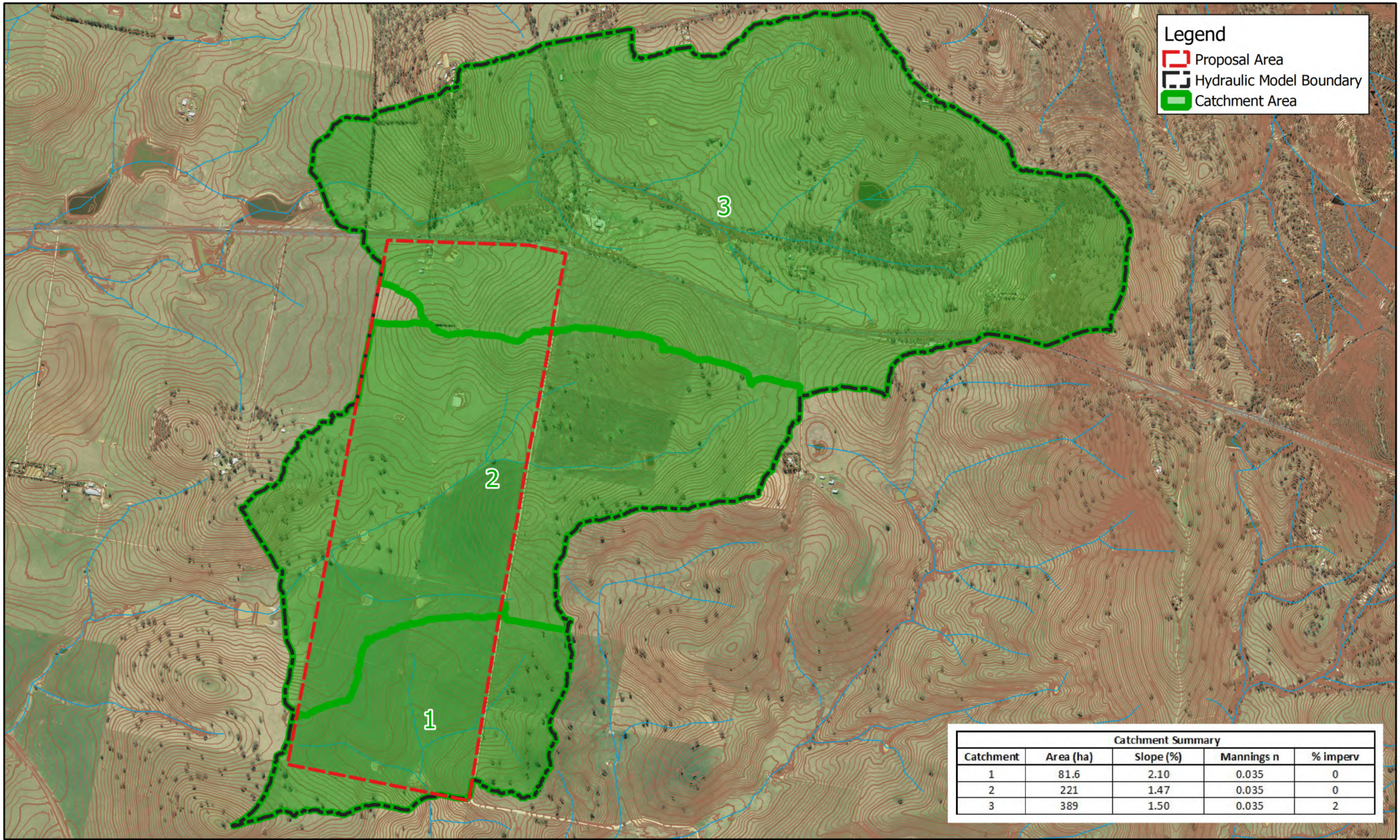
6.7. Erosion Management

Any areas of existing erosion within the proposed development footprint should be appropriately treated prior to the erection of solar array modules to ensure their ongoing stability.

For further information refer to Saving Soil: A Landowners Guide to Preventing and Repairing Soil Erosion, NSW DPI (2009) available at https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf

APPENDIX A

Catcment Plan



Catchment Summary				
Catchment	Area (ha)	Slope (%)	Mannings n	% imperv
1	81.6	2.10	0.035	0
2	221	1.47	0.035	0
3	389	1.50	0.035	2

footprint.
sustainable engineering.
210 jamberoo rd, jamberoo,
nsw 2533 p: (02) 4237 6770

200 0 200 400 m

Scale 1:15,000 at A3

GLANMIRE SOLAR FARM

FIGURE 1.1

CATCHMENT PLAN

Rev 1 - 26 AUGUST 2022

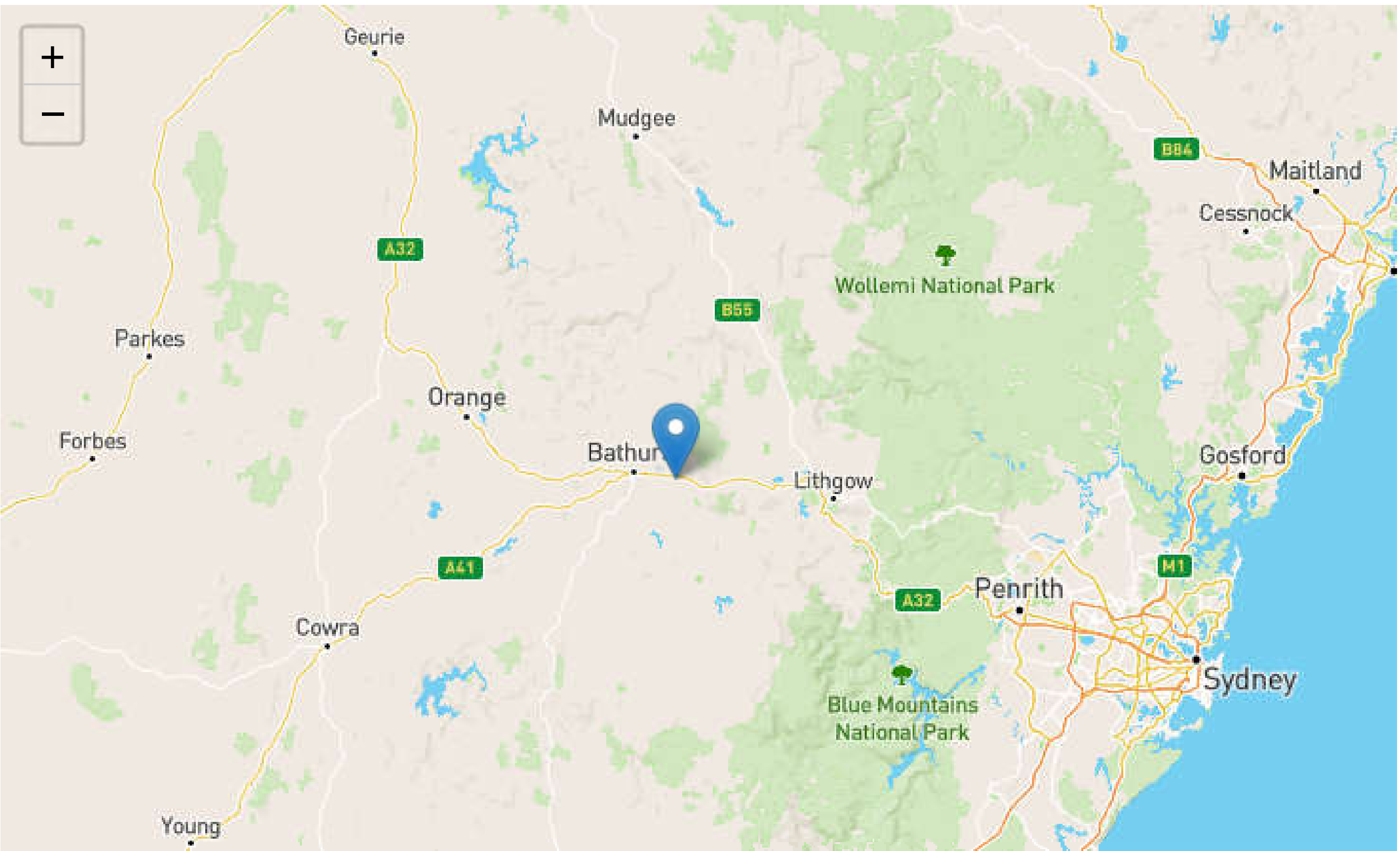
APPENDIX B

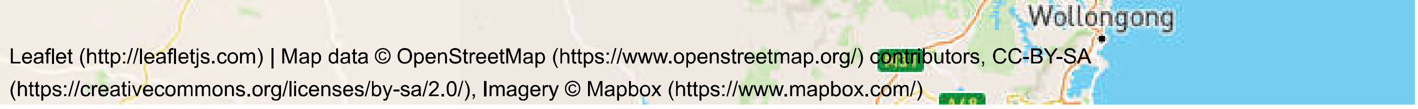
ARR Data Hub

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	149.701
Latitude	-33.436
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show





Data

River Region

Division	Murray-Darling Basin
River Number	22
River Name	Macquarie-Bogan Rivers

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2016_v1

ARF Parameters

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

Zone	a	b	c	d	e	f	g	h	i
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033

Short Duration ARF

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

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

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

ID	10898.0
Storm Initial Losses (mm)	33.0
Storm Continuing Losses (mm/h)	5.9

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/CS.zip)

code	CS
Label	Central Slopes

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_CS.zip)

code	CS
arealabel	Central Slopes

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-33.436333&longitude=149.701278&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	18 August 2022 02:57PM

Median Preburst Depths and Ratios

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.9 (0.050)	0.8 (0.032)	0.7 (0.024)	0.6 (0.018)	0.5 (0.013)	0.4 (0.010)
90 (1.5)	1.0 (0.047)	1.3 (0.045)	1.5 (0.044)	1.6 (0.044)	1.7 (0.040)	1.8 (0.037)
120 (2.0)	1.5 (0.063)	1.0 (0.034)	0.8 (0.021)	0.5 (0.012)	0.7 (0.015)	0.9 (0.016)
180 (3.0)	0.6 (0.023)	0.8 (0.023)	0.9 (0.022)	1.0 (0.022)	1.0 (0.019)	1.0 (0.017)
360 (6.0)	1.8 (0.055)	1.8 (0.041)	1.8 (0.035)	1.8 (0.031)	1.1 (0.016)	0.6 (0.007)
720 (12.0)	0.0 (0.000)	0.4 (0.008)	0.7 (0.011)	1.0 (0.013)	6.3 (0.070)	10.2 (0.102)
1080 (18.0)	0.0 (0.000)	1.0 (0.015)	1.7 (0.022)	2.3 (0.026)	3.7 (0.036)	4.7 (0.041)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.3 (0.004)	0.4 (0.004)	3.2 (0.028)	5.2 (0.041)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

