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Proposed Solar Farm, Tilbuster, New South Wales

Hydrological and Hydraulic Analysis

Project No. 1908
Date: 12 July 2021

Prepared for: ngh consulting

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Document and Distribution Status									
Author(s)			Reviewer(s)			Signatures			
Ashley Bond						[signature]			
Revision No.	Status	Release Date	Document Distribution						
			Louiza Romane (ngh)	Clancy Bowman (ngh)					
1	DRAFT	05/03/20	PDF						
2	FINAL	21/04/20	PDF						
3	REVISED	12/07/21		PDF					

Distribution Types: F = Fax, H = Hard Copy, P = PDF, E = Other Electronic Document. Digits indicate number of copies.

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (*Footprint*) has been engaged by NGH Consulting to undertake a hydrological and hydraulic analysis in support of a proposed solar farm located approximately 15km north of Armidale.

The purpose of the analysis is to define the flood behaviour, including depth of inundation and flood velocity over that part of Duval Creek within the proposal area and the numerous ephemeral watercourses/overland flow paths that traverse the proposal area. 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.
3. Undertake two-dimensional 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 both the pre and post development scenarios.
4. 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 Tilbuster Solar Farm proposal is to be located on a property of approximately 880ha located approximately 15km north of Armidale.

The proposal area occupies an area of approximately 310 hectares includes parts of Lot 1 DP585523, Lot1 DP225170 and Lot 3 DP800611, of which approximately 170 hectares would be developed for the solar farm and associated infrastructure (Development Footprint)

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

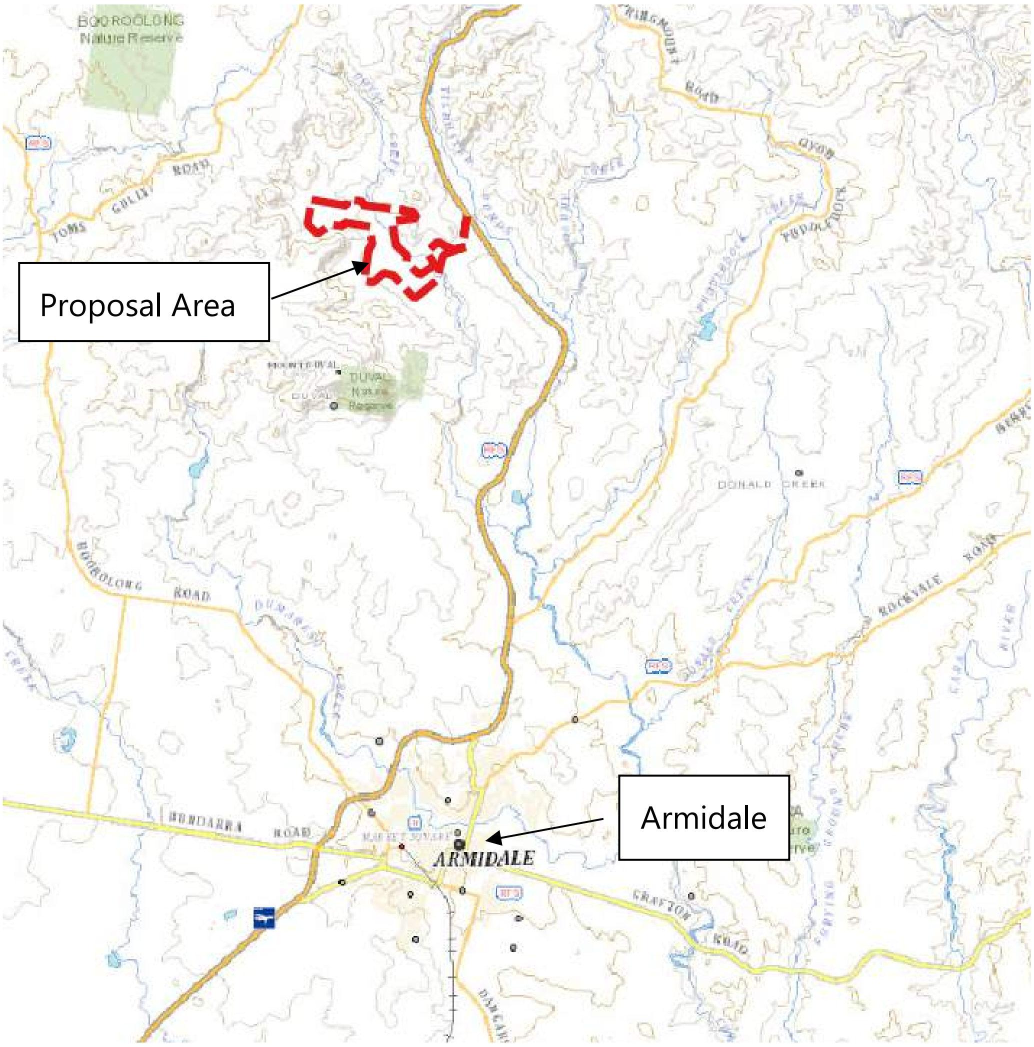


Figure 1: Location and Extent of Proposal Area

The proposal area is traversed by Duval Creek, largely along its western flank, and contains numerous other minor un-named tributaries of Duval Creek, most of which are first, second or third order watercourses.

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 4 small farm dams within the proposal area that are currently used for stock water.

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

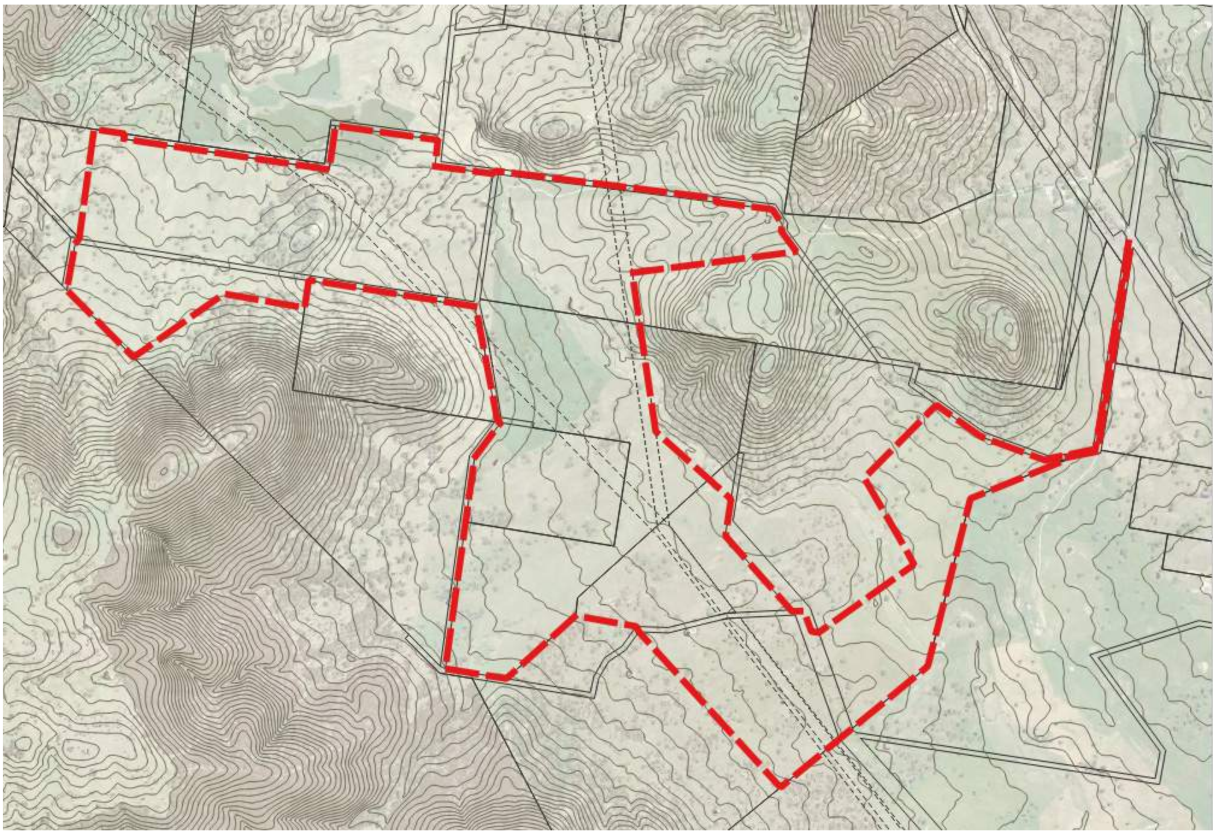


Figure 2: View of Proposal Area (outlined in red)

The proposal area typically falls from north-west to south-east with elevation ranging from about 1150m AHD to 1050m AHD. On its northern and western flanks, the proposal area is bound by relatively steep terrain which rises to an elevation of about 1300m AHD.

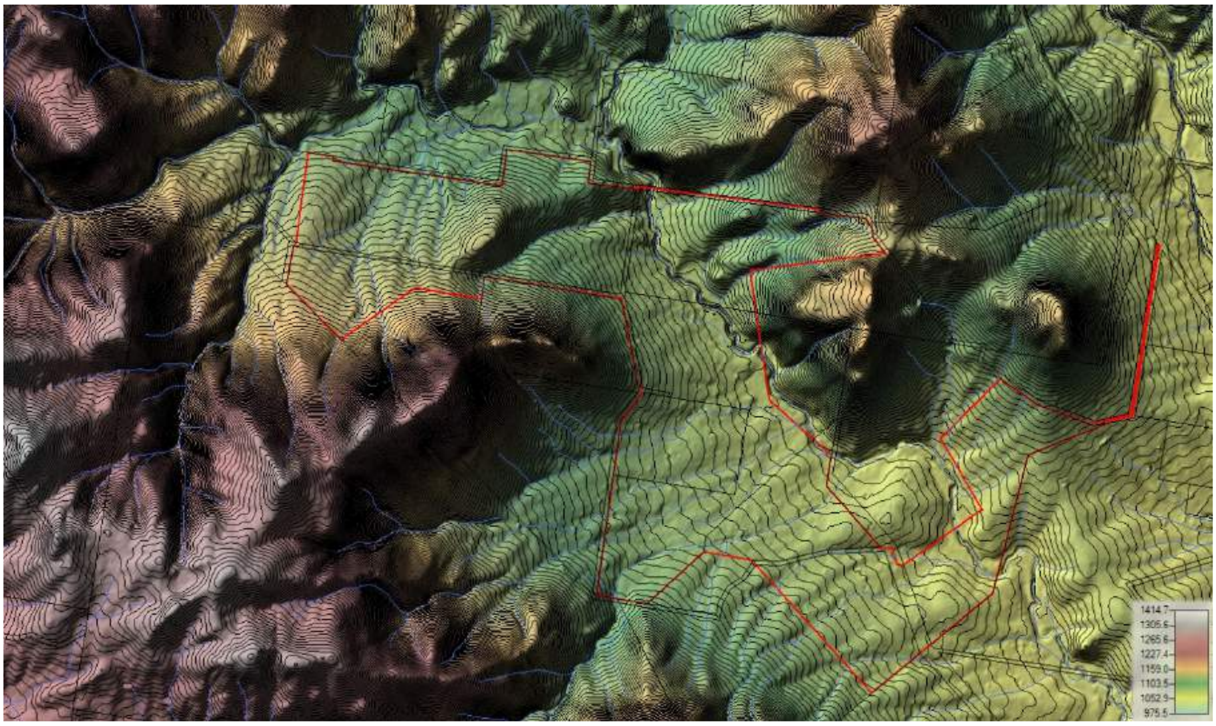


Figure 3: Terrain Analysis over Proposal Area (2m contour interval)

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

The total catchment area contributing Duval Creek at the southern boundary of the proposal area was estimated to be approximately 2765 hectares (27.65km^2) and was determined using 5m Digital Elevation Models (DEM) covering the areas which were obtained through the Australian Foundation Spatial Data web portal.

The overall catchment was dissected into 25 sub-catchments using hydrologic analysis software package Catchment SIM and ranged in size from 3.30 to 211.31 hectares, with an average size of approximately 100 hectares. Sub-catchment slopes were derived by CatchmentSIM using the above terrain data.

A catchment plan and summary of the sub-catchments is shown in Figure 1.1 in Appendix A.

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)	15	Value for South East Coast (NSW) obtained through ARR data hub (refer Appendix B)
Pervious Area Continuing Loss (mm/h)	1.7	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 (%)	0	Based on aerial photography
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	Varies 0.025 – 0.08	Based on aerial photography and varies from 0.025 for rural pasture lands to 0.08 for heavily wooded areas. Refer to Figure 1.1 in Appendix A.

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 East Coast South (ECsouth) region was used as these cover the subject site (latitude -30.377, longitude 151.656).

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 D) 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	150
0.50	220
0.75	280
1.0	330
1.5	430
2.0	500
3.0	600

Due to the inability of DRAINS (and HEC-RAS) to model spatially variable rainfall no adjustment to the point values above where made.

The hydrological results obtained through modelling point PMP values in lieu of spatially variable PMP values would therefore be slightly higher than actual flows and therefore conservative.

The PMP Calculation spreadsheet is included in Appendix E

3.6. Flow Routing

The routing of flows through the catchment was undertaken by extracting a representative cross section from the LiDAR DEM over the watercourse linking each sub-catchment area. Manning's n values were applied to the full width of the cross section based on an assessment of aerial photography.

Flows were routed along each link within DRAINS which applies the full S.t Venant equations of unsteady flow to overland flow routes. This allows water levels along these routes to be determined accurately, allowing for varied water surface flow profiles, including subcritical and supercritical flows.

3.7. Results

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 are shown in Table 3.

Table 3: Summary of Critical Durations and Storms

Event	Critical Duration	Median Storm from Ensemble	Peak Flow at Outlet (m^3/s)
5% AEP	1.5 hours	Storm 9	209
1% AEP	1 hour	Storm 7	345
PMF	1.5 hours	N/A	2483

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady direct rainfall two-dimensional HEC-RAS model (Version 5.0.7) which covered the entire catchment draining to the subject site.

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 5m gridded digital elevation models (Guyra2011.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 5m DEM grid was imported into HEC-RAS and used as the basis for development of a 10m x 10m terrain model. The DEM grid was further refined where required by applying breaklines to enforce abrupt changes in geometry, such as along existing watercourses.

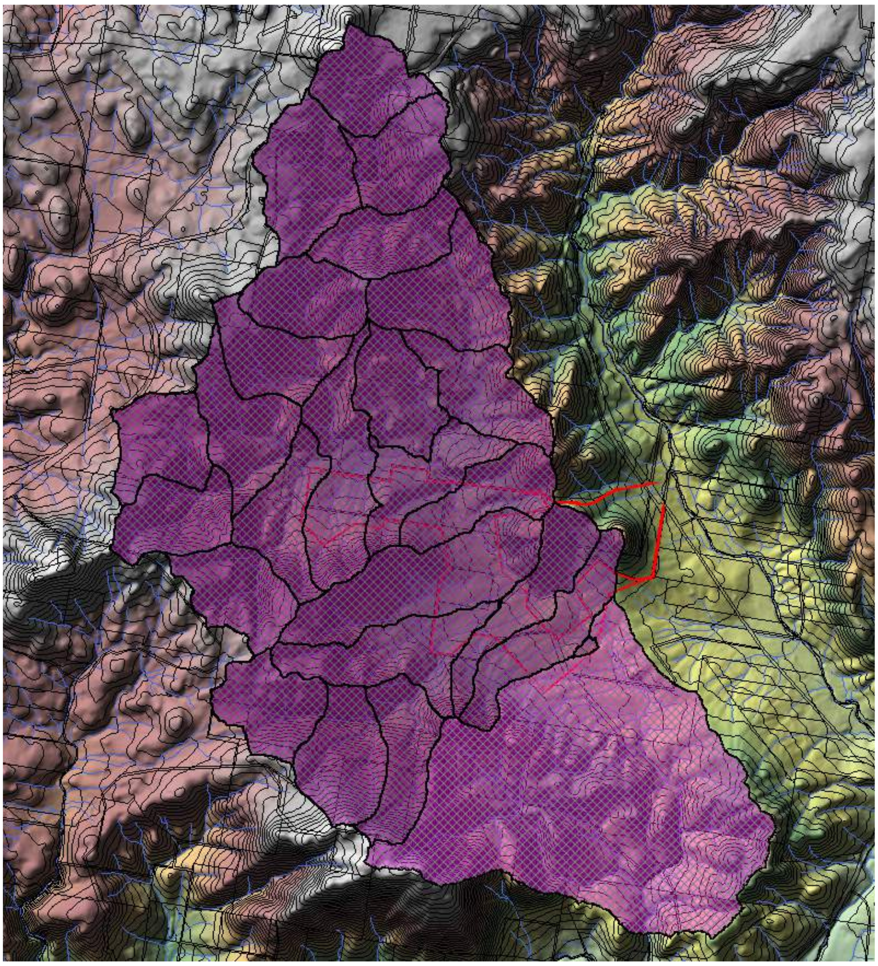


Figure 4: Two-Dimensional Flow Area

4.2. Manning’s Roughness

HEC-RAS 5.0.7 is currently limited to modelling constant roughness which does not consider changes to roughness with changes in flow depth. As direct rainfall models frequently experience shallow flow conditions over large areas of the catchment this approach can magnify the impact of depth-variation in roughness for shallow flows and lead to under-estimation of over-estimation of effective roughness depending on surface type, hence resulting in faster or slower routing of catchment runoff.

