APPENDIX J HYDROLOGY REPORT

footprint.
sustainable engineering.

Proposed Solar Plant, Wellington North, New South Wales

Hydrological and Hydraulic Analysis

Project No. 1760
Date: 12 June 2018

Prepared for: AGL

Footprint (NSW) Pty Ltd
15 Meehan Drive
Kiama Downs, NSW 2533, Australia
CAN 131 571 929 ABN 44 131 571 929
Phone: 02 4237 6770
Mobile: 0430 421 661
Email: ashley@footprinteng.com.au

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (*Footprint*) has been engaged by ngh environmental Pty. Ltd. on behalf of AGL to undertake a hydrological and hydraulic analysis in support of a proposed solar plant located north-east of Wellington, New South Wales.

The purpose of the analysis is to define the flood behaviour, including depth of inundation, over three ephemeral watercourses/overland flow paths that traverse the subject site 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 site survey, topographic maps, proposed development plans.
2. Undertake hydrologic calculations to determine peak flows arriving at the site for each watercourse for the 20%, 10%, 5%, 2% and 1% AEP events.
3. Undertake hydraulic modelling (using HEC-RAS) to determine the depth and extent of flooding over the subject site for each of the above rainfall events.
4. Preparation of a concise hydrological and hydraulic report defining the methodology and result of the above investigation.

2.0 SUBJECT SITE

The subject site includes Lots 75- 84, 88, and 119- 121/DP2987; Lots 100 and 109/DP750760; Lots 1, 2 and 3/DP808748; Lot 1 and 2/DP1104720; Lot 3/DP976701; Lot 1/DP664645 and Lot 1/DP1206579 and is located approximately 7 kilometers north-east of the township of Wellington. The site location in relation to Wellington is shown in Figure 1.

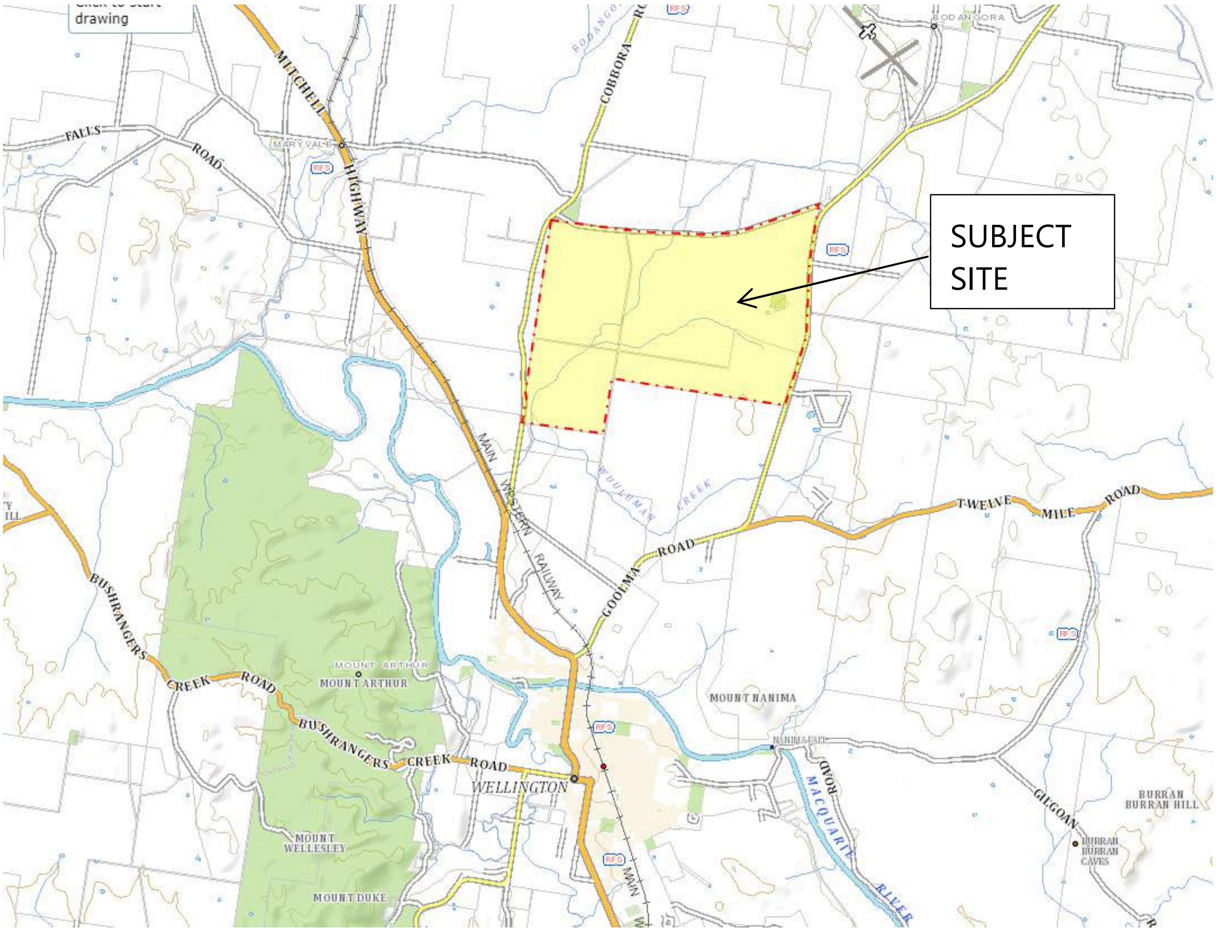


Figure 1: Location of Subject Site

The site consists of an area of approximately 970 hectares and is traversed by several unnamed tributaries of Wuuluman Creek. The main tributary traverses the site in a north-south direction and joins with Wuuluman Creek just south of the southern boundary of the subject site. A second tributary traverses the site in a west to east direction through the southern half of the site where it meets with the main. Three other minor tributaries ae also present on the subject site.

Except for the main tributary described above (in which water is understood to constantly flow) all watercourses are described as ephemeral and would only contain flowing water during rainfall.

Wuuluman Creek is a tributary of the Macquarie River, which is located approximately 1.3km west of the subject site.

As shown in Figure 2, the site comprises several large paddocks which consist of undulating hills that have been largely cleared for cropping and grazing. Any areas of remnant vegetation have been highly disturbed and lack native understorey due to grazing and pasture improvements practices. Planting of native species have been used as wind breaks and for rehabilitation along waterways in some isolated areas.

Figure 2: Aerial View of Subject Site (outlined in red)

Elevations over the site range from RL310 m AHD to RL390 m AHD as depicted in Figure 3.

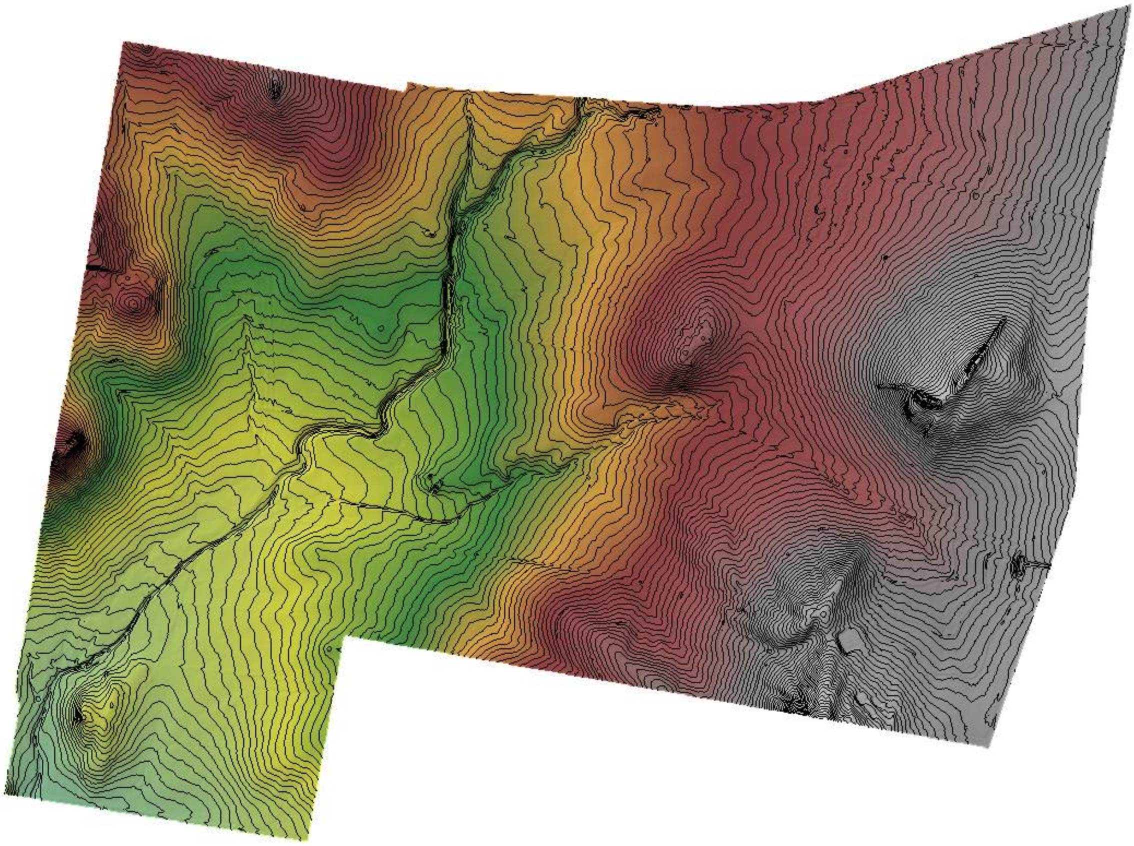


Figure 3: Terrain Analysis over Subject Site (1m contour interval)

3.0 HYDROLOGICAL MODELLING

3.1. Model Adoption

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

3.2. Catchment Areas

The total catchment area contributing to the subject site is estimated to be approximately 4,490 hectares (44.9km^2) and was determined using 10m contour data obtained through the NSW Government Spatial Services portal.