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

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

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

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

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

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	11.3 (0.602)	10.0 (0.400)	9.1 (0.310)	8.2 (0.244)	7.1 (0.179)	6.2 (0.141)
90 (1.5)	11.6 (0.544)	12.5 (0.443)	13.0 (0.396)	13.6 (0.360)	14.7 (0.334)	15.6 (0.317)
120 (2.0)	17.7 (0.754)	14.7 (0.478)	12.7 (0.355)	10.8 (0.264)	13.5 (0.283)	15.5 (0.292)
180 (3.0)	9.3 (0.349)	11.6 (0.332)	13.1 (0.322)	14.5 (0.314)	15.6 (0.289)	16.5 (0.274)
360 (6.0)	14.2 (0.421)	18.6 (0.420)	21.4 (0.416)	24.2 (0.412)	23.8 (0.347)	23.6 (0.308)
720 (12.0)	5.1 (0.118)	8.8 (0.155)	11.3 (0.169)	13.6 (0.179)	28.8 (0.323)	40.2 (0.403)
1080 (18.0)	1.6 (0.032)	7.3 (0.112)	11.2 (0.145)	14.8 (0.168)	20.1 (0.193)	24.0 (0.206)
1440 (24.0)	0.5 (0.010)	5.0 (0.069)	7.9 (0.093)	10.8 (0.110)	15.8 (0.138)	19.6 (0.152)
2160 (36.0)	0.0 (0.000)	2.1 (0.026)	3.5 (0.037)	4.9 (0.044)	6.2 (0.048)	7.2 (0.050)
2880 (48.0)	0.0 (0.000)	0.7 (0.007)	1.1 (0.010)	1.5 (0.013)	2.9 (0.021)	3.9 (0.025)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.3 (0.002)	0.4 (0.002)

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	34.5 (1.835)	30.4 (1.221)	27.7 (0.949)	25.2 (0.749)	20.1 (0.510)	16.4 (0.371)
90 (1.5)	27.3 (1.276)	32.0 (1.136)	35.1 (1.067)	38.1 (1.011)	39.8 (0.902)	41.0 (0.835)
120 (2.0)	32.1 (1.372)	33.8 (1.101)	34.9 (0.976)	36.0 (0.880)	42.1 (0.881)	46.7 (0.878)
180 (3.0)	20.3 (0.762)	29.7 (0.851)	35.9 (0.883)	41.8 (0.903)	45.4 (0.841)	48.2 (0.802)
360 (6.0)	33.1 (0.981)	46.4 (1.052)	55.3 (1.075)	63.8 (1.086)	60.4 (0.879)	57.8 (0.756)
720 (12.0)	20.0 (0.464)	35.6 (0.626)	45.9 (0.691)	55.8 (0.734)	71.0 (0.795)	82.4 (0.825)
1080 (18.0)	13.5 (0.273)	23.1 (0.351)	29.4 (0.382)	35.5 (0.402)	48.6 (0.467)	58.4 (0.501)
1440 (24.0)	11.5 (0.211)	19.2 (0.265)	24.3 (0.286)	29.2 (0.299)	44.2 (0.384)	55.5 (0.431)
2160 (36.0)	7.6 (0.122)	12.8 (0.156)	16.3 (0.169)	19.7 (0.178)	28.1 (0.216)	34.4 (0.236)
2880 (48.0)	1.8 (0.027)	6.5 (0.073)	9.6 (0.092)	12.6 (0.106)	15.3 (0.109)	17.3 (0.111)
4320 (72.0)	2.7 (0.036)	4.1 (0.042)	5.1 (0.045)	6.1 (0.046)	7.0 (0.046)	7.6 (0.045)

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.972 (4.9%)**	0.847 (4.2%)	**1.052 (5.3%)**
2040	**1.225 (6.2%)**	1.127 (5.7%)	**1.495 (7.6%)**
2050	**1.452 (7.3%)**	1.406 (7.1%)	**1.971 (10.1%)**
2060	**1.653 (8.4%)**	1.685 (8.6%)	**2.480 (12.9%)**
2070	**1.827 (9.3%)**	1.963 (10.1%)	**3.023 (15.9%)**
2080	**1.974 (10.1%)**	2.241 (11.6%)	**3.599 (19.2%)**
2090	**2.095 (10.8%)**	2.518 (13.1%)	**4.208 (22.8%)**

Layer Info

Time Accessed	18 August 2022 02:57PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	18.9	12.6	11.2	11.7	12.2	12.0
90 (1.5)	21.4	13.5	11.3	11.2	10.6	8.9
120 (2.0)	23.4	12.6	11.3	11.9	11.3	9.5
180 (3.0)	26.7	15.7	13.1	12.4	11.8	10.0
360 (6.0)	24.1	14.2	12.1	11.9	10.9	8.6
720 (12.0)	27.5	19.0	16.9	15.7	12.3	7.4
1080 (18.0)	29.3	21.7	20.0	18.8	16.2	11.0
1440 (24.0)	30.3	23.2	21.9	21.8	17.8	12.1
2160 (36.0)	31.7	25.5	25.4	26.0	23.0	16.1
2880 (48.0)	33.2	27.5	27.7	28.6	26.3	20.9
4320 (72.0)	33.6	28.4	29.3	30.2	28.1	26.2

Layer Info

Time Accessed	18 August 2022 02:57PM

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

Download TXT (downloads/329926d7-bf6a-482d-86c9-712632bf0ffe.txt)

Download JSON (downloads/9ea934dd-26ee-4e9d-a08b-bf8ef3796110.json)

Generating PDF... (downloads/5033947a-2e41-424e-a3b0-40c5ab2f9d55.pdf)

APPENDIX C

Rainfall Data

Location

Label: Glanmire Solar Farm

Latitude: -33.436 [Nearest grid cell: 33.4375 (S)]

Longitude: 149.701 [Nearest grid cell: 149.7125 (E)]

IFD Design Rainfall Depth (mm)

Issued: 30 August 2022

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.50	1.67	2.25	2.66	3.08	3.65	4.10
2 min	2.51	2.79	3.66	4.25	4.84	5.61	6.21
3 min	3.48	3.86	5.10	5.95	6.80	7.92	8.80
4 min	4.34	4.83	6.42	7.53	8.64	10.1	11.3
5 min	5.10	5.70	7.62	8.97	10.3	12.2	13.6
10 min	7.94	8.91	12.1	14.3	16.6	19.7	22.2
15 min	9.83	11.0	14.9	17.7	20.6	24.5	27.6
20 min	11.2	12.6	17.0	20.2	23.4	27.8	31.4
25 min	12.3	13.8	18.6	22.0	25.5	30.3	34.1
30 min	13.2	14.8	19.9	23.5	27.2	32.2	36.3
45 min	15.3	17.1	22.8	26.8	30.9	36.5	40.9
1 hour	16.9	18.8	24.9	29.3	33.6	39.5	44.2
1.5 hour	19.3	21.4	28.2	32.9	37.7	44.1	49.1
2 hour	21.1	23.4	30.7	35.8	40.9	47.8	53.2
3 hour	24.1	26.7	34.9	40.6	46.3	54.0	60.1
4.5 hour	27.6	30.6	39.9	46.5	53.0	61.9	68.9
6 hour	30.5	33.7	44.2	51.5	58.7	68.7	76.5
9 hour	35.1	38.9	51.2	59.7	68.3	80.1	89.3
12 hour	38.8	43.1	56.8	66.5	76.1	89.4	99.9
18 hour	44.6	49.6	65.8	77.0	88.3	104	116

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

This page was created at **17:34 on Tuesday 30 August 2022 (AEST)**

APPENDIX D

PMP Calculations

GSDM Calculation Sheet

Location Information				
Catchment	Glanmire Solar	Area (km2)	2.2	
State	NSW	Duration Limit (hrs)	3	
Latitude	-31.436	Longitude	149.701	
Proportion of Area Considered:				
Smooth S= (0.0 - 1.0)	0	Rough R= (0.0-1.0)	1	
Elevation Adjustment Factor (EAF)				
Mean Elevation (m AHD)			755	
Adjustment for Eelvation (-0.05 per 300m above 1500m)			0	
EAF = (0.85-1.00)			1	
Moisture Adjustment Factor (MAF)				
MAF = (0.40 - 1.00)			0.7	
PMP Values				
Duarion (hrs)	Initial Depth - Smooth	Initial Depth - Rough	PMP Estimate	Rounded PMP Estimate (nearest 10mm)
0.25	240	240	168	170
0.50	340	340	238	240
0.75	435	435	305	300
1.0	495	495	347	350
1.5		645	452	450
2.0		750	525	530
2.5		835	585	580
3.0		910	637	640
4.0				
5.0				
6.0				