An iterative approach was therefore adopted by adjusting the surface roughness over the catchment until the hydrographs at the outlet of sub-Catchment 1.11 at the southern boundary of the subject site closely aligned with those produced by the DRAINS hydrological model.

Final Manning’s roughness values adopted for design event modelling are shown in Figure 2.1 in Appendix F

4.3. Direct Rainfall Boundary Condition

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

The current limitation of HEC-RAS means that precipitation can only be used to apply rainfall excess (rainfall minus losses due to interception/infiltration) directly to the two-dimensional grid.

Rainfall excess hyetographs for each of the critical duration median storm events shown in Table 3 were generated in Microsoft Excel by subtracting initial losses plus pre-burst rainfall (where applicable) from the design rainfall data starting from the beginning of the data set. An example of this for the 1% AEP, 1-hour storm event is shown in Figure 5: 1% AEP Hyetograph.

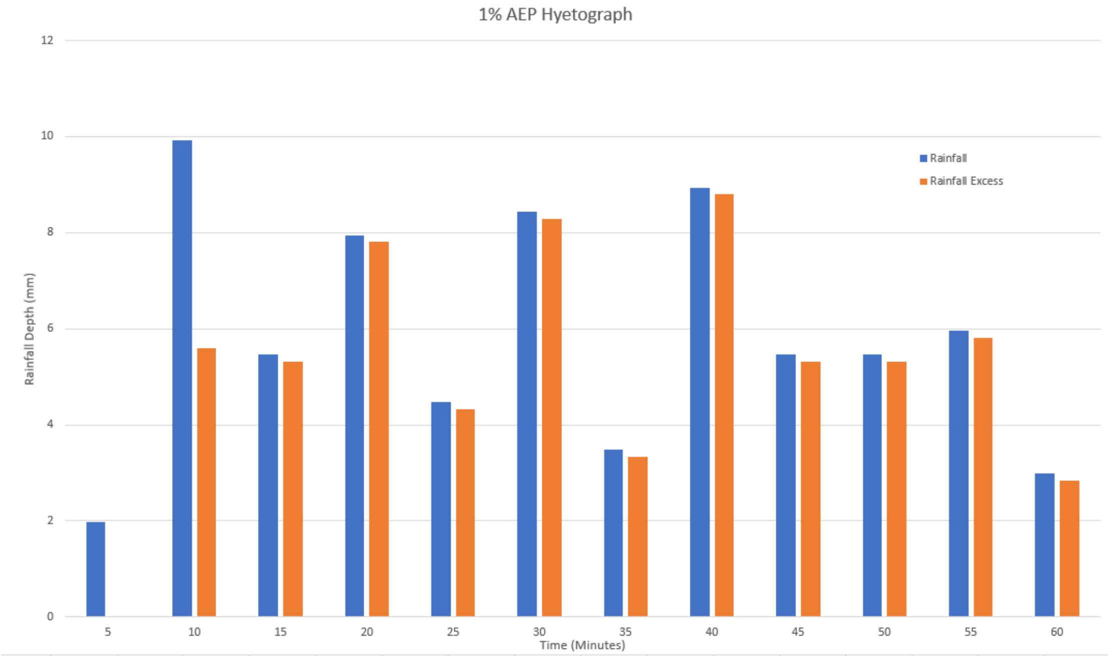


Figure 5: 1% AEP Hyetograph

4.3.1. 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 G and include the mapping shown in Table 4.

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

Table 4: Summary of Results

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

4.4.1. Comparison to Hydrological Model Results

As described in Section 4.2 an iterative process was undertaken by adjusting the surface roughness over the catchment until the hydrographs produced by the hydraulic model approximated those produced by the hydrological model.

The comparison of hydrographs generated for the hydrological and hydraulic models on Duval Creek immediately downstream of the subject site (sub-catchment outlet 1.11) are provided in Figure 6 for the 5% AEP and 1% AEP events and Figure 7 for the PMF event.

The comparison shows reasonable correlation between both the peak and the shape of the hydrographs, with the hydraulic model typically taking longer to generate runoff and peaking slightly later and a little higher than the hydrological model for both the 5% and 1% AEP events. In the PMF event the hydraulic model is shown to be shedding runoff slightly faster and generating a slightly earlier and higher peak than the hydrological model.

A comparison of peak flows and hydrograph volumes is provided in Table 5 and again shows reasonable correlation between the results, with peak flows being typically 10-16% higher for the hydraulic model. Runoff volumes were also comparable with variations of -2 to +8%.

Table 5: Comparison of Peak Flows and Runoff Volumes

Event	PEAK FLOW (m^3/s)			VOLUME (m^3x10^3)		
	DRAINS	HEC-RAS	%	DRAINS	HEC-RAS	%
5%AEP	209	232	11.0%	1025	940	8.3%
1% AEP	345	402	16.5%	1514	1451	4.2%
PMF	2483	2738	10.3%	11168	10928	-2.1%

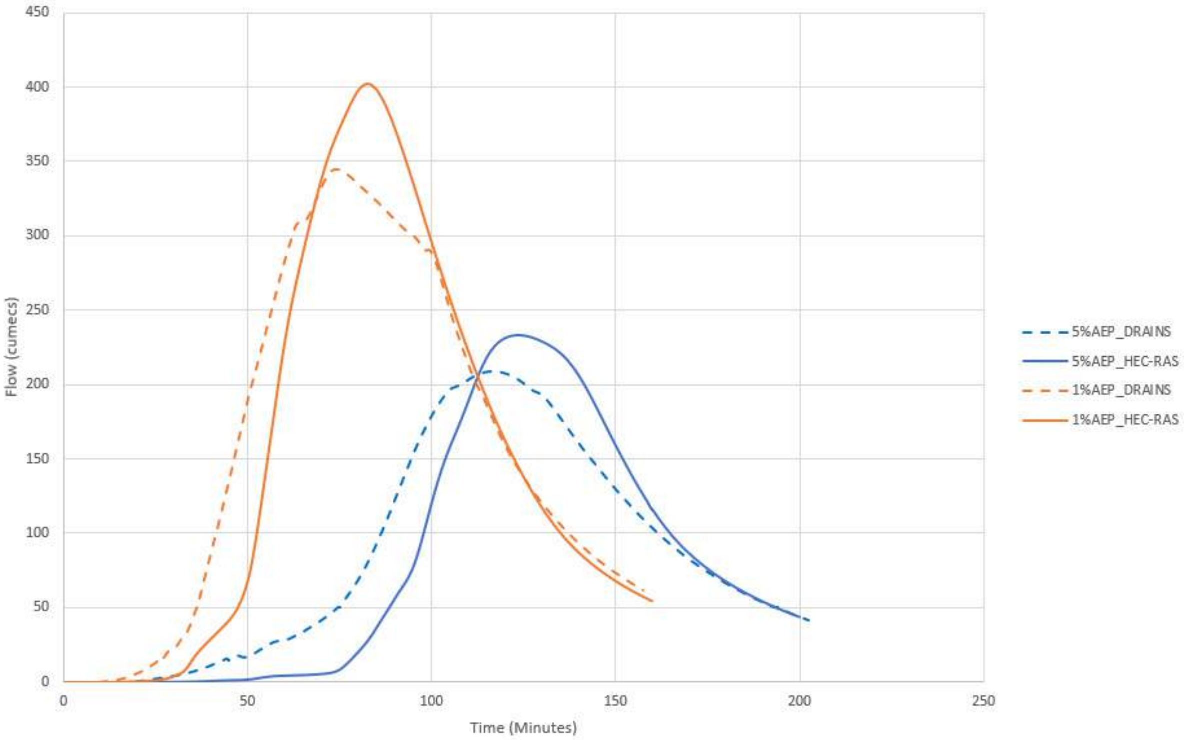


Figure 6: Comparison of Hydrographs at Sub-Catchment 1.11 outlet - 5% and 1% AEP

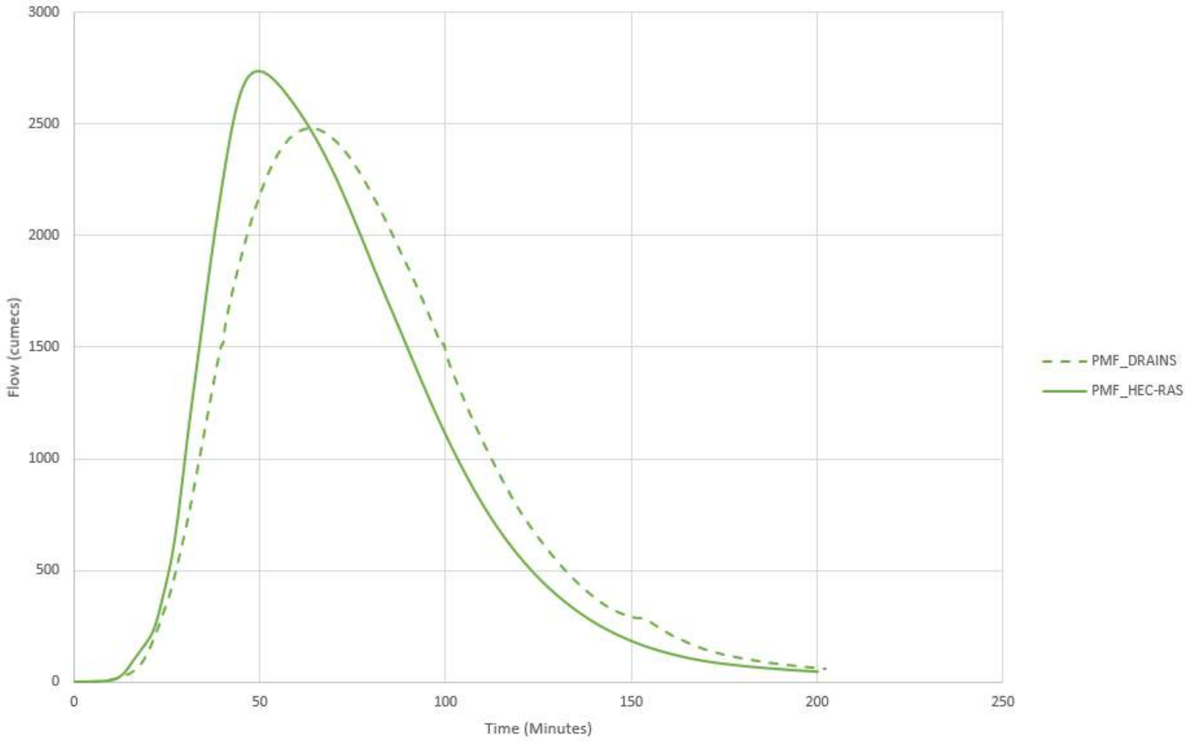


Figure 7: Comparison of Hydrographs at Sub-Catchment 1.11 Outlet - PMF

4.4.2. Comparison to Regional Flood Frequency Model

A comparison of peak flows for the 5% and 1% AEP events from both DRAINS and HEC-RAS were compared to the peak flows obtained through the Regional Flood Frequency Estimation (RFFE) Model and the results are shown in Table 6, with a copy of the RFFE Model report contained in Appendix H.

The comparison shows that peak flows derived by both the DRAINS hydrological and HEC-RAS Hydraulic model are significantly higher than those estimated by the RFFE Model.

Comparing the results to Catchment 2 from the RFFE model which is located approximately 10km north of the subject site (see Figure 8) in what appears to be a similar topographical area shows that this 14km^2 catchment generates a peak flow of about 150-200 cumecs. Extrapolating this out to the subject catchment which is approximately twice the size peak flows should be in the order of 300-400 cumecs, which better aligns with the DRAINS and HEC-RAS results achieved.

Table 6: Comparison to RFFE Model

AEP	Peak Flow Rate (cumecs)				
	DRAINS	HEC-RAS	Regional Flood Frequency Estimation Model		
			Discharge	Lower (5%)	Upper (95%)
5%	209	232	25.8	11.2	59.7
1%	345	402	51.4	20	131

Figure 8: Outlet and Centroid of Tilbuster Solar Catchment in Comparison to nearby catchments from RFFE

4.4.3. Comparison to Probabilistic Rational Method

Considering the discrepancy of the RFFE Model results a check was undertaken using the Probabilistic Rational Method and the results are provided in Table 7. The comparison shows that the results of the hydrological and hydraulic models, whilst slightly lower, are much more consistent with the Probabilistic Rational Method results than the RFFE model results and therefore the RFFE Model results are not considered reliable and should not be used as a basis for comparison.

Table 7: Comparison of Results to Probabilistic Rational Method (PRM)

Event	Peak Flows (cumecs)		
	DRAINS	HEC-RAS	PRM
5%	209	232	285
1%	345	402	492

4.5. Hazard Vulnerability

The flood hazard vulnerability over the subject site was mapped in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2019) and is shown in Figures 3.3, 4.3 and 5.3 in Appendix G for the 5%AEP, 1%AEP and PMF events respectively.

The mapping shows that flooding within the proposal area is primarily classified as a H1 hazard vulnerability in the 5% AEP and 1% AEP events, except for flooding within Duval Creek which reached H6 classification and the third order watercourse that discharges into Duval Creek through the south-western corner of the proposal area, which reaches H5 classification in parts. As expected, hazard increases over the proposal area in the PMF event.

Table 6.7.3 of Australian Rainfall and Runoff (below) describes the hazard thresholds for community interaction with floodwaters.

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.

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 152 Megawatts (AC) to be supplied directly to the national electricity grid. The Proposal would provide enough clean, renewable energy for about 48,000 average NSW homes while displacing approximately 250,000 metric tons of carbon dioxide annually. The proposal site is approximately 310 hectares of which approximately 170 hectares would be developed for the solar farm and associated infrastructure (Development Footprint). Two existing TransGrid transmission lines transect the site, a 132 kilovolts eastern line and a 330 kilovolts central line. The 330 kilovolts transmission line would be used to connect the solar farm to the national electricity grid.

The primary access point during construction and operation for light and heavy vehicles would be off New England Highway, east of the site.

Key development and infrastructure components would include:

- Installation of approximately 400,878 PV solar modules mounted on either fixed or horizontal single-axis tracking system
- Steel mounting frames with pile foundation
- Installation of up to 30 Power Conversion Units – totalling 60 inverters, 30 transformers and associated ancillary equipment
- Electrical cabling including overhead lines and underground electrical conduits to connect PV modules to outdoor substation
- Outdoor 330 kV substation including switchgears and ancillary equipment
- Onsite energy storage facility – Storage requirements will be 40 MW/h or less, battery technology is yet to be determined and subject to change based on detail design
- Monitoring container as required for operation and maintenance
- Construction facilities including laydown, parking, site offices and staff facilities
- Storage container (40 ft)
- IB (Combiner) boxes
- Internal access road and upgrades including primary access on New England Highway – up to 6.8km in length
- Perimeter security fencing
- Security camera poles
- Construction of creek crossing as required
- Native vegetative screening as required

In total, the construction phase of the proposal is expected to take 12 months, and the facility would be expected to operate for around 30 years or extended pending further approvals. Up to five 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.

The Proposal would require subdivision of Deposited Plan Lots within the proposal site for lease and purchase agreement purposes with the involved landowner.

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 5-6m. 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 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 8. 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 which are variable across the site 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 8: 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 values shown in Figure 2.1 in Appendix F over the extent of the proposed solar array footprint.

The area nominated for the proposed substation and car parking areas was assigned a Manning's n value of 3 to reflect the impact of the proposed buildings and structures 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 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.

Furthermore, watercourse crossings have not been included in the model as fords or bridges, which minimise any hydraulic impact, have been recommended (see Section 6.4).

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 6.1, 6.2 and 6.3 in Appendix G.

The results in Figures 6.1, 6.2 and 6.3 demonstrate that there is not predicted to be a significant impact on flood behaviour within the floodplain as a result of the proposed works, with flood levels, depths, velocities and hazards remaining relatively unchanged.

This is better demonstrated in Figures 7.1 and 7.2 (Appendix G) which show the change in maximum flood level and peak flood velocity resulting from the proposed development. These figures show that peak flood levels and velocities over most of the proposal area are anticipated to remain unchanged, due primarily to the infrastructure being located outside of areas subject to flooding. Some minor increases in flood levels and corresponding decreases in velocity are shown to occur near the middle of the proposal area near the proposed substation and car parking precinct, however these changes are very localised and not anticipated to adversely affect adjoining properties.

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, except where required as an emergency flood refuge (see Section 6.2) where the floor level should eb a minimum of 500mm above the PMF flood level.

At the substation site slight raising of the adjacent roadway (or similar type bunding) is recommended in order to divert upslope runoff around this critical piece of infrastructure.

6.2. Flood Management

Access to a significant portion of the site (including operation and maintenance buildings) will require the crossing of Duval Creek. If the proposed crossing structures over Duval Creek will be rendered impassable during significant flood events it is recommended that:

i. Flood warning signs and flood level indicators should be placed on each approach to the proposed crossings.
ii. A flood refuge building or structure be provided within the proposal area on the eastern side of Duval Creek, such that in the event the proposed Duval Creek crossings are not trafficable any staff on-site have access to a weatherproof, flood free structure to seek temporary refuge. Such refuge area should be located a minimum of 500mm above the PMF level.
iii. A Business Floodsafe Plan be prepared for the development to ensure the safety of employees during flood events in general accordance with the NSW SES "Business Floodsafe Toolkit and Plan"

6.3. 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 6.1 and 6.2 respectively in Appendix G.