The overall catchment was dissected into 11 sub-catchments ranging in size from 125 t0 795 hectares. A summary of the catchment areas is provided in Table 1, whilst a breakup of catchments is depicted in Figure 4.

Table 1: Summary of Catchment Areas

Catchment	Area (ha)
1.1	790
1.2	235
1.3	795
1.4	762
2.1	383
2.2	214
2.3	289
2.4	533
3.1	132
3.2	125
3.3	231
TOTAL	4,489

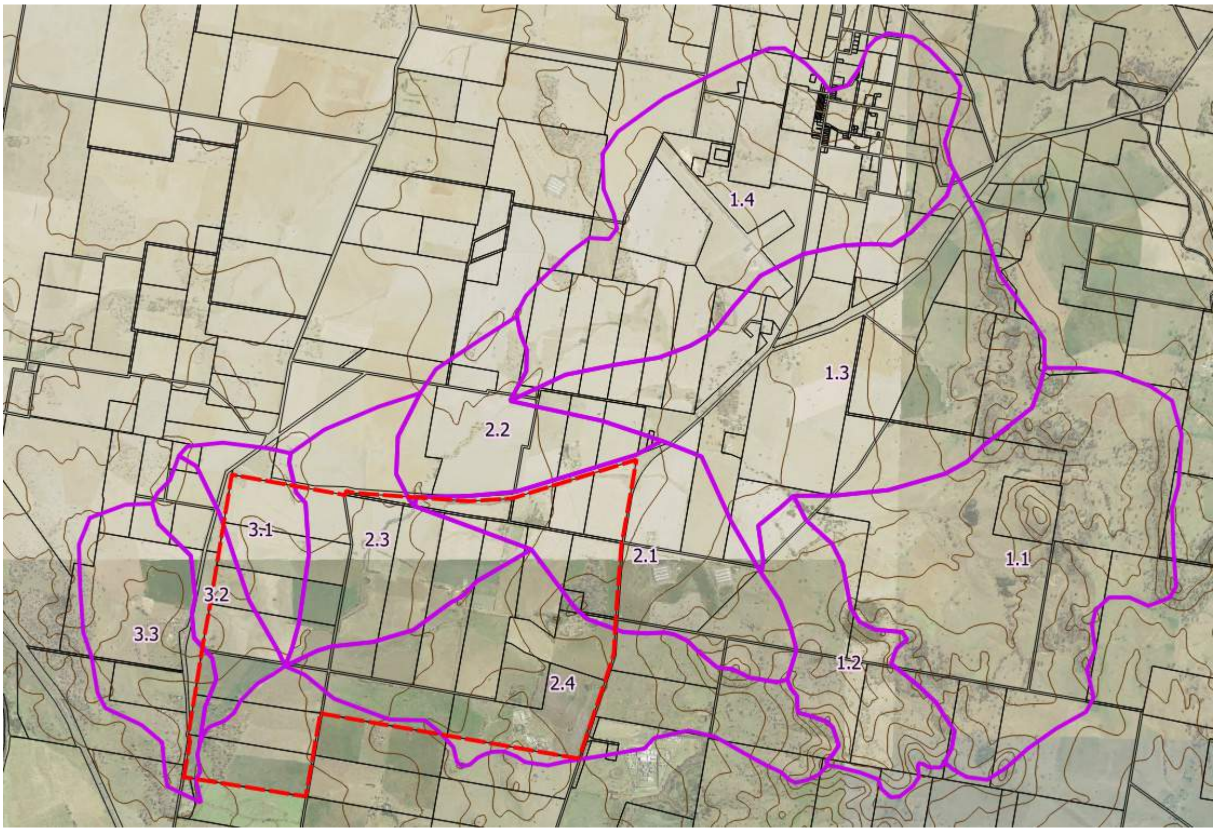


Figure 4: Sub-catchment Plan

3.3. Modelling Input Parameters

The parameters adopted for hydrological modelling are shown in Table *2*.

Table 2: Hydrological Parameters Adopted

Parameter	**Value Adopted**	**Justification/Source**
Pervious Area Initial Loss (mm)	25	Recommended value for Central NSW obtained through ARR 2016 data hub (refer Appendix A)
Pervious Area Continuing Loss (mm/h)	2.0	Recommended value for Central NSW obtained through ARR 2016 data hub (refer Appendix A)
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 4
Impervious Area (%)	Varies	Value determined conservatively based on areal imagery of the catchments
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	0.025	Typical value for rural pasture lands

3.4. Rainfall Data

IFD design rainfall depth data and temporal pattern was derived in accordance with Australian Rainfall and Runoff (2016) using the Bureau of Meteorology's 2016 Rainfall IFD on-line Data System.

The temporal pattern for the Central Sloped region was used as this covers the subject site (latitude -32.495687, longitude 148.957014).

A copy of the Rainfall depths for the range of storm durations used can be found in Appendix B. Storm probabilities in ARR2016 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).

The median pre-burst rainfall depths have also been included in Appendix B. These vary according to storm frequency and duration and act to reduce the storm initial loss, on the assumption that the catchment has been wet by pre-burst rainfall preceding the actual storm burst.

No pre-burst rainfall depths are provided on the ARR2016 data hub for storm durations less than 1 hour, or for either the 4.5 hour and 9 hour durations. Therefore, it was assumed that:

- the pre-burst rainfall depth for the 1 hour storm also applies for storm durations less than 1 hour;
- the 6 hour depth applies for the 4.5 hour storm; and
- the 12 hour depth applies for the 9 hr.

These assumptions most likely result in conservative runoff values for these durations, as the pre-burst depth generally increases with duration (up until the 12 hour duration after which there is very minor pre-burst rainfall).

3.5. Results

The RAFTS DRAINS Model was run for storm durations ranging from 10 minutes to 24 hours and hydrographs at the outlet (southern boundary of the subject site) for the median storm for the range of events modelled are shown in Figure 5.

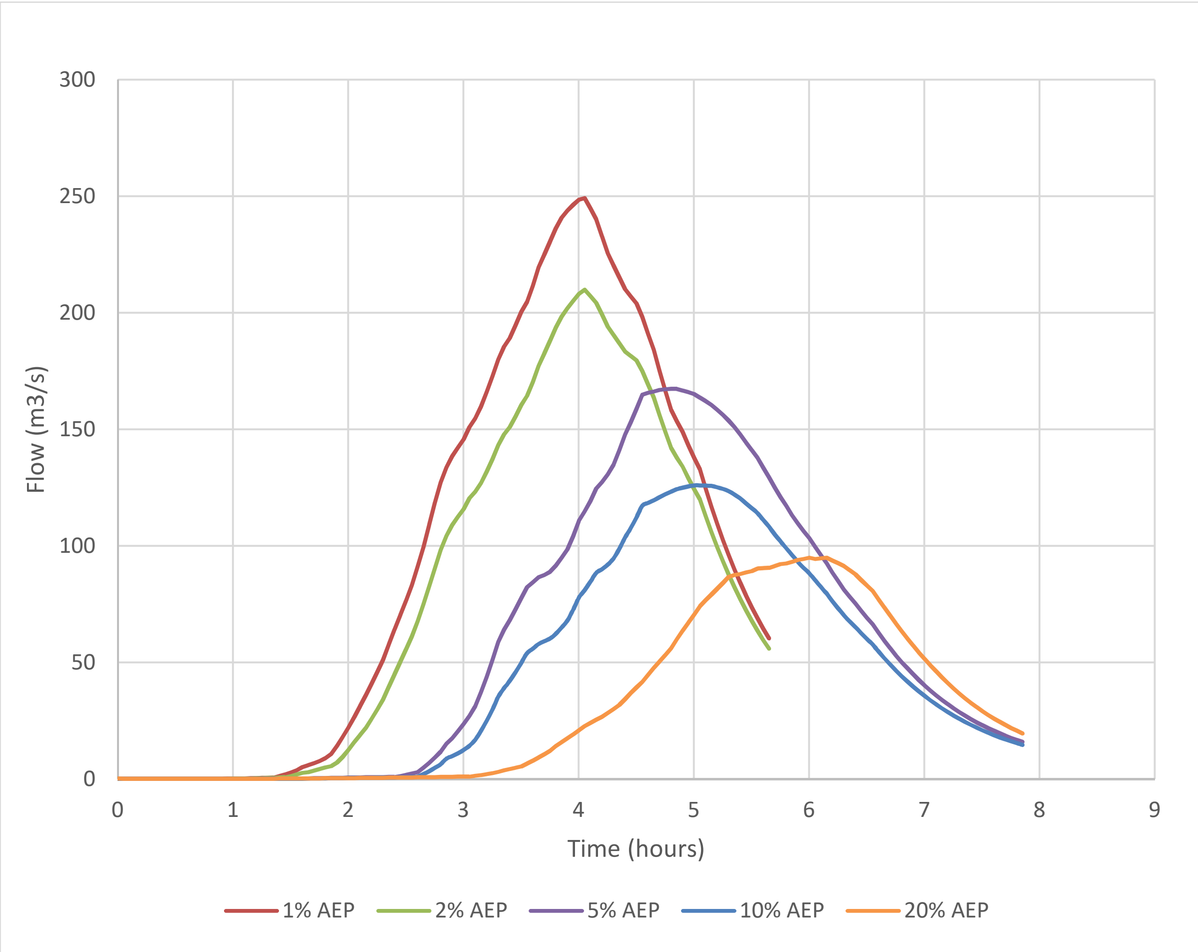


Figure 5: Median Flood Hydrographs Derived from Hydrological Model

The peak flows derived in DRAINS were compared to those derived using the Australian Rainfall and Runoff Regional Flood Frequency Estimation (RFFE) Model and the results are shown in Table 3 and Figure 6.