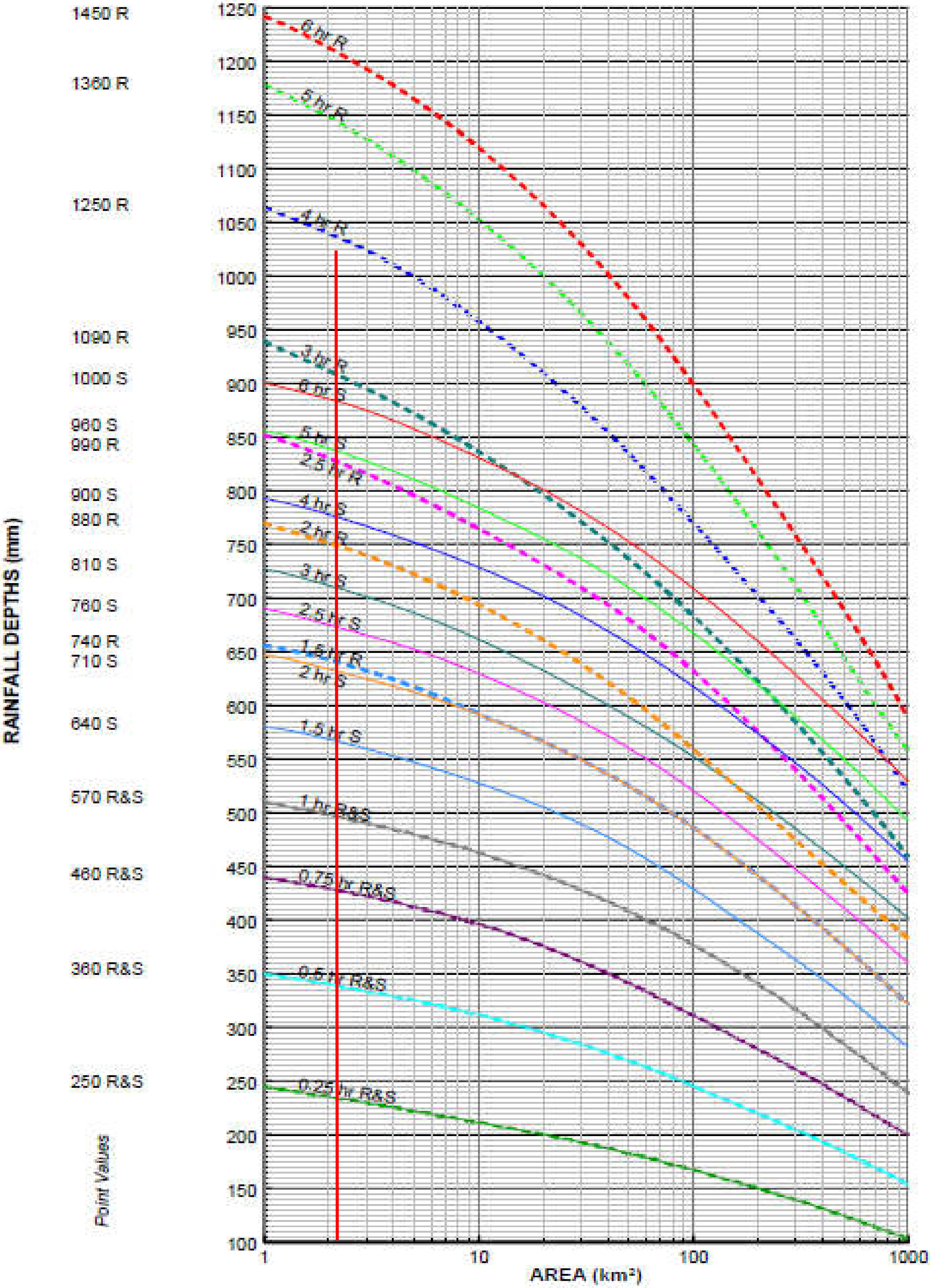
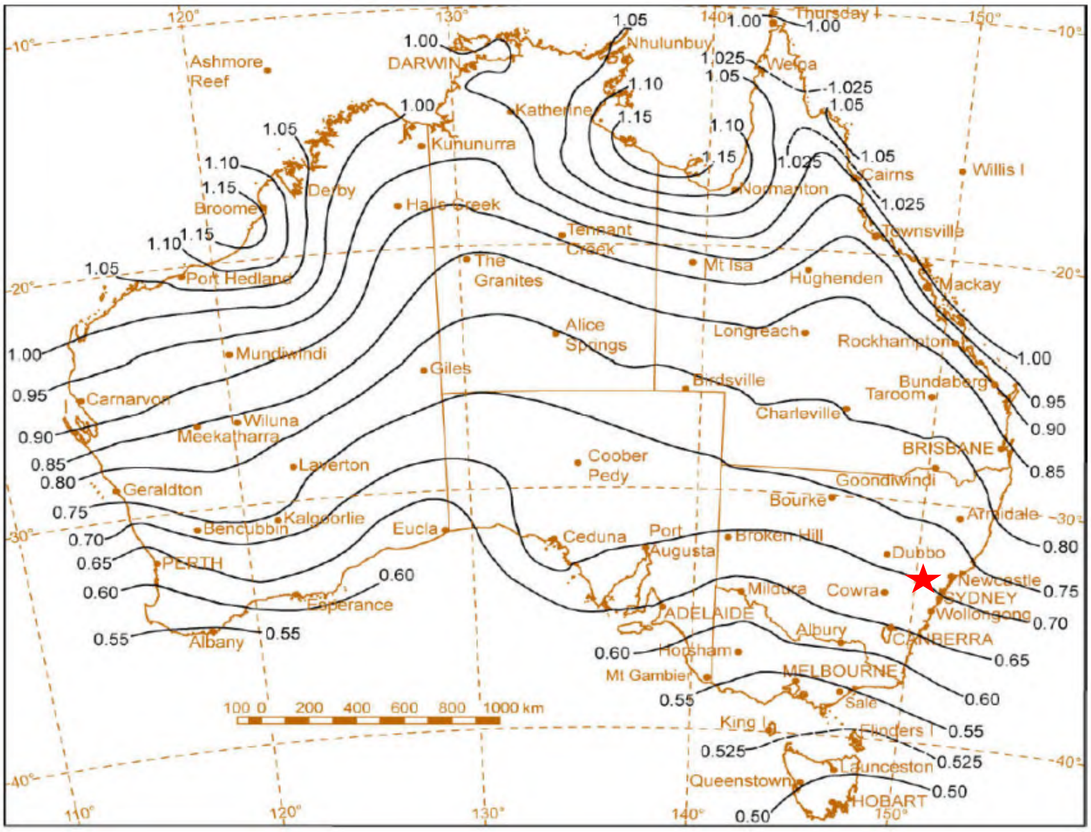


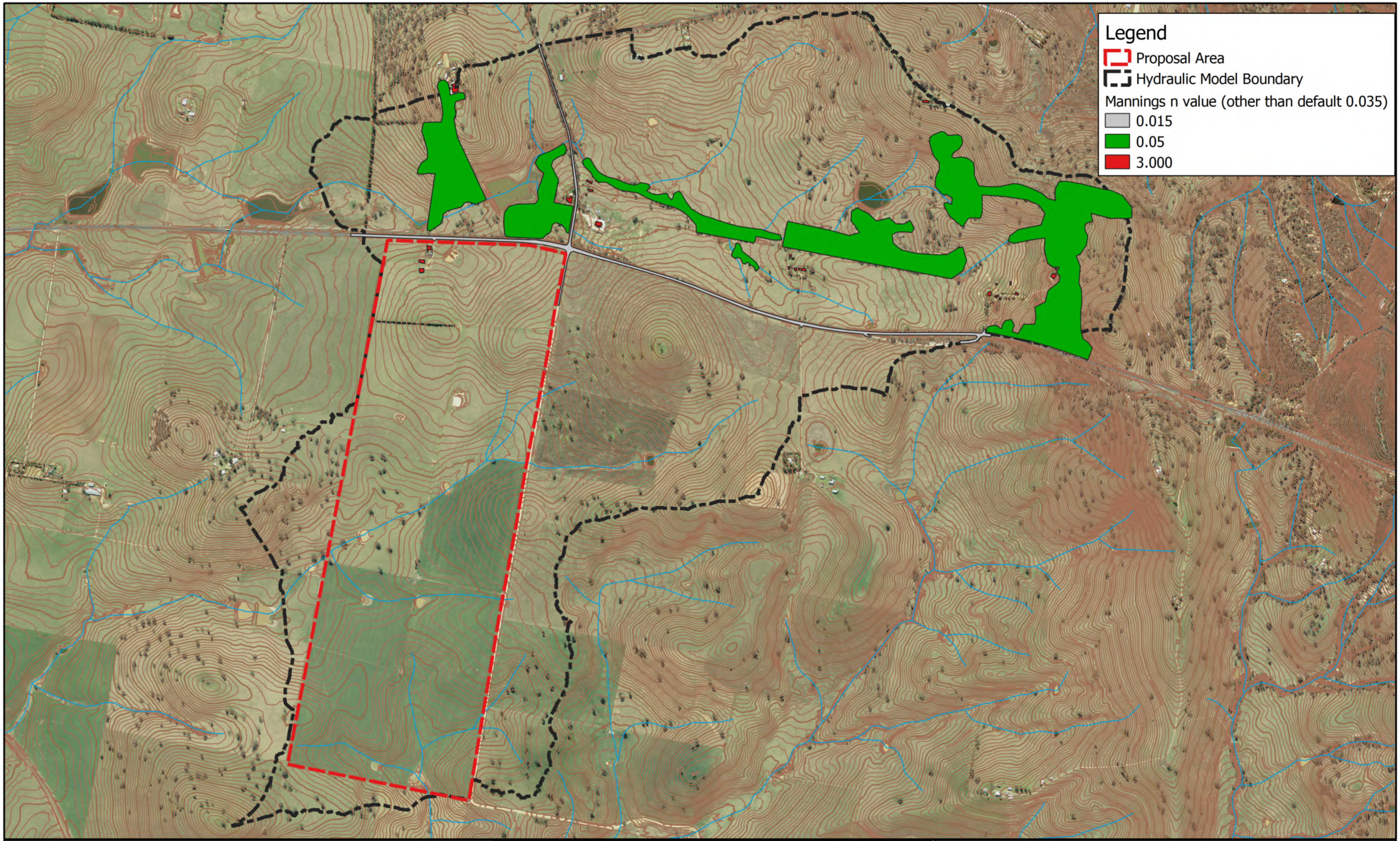
Figure 4: Depth-Duration-Area Curves of Short Duration Rainfall



Ashmore Reef
DARWIN
Nhulunbuy
Thursday I
Weipa
Katherine
Kununurra
Derby
Broome
Halls Creek
Tennant Creek
Normanton
Cairns
Willis I
Townsville
Port Hedland
The Granites
Mt Isa
Hughenden
Mackay
Alice Springs
Longreach
Rockhampton
Mundiwindi
Giles
Birdsville
Bundaberg
Taroom
Carnarvon
Wiluna
Meekatharra
Charleville
BRISBANE
Laverton
Coober Pedy
Goondiwindi
Geraldton
Bourke
Armidale
Bencubbin
Kalgoorlie
Eucla
Ceduna
Port Augusta
Broken Hill
Dubbo
PERTH
Newcastle
SYDNEY
Wollongong
Mildura
Cowra
Esperance
ADELAIDE
Albury
CANBERRA
Albany
Horsham
Mt Gambier
MELBOURNE
Sale
King I
Flinders I
Launceston
Queenstown
HOBART
100 0 200 400 600 800 1000 km

APPENDIX E

Mannings n Plan
(Pre Development)



footprint.
sustainable engineering.
210 jamberoo rd, jamberoo,
nsw 2533 p: (02) 4237 6770