6.4. 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.

6.5. 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.

Fencing across Duval Creek should be avoided in preference to creating two separate fenced compounds on either side of the creek.

6.6. Watercourse Crossings

Watercourses on the subject site have been classified by the Strahler System in accordance with the Guidelines for Riparian Corridors on Waterfront Land (DPI Water, 2012) and are shown in Figure 8.1 in Appendix I. Any road crossings on watercourses within the subject site should be of the type defined in Table 2 of this same document (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)

6.7. 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.

6.8. 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

7.0 SEAR'S COMPLIANCE

The Department of Planning and Environment issued environmental assessment requirements (SEARs) for the preparation of an Environmental Impact Assessment (EIS) for the proposed development on 12 October 2018, which included requirements from the Office of Environmental and Heritage (OEH) pertaining to flooding. Table 9 below demonstrates how this report addresses the OEH SEAR's requirements with respect to flooding.

Table 9: Assessment of Compliance with SEAR's

OEH Requirement	Response
12. The EA must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005), including:	
a. Flood Prone Land.	Flood Prone Land for the 5% AEP, 1% AEP and PMF have been defined over the proposal area as defined in Section 4.4 of this report.
b. Flood Planning Area, the area below the flood planning level.	Whilst an important tool in the management of flood risk the delineation of a flood planning areas is not considered relevant for the proposed development as the development does not comprise filling or habitable structures within the floodplain. Notwithstanding, Section 6.3 recommends setting proposal solar array panels a minimum of 500mm above the 1% AEP flood level.
c. Hydraulic Categorisation (floodways and flood storage areas).	Hydraulic categorisation is not considered relevant for the proposed development as they are a tool to assist in the preparation of appropriate floodplain risk management plans. The Floodplain Development Manual (2005) states that "they are not to be used for assessment of development proposals on an isolated or individual basis".

d. Flood Hazard.	Flood Hazard Categorisation for all design storm events modelled was undertaken in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2016) and is included in Section 4.5 of this report.
e. The EA must describe the flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% AEP, 1% AEP flood levels and the PMF, or equivalent extreme event.	The methodology and modelling undertaken in determining flood levels and velocities is described in details in Sections 3.0 and 4.0 of this report.
f. The EA must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	
g. Current flood behaviour for a range of design events as identified in 15 above. This includes the 0.5% and 0.2% year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	The impact of the proposed development on flood behaviour is described in detail in Section 5.2 of this report. Modelling for 1% AEP only was undertaken and shows minimal impact on existing flood behaviour. It is not considered necessary to model the 0.5% and 0.2% AEP events as proxies for assessing the sensitivity to an increase in rainfall intensity as the proposed development is relatively insensitive to flooding and will incorporate measures (such a solar array panels being a minimum of 500mm above the 1% AEP flood level) to minimise flood damages to proposed infrastructure.
13. Modelling in the EA must consider and document:	
14. Existing Council flood studies in the area and examine consistency to the flood behaviour documented in these studies.	No existing studies are known to exist within proximity of the proposal area.
15. The impact on existing flood behaviour for a full range of flood events including up to the probably maximum flood, or equivalent extreme flood.	The impact of existing flood behaviour up to the PMF event has been included in this assessment

16. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazard categories and hydraulic categories	Section 5.2 of this report demonstrates that the impacts of the proposed development are very minor change in flood level and velocity within the proposal area. Importantly the modelling demonstrates that changes in peak flood levels are limited to within the proposal area and are therefore not anticipated to adversely affect adjoining properties
17. Relevant provision of the NSW Floodplain Development Manual 2005	This report is considered to address the relevant provisions of the NSW Floodplain Development Manual.
18. The EA must assess the impact on the proposed development on flood behaviour including:	
a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	The post development modelling presented in Section 5.2 shows that the proposed development will have negligible impact on existing flood behaviour, and no change in flood behaviour of other properties, assets or infrastructure.
b. Consistency with Council Floodplain Risk Management Plans	No known Floodplain Risk Management Plan exists for the proposal area.
c. Consistency with any Rural Floodplain Management Plan	No known Rural Floodplain Management Plans exist for the proposal area.
d. Compatibility with the flood hazard of the land	The development is compatible with the flood hazard of the site as infrastructure proposed as part of the development is typically located on low flood hazard land.
e. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	The layout proposed infrastructure has been undertaken in consideration of flood risk with development located outside land subject to mainstream flooding and where located within the floodplain typically located on land with low associated flood risk.
f. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	The proposed development will not result in any change to the current flooding regime on the proposal area and beneficial inundation of the floodplain environment will continue to occur.

g. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Section 5.2 indicates that changes in peak velocity resulting from the proposed development are expected to be in the range of plus or minus 0.25m/s which will ensure the stability of the bed and banks of existing watercourses and minimise further erosion potential. Further Section 6.8 recommends that 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
h. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the NSW SES and Council.	No known community emergency management arrangement exists in proximity of the proposal area.
i. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the NSW SES and Council.	Recommendations regarding specific measures to manage the risk to life from flooding and evacuation are provided in Section 6.2 and include flood warning signs, a flood refuge structure and preparation of a Business Floodsafe Plan. Whilst not discussed with the NSW SES or Council they are considered standard flood management measures.
j. Emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the NSW SES.	
k. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	The proposed development is not anticipated to have any adverse impact on the social and economic costs to the community as a result of flooding.

8.0 INFILL OVER MAPPED WATERCOURSES

The development layout proposes the erection of solar panel infrastructure over areas currently mapped as watercourses as shown on the NSW Hydroline Dataset and therefore a merit-based assessment has been undertaken to assess whether the watercourses are considered waterfront land under the Water management Act.

Ground truthing of the watercourses within the proposed area was undertaken by ngh consulting in May 2021 and provided to Footprint in the form of descriptions and photographs for assessment. The ground truthing locations and representative photographs of the watercourse at each location are provided in Appendix J and a summary of the merit-based assessment is provided in Table 10.

The merit -based assessment identified that all of the areas on which solar panel infrastructure is proposed to be located do not exhibit the typical attributes of a watercourse (i.e. defined bed and banks) and are therefore not considered to be waterfront land for the purposes of the Water Management Act.

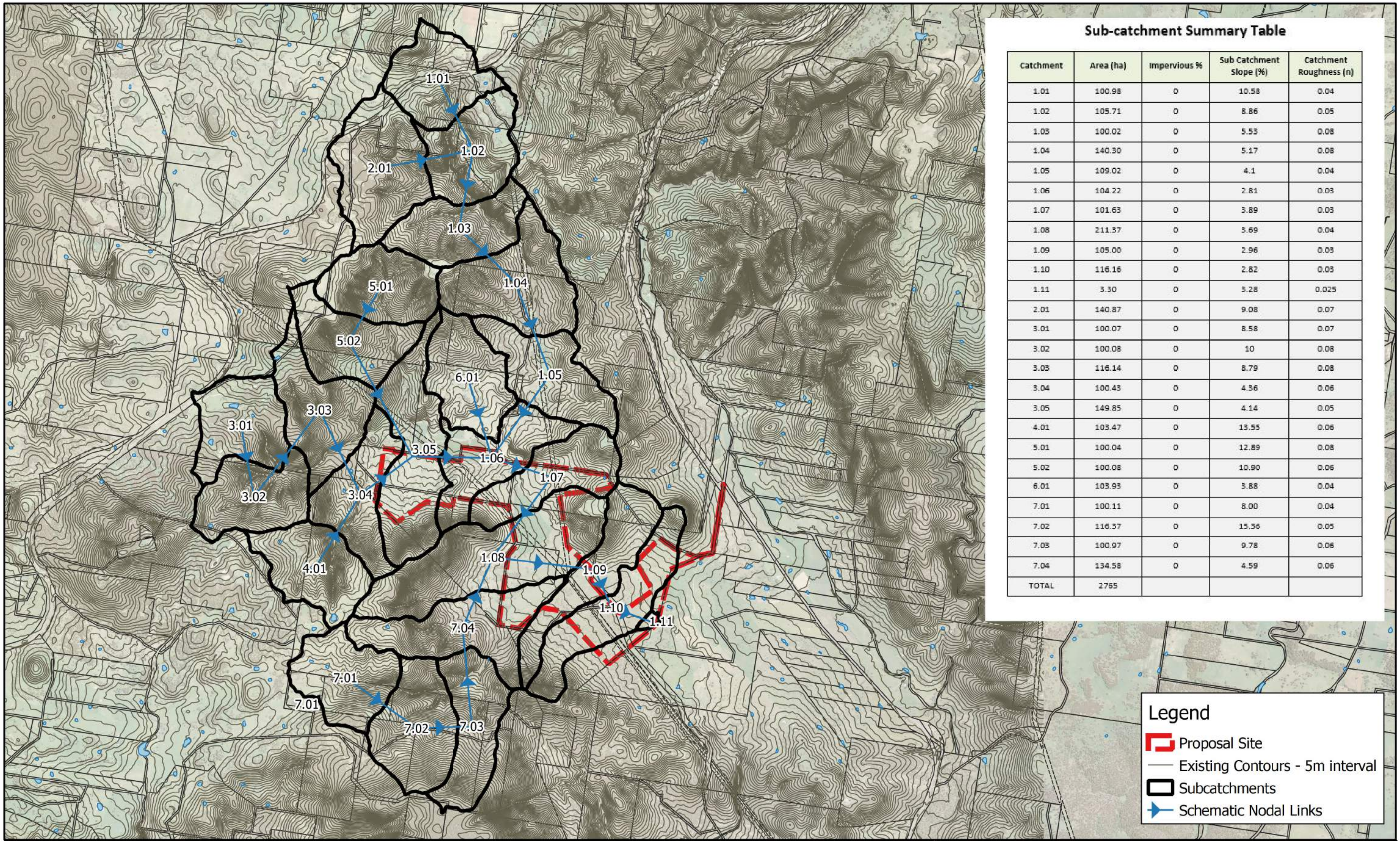
It is acknowledged that development is proposed over some streams currently classified as third order streams as shown in Figure 8.1 in Appendix I. However neither the subject watercourses, nor any of the watercourses upstream of that point exhibit the typical attributes of a watercourse and the mapping is not a realistic representation of actual conditions and therefore the stream order classification is considered to be over estimated and conservative.

Table 10: Summary of Merit Based Assessment for Watercourses

Location	Stream Order	Watercourse Features Present
1 and 2	2	N
3	2	N
4	2	N
5	2	N
6	2	N
7	2	N
8	2	N
9	2	N
10	2	Y
11	3	N
12	3	Y
13	3	N
14	2	N

APPENDIX A

Catchment Plan



Sub-catchment Summary Table

Catchment	Area (ha)	Impervious %	Sub Catchment Slope (%)	Catchment Roughness (n)
1.01	100.98	0	10.58	0.04
1.02	105.71	0	8.86	0.05
1.03	100.02	0	5.53	0.08
1.04	140.30	0	5.17	0.08
1.05	109.02	0	4.1	0.04
1.06	104.22	0	2.81	0.03
1.07	101.63	0	3.89	0.03
1.08	211.37	0	3.69	0.04
1.09	105.00	0	2.96	0.03
1.10	116.16	0	2.82	0.03
1.11	3.30	0	3.28	0.025
2.01	140.87	0	9.08	0.07
3.01	100.07	0	8.58	0.07
3.02	100.08	0	10	0.08
3.03	116.14	0	8.79	0.08
3.04	100.43	0	4.36	0.06
3.05	149.85	0	4.14	0.05
4.01	103.47	0	13.55	0.06
5.01	100.04	0	12.89	0.08
5.02	100.08	0	10.90	0.06
6.01	103.93	0	3.88	0.04
7.01	100.11	0	8.00	0.04
7.02	116.37	0	15.36	0.05
7.03	100.97	0	9.78	0.06
7.04	134.58	0	4.59	0.06
TOTAL	2765			

footprint.
sustainable engineering.
15 meehan drive, kiama downs,
nsw 2533 p: (02) 4237 6770

500 0 500 1000 m

Scale 1:40,000 at A3

TILBUSTER SOLAR FARM

FIGURE 1.1
CATCHMENT PLAN

Rev 2 - 21 April 2020

APPENDIX B

ARR Hub Data

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	151.656
Latitude	-30.377
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	South East Coast (NSW)
River Number	6
River Name	Macleay River

Layer Info

Time Accessed	05 September 2019 12:23PM
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
East Coast North	0.327	0.241	0.448	0.36	0.00096	0.48	-0.21	0.012	-0.0013

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	05 September 2019 12:23PM
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	23453.0
Storm Initial Losses (mm)	15.0
Storm Continuing Losses (mm/h)	4.2

Layer Info

Time Accessed	05 September 2019 12:23PM
Version	2016_v1

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

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	05 September 2019 12:23PM
Version	2016_v2

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

code	ECsouth
arealabel	East Coast South

Layer Info

Time Accessed	05 September 2019 12:23PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-30.377272&longitude=151.656333&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	05 September 2019 12:23PM

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)	0.5 (0.020)	1.0 (0.027)	1.3 (0.030)	1.6 (0.032)	1.8 (0.029)	1.9 (0.027)
90 (1.5)	0.6 (0.019)	0.8 (0.019)	0.9 (0.018)	1.0 (0.018)	1.0 (0.014)	0.9 (0.012)
120 (2.0)	1.5 (0.048)	2.1 (0.047)	2.4 (0.046)	2.7 (0.045)	1.7 (0.024)	1.0 (0.012)
180 (3.0)	0.4 (0.012)	0.4 (0.009)	0.4 (0.007)	0.4 (0.006)	0.9 (0.011)	1.2 (0.014)
360 (6.0)	0.7 (0.017)	0.8 (0.015)	0.9 (0.014)	1.0 (0.013)	2.9 (0.032)	4.3 (0.042)
720 (12.0)	1.5 (0.029)	1.1 (0.016)	0.8 (0.010)	0.5 (0.006)	3.1 (0.029)	5.0 (0.042)
1080 (18.0)	0.0 (0.000)	0.2 (0.002)	0.3 (0.003)	0.4 (0.004)	3.5 (0.030)	5.8 (0.044)
1440 (24.0)	0.0 (0.000)	0.2 (0.002)	0.3 (0.004)	0.5 (0.004)	5.2 (0.041)	8.8 (0.062)
2160 (36.0)	0.0 (0.000)	0.1 (0.001)	0.2 (0.002)	0.3 (0.002)	1.8 (0.012)	2.9 (0.018)
2880 (48.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)	0.2 (0.001)	0.4 (0.002)	0.5 (0.003)
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	05 September 2019 12:23PM
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	05 September 2019 12:23PM
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)	0.1 (0.002)	0.2 (0.003)
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	05 September 2019 12:23PM
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)	9.7 (0.361)	9.0 (0.240)	8.4 (0.189)	7.9 (0.152)	13.4 (0.215)	17.5 (0.249)
90 (1.5)	10.2 (0.339)	10.7 (0.258)	11.0 (0.223)	11.3 (0.196)	9.9 (0.144)	8.9 (0.114)
120 (2.0)	12.2 (0.375)	13.0 (0.294)	13.6 (0.258)	14.1 (0.230)	14.1 (0.192)	14.0 (0.169)
180 (3.0)	9.4 (0.262)	11.6 (0.240)	13.1 (0.228)	14.5 (0.218)	17.4 (0.219)	19.6 (0.218)
360 (6.0)	13.6 (0.322)	15.1 (0.269)	16.1 (0.244)	17.1 (0.224)	25.8 (0.284)	32.4 (0.316)
720 (12.0)	14.5 (0.285)	14.7 (0.220)	14.8 (0.190)	14.9 (0.166)	35.3 (0.333)	50.5 (0.424)
1080 (18.0)	3.0 (0.053)	6.9 (0.093)	9.4 (0.109)	11.9 (0.119)	28.4 (0.242)	40.8 (0.309)
1440 (24.0)	5.7 (0.093)	8.7 (0.108)	10.7 (0.113)	12.6 (0.116)	23.7 (0.186)	32.0 (0.224)
2160 (36.0)	0.0 (0.000)	4.5 (0.050)	7.5 (0.070)	10.3 (0.085)	15.3 (0.106)	18.9 (0.118)
2880 (48.0)	0.0 (0.000)	3.6 (0.036)	6.0 (0.052)	8.2 (0.062)	9.5 (0.061)	10.4 (0.060)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.7 (0.004)	1.2 (0.006)