Table 3: Comparison of Peak Flows to Regional Flood Frequency Estimation Model

Annual Exceedance Probability (AEP)	Peak Flow Rate (cumecs)			
	RAFTS	Regional Flood Frequency Estimation Model		
		Discharge	Lower (5%)	Upper (95%)
20%	95	37.2	16	86.2
10%	126	58.3	25.3	134
5%	167	84.6	36.6	196
2%	210	129	55.3	303
1%	249	172	72.8	408

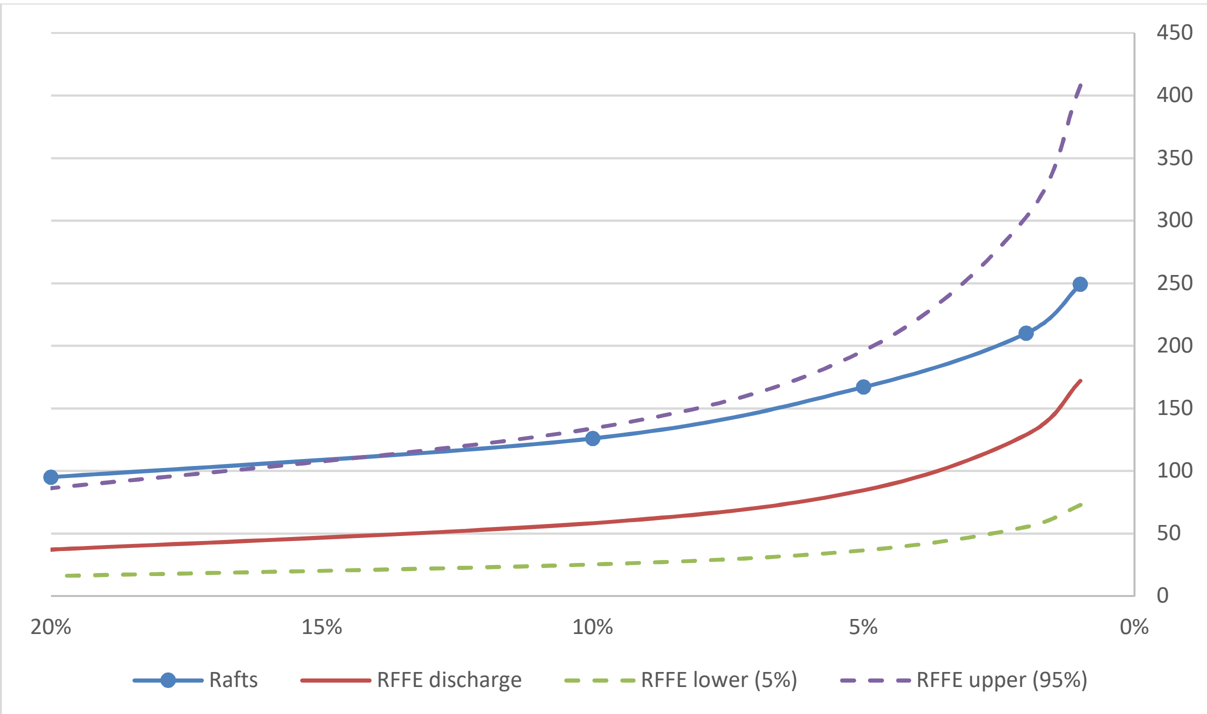


Figure 6: Comparison of Peak Flows to Regional Flood Frequency Estimation Model

The comparison of results shows that the runoff routing model results tend to estimate peak flows higher than the RFFE method. Without calibration reasons for this are not able to be determined. However possible causes could be due to routing effects and/or surface roughness which may result in increased peak flows from the RAFTS routing model. Further, catchments used in the determination of the RFFE method results range from about 100km^2 to over 1,000km^2 and are therefore substantially larger than the subject catchment which could also explain the differences observed.

The results are typically well within the confidence limits for flows estimations based on gauged events from regional catchment, except for the 20%AEP and are therefore considered suitable for the purposes of this investigation.

Outputs from the RFFE method are included in Appendix C.

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady two-dimensional HEC-RAS model (Version 5.0.3) run in mixed flow regime to enable both subcritical and supercritical flow regimes to be assessed.

4.1. Model Inputs

4.1.1. Two-Dimensional Domain

A digital elevation model (DEM) of the subject site was provided by AGL and was based on a drone survey conducted by Australian UAV.

A two-dimensional flow area (i.e. active cells) was defined over the subject site over an extent considered large enough to accommodate the expected flows. The extent of the two-dimensional flow area is shown in Figure 7.

The 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 over each watercourse by applying breaklines with a minimum cell spacing of 1m and a maximum cell spacing of 5m. An example of the additional definition along each watercourse is shown in Figure 8.

The two-dimensional flow area was assigned a Manning's n value of 0.025 which is considered representative of the current condition of the land.

4.1.2. Boundary Conditions

The hydrographs derived using DRAINS were used to define the upstream boundary condition within each watercourse for each of the modelled events. Hydrographs for each storm event at each of the inflow locations are provided in Appendix D and were derived using total hydrographs from sub-catchment outlets as defined in Table 4.

Table 4: Adopted hydrographs for inflow boundaries

Inflow Boundary	Total Hydrograph from Sub-Catchment Outlet
Inflow 1	2.3
Inflow 2	2.1
Inflow 3	2.4
Inflow 4	3.1
Inflow 5	3.2
Inflow 6	3.3

The upstream boundaries were extended along the upstream face of the two-dimensional domain at each location over a sufficient length to enable the model to appropriately distribute the flow to the cells that are wet. At any given time-step, only a portion of the boundary condition line may be wet, thus only the cells in which the water surface elevation is higher than their outer boundary face terrain will receive water.

Flows leaving the two-dimensional area were defined with a normal depth downstream boundary condition with a friction slope of 1.0% which is based on 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.

The location and extent of the upstream and downstream boundary condition lines is shown in Figure 7.