200 0 200 400 m
Scale 1:15,000 at A3

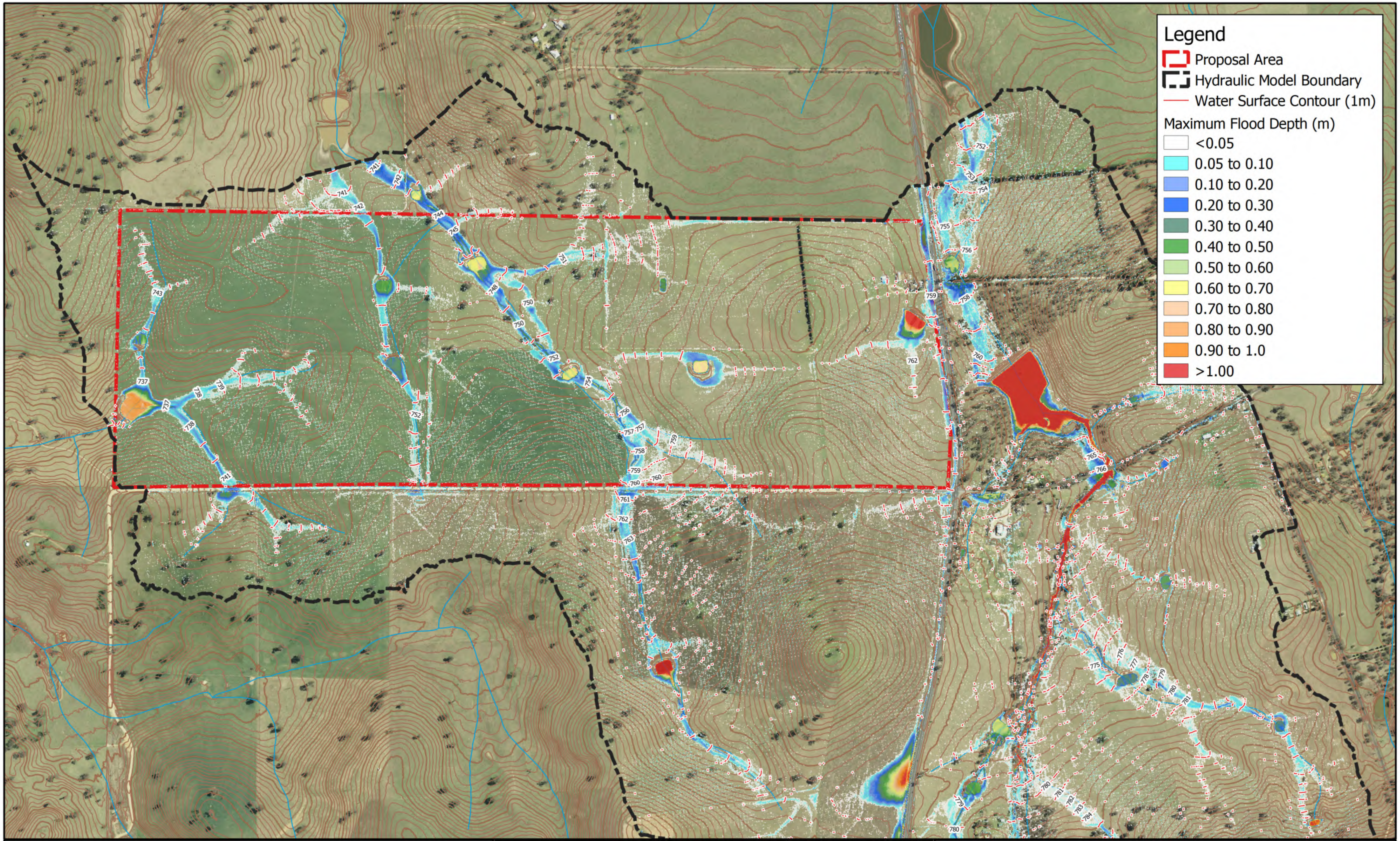
GLANMIRE SOLAR FARM

FIGURE 1.2
ADOPTED MANNING'S N VALUES

Rev 1 - 26 AUGUST 2022

APPENDIX F

Flood Mapping



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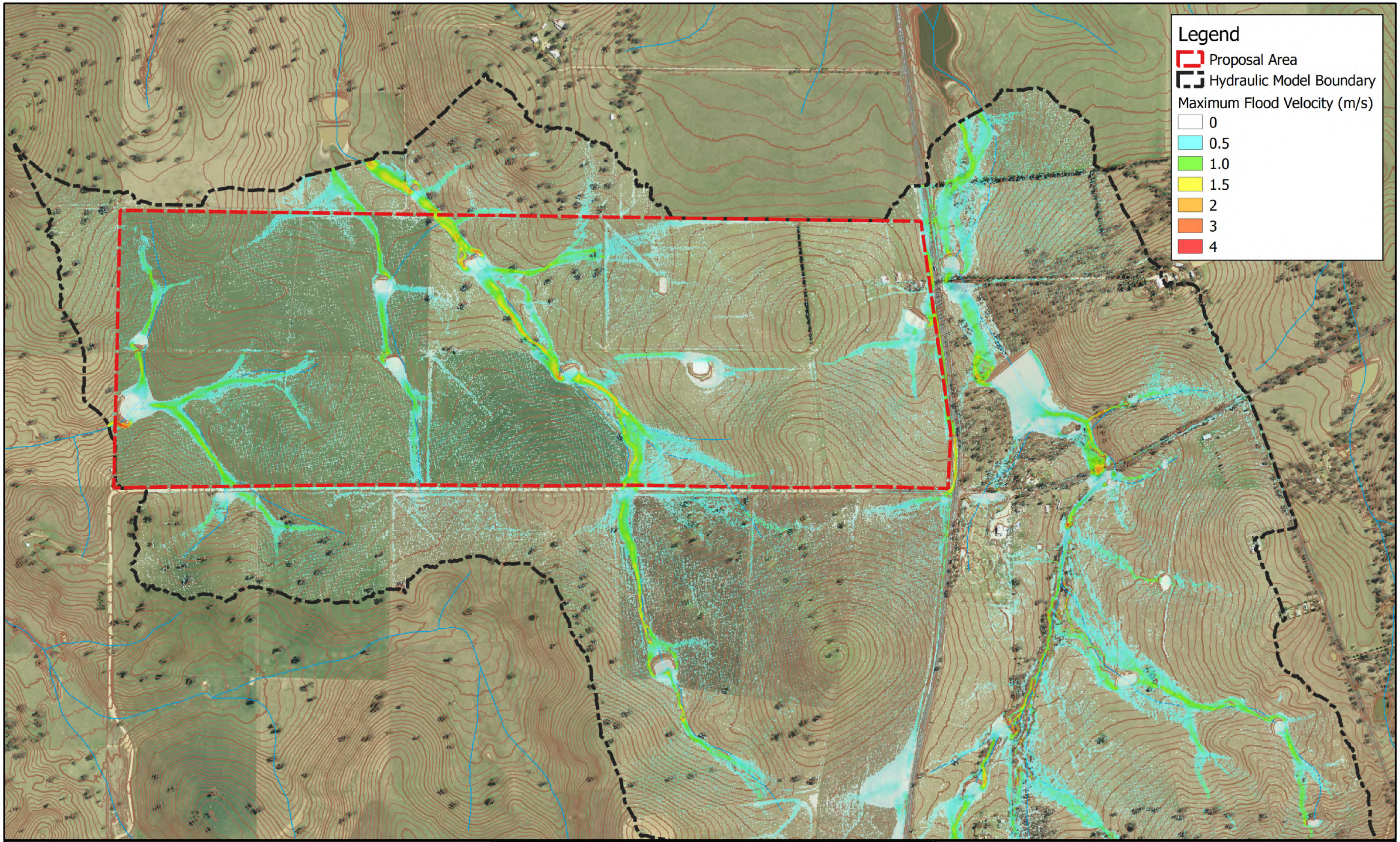
GLANMIRE SOLAR FARM

FIGURE 2.1

PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

Rev 1 - 22 AUGUST 2022



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sustainable engineering.

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100 0 100 200 300 400 m

Scale 1:10,000 at A3

GLANMIRE SOLAR FARM

FIGURE 2.2

PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD VELOCITY

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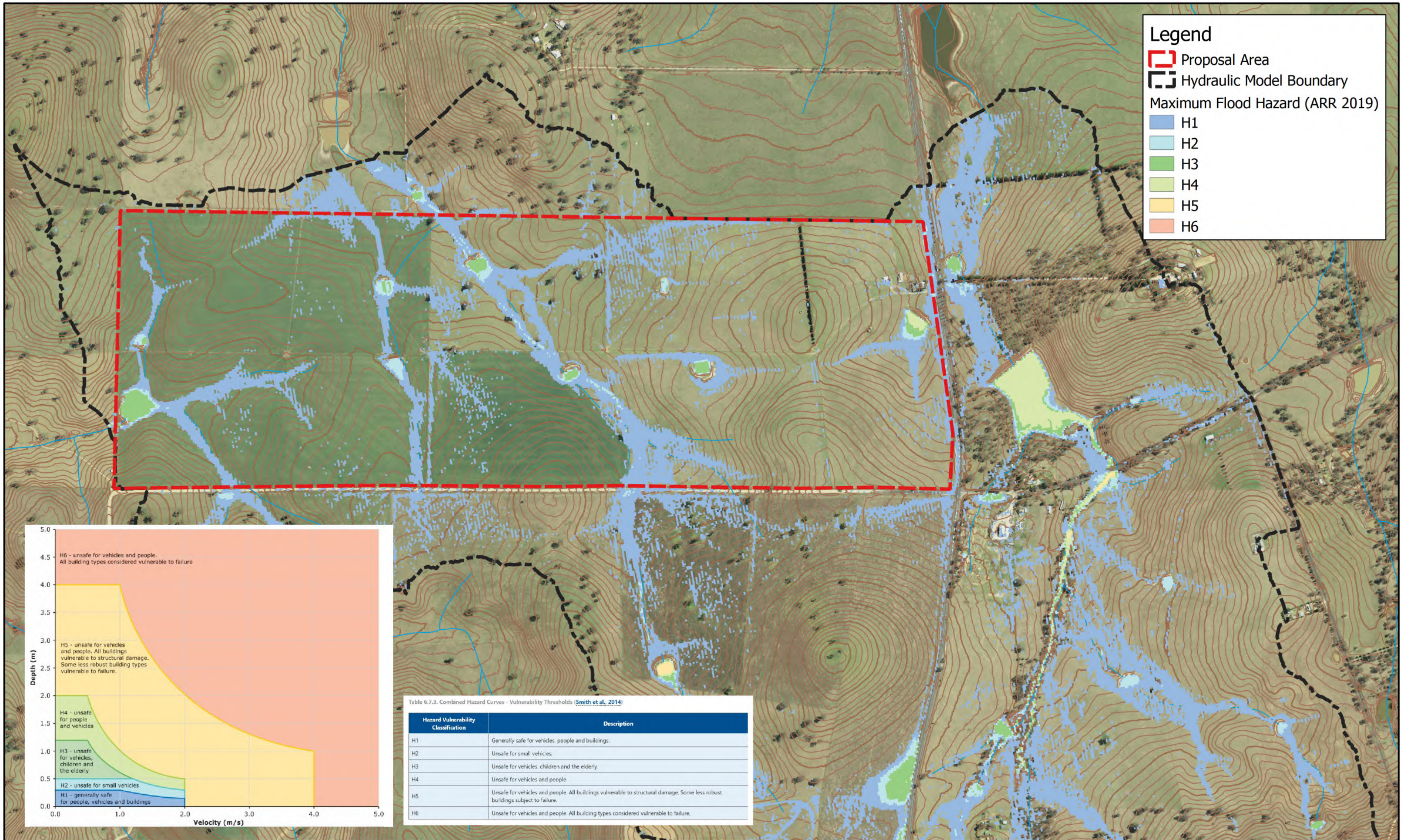