Layer Info

Time Accessed	05 September 2019 12:23PM
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)	34.7 (1.287)	30.4 (0.813)	27.5 (0.615)	24.7 (0.474)	66.1 (1.060)	97.2 (1.379)
90 (1.5)	29.6 (0.980)	27.7 (0.670)	26.5 (0.537)	25.4 (0.441)	36.0 (0.522)	43.9 (0.564)
120 (2.0)	42.6 (1.313)	48.2 (1.088)	51.8 (0.983)	55.4 (0.902)	56.2 (0.767)	56.9 (0.687)
180 (3.0)	24.5 (0.686)	32.5 (0.672)	37.8 (0.659)	42.9 (0.644)	58.9 (0.742)	70.9 (0.791)
360 (6.0)	39.5 (0.933)	47.2 (0.840)	52.4 (0.790)	57.3 (0.749)	79.5 (0.875)	96.2 (0.939)
720 (12.0)	30.6 (0.604)	41.2 (0.618)	48.1 (0.617)	54.8 (0.612)	72.6 (0.685)	85.9 (0.720)
1080 (18.0)	28.4 (0.500)	34.2 (0.460)	38.0 (0.438)	41.7 (0.419)	64.6 (0.549)	81.8 (0.619)
1440 (24.0)	29.3 (0.475)	31.3 (0.388)	32.6 (0.346)	33.8 (0.313)	57.9 (0.454)	75.9 (0.531)
2160 (36.0)	8.1 (0.117)	19.4 (0.214)	26.9 (0.254)	34.1 (0.281)	40.5 (0.282)	45.2 (0.282)
2880 (48.0)	4.8 (0.063)	10.9 (0.111)	15.0 (0.130)	18.9 (0.143)	30.3 (0.195)	38.9 (0.224)
4320 (72.0)	0.8 (0.010)	4.0 (0.036)	6.1 (0.047)	8.0 (0.054)	20.6 (0.119)	30.0 (0.156)

Layer Info

Time Accessed	05 September 2019 12:23PM
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	**0.869 (4.3%)**	0.783 (3.9%)	**0.983 (4.9%)**
2040	**1.057 (5.3%)**	1.014 (5.1%)	**1.349 (6.8%)**
2050	**1.272 (6.4%)**	1.236 (6.2%)	**1.773 (9.0%)**
2060	**1.488 (7.5%)**	1.458 (7.4%)	**2.237 (11.5%)**
2070	**1.676 (8.5%)**	1.691 (8.6%)	**2.722 (14.2%)**
2080	**1.810 (9.2%)**	1.944 (9.9%)	**3.209 (16.9%)**
2090	**1.862 (9.5%)**	2.227 (11.5%)	**3.679 (19.7%)**

Layer Info

Time Accessed	05 September 2019 12:23PM
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**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	17.5	11.7	11.4	12.4	10.0	6.6
90 (1.5)	17.7	12.3	12.0	13.2	12.0	10.4
120 (2.0)	16.1	11.0	10.4	11.3	10.1	7.5
180 (3.0)	18.1	12.6	11.7	12.2	10.6	6.7
360 (6.0)	16.4	11.6	11.3	11.0	9.9	5.0
720 (12.0)	17.0	12.5	12.2	12.4	9.9	5.1
1080 (18.0)	19.5	14.3	14.5	14.7	11.1	5.5
1440 (24.0)	19.5	14.4	15.1	15.1	12.1	7.0
2160 (36.0)	23.6	17.6	17.2	16.5	15.3	7.9
2880 (48.0)	24.2	19.3	19.1	19.5	17.7	9.7
4320 (72.0)	25.7	21.5	22.8	24.9	20.7	14.3

Layer Info

Time Accessed	05 September 2019 12:23PM
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/60050869-5bcd-4409-b229-e28e23a25397.txt)

Download JSON (downloads/5220bb5d-8532-46af-b6c3-1c5de7537579.json)

Generating PDF... (downloads/2d65c5ae-f575-4bfe-bc85-fbe13597c7c5.pdf)

APPENDIX C

Rainfall Depths

Location

Label: Tilbuster Solar Farm

Latitude: -30.3875 [Nearest grid cell: 30.3875 (S)]

Longitude:151.6625 [Nearest grid cell: 151.6625 (E)]

IFD Design Rainfall Depth (mm)

Issued: 04 March 2020

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	2.00	2.27	3.17	3.79	4.42	5.26	5.93
2 min	3.41	3.87	5.35	6.40	7.47	8.90	9.99
3 min	4.73	5.37	7.42	8.88	10.3	12.3	13.8
4 min	5.92	6.72	9.31	11.1	13.0	15.4	17.3
5 min	6.99	7.94	11.0	13.2	15.3	18.3	20.5
10 min	11.0	12.6	17.6	21.0	24.5	29.2	32.9
15 min	13.8	15.7	22.0	26.4	30.7	36.6	41.3
20 min	15.8	18.1	25.3	30.3	35.3	42.2	47.6
25 min	17.4	19.9	27.8	33.4	38.9	46.5	52.5
30 min	18.8	21.4	29.9	35.8	41.8	50.0	56.4
45 min	21.7	24.7	34.3	41.1	48.0	57.4	64.9
1 hour	23.8	27.0	37.3	44.7	52.2	62.4	70.5
1.5 hour	26.7	30.2	41.4	49.5	57.7	68.9	77.8
2 hour	28.8	32.4	44.3	52.7	61.4	73.3	82.8
3 hour	32.0	35.8	48.4	57.4	66.6	79.4	89.6
4.5 hour	35.4	39.5	52.8	62.3	72.1	85.8	96.8
6 hour	38.1	42.3	56.3	66.3	76.5	90.8	102
9 hour	42.4	47.0	61.9	72.6	83.6	99.0	112
12 hour	45.9	50.7	66.6	78.0	89.6	106	119
18 hour	51.4	56.8	74.3	86.8	99.6	118	132
24 hour	55.8	61.6	80.6	94.2	108	127	143
30 hour	59.5	65.7	86.1	101	115	136	152
36 hour	62.7	69.3	90.8	106	122	143	160
48 hour	68.0	75.2	98.7	115	132	156	174
72 hour	75.8	84.0	110	129	148	174	193
96 hour	81.3	90.2	118	138	158	185	205
120 hour	85.6	94.8	124	144	165	191	211

144 hour	88.9	98.3	128	148	168	194	214
168 hour	91.5	101	131	151	170	195	215

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 **17:11 on Wednesday 04 March 2020 (AEDT)**

APPENDIX D

Pre-burst Rainfall Depths

Table E1: NSW Transformation Pre-Burst Rainfall Depths

Storm Duration		Pre-Burst Rainfall Depth (mm)	
		AEP (%)	
min	**hrs**	**5**	**1**
60	1	2.8	8.7
90	1.5	2.1	4.8
120	2	3.9	7.8
180	3	3.1	8.6
360	6	4.3	10.3

APPENDIX E

PMP Calculations

GSDM Calculation Sheet

Location Information				
Catchment	Tilbuster Solar	Area (km2)	27.65	
State	NSW	Duration Limit (hrs)	3	
Latitude	-30.37951	Longitude	151.65415	
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)			1200	
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)			0.77	

PMP Values

Duarion (hrs)	Initial Depth - Smooth	Initial Depth - Rough	PMP Estimate	Rounded PMP Estimate (nearest 10mm)
0.25	195	195	150	150
0.50	285	285	219	220
0.75	365	365	281	280
1.0	435	435	335	330
1.5	495	555	427	430
2.0	555	645	497	500
2.5	590	715	551	550
3.0	625	780	601	600
4.0	0	0	0	0
5.0	0	0	0	0
6.0	0	0	0	0

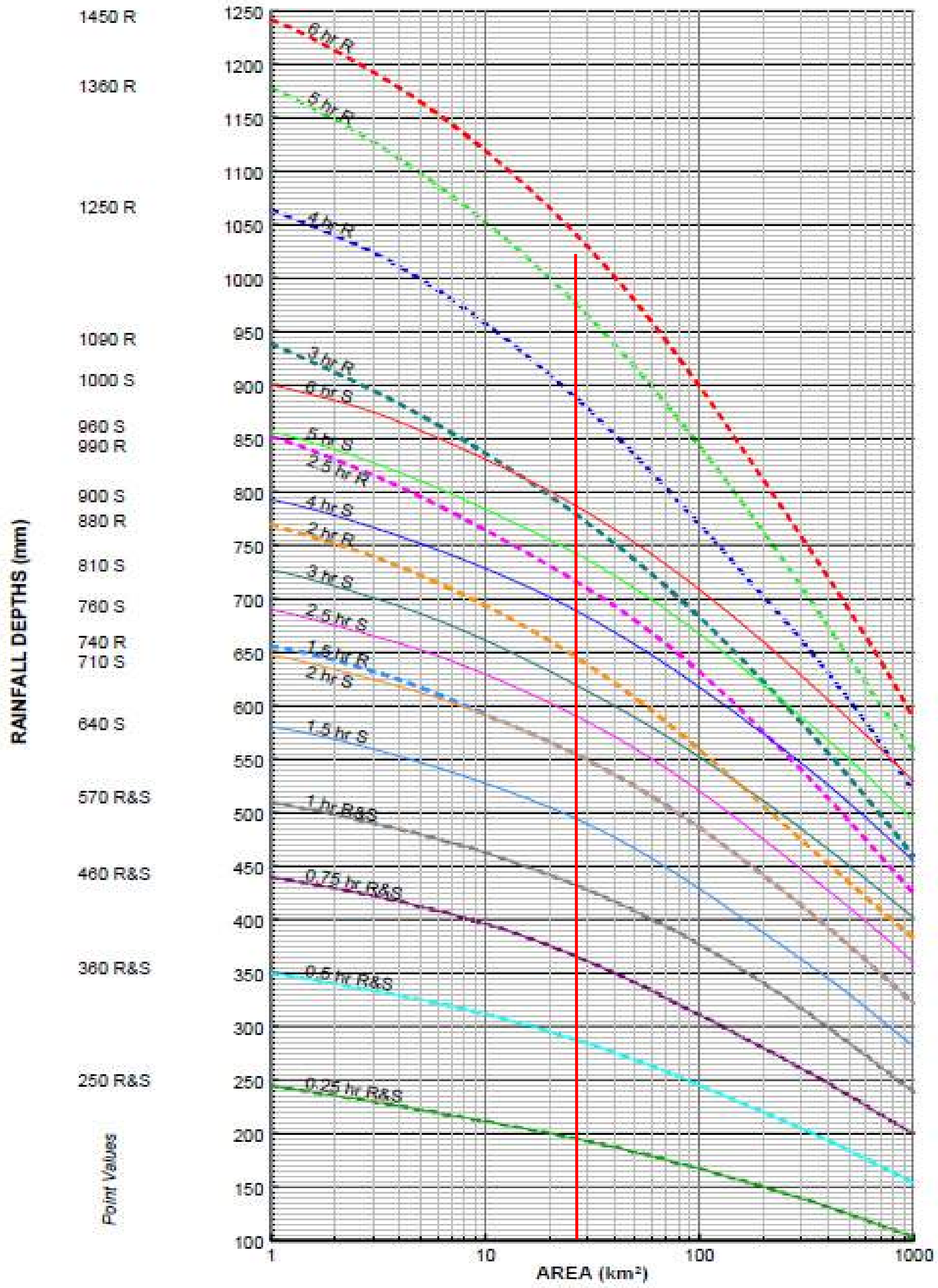
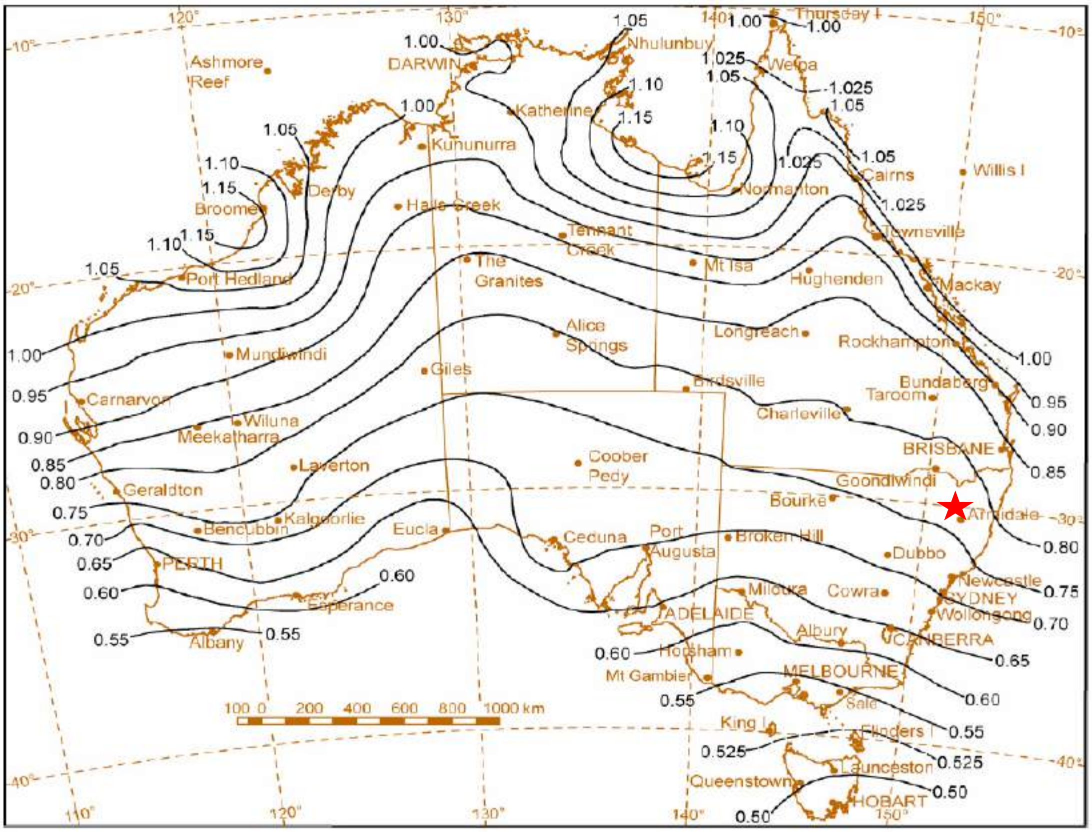


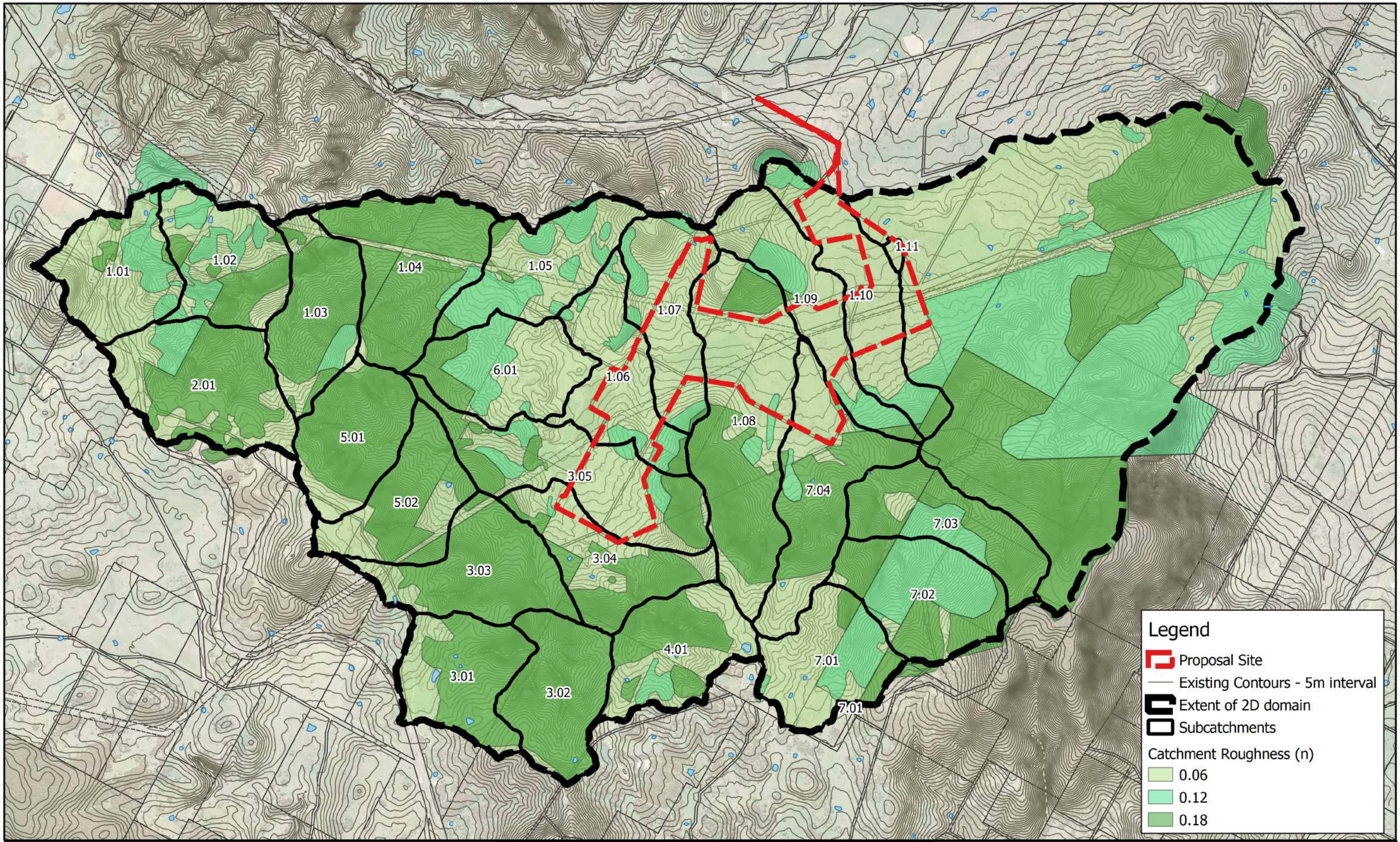
Figure 4: **Depth-Duration-Area Curves of Short Duration Rainfall**