Figure 7: Two-Dimensional Flow Area and Hydraulic Boundary Conditions

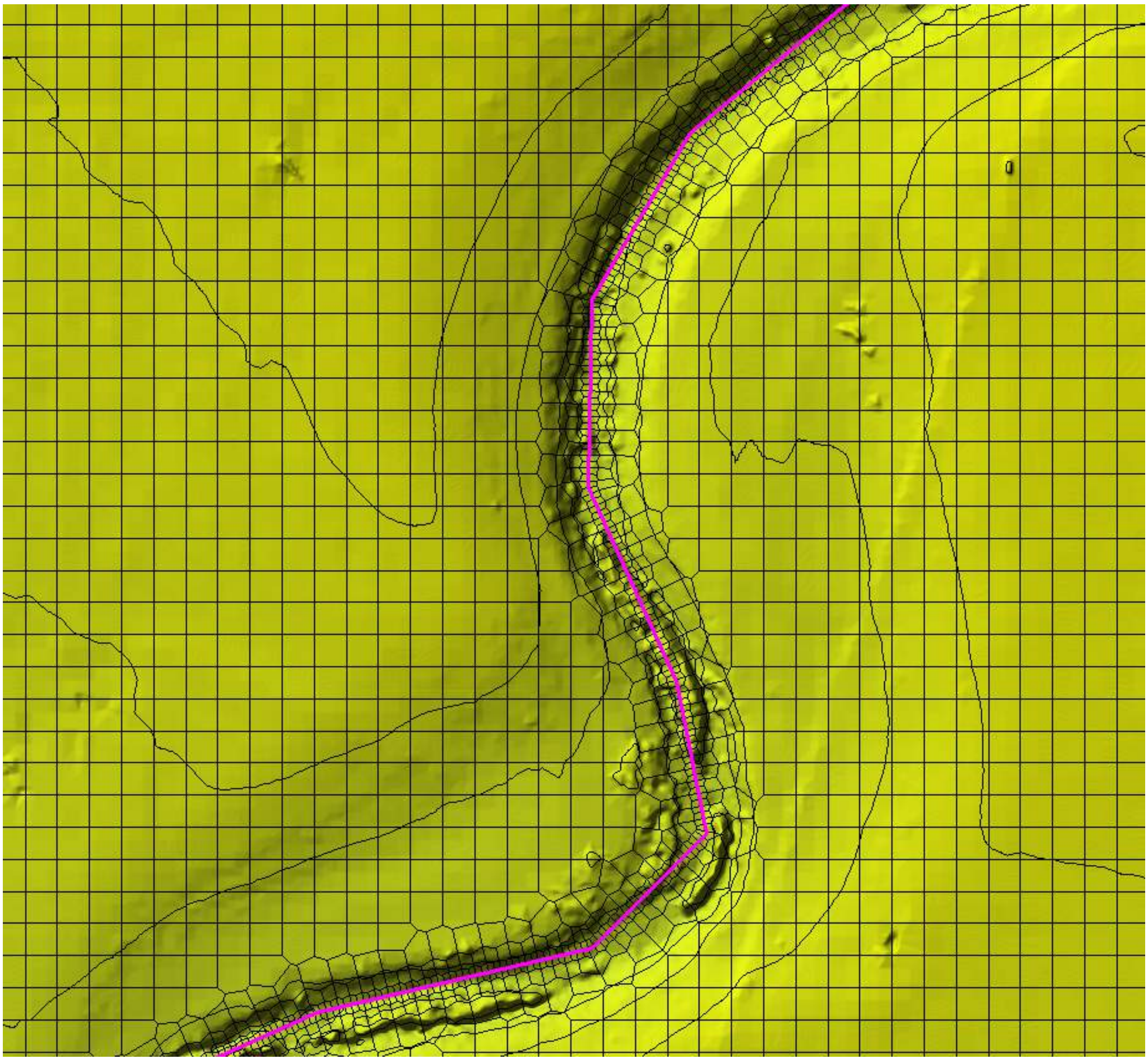


Figure 8: Example of additional definition along watercourses

4.2. Results

Results of the hydraulic modelling are included in Appendix E and include the following:

Figure 1.1 – 1% AEP Flood Levels and Depths

Figure 1.2 – 1% AEP Flood Velocities

Figure 2.1 – 2% AEP Flood Levels and Depths

Figure 2.2 – 2% AEP Flood Velocities

Figure 3.1 – 5% AEP Flood Levels and Depths

Figure 3.2 – 5% AEP Flood Velocities

Figure 4.1 – 10% AEP Flood Levels and Depths

Figure 4.2 – 10% AEP Flood Velocities

Figure 5.1 – 20% AEP Flood Levels and Depths

Figure 5.2 – 20% AEP Flood Velocities

The results show that flooding in all events is largely confined to the existing watercourse channels with minimal out of bank flows of any significant depth except for that area downstream of the junction of the northern and eastern tributaries in the south-western portion of the site where the watercourse is less defined, and the overbanks are typically wider and flatter.

In this area flood depths of up to about 600mm are predicted to occur for distances up to about 150m from the main channel in the 1% AEP event.

5.0 IMPACT OF PROPOSED WORKS

Whilst the precise layout and extent of the proposed development is yet to be determined the proposal would comprise an array of solar panels and related infrastructure as generally as follows:

- PV modules mounted on a horizontal tracking structure;
- Power conversion stations (PCS) to allow conversion of DC module output to AC electricity;
- An onsite substation containing transformers and associated switchgear;
- Underground electrical conduits and cabling to connect the arrays on the array site;
- Internal access tracks and upgrades to existing access roads, where required;
- Internal access tracks to allow for site maintenance;
- Area for future battery storage facility;
- Site office and maintenance building with associated car park;
- Perimeter security fencing and CCTV;
- Native vegetation planting to provide visual screening from specific viewpoints, as required; and
- Up to approximately 7km of high voltage, overhead or underground transmission line to the existing substation (132 kV or 330 kV).

It is understood the solar modules will be erected on a frame supported on piers at an approximate grid spacing of 4-8 metres.

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 development was assessed using the Modified Cowan Method for Floodplain Roughness and is shown in Table 5. It demonstrates that the roughness is anticipated to slightly increase because of the development.

Table 5: Modified Cowan Method for Estimation of Floodplain Roughness

Roughness Component	Existing (Grazed Pasture)	Proposed (Solar Array)
Floodplain Material (n_b)	0.020	0.020
Degree of Irregularity (n_1)	0.001	0.001
Variation in Floodplain Cross Section (n_2)	N/A	N/A
Effect of Obstructions (n_3)	0.000	0.003[1]
Amount of Vegetation (n_4)	0.004	0.004
Total (n)	0.025	0.028

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

The extent of the change in floodplain roughness was applied over the extent shown in Figures 6.1 and 6.2 in Appendix F. This extent defines the maximum extent of the envelope of the proposed development and is therefore likely to be conservative.

The envelope defined is understood to contain all infrastructure proposed as part of the development, including any proposed access roads.

less post development of 0.028any proposed roads is accounted for in the increase in roughness adopted for the solar array modules.Was bed level crossings (i.e. causeways or fords) have been recommended in Section 6 .based on the information currently at hand

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 are included in Appendix F.

7.1 depict the change in maximum water surface elevation (flood level) for the post development model run when compared to the pre-development (existing) conditions. The maximum increase in flood level resulting from the proposed development is predicted to be in the order of 30mm, although changes are typically within the range of -10mm to +20mm as shown in Figure 9.

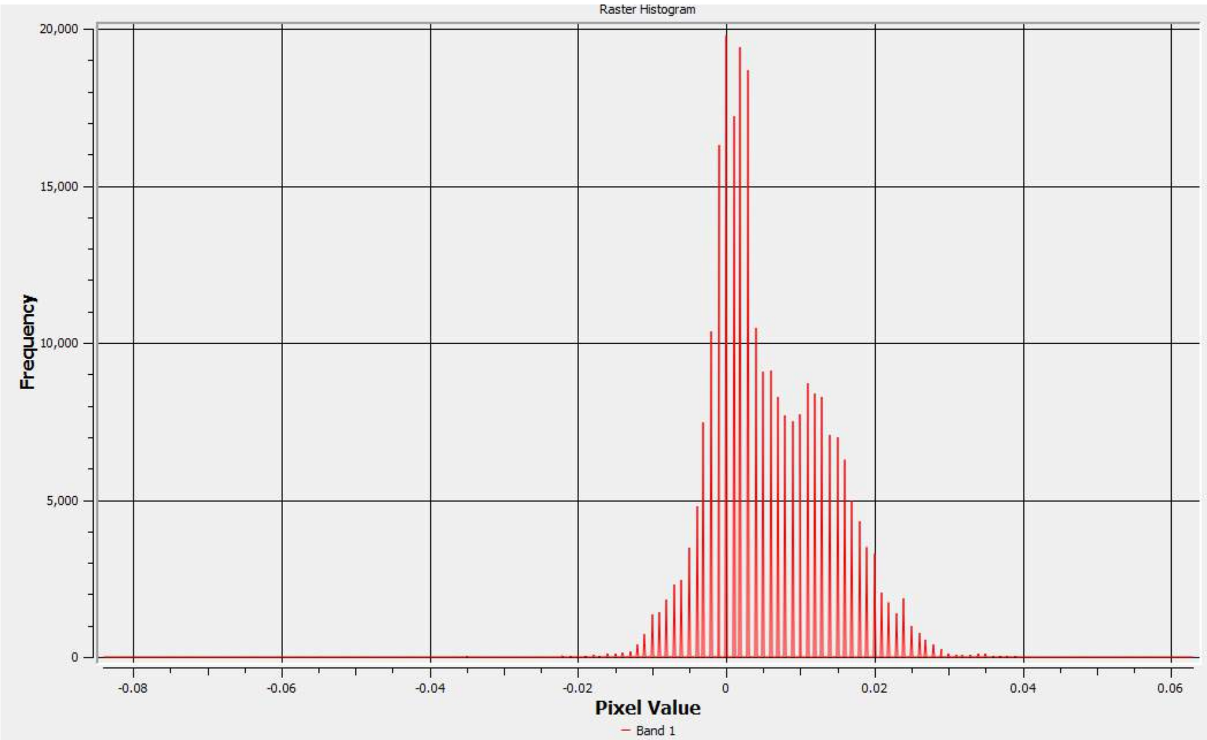


Figure 9: Histogram of Change in Flood Level resulting from Change in Floodplain Roughness

Importantly the modelling demonstrates that the change in flood levels are wholly confined to the subject site.

An assessment of the impact of the proposed works on peak velocity in the 1% AEP flood event was also undertaken and the results are presented in Figure 7.2 in Appendix F. The results indicate that the proposed development is anticipated to have a negligible impact on velocity in any of the watercourses or their associated overbanks therefore ensuring the stability of their bed and banks and minimising the erosion potential over the site.

6.0 FLOOD MANAGEMENT RECOMMENDATIONS

6.1. Solar Array Field

The upper half of the east-west orientated watercourse should be realigned back to its original alignment to lie within the proposed riparian buffer and the existing dam and associated overflow channel decommissioned. Alternatively, this buffer should be relocated over the existing overflow channel.

Within the area of inundation, the mounting height of the solar module frames should be designed such that the lower edge of the module is clear of the predicted 1% AEP flood level so as not to impact on existing flood behaviour and to prevent the infrastructure from being damaged because of flooding.

In the event of a significant flood event the modules should be rotated to provide maximum clearance from the panels to the ground to keep them positioned well above 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 F.

6.2. 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.

6.3. 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.