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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GLANMIRE SOLAR FARM

FIGURE 2.3
PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

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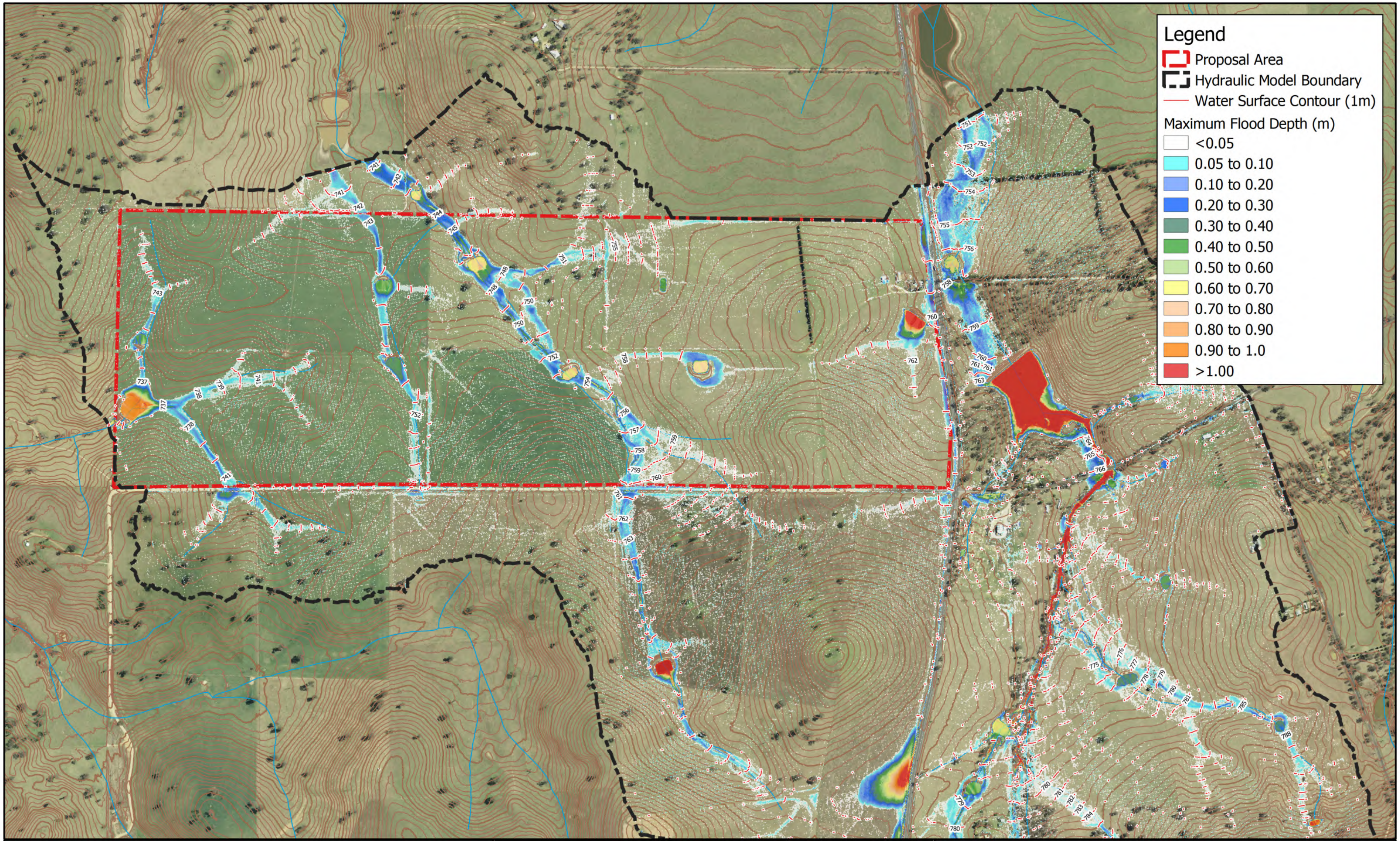

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GLANMIRE SOLAR FARM

FIGURE 3.1

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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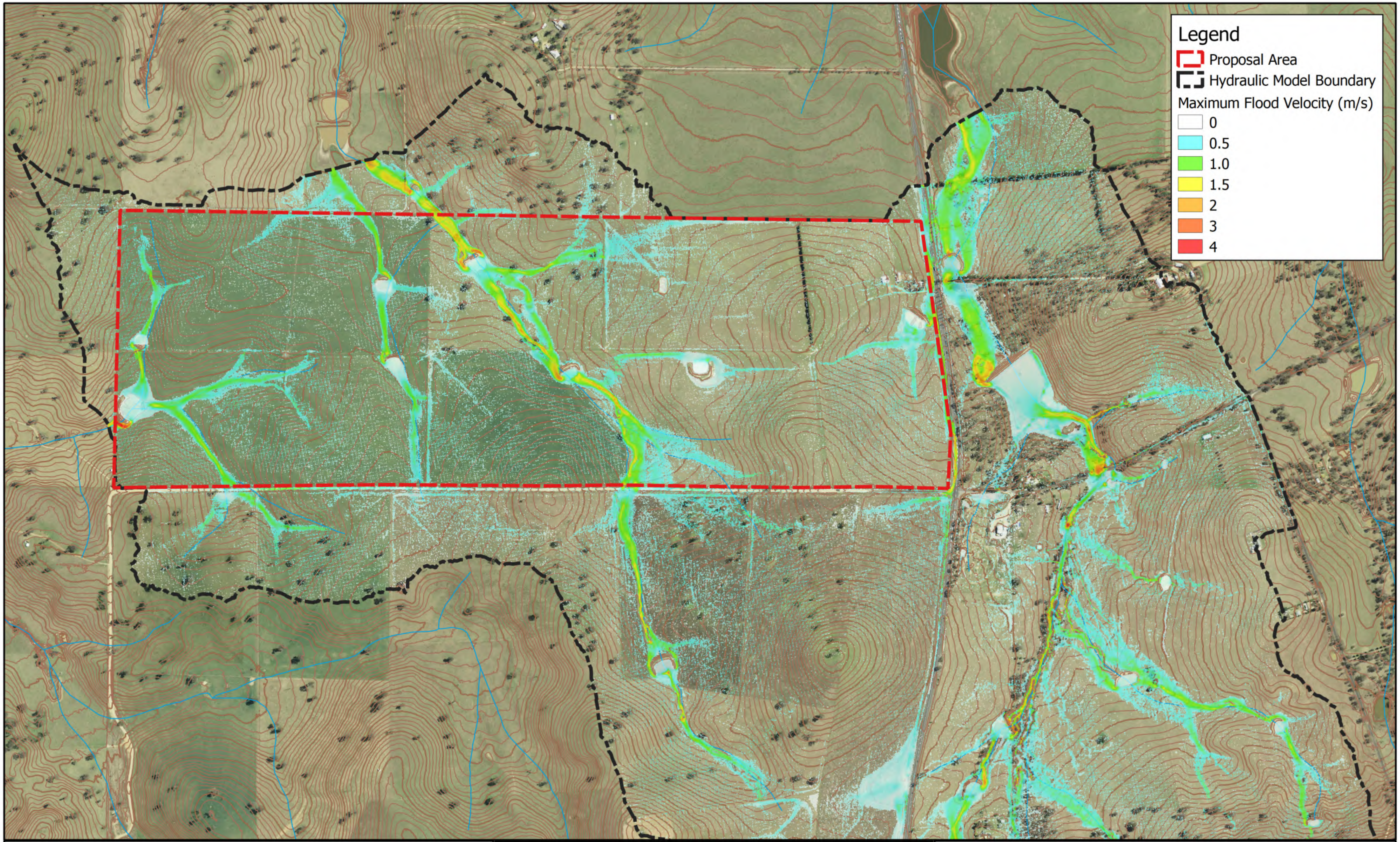

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GLANMIRE SOLAR FARM

FIGURE 3.2

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD VELOCITY

Rev 1 - 22 AUGUST 2022

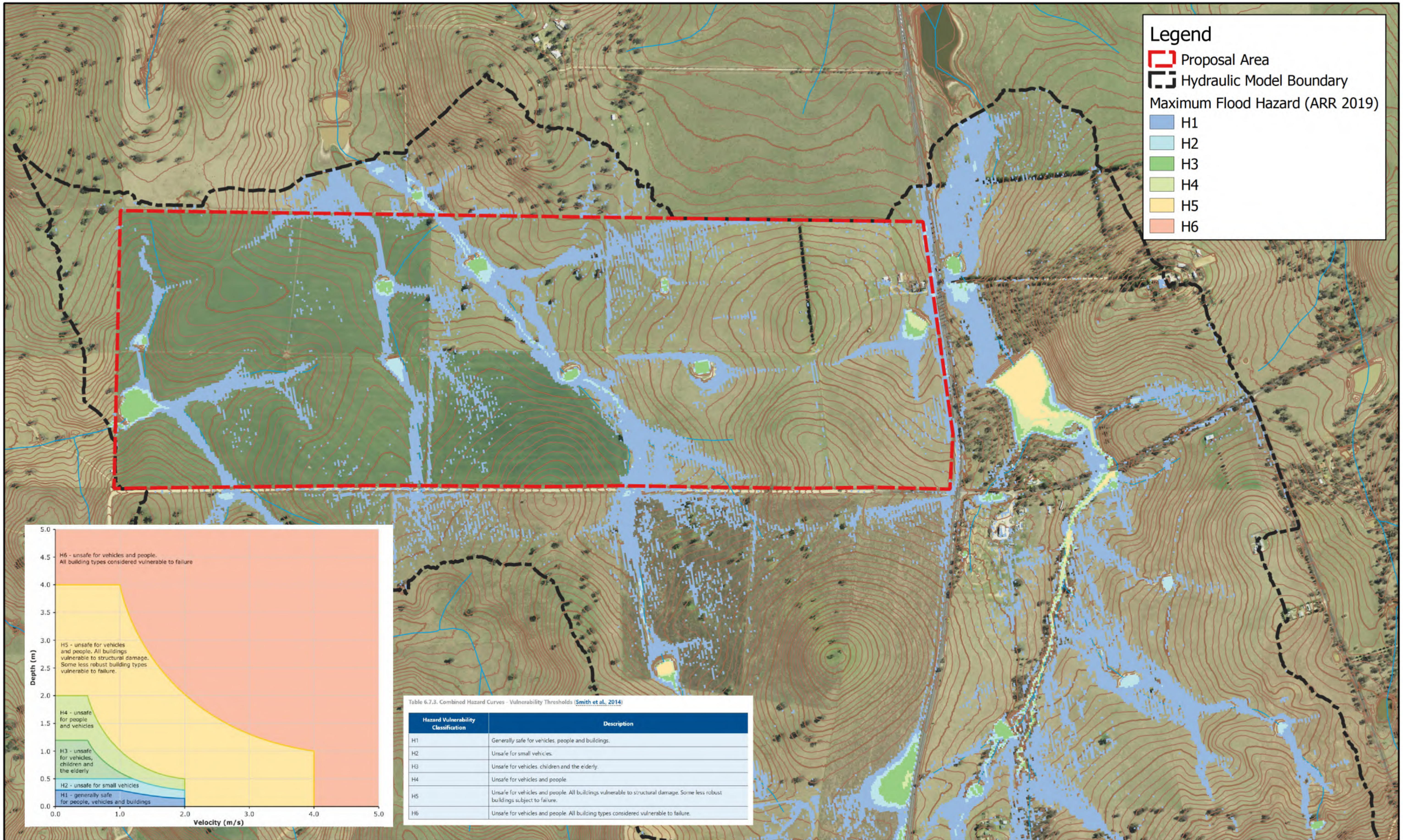

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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100 0 100 200 300 400 m