DARWIN
Nhulunbuy
Thursday I
Weipa
Ashmore Reef
Katherine
Kununurra
Derby
Broome
Halls Creek
Cairns
Willis I
Normanton
Townsville
Tennant Creek
Mt Isa
Port Hedland
The Granites
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
Esperance
Mildura
Cowra
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 F

Adopted Manning's Values



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TILBUSTER SOLAR FARM

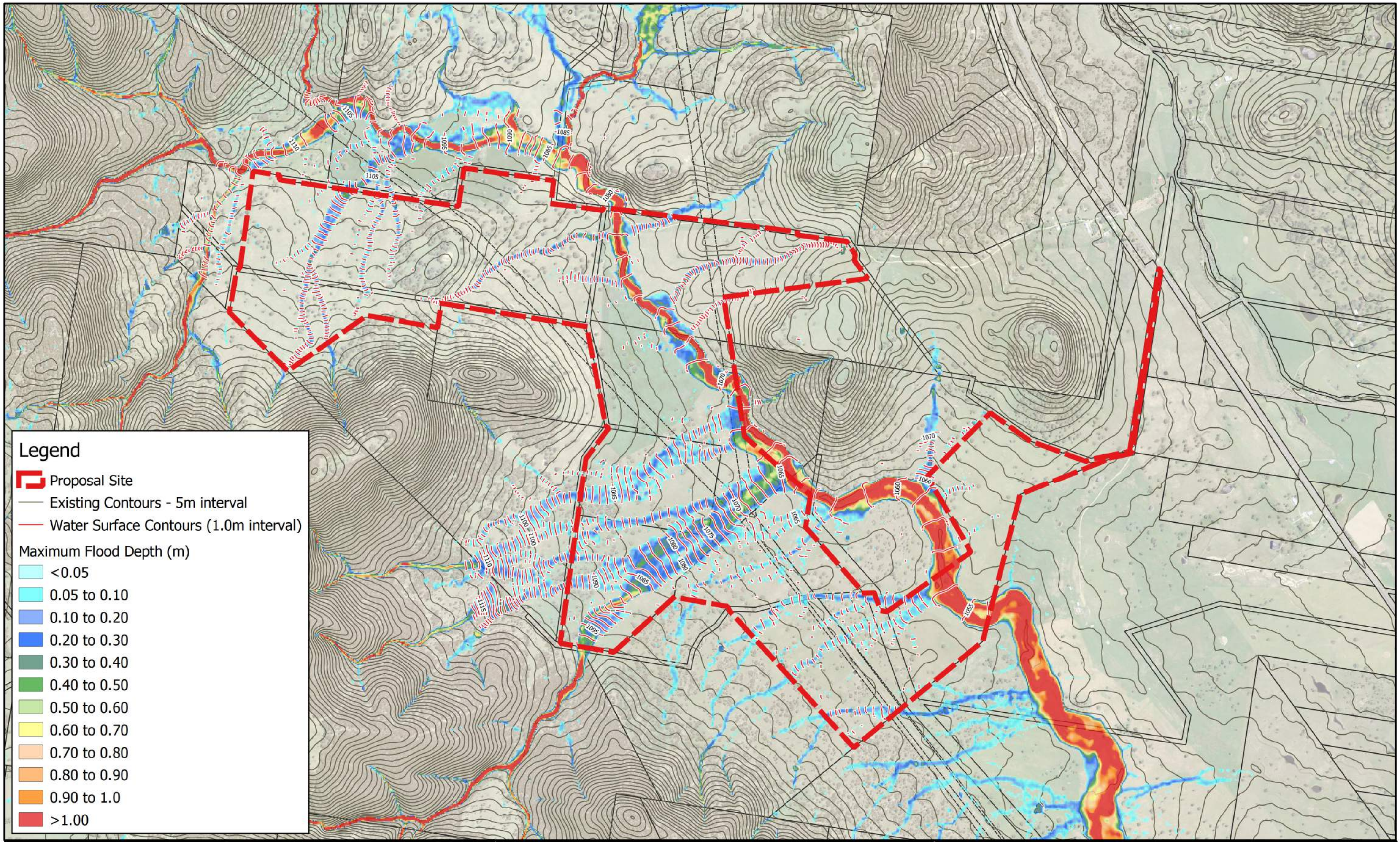
FIGURE 2.1

CATCHMENT ROUGHNESS PLAN

Rev 2 - 21 April 2020

APPENDIX G

Floood Mapping



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200 0 200 400 m

Scale 1:15,000 at A3

TILBUSTER SOLAR FARM

FIGURE 3.1

PRE-DEVELOPMENT PEAK FLOOD LEVELS AND DEPTHS

5% AEP

Rev 2 - 21 April 2020

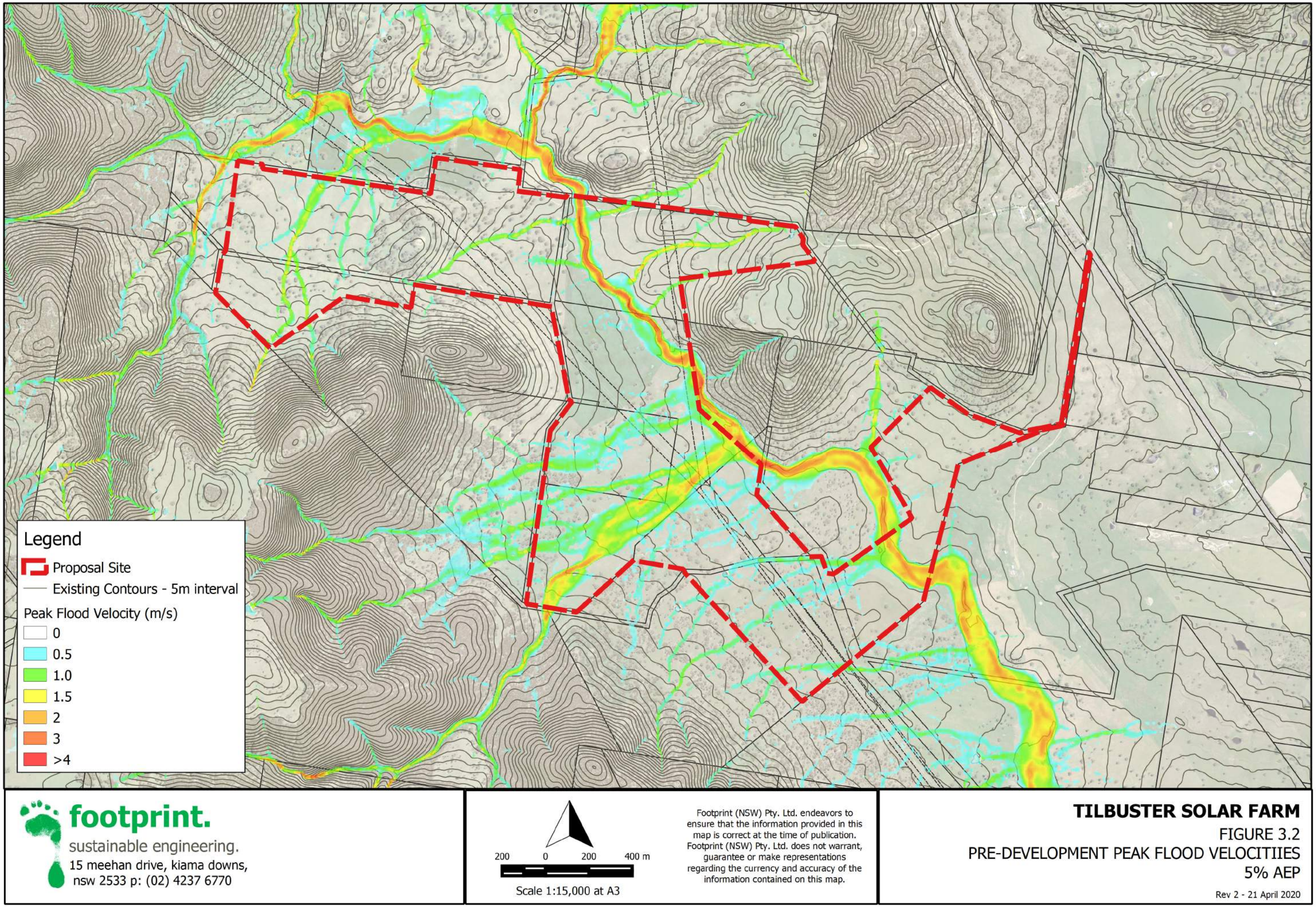

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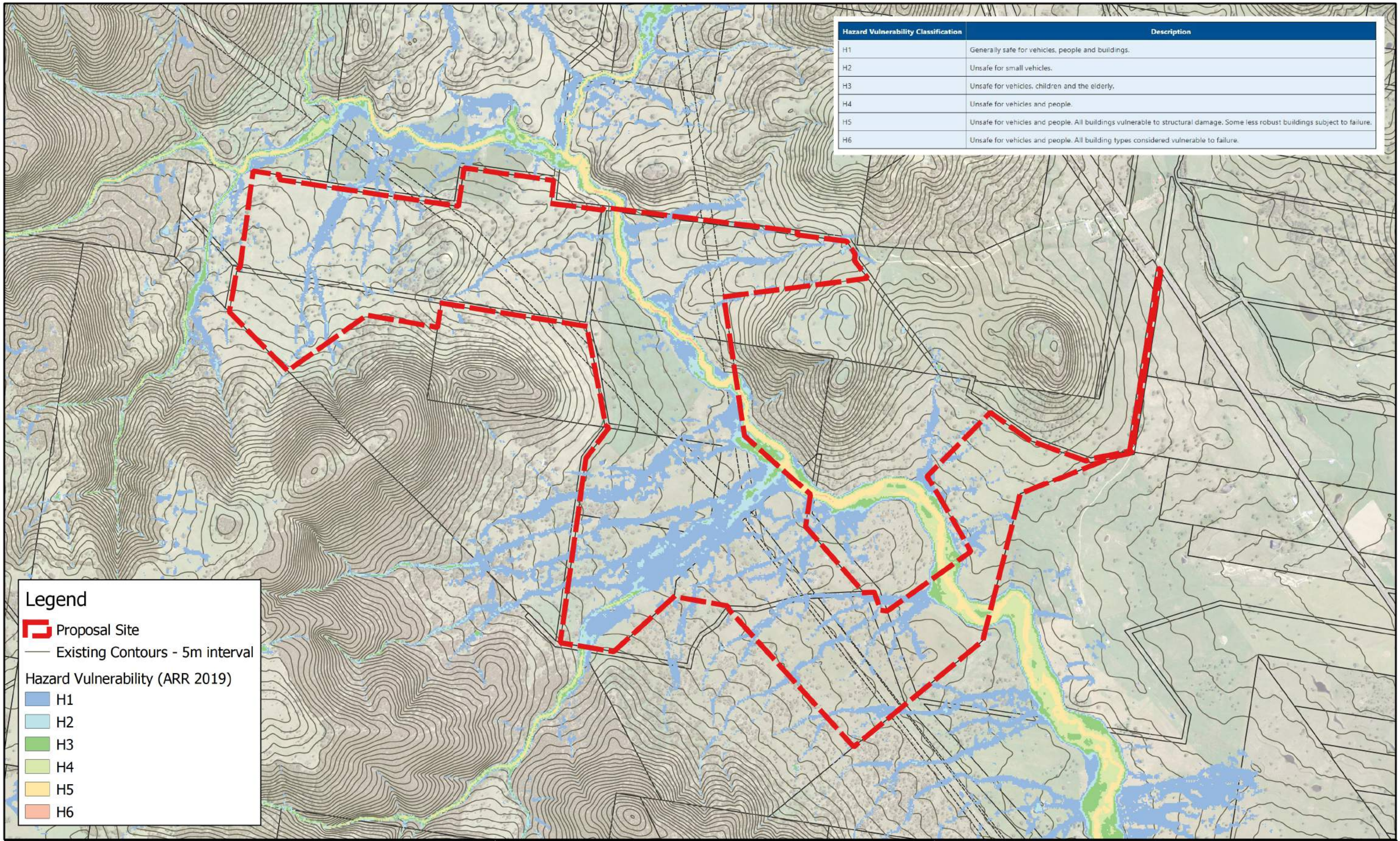
FIGURE 3.2

PRE-DEVELOPMENT PEAK FLOOD VELOCITIIES

5% AEP

Rev 2 - 21 April 2020



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

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FIGURE 3.3
PRE-DEVELOPMENT HAZARD VULNERABILITY
5% AEP

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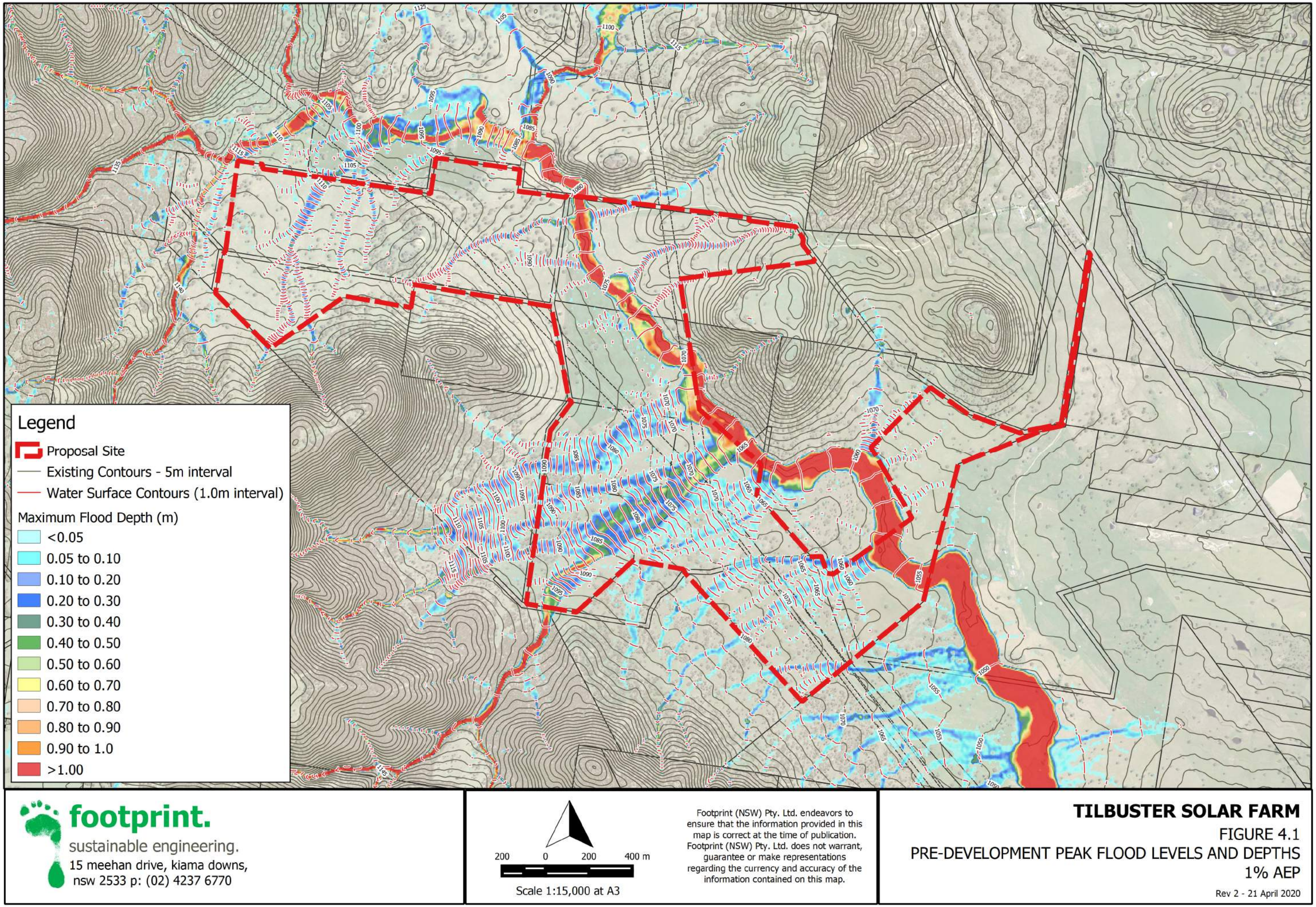