6.4. 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 10. 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).

Figure 10: Stream Order

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)

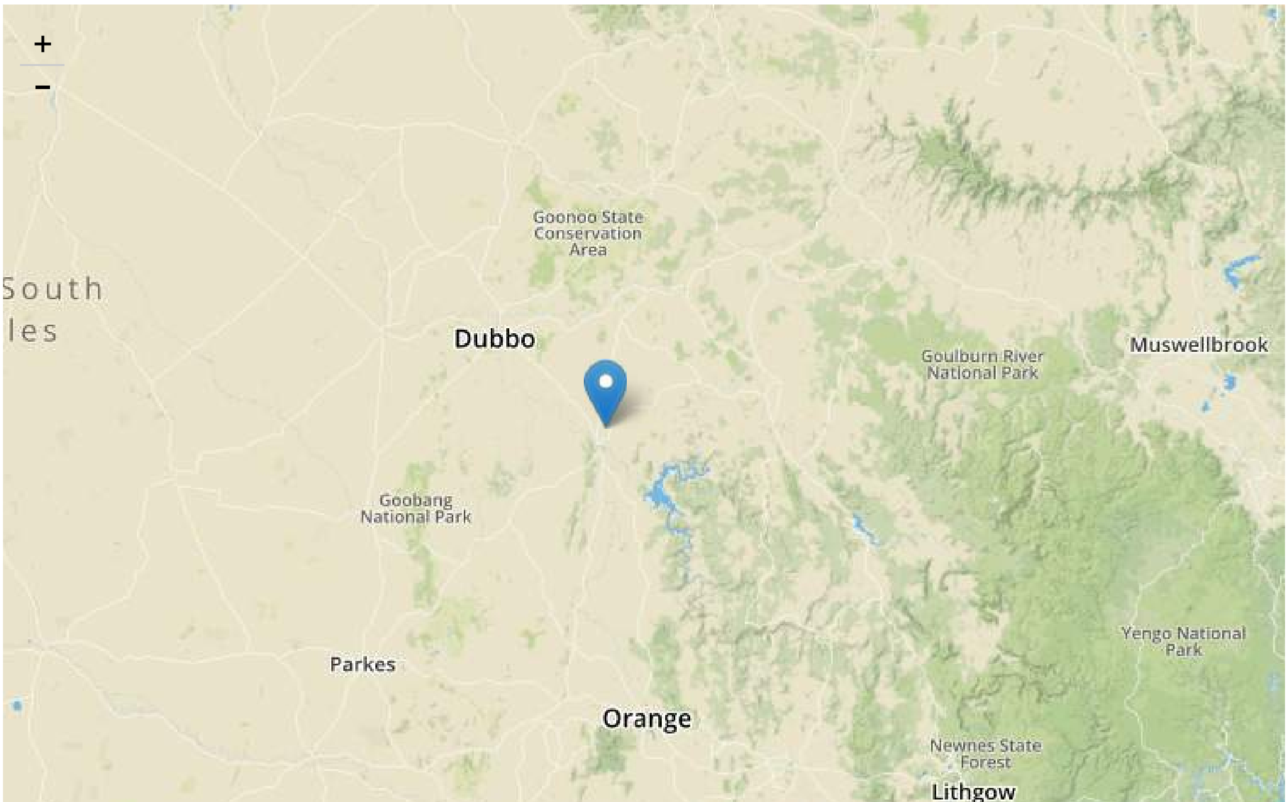
APPENDIX A

BOM ARR 2016 Hub Data

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.957
Latitude	-32.494
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Temporal Patterns	show
Areal Temporal Patterns	show
Interim Climate Change Factors	show



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Region Information

Data Category	Region
River Region	Macquarie-Bogan Rivers
ARF Parameters	Central NSW
Temporal Patterns	Central Slopes

Data

River Region

division	Murray-Darling Basin
rivregnum	22
River Region	Macquarie-Bogan Rivers

Layer Info

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Version	2016_v1

ARF Parameters

Long Duration ARF

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

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

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

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Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

Storm Initial Losses (mm)	25.0
Storm Continuing Losses (mm/h)	2.0

Layer Info

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Version	2016_v1

Temporal Patterns | Download (.zip) (./temporal_patterns/tp/CS.zip)

code	CS
Label	Central Slopes

Layer Info

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Version	2016_v2

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

code	CS
arealabel	Central Slopes

Layer Info

Time Accessed	08 April 2018 07:53PM
Version	2016_v2

BOM IFD Depths

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-32.49416667&longitude=148.95742&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

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Version	2016_v2

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)	1.4 (0.062)	1.0 (0.032)	0.7 (0.019)	0.4 (0.011)	0.5 (0.01)	0.5 (0.009)
90 (1.5)	0.9 (0.035)	1.1 (0.031)	1.2 (0.03)	1.4 (0.029)	0.7 (0.013)	0.2 (0.004)
120 (2.0)	0.9 (0.033)	0.9 (0.024)	0.9 (0.02)	0.9 (0.017)	0.8 (0.013)	0.8 (0.011)
180 (3.0)	0.5 (0.015)	0.7 (0.017)	0.9 (0.017)	1.0 (0.017)	1.4 (0.02)	1.6 (0.022)
360 (6.0)	0.8 (0.02)	1.9 (0.035)	2.6 (0.042)	3.3 (0.046)	5.8 (0.07)	7.6 (0.082)
720 (12.0)	0.0 (0.001)	3.1 (0.049)	5.2 (0.069)	7.2 (0.083)	9.1 (0.089)	10.6 (0.092)
1080 (18.0)	0.0 (0.0)	0.8 (0.011)	1.3 (0.015)	1.8 (0.018)	5.1 (0.044)	7.6 (0.058)
1440 (24.0)	0.0 (0.0)	0.1 (0.001)	0.1 (0.001)	0.2 (0.002)	3.2 (0.025)	5.5 (0.038)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.003)	0.7 (0.004)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Layer Info

Time Accessed	08 April 2018 07:53PM
Version	2016_v2

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.977 (4.9%)**	0.892 (4.5%)	**1.057 (5.3%)**
2040	**1.225 (6.1%)**	1.129 (5.6%)	**1.485 (7.4%)**
2050	**1.477 (7.4%)**	1.422 (7.1%)	**1.953 (9.8%)**
2060	**1.687 (8.4%)**	1.705 (8.5%)	**2.469 (12.3%)**
2070	**1.832 (9.2%)**	1.948 (9.7%)	**3.047 (15.2%)**
2080	**1.978 (9.9%)**	2.216 (11.1%)	**3.621 (18.1%)**
2090	**2.039 (10.2%)**	2.515 (12.6%)	**4.163 (20.8%)**

Layer Info

Time Accessed	08 April 2018 07:53PM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

Download TXT (downloads/1523181181.txt) Generating PDF... (downloads/1523181181.pdf)

APPENDIX B

ARR 2016 IFD Data

Australian Government
Bureau of Meteorology

Location

Label: Not provided

Latitude: -32.49416667 [Nearest grid cell: 32.4875 (S)]

Longitude: 148.95742 [Nearest grid cell: 148.9625 (E)]

IFD Design Rainfall Depth (mm)

Issued: 08 April 2018

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

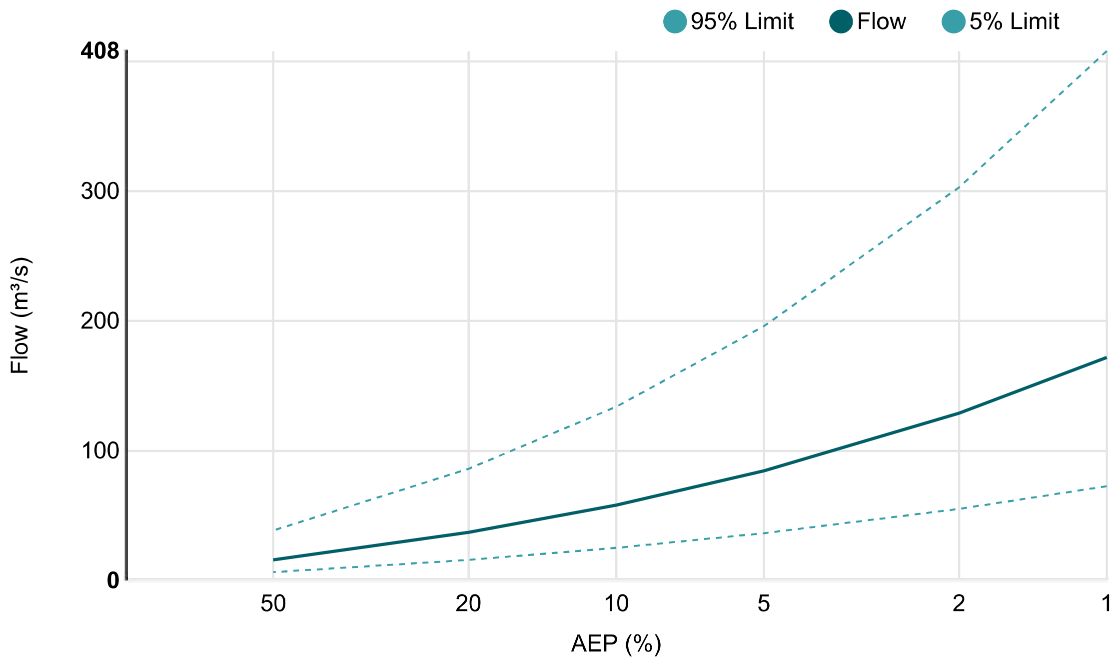
	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.84	2.07	2.79	3.30	3.80	4.49	5.03
2 min	3.11	3.50	4.75	5.60	6.44	7.52	8.33
3 min	4.29	4.83	6.55	7.72	8.89	10.4	11.5
4 min	5.35	6.02	8.14	9.61	11.1	13.0	14.5
5 min	6.29	7.07	9.56	11.3	13.0	15.3	17.1
10 min	9.78	11.0	14.8	17.5	20.2	23.9	26.8
15 min	12.1	13.6	18.3	21.6	25.0	29.6	33.3
20 min	13.8	15.5	20.9	24.7	28.5	33.8	37.9
30 min	16.2	18.2	24.6	29.1	33.6	39.7	44.5
45 min	18.7	21.0	28.4	33.6	38.7	45.7	51.1
1 hour	20.5	23.0	31.2	36.8	42.4	49.9	55.7
1.5 hour	23.1	26.0	35.2	41.5	47.8	56.1	62.5
2 hour	25.1	28.3	38.3	45.1	51.8	60.8	67.6
3 hour	28.3	31.8	42.9	50.5	58.0	67.9	75.6
6 hour	34.6	38.9	52.3	61.5	70.6	82.9	92.4
12 hour	42.5	47.5	63.8	75.2	86.5	102	115
24 hour	51.5	57.5	77.3	91.6	106	127	144
48 hour	60.7	67.8	91.8	110	128	155	177
72 hour	65.6	73.4	100	120	141	171	196
96 hour	68.8	77.2	106	127	150	183	209
120 hour	71.2	80.0	110	133	157	191	219
144 hour	73.1	82.4	114	138	162	197	226
168 hour	74.8	84.5	117	141	167	202	231