Scale 1:10,000 at A3

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FIGURE 3.3
PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

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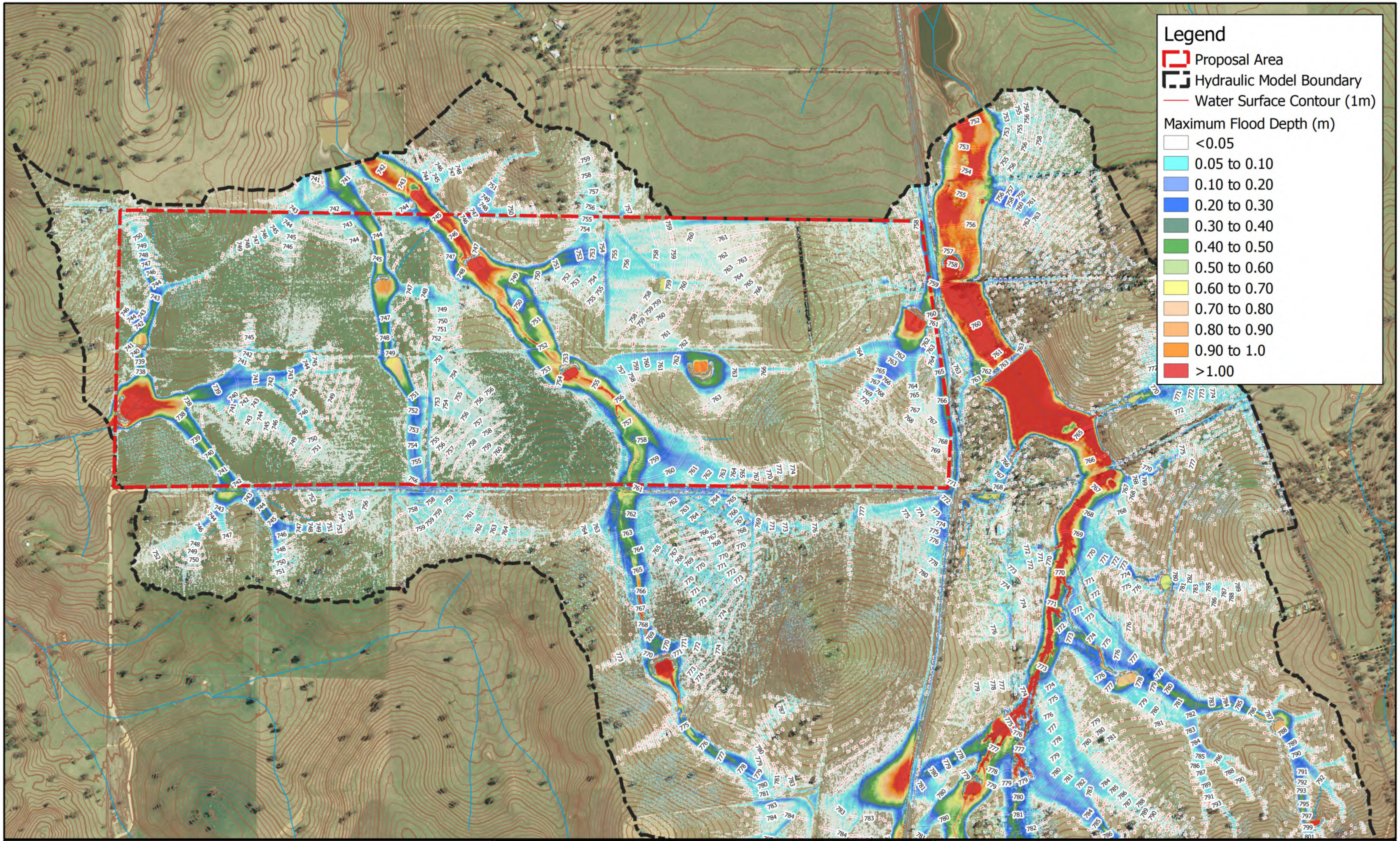

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FIGURE 4.1

PRE-DEVELOPMENT PMF MAXIMUM FLOOD LEVELS AND DEPTHS

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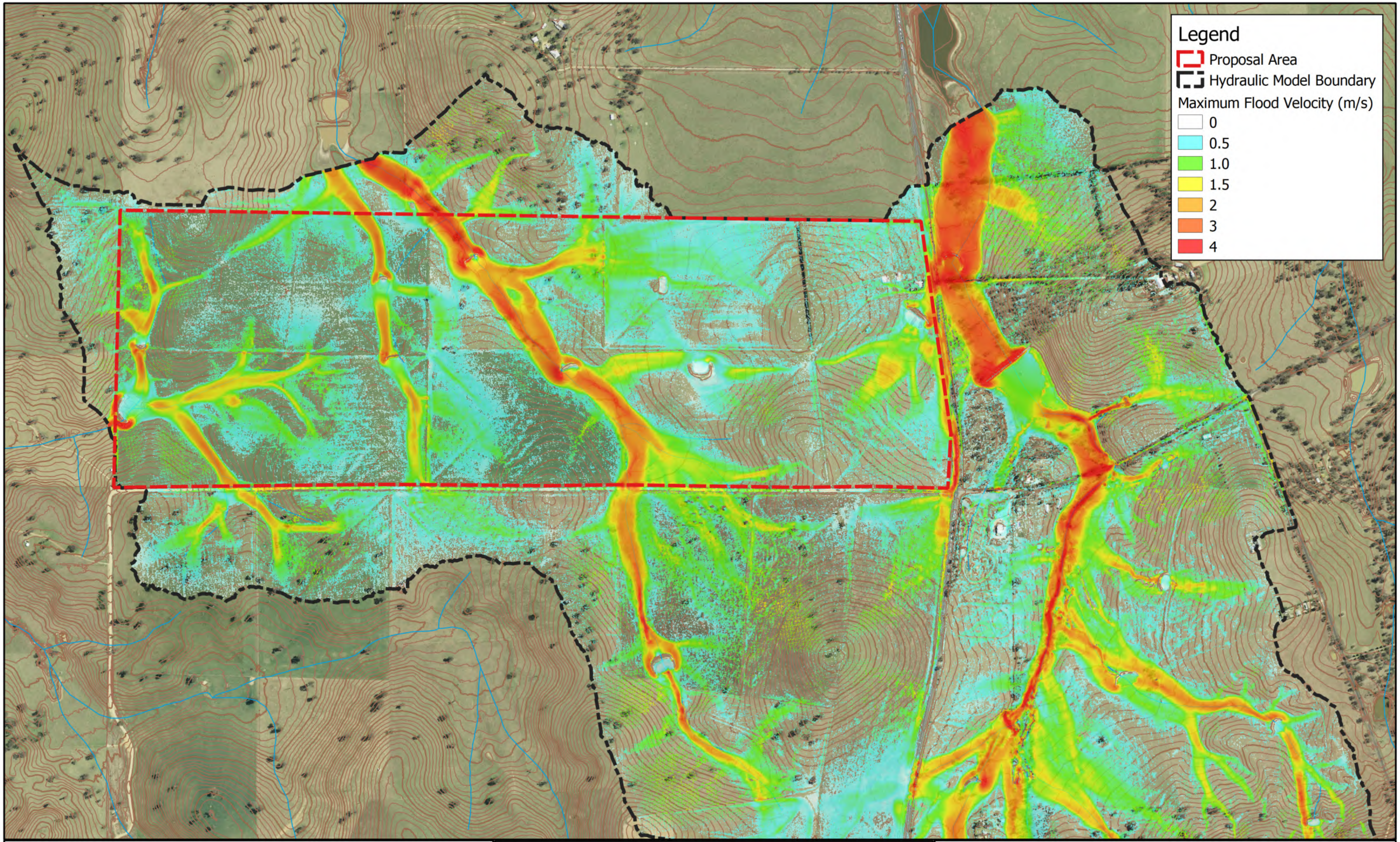