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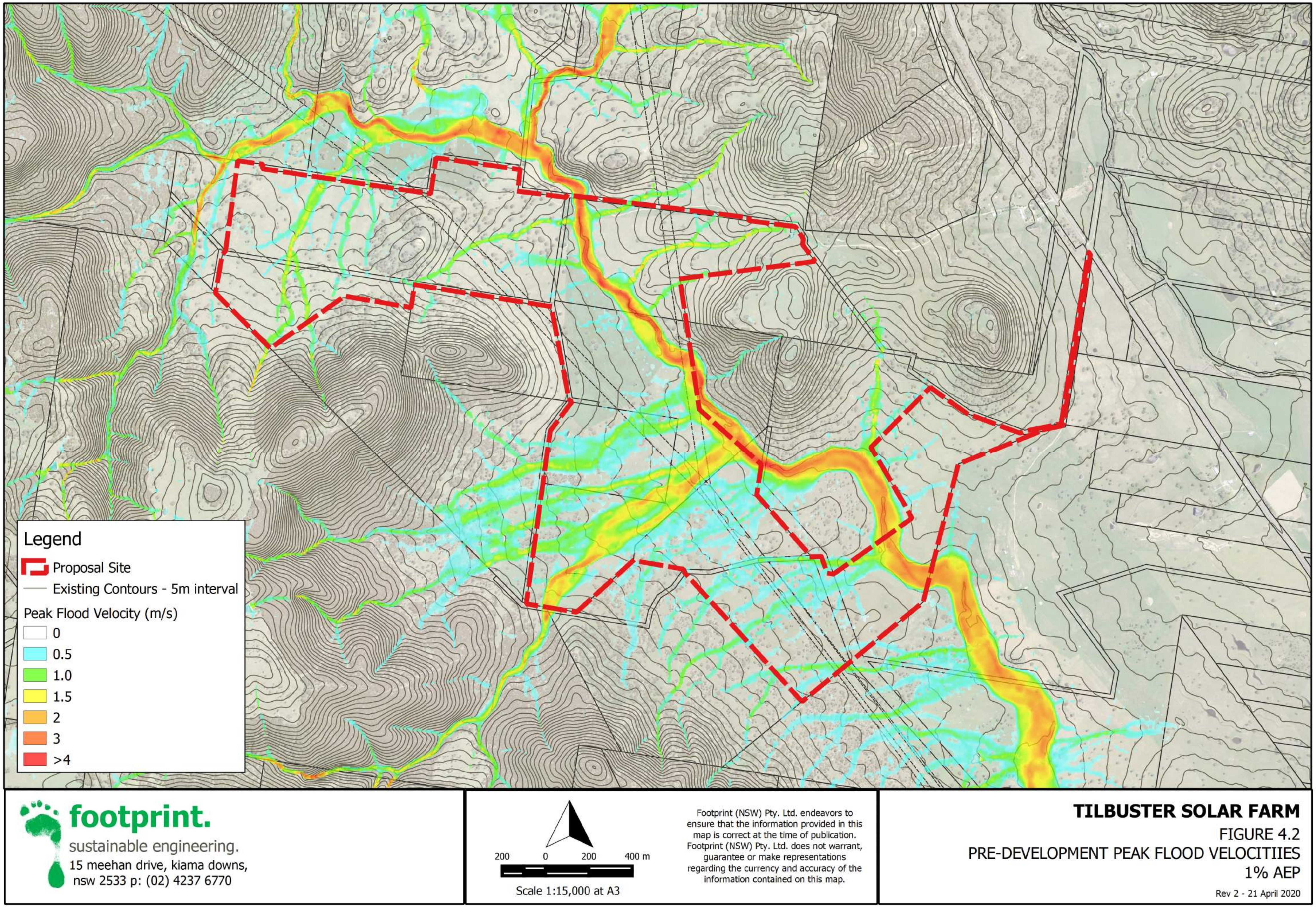
TILBUSTER SOLAR FARM

FIGURE 4.1
PRE-DEVELOPMENT PEAK FLOOD LEVELS AND DEPTHS
1% AEP

Rev 2 - 21 April 2020



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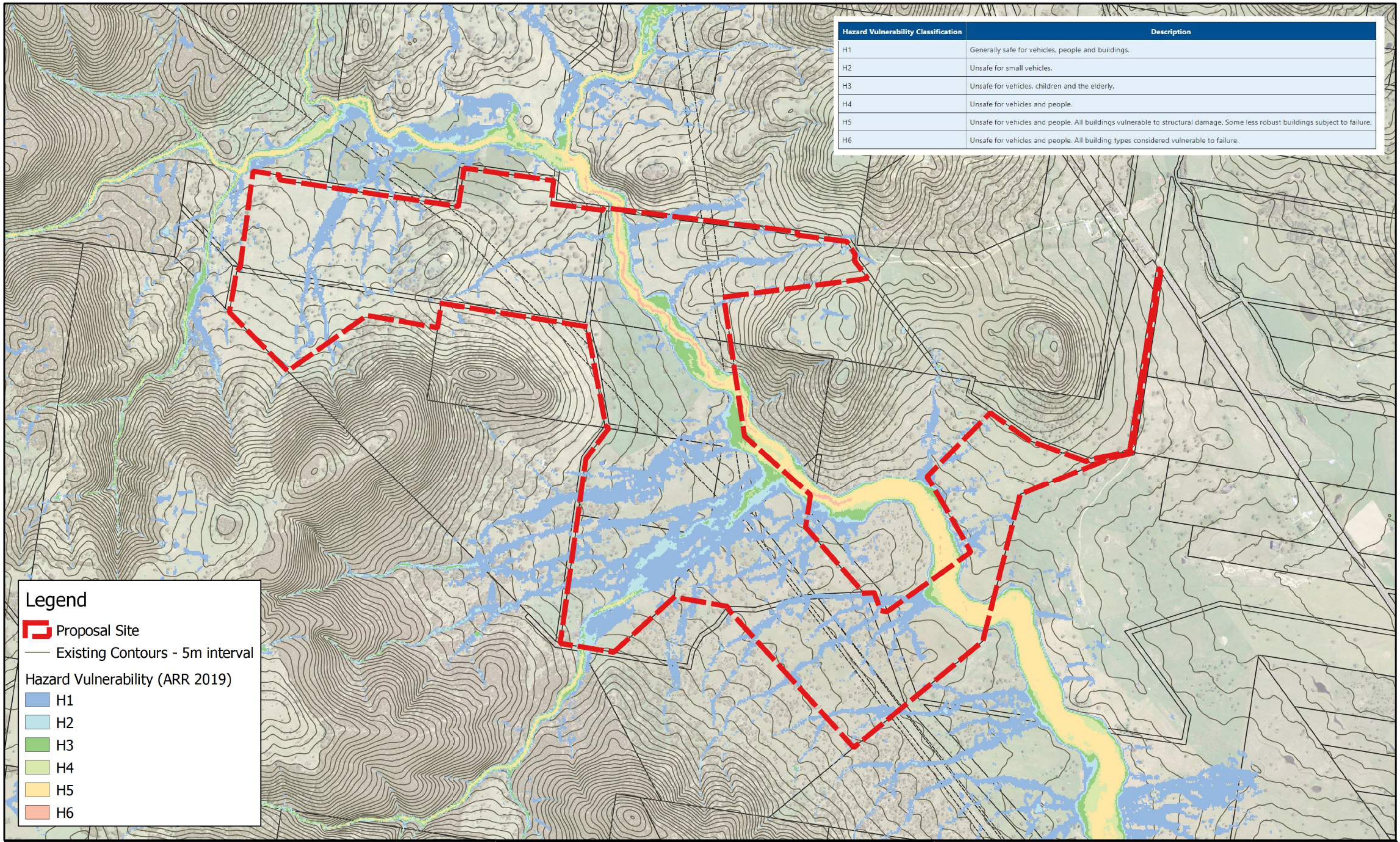
TILBUSTER SOLAR FARM

FIGURE 4.2

PRE-DEVELOPMENT PEAK FLOOD VELOCITIIES

1% AEP

Rev 2 - 21 April 2020



Hazard Vulnerability Classification	Description
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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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200 0 200 400 m

Scale 1:15,000 at A3

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FIGURE 4.3

PRE-DEVELOPMENT HAZARD VULNERABILITY

1% AEP

Rev 3 - 09 July 2021

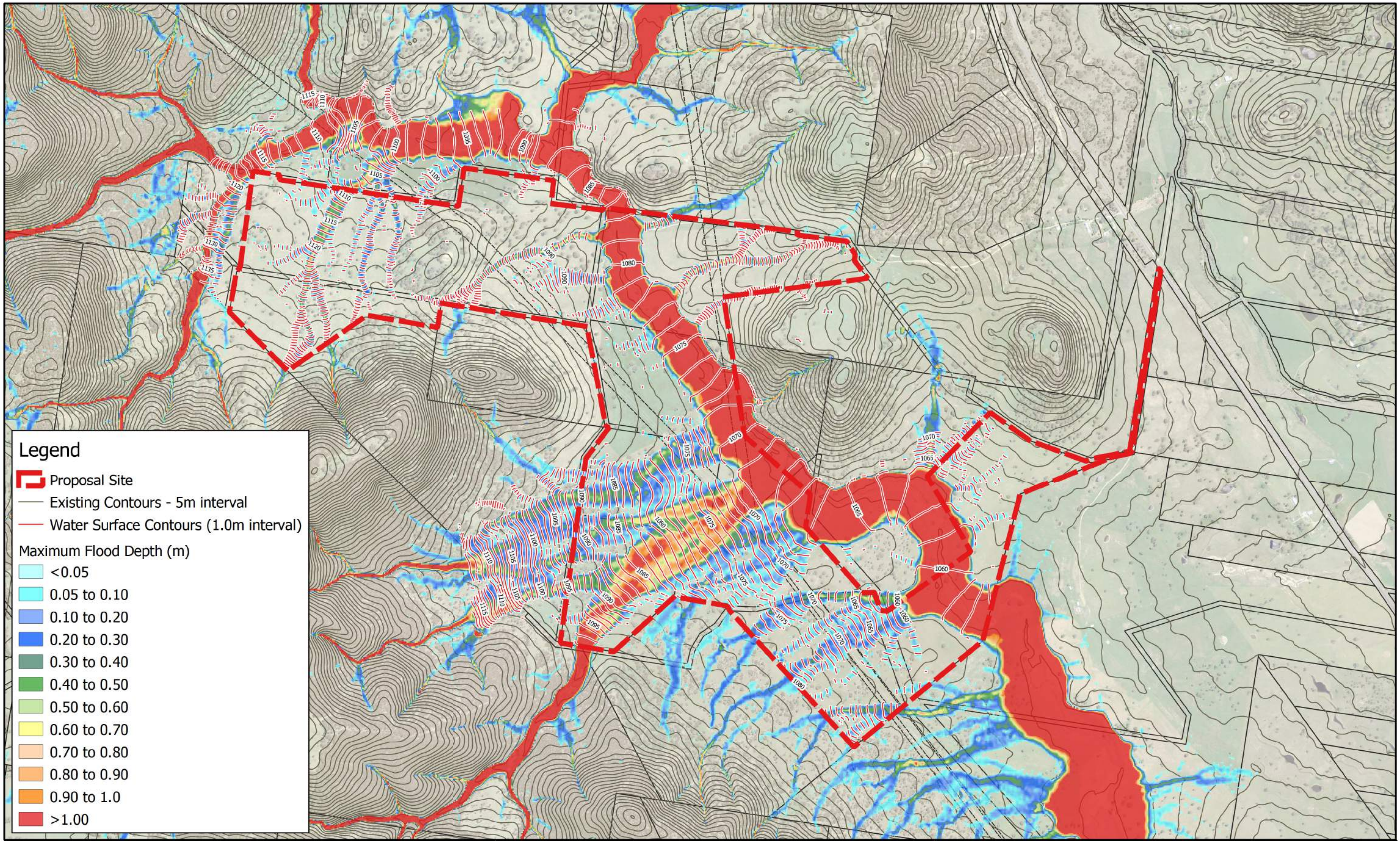

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FIGURE 5.1

PRE-DEVELOPMENT PEAK FLOOD LEVELS AND DEPTHS PMF

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FIGURE 5.2

PRE-DEVELOPMENT PEAK FLOOD VELOCITIIES

PMF

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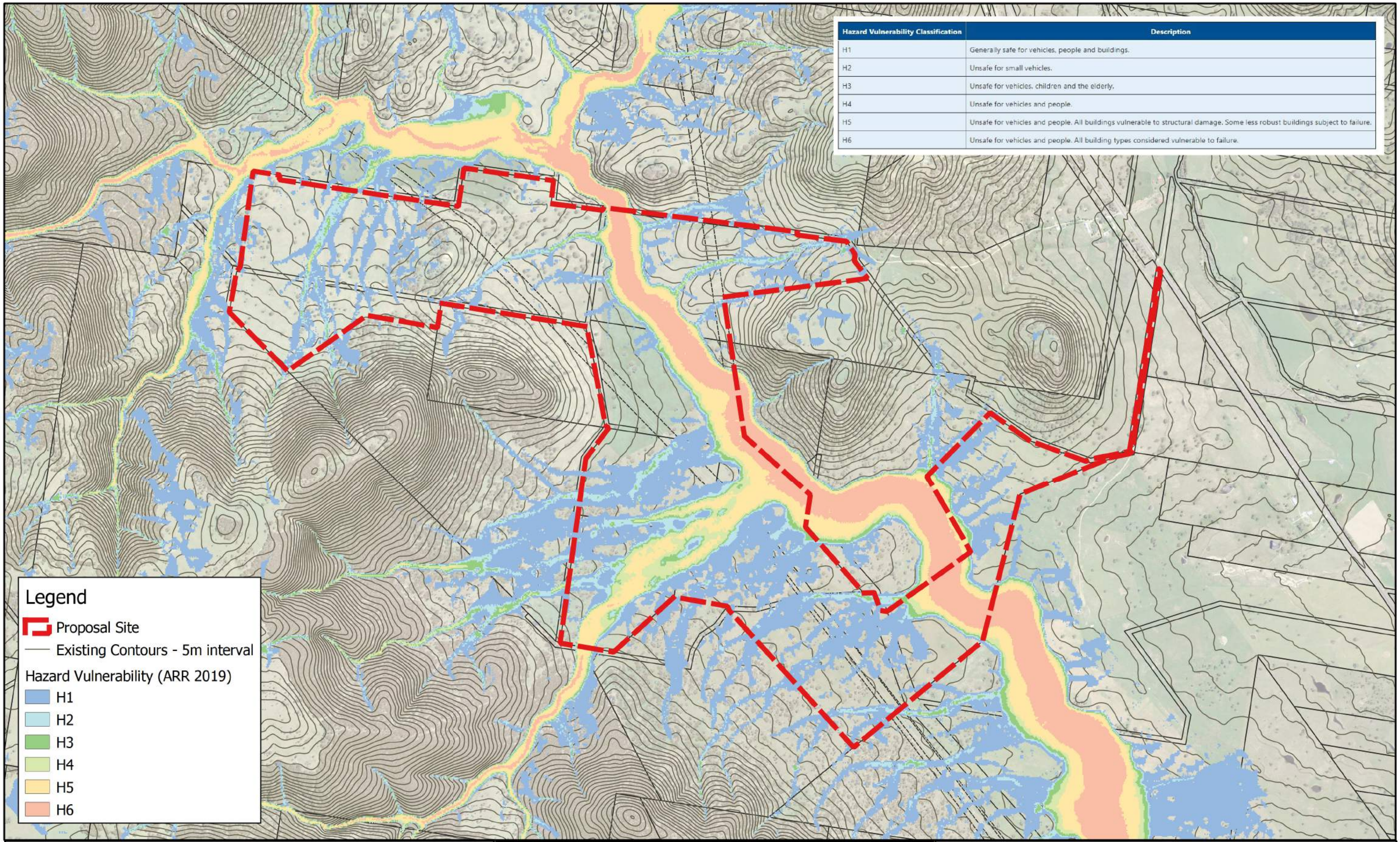

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some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