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.

APPENDIX C

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	16.1	6.60	38.7
20	37.2	16.0	86.2
10	58.3	25.3	134
5	84.6	36.6	196
2	129	55.3	303
1	172	72.8	408

Statistics

Variable	Value	Standard Dev
Mean	2.783	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

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

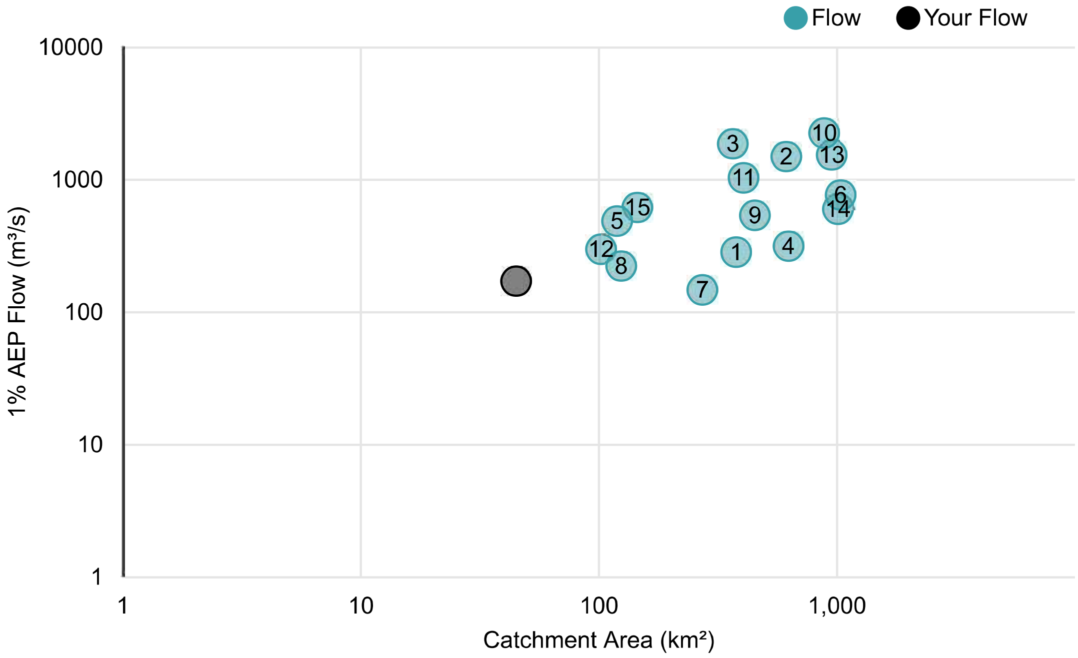
Correlation

Correlation

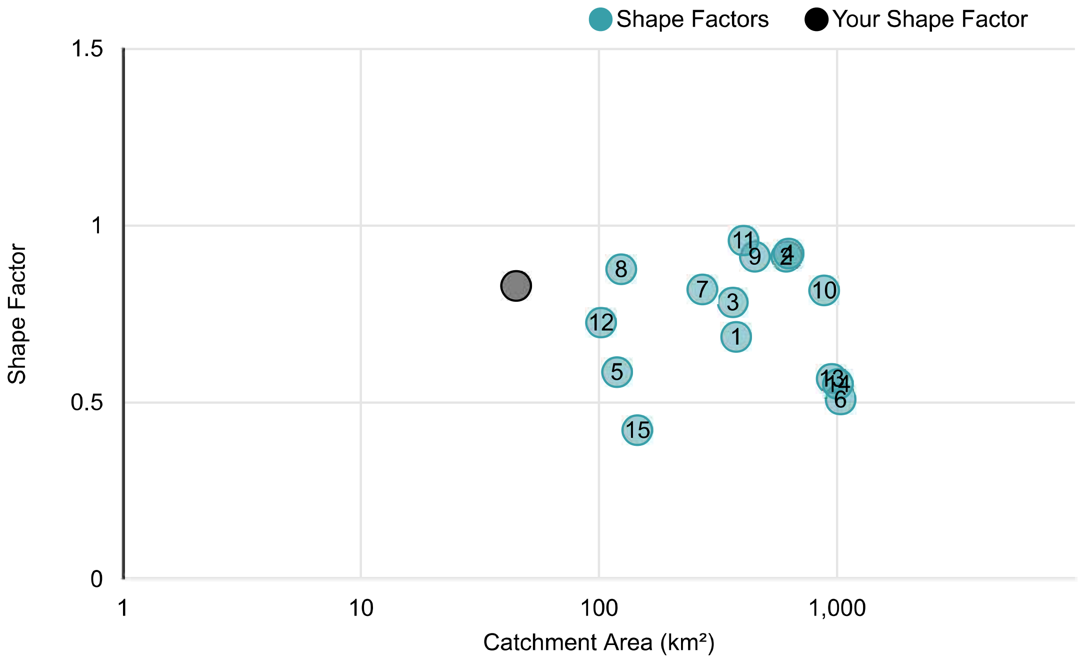
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