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FIGURE 4.2

PRE-DEVELOPMENT PMF MAXIMUM FLOOD VELOCITY

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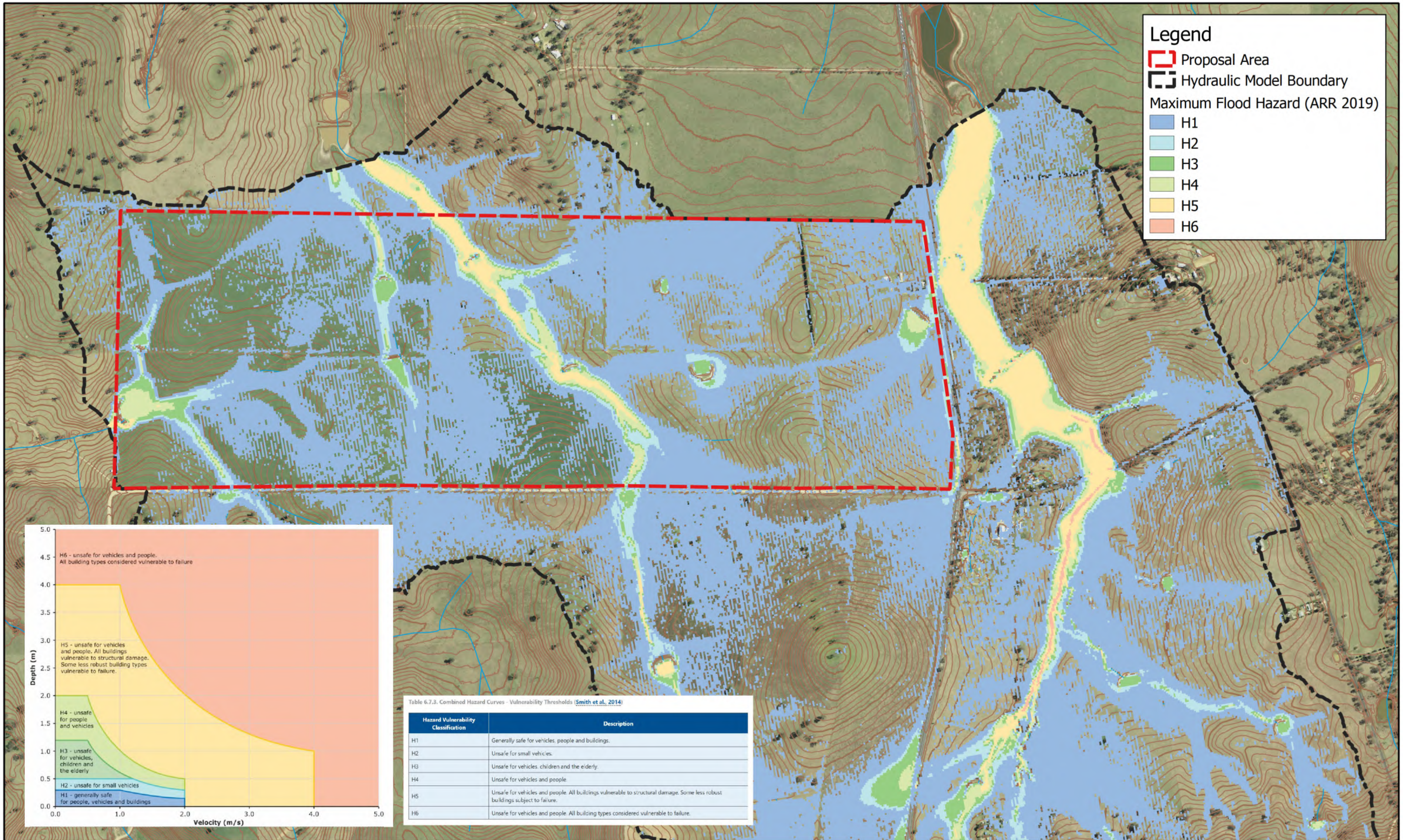

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

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Scale 1:10,000 at A3

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FIGURE 4.3

PRE-DEVELOPMENT PMF MAXIMUM FLOOD HAZARD (ARR 2019)

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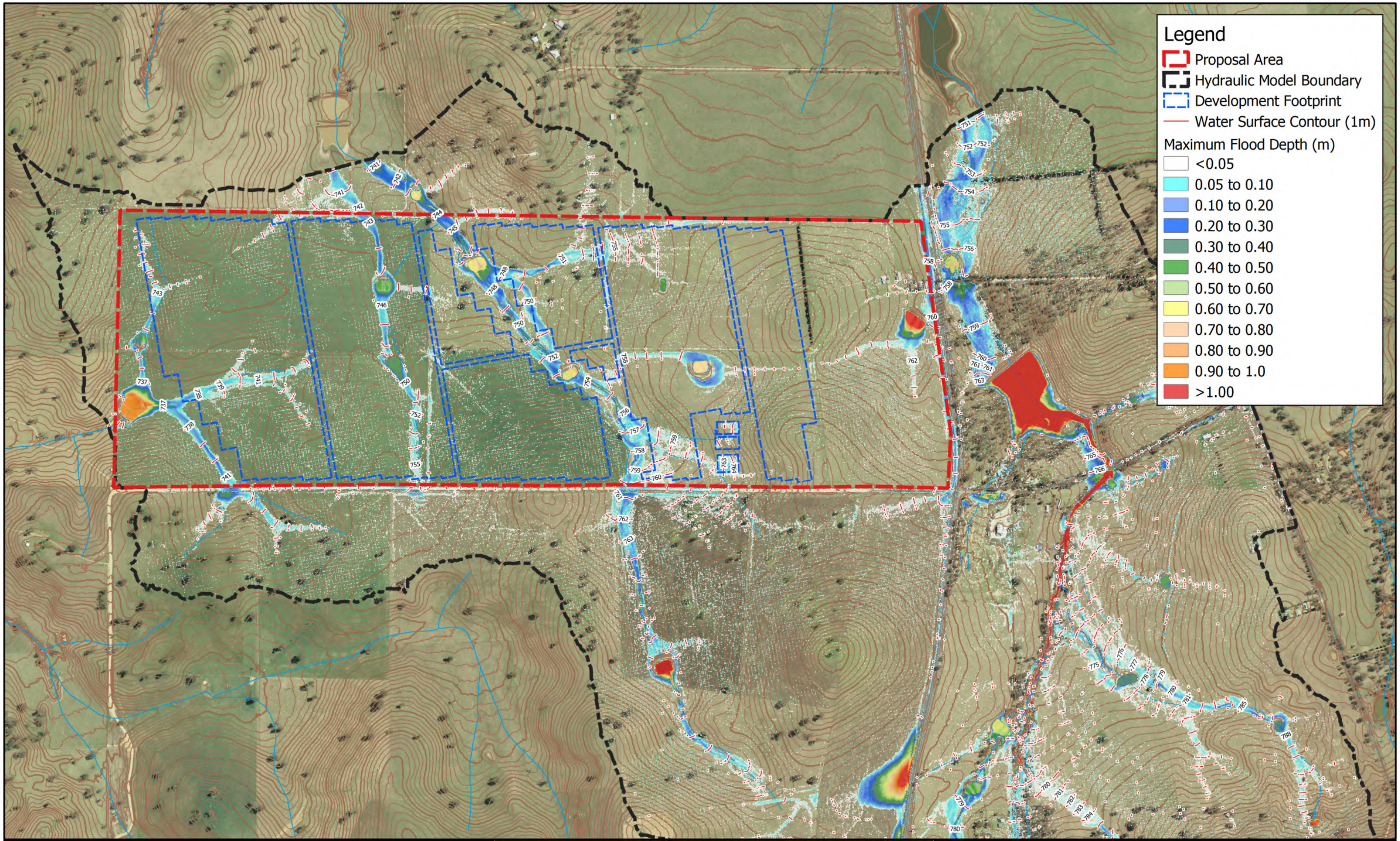

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100 0 100 200 300 400 m

Scale 1:10,000 at A3

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FIGURE 5.1

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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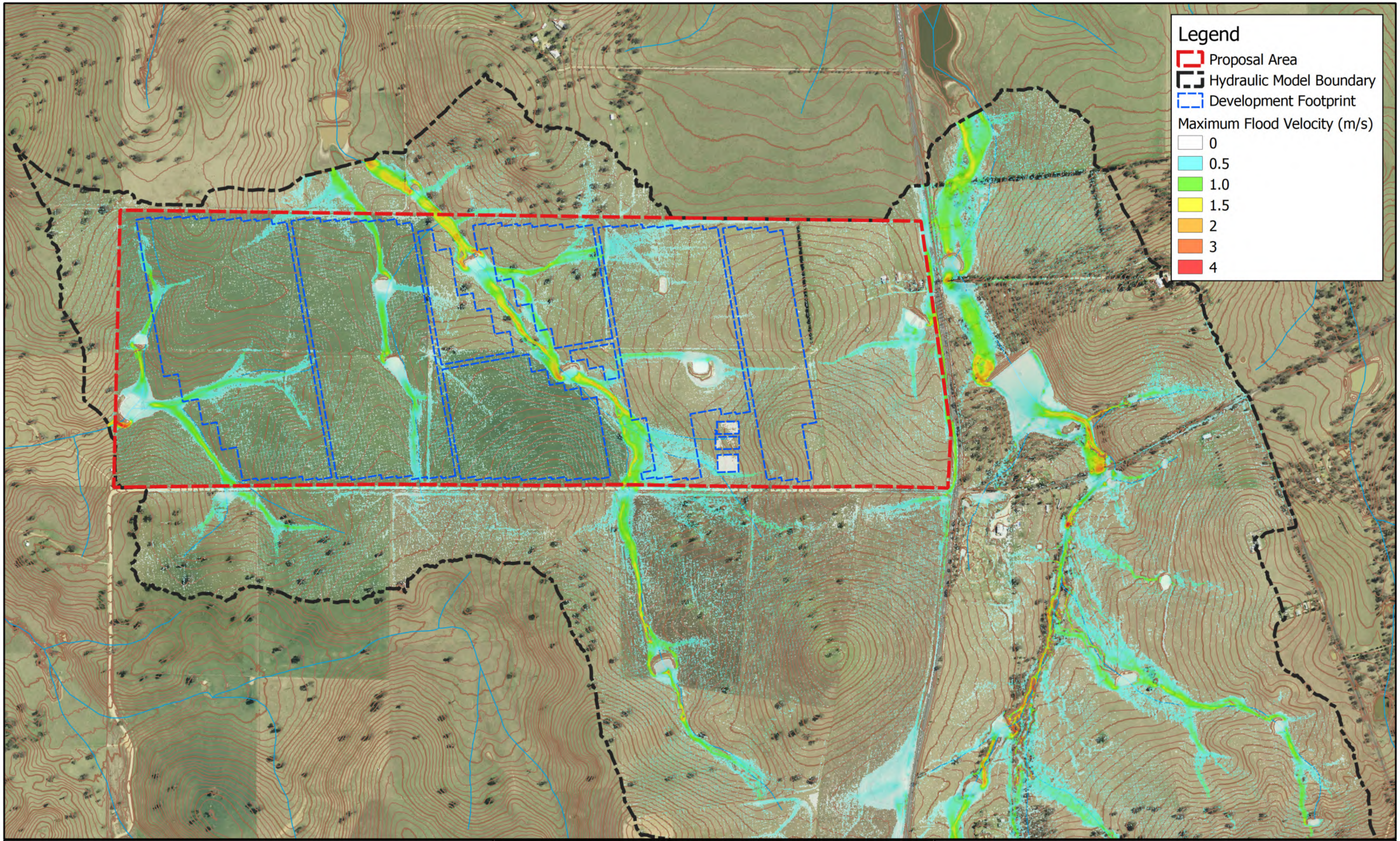