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Scale 1:15,000 at A3

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FIGURE 5.3

PRE-DEVELOPMENT HAZARD VULNERABILITY

PMF

Rev 3 - 09 July 2021

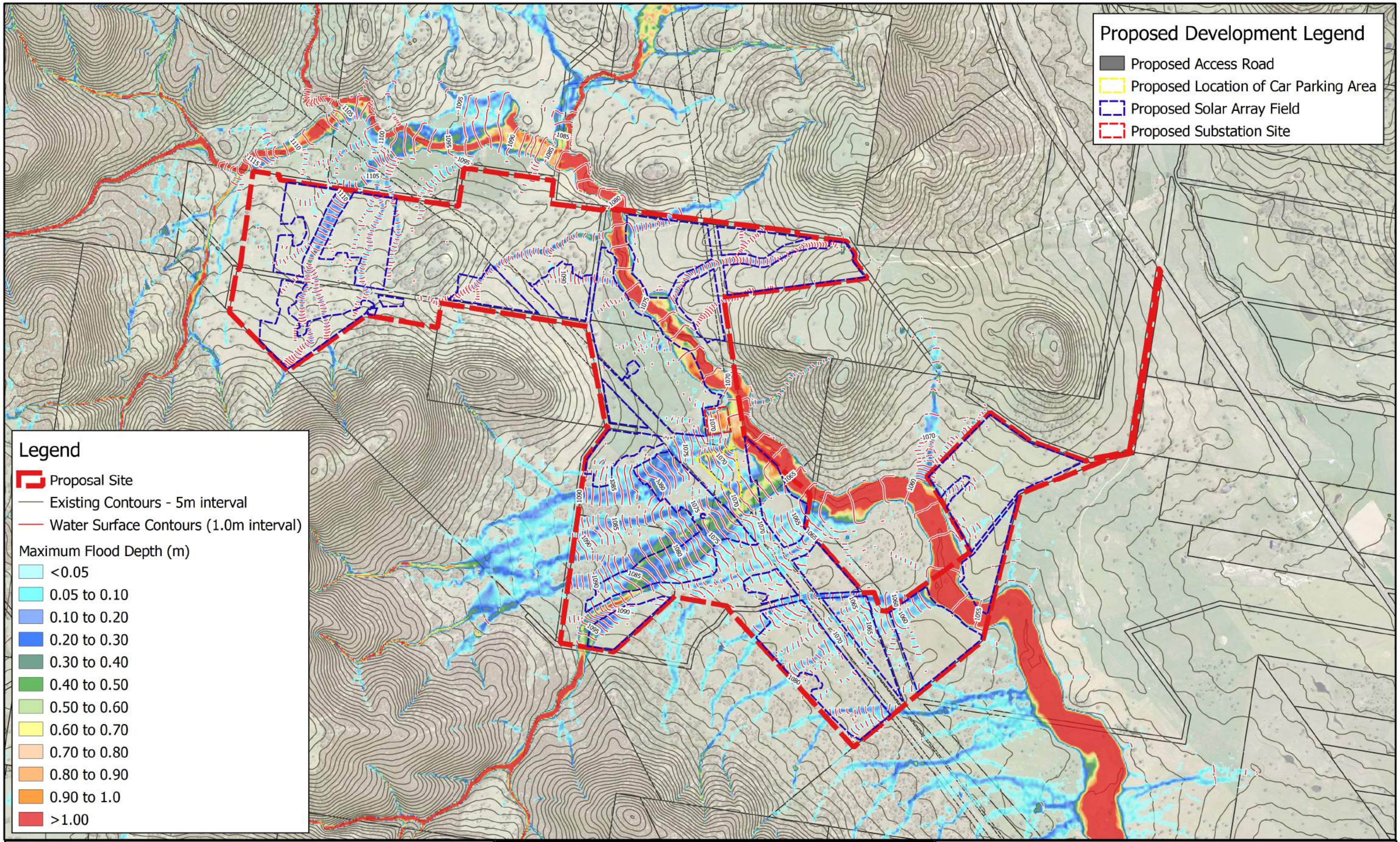

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FIGURE 6.1
POST DEVELOPMENT PEAK FLOOD LEVELS AND DEPTHS
1% AEP

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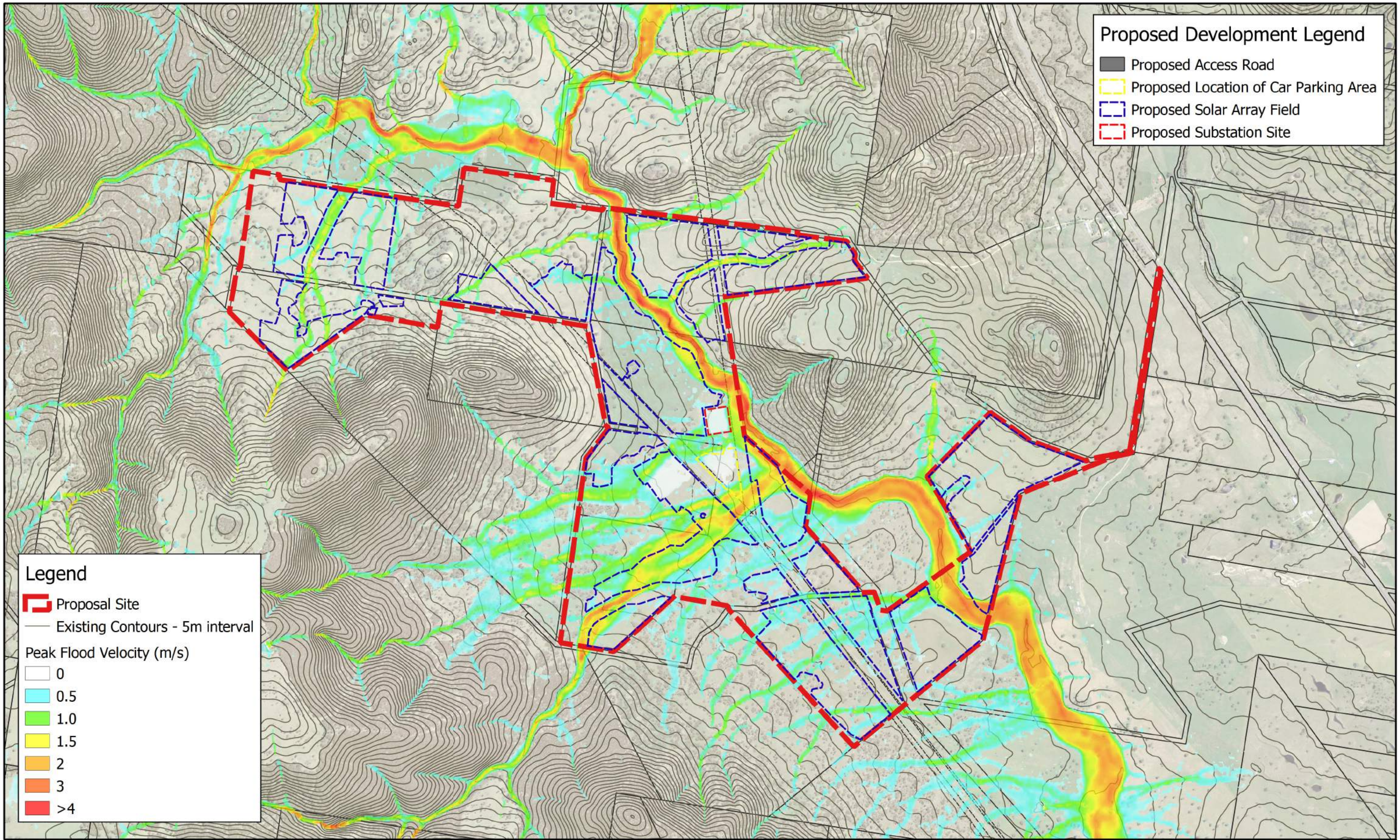

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200 0 200 400 m

Scale 1:15,000 at A3

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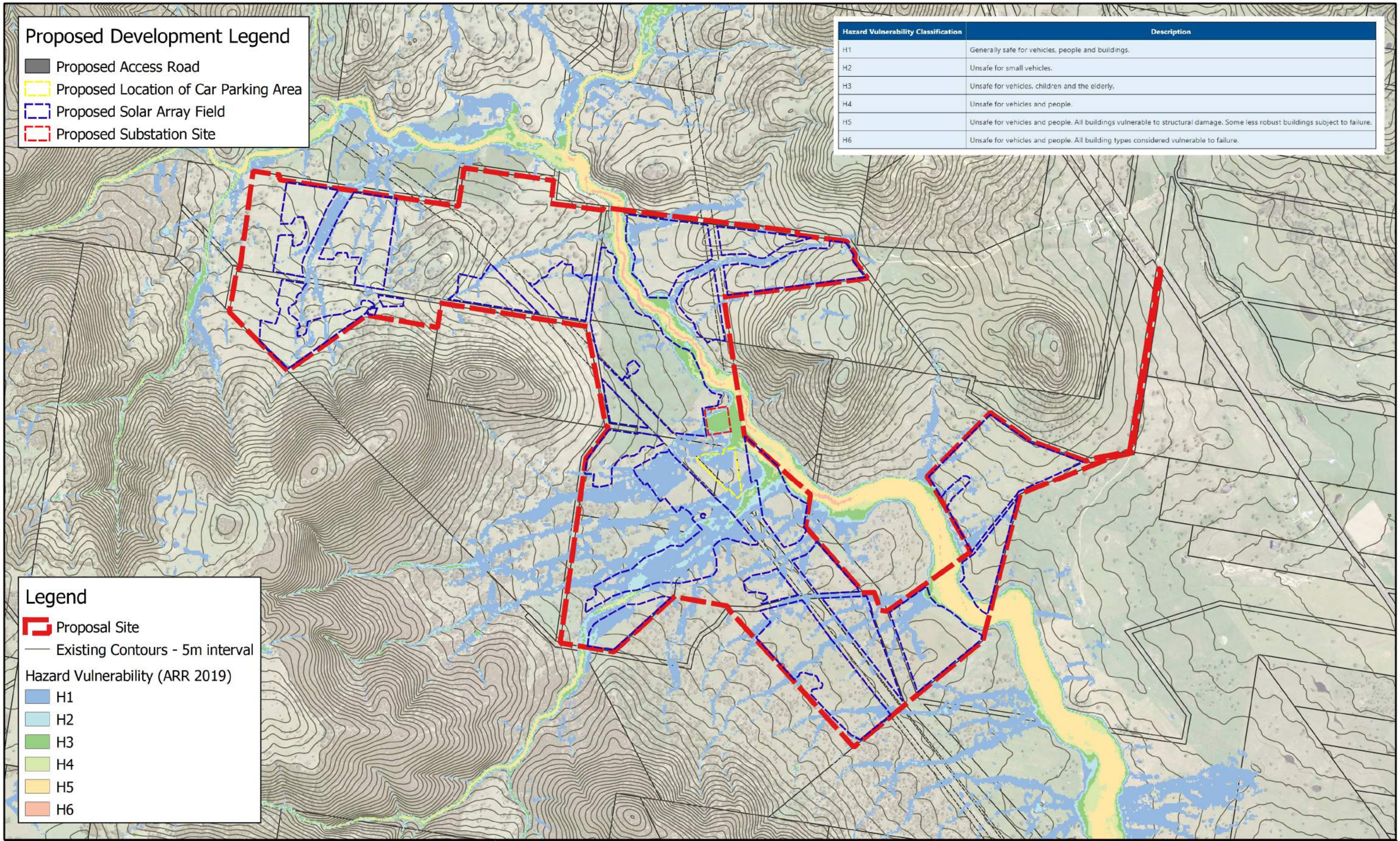
FIGURE 6.2

POST DEVELOPMENT PEAK FLOOD VELOCITIIES

1% AEP

Rev 3 - 09 July 2021



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200 0 200 400 m

Scale 1:15,000 at A3

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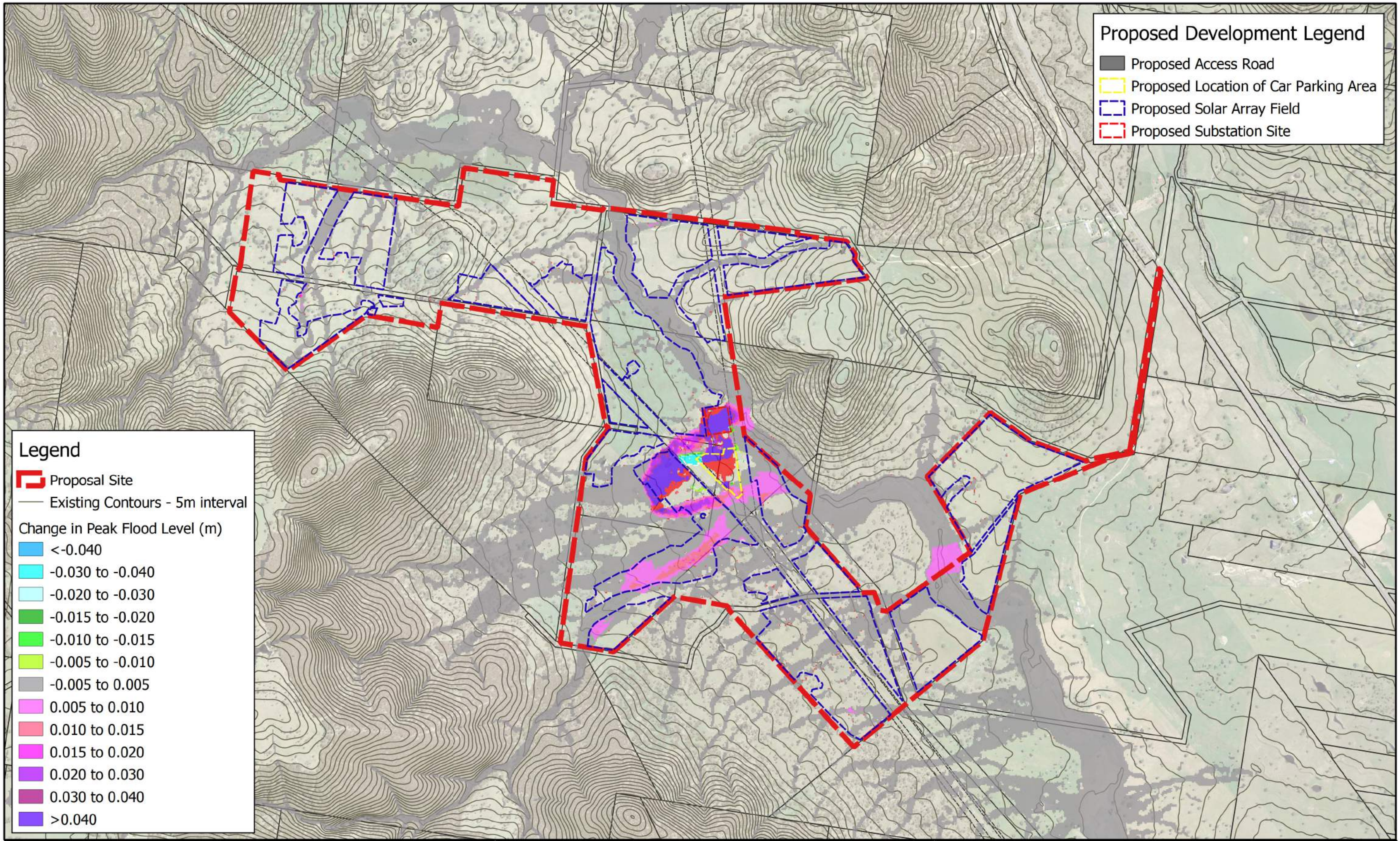
FIGURE 6.3

POST DEVELOPMENT HAZARD VULNERABILITY

1% AEP

Rev 3 - 09 July 2021



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TILBUSTER SOLAR FARM

FIGURE 7.1

IMPACT OF PROPOSAL ON FLOOD LEVELS

1% AEP

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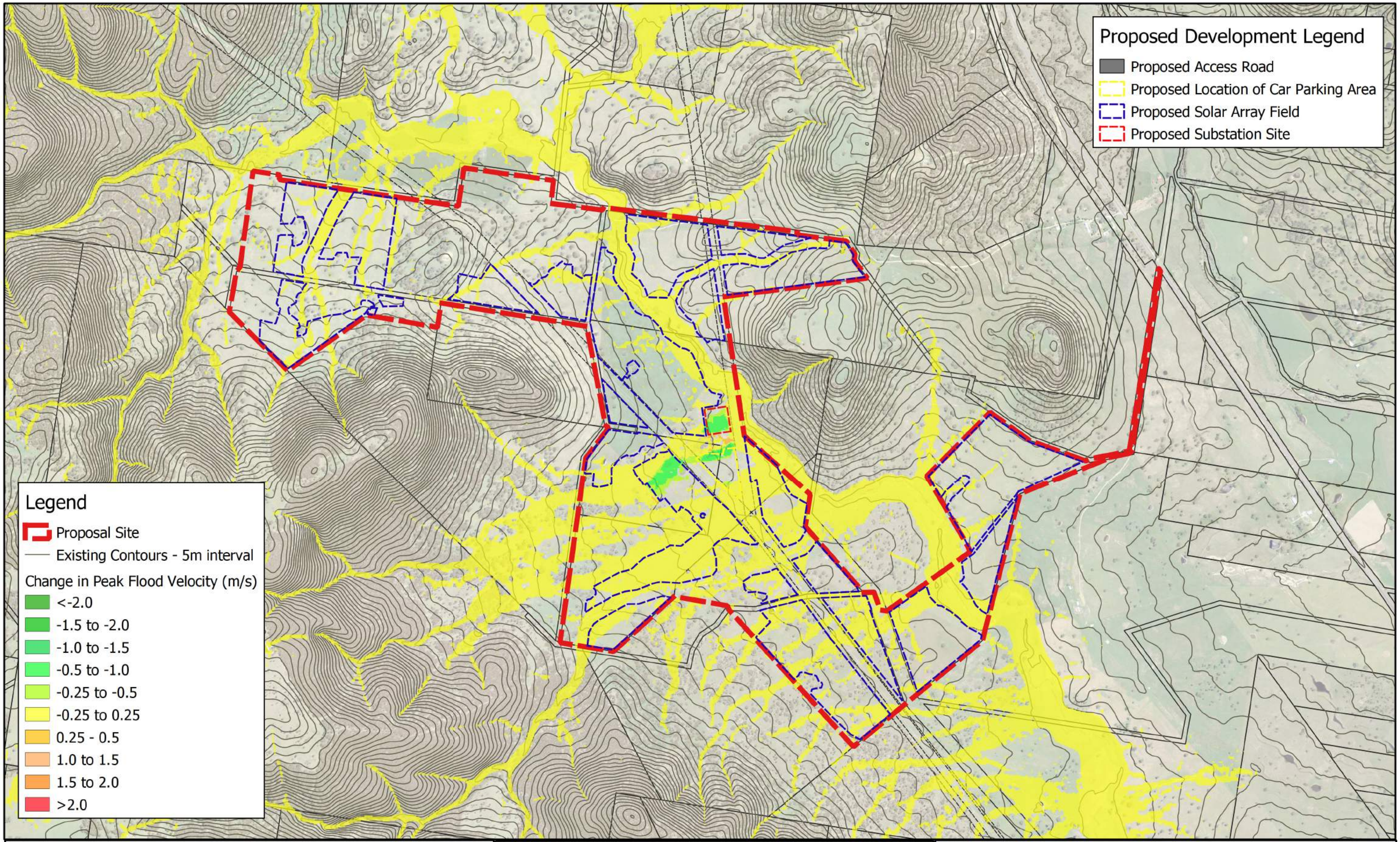