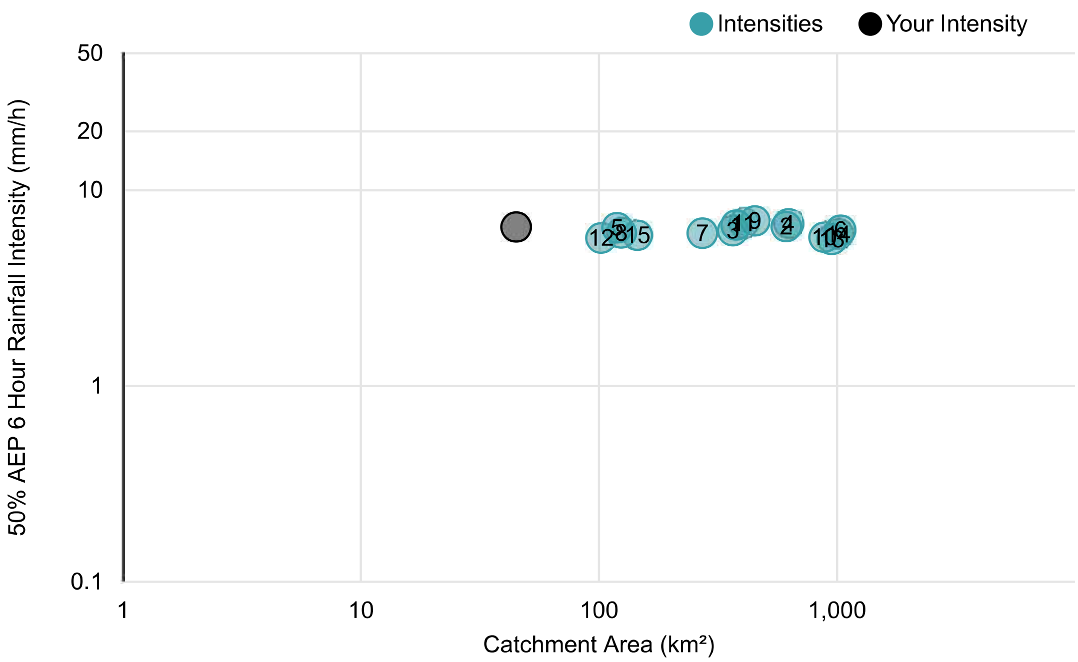
1% AEP Flow vs Catchment Area



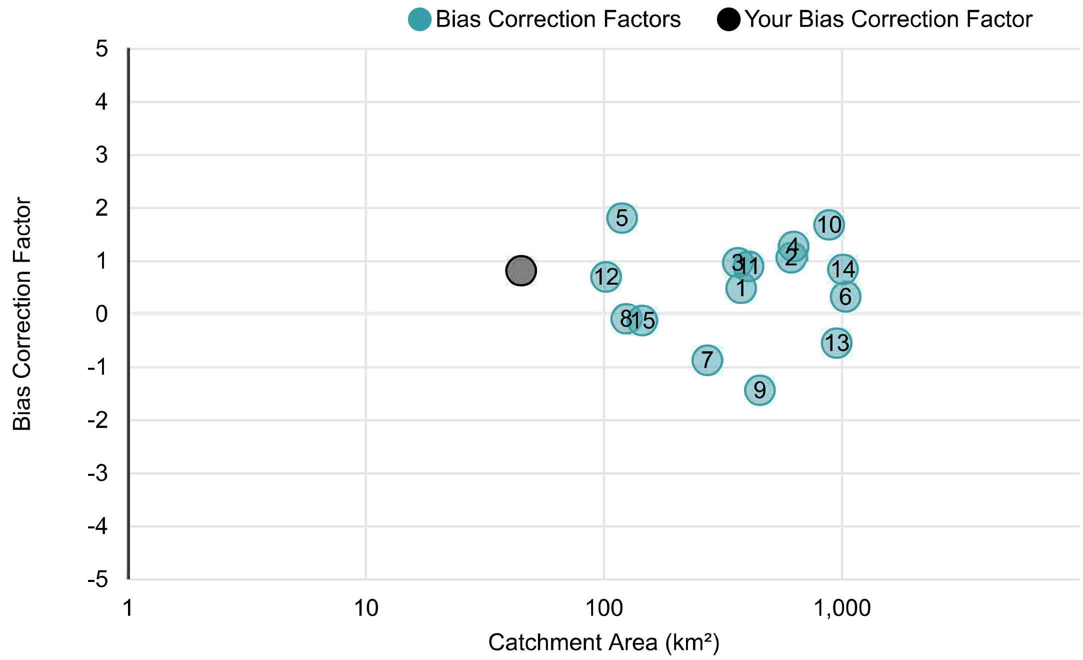
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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TXT PDF Nearby JSON

Input Data

Date/Time	2018-03-13 14:23
Catchment Name	Wellington North
Latitude (Outlet)	-32.511894
Longitude (Outlet)	148.936291
Latitude (Centroid)	-32.483191
Longitude (Centroid)	148.985204
Catchment Area (km^2)	44.89804
Distance to Nearest Gauged Catchment (km)	35.49
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.485322
2% AEP 6 Hour Rainfall Intensity (mm/h)	13.791008
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast

Input Data

Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.83
Interpolation Method	Natural Neighbour
Bias Correction Value	0.818

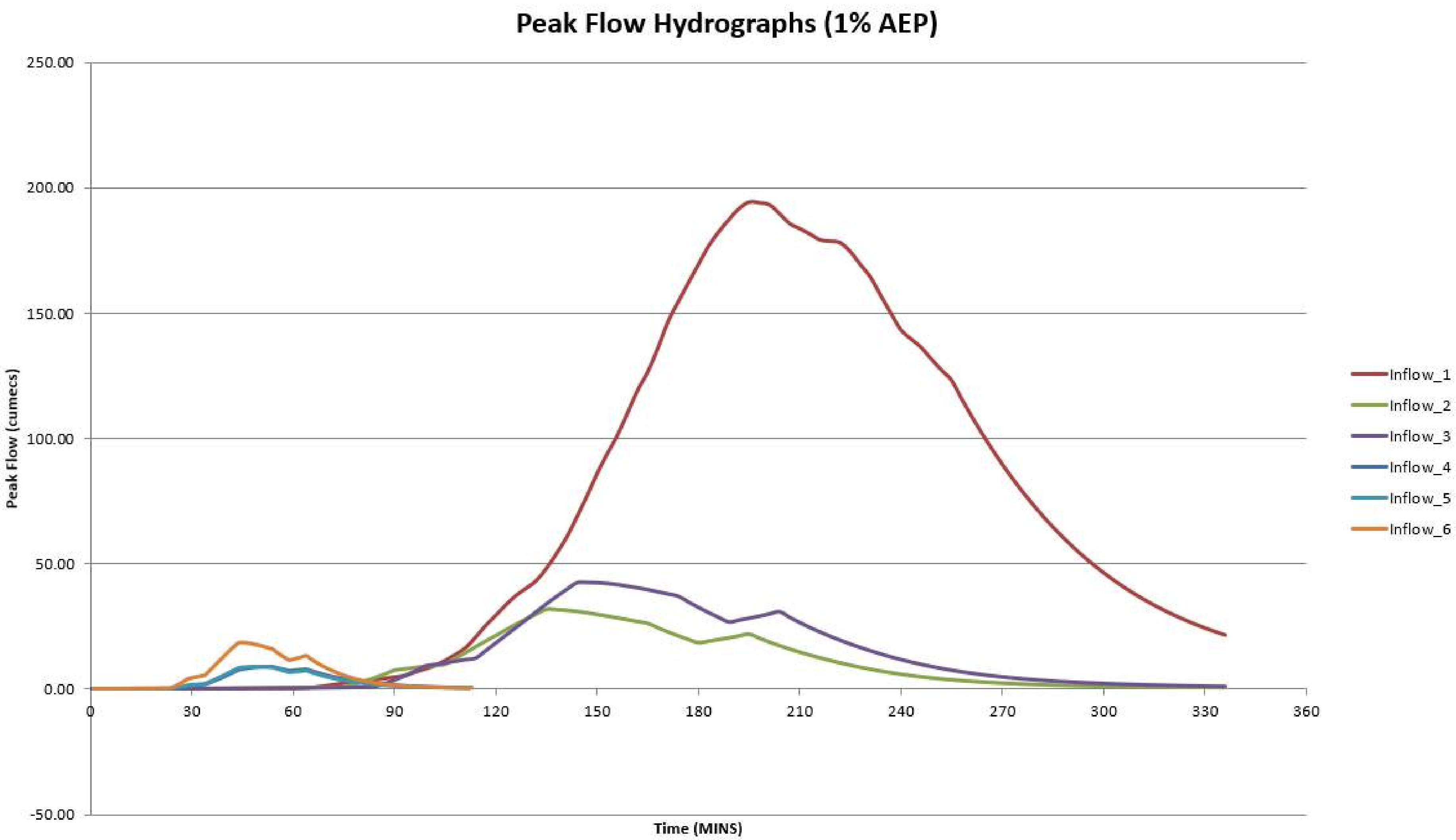
Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions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

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

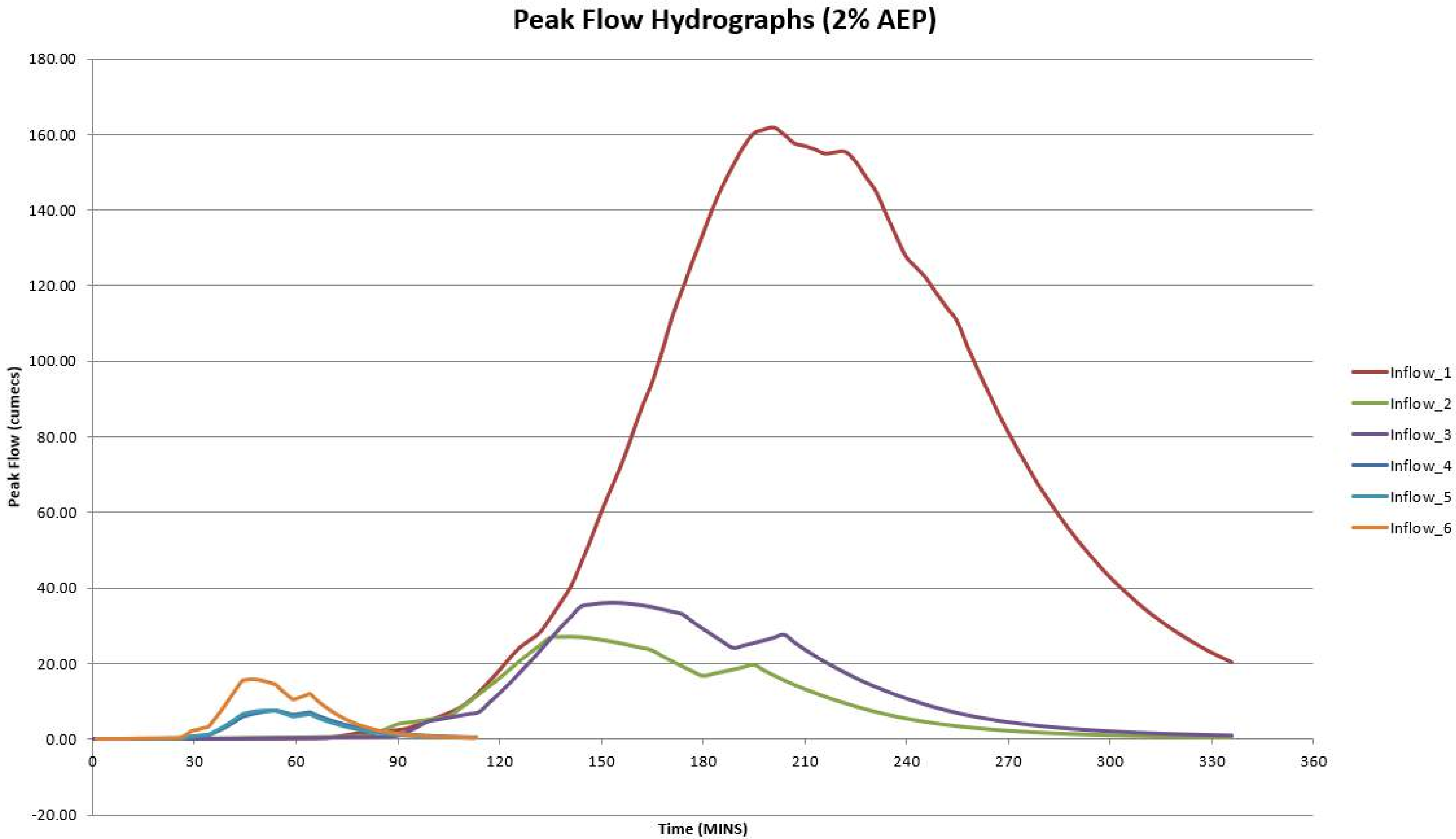
WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