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FIGURE 5.2

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD VELOCITY

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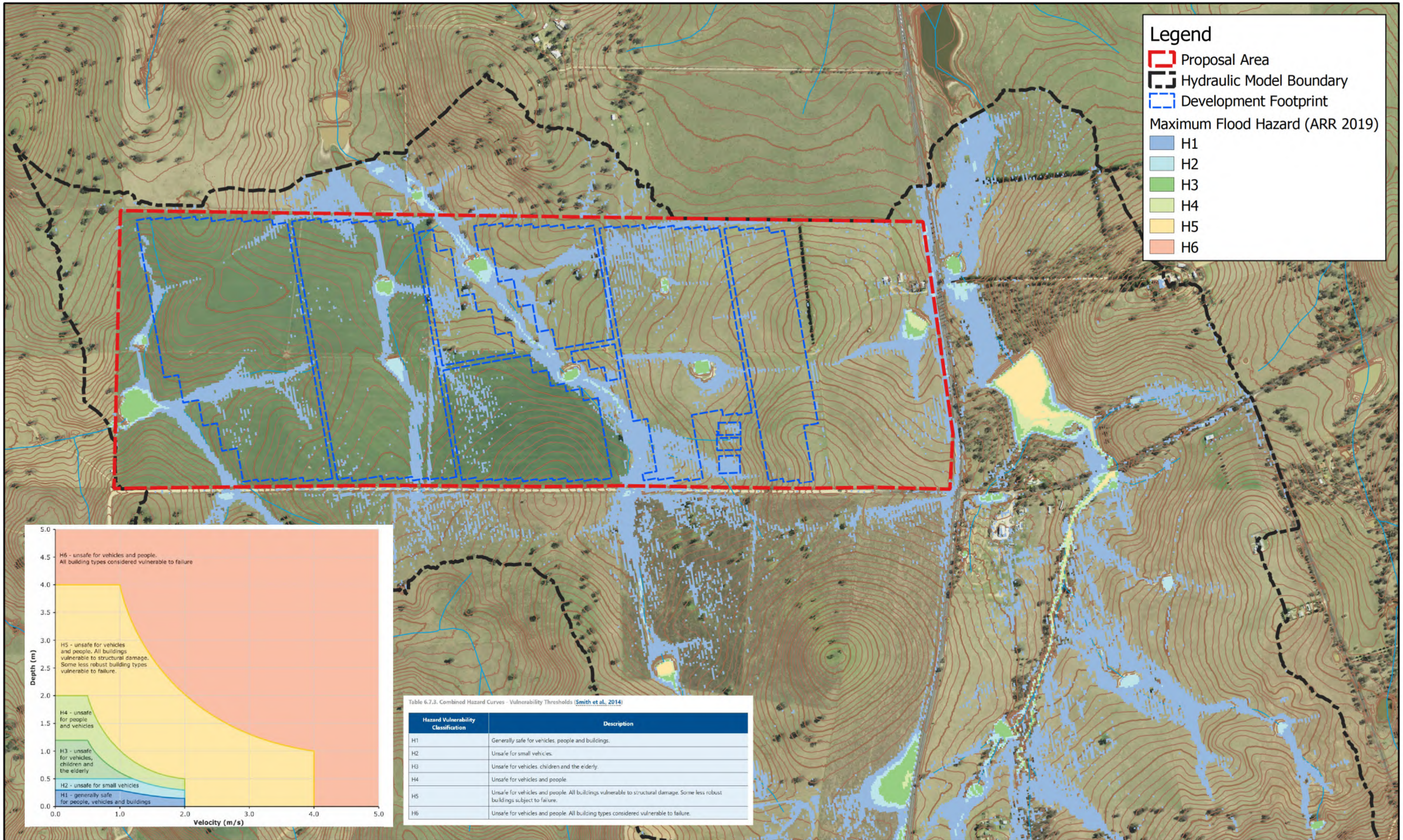

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FIGURE 5.3

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

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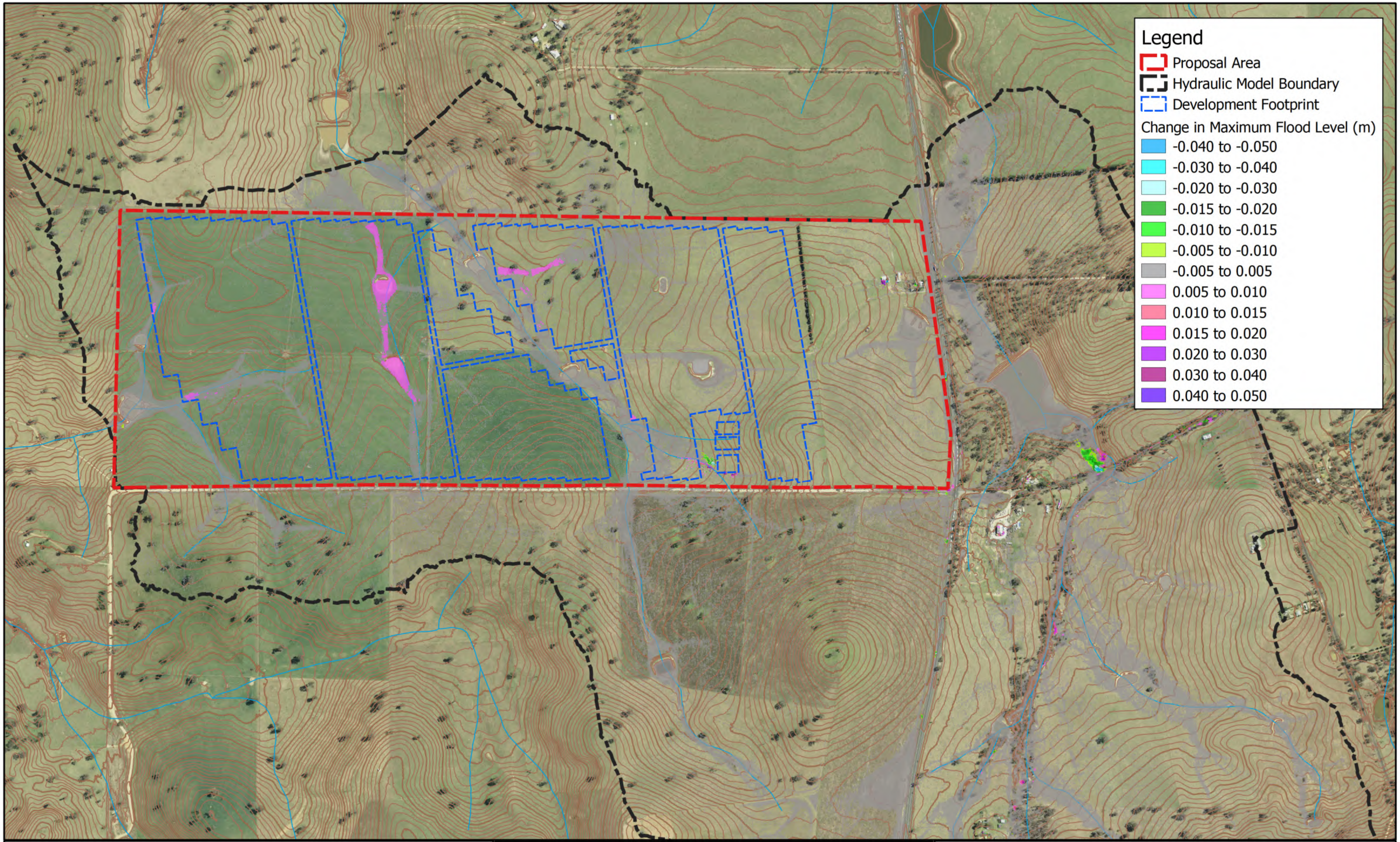

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FIGURE 6.1

PRE TO POST DEVELOPMENT 1% AEP MAXIMUM CHANGE IN FLOOD LEVEL

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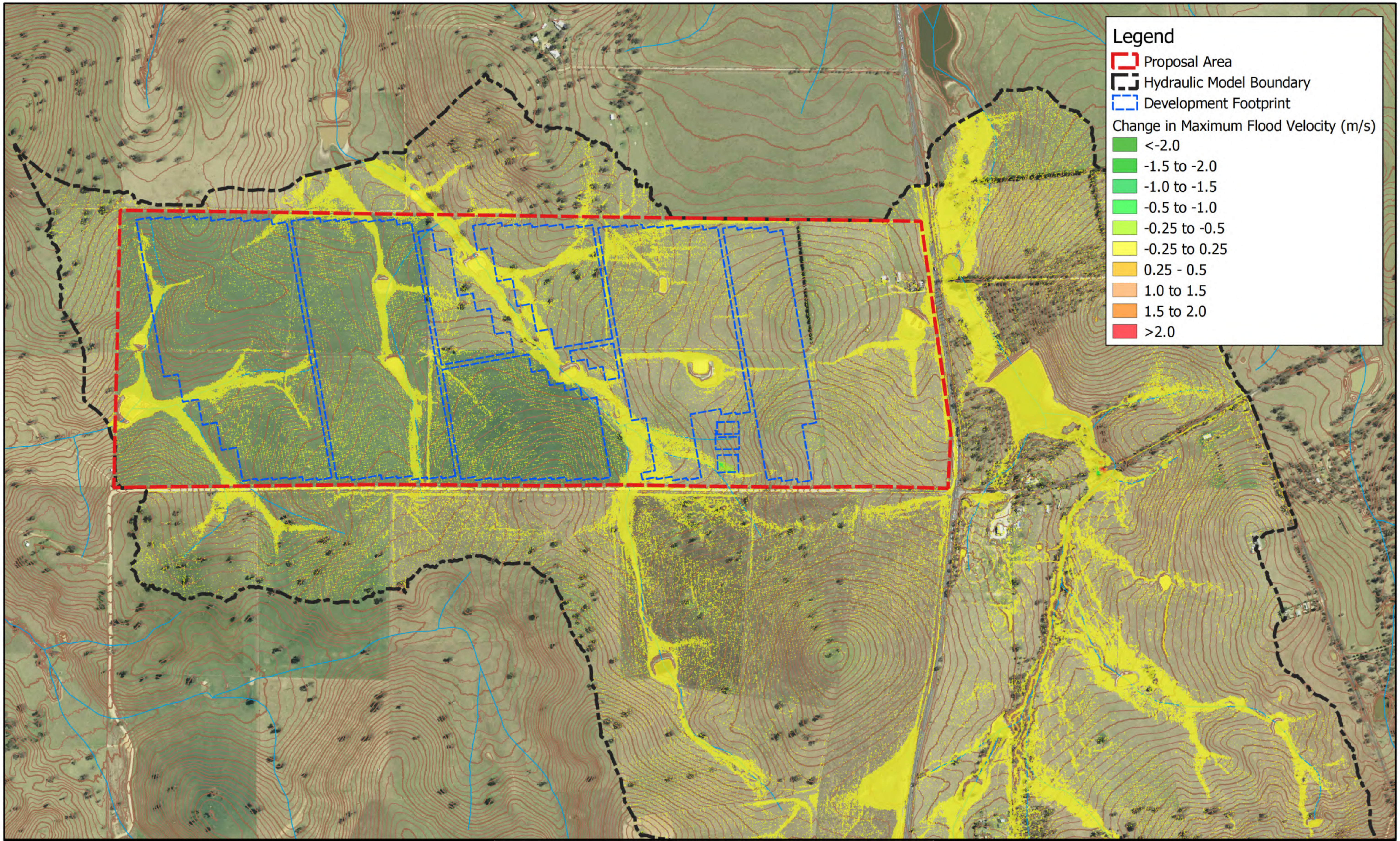

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FIGURE 6.2
PRE TO POST DEVELOPMENT 1% AEP MAXIMUM CHANGE IN FLOOD VELOCITY

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