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TILBUSTER SOLAR FARM

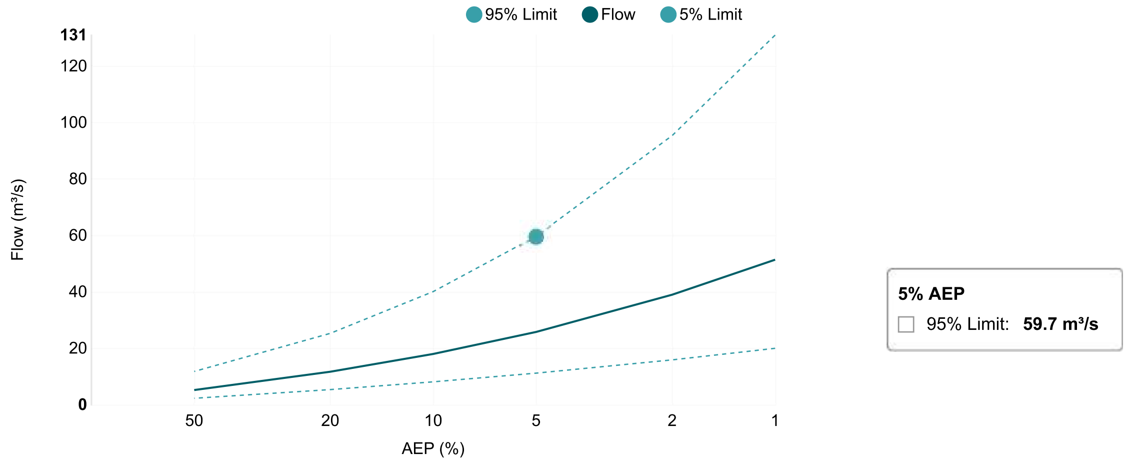
FIGURE 7.2
IMPACT OF PROPOSAL ON FLOOD VELOCITY
1% AEP

Rev 3 - 09 July 2021

APPENDIX H

RFFE Method Results

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	5.21	2.29	11.8
20	11.7	5.37	25.3
10	18.0	8.12	40.1
5	25.8	11.2	59.7
2	39.0	15.9	95.4
1	51.4	20.0	131

Statistics

Variable	Value	Standard Dev
Mean	1.658	0.493
Standard Dev	0.924	0.203
Skew	0.109	0.028

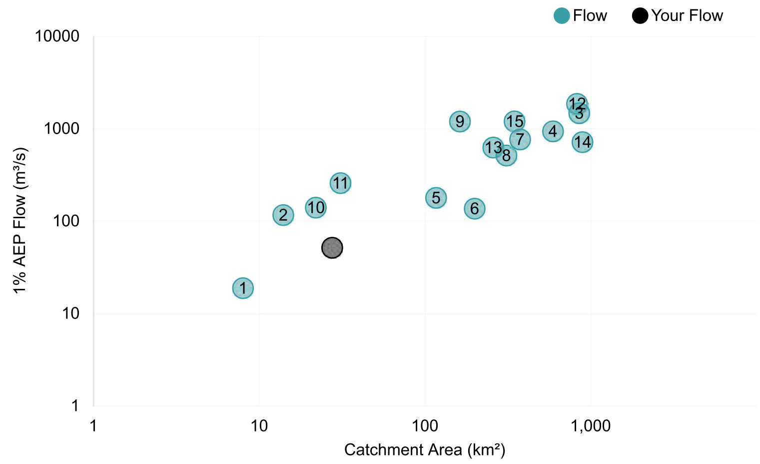
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

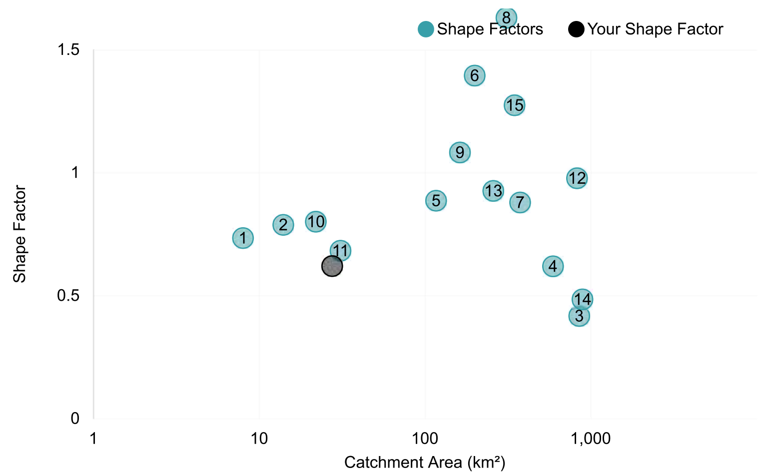
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

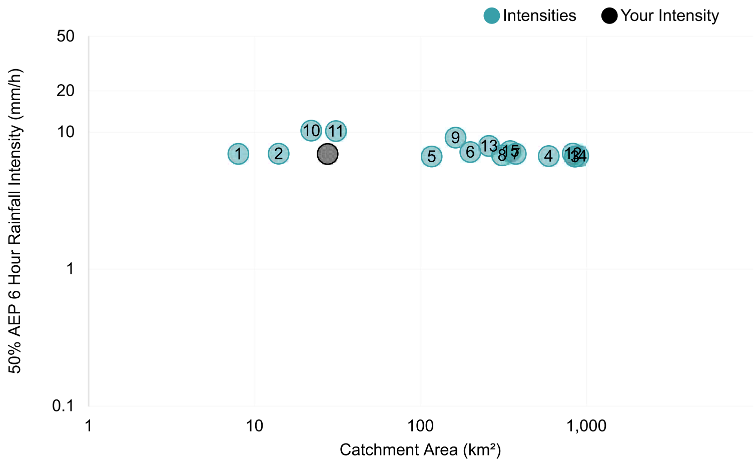
1% AEP Flow vs Catchment Area



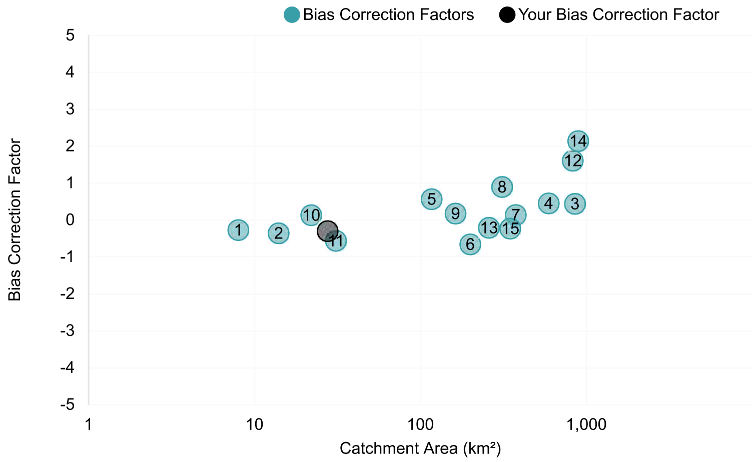
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

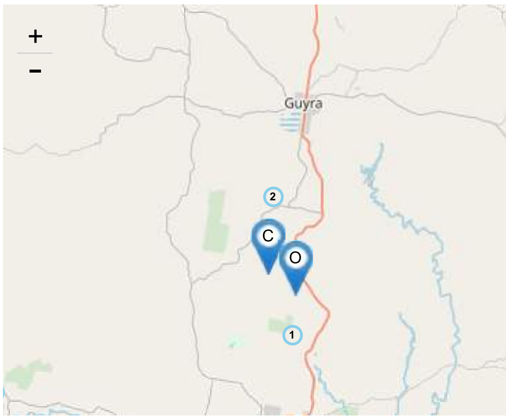
TXT Nearby JSON

Input Data

Date/Time	2019-09-05 20:51

Input Data

Catchment Name	Tilbuster Solar Farm
Latitude (Outlet)	-30.385865
Longitude (Outlet)	151.663032
Latitude (Centroid)	-30.367376
Longitude (Centroid)	151.636454
Catchment Area (km^2)	27.62
Distance to Nearest Gauged Catchment (km)	3.81
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.903713
2% AEP 6 Hour Rainfall Intensity (mm/h)	14.521334
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.62
Interpolation Method	Natural Neighbour
Bias Correction Value	-0.306



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Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

APPENDIX I

Stream Order

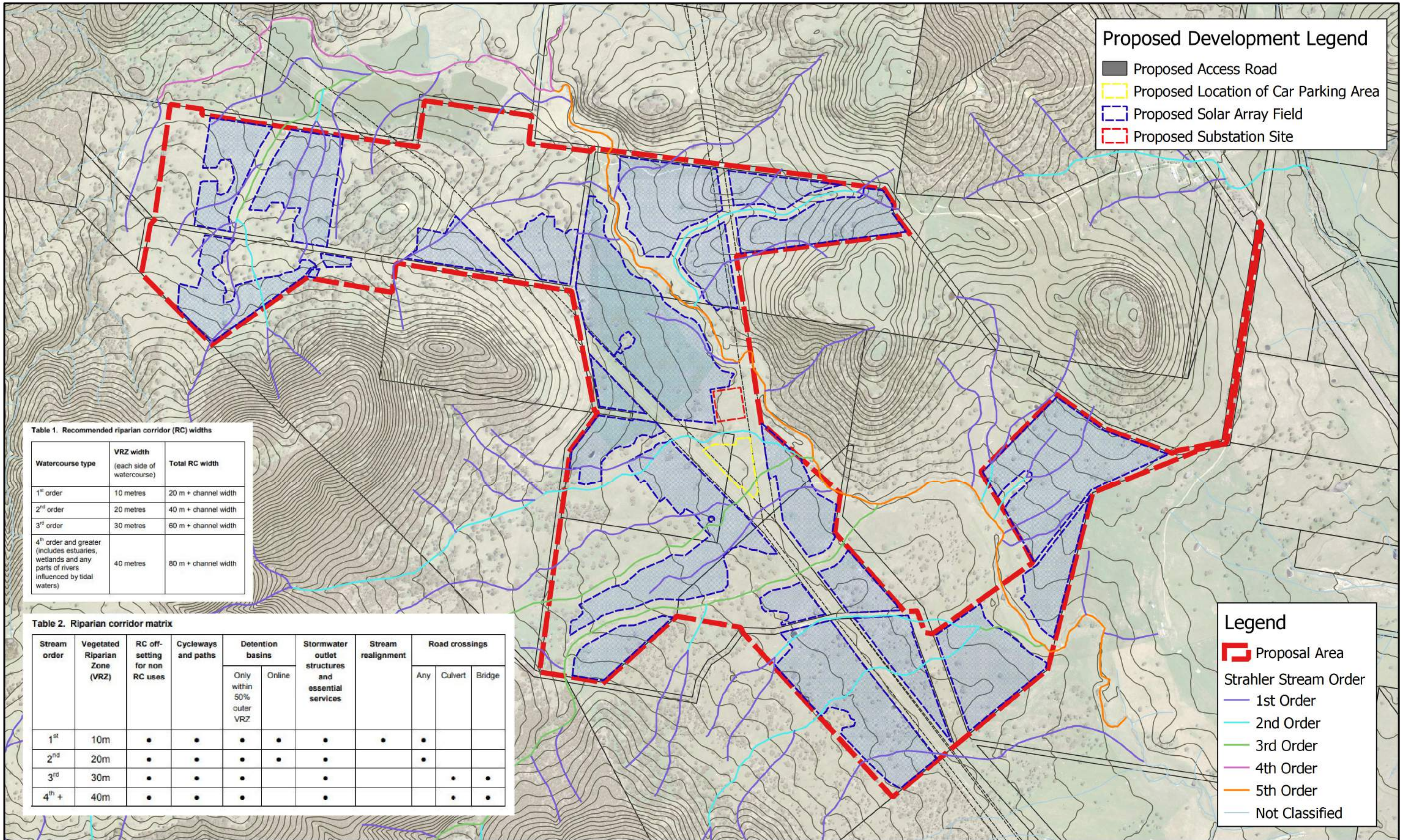

Table 1. Recommended riparian corridor (RC) widths

Watercourse type	VRZ width (each side of watercourse)	Total RC width
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

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	•	•	•		•			•	•

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sustainable engineering.

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200 0 200 400 m

Scale 1:12,500 at A3

TILBUSTER SOLAR FARM

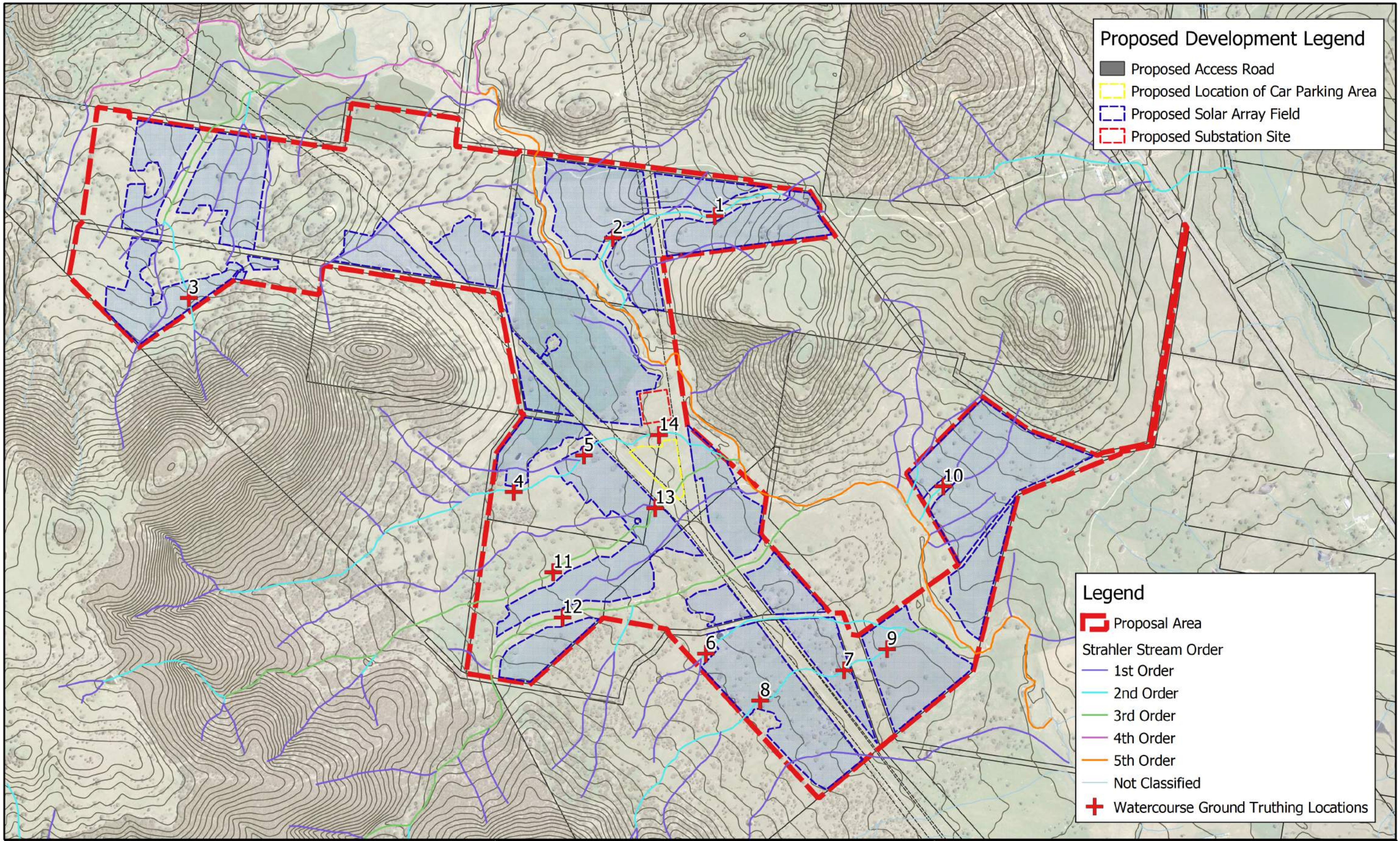
FIGURE 8.1

STREAM CLASSIFICATION

Rev 4 - 09 July 2021

APPENDIX J

Watercourse Ground Truthing



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sustainable engineering.
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200 0 200 400 m

Scale 1:12,500 at A3

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TILBUSTER SOLAR FARM

FIGURE 9.1

WATERCOURSE GROUND TRUTHING LOCATIONS

Rev 1 - 09 July 2021

Plate 1: Sites 1 and 2

Plate 2: Site 3

Plate 3: Site 4

Plate 4: Site 5

Plate 5: Site 6

Plate 6: Site 7

Plate 7: Site 8

Plate 8: Site 9

Plate 9: Site 10

Plate 10: Site 12

Plate 11: Site 13

Plate 12: Site 14