APPENDIX D

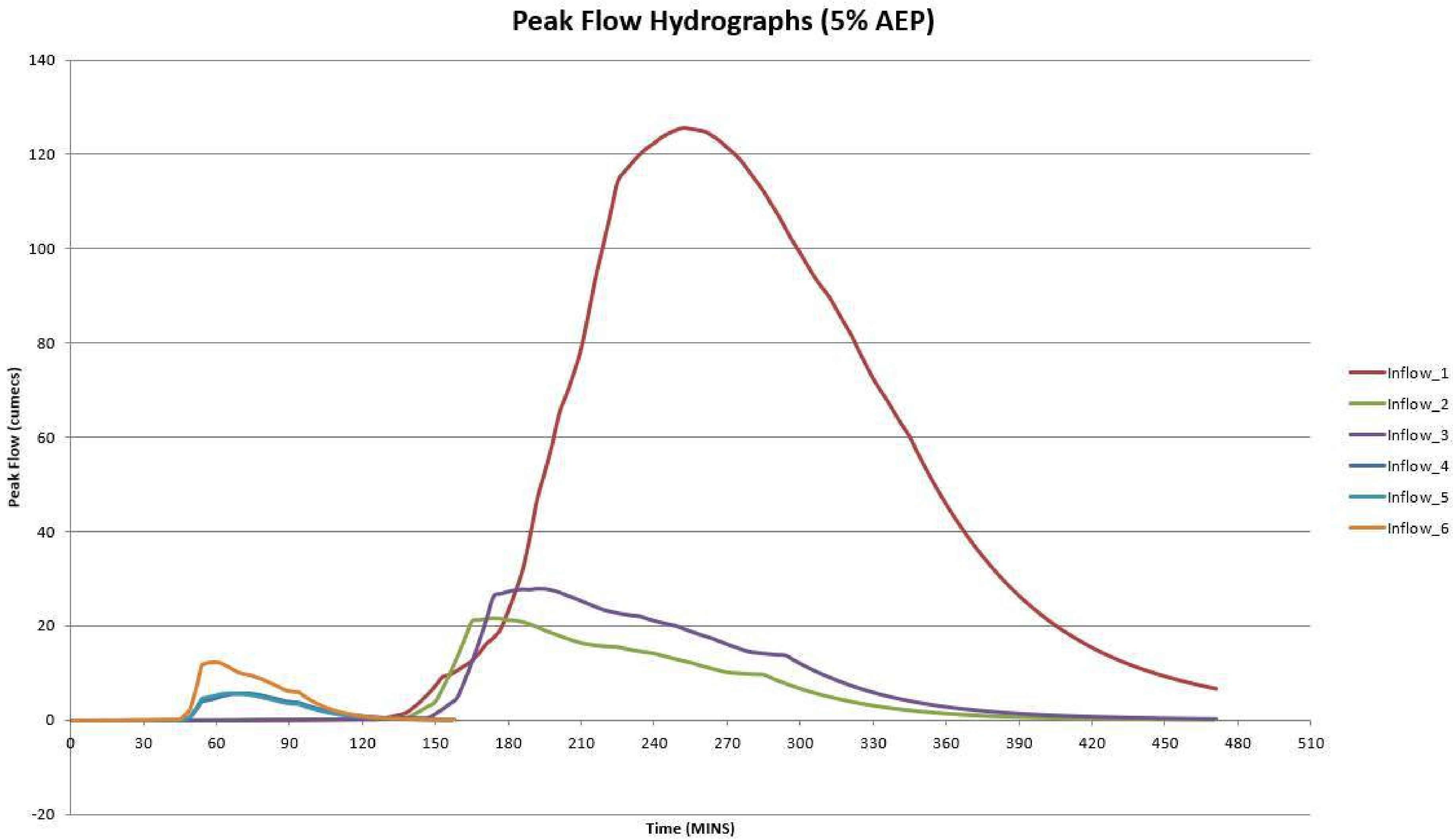
Inflow Hydrographs



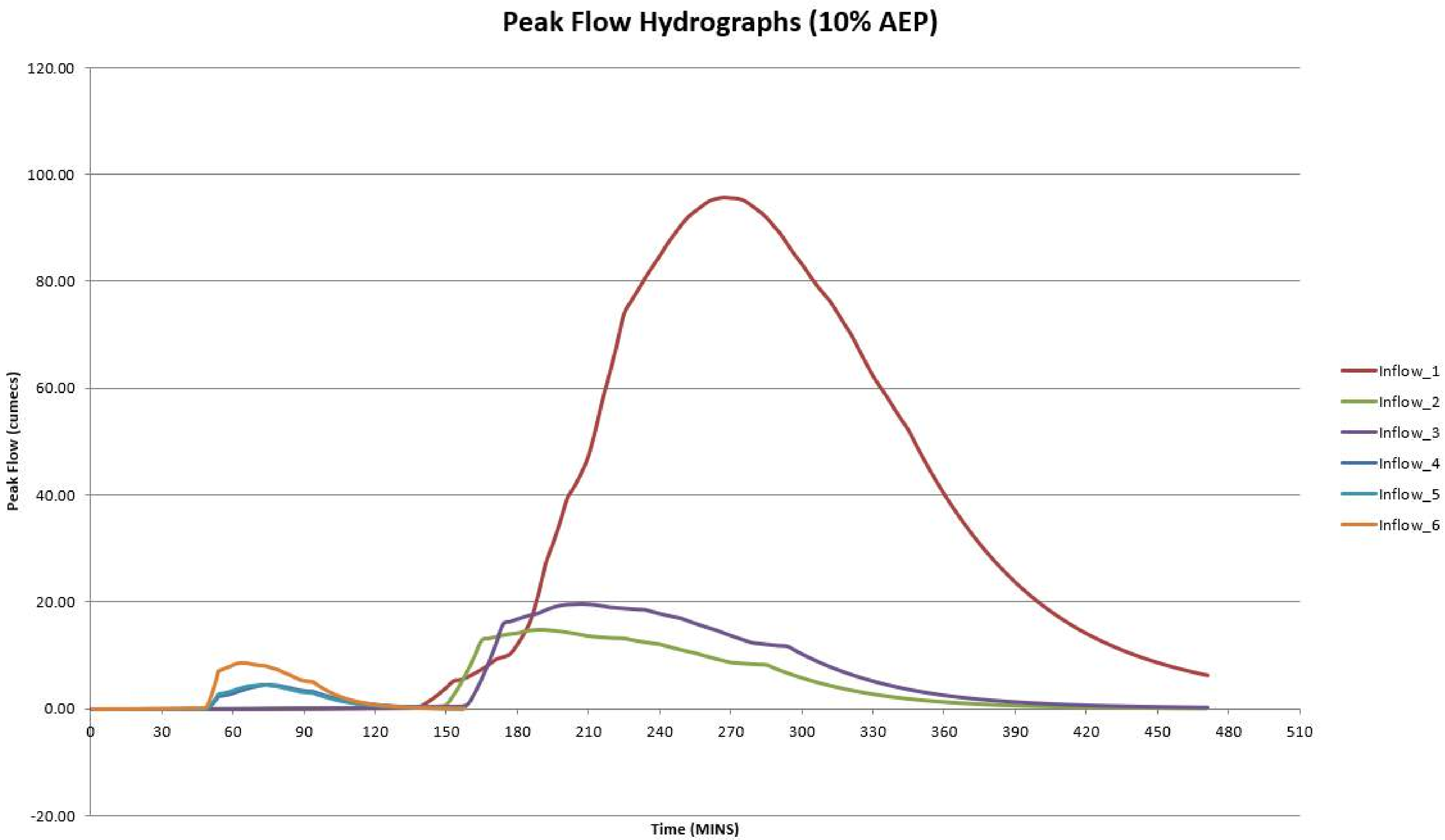
Peak Flow Hydrographs (1% AEP)
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
Peak Flow (cumecs)
0
30
60
90
120
150
180
210
240
270
300
330
360
Time (MINS)
Inflow_1
Inflow_2
Inflow_3
Inflow_4
Inflow_5
Inflow_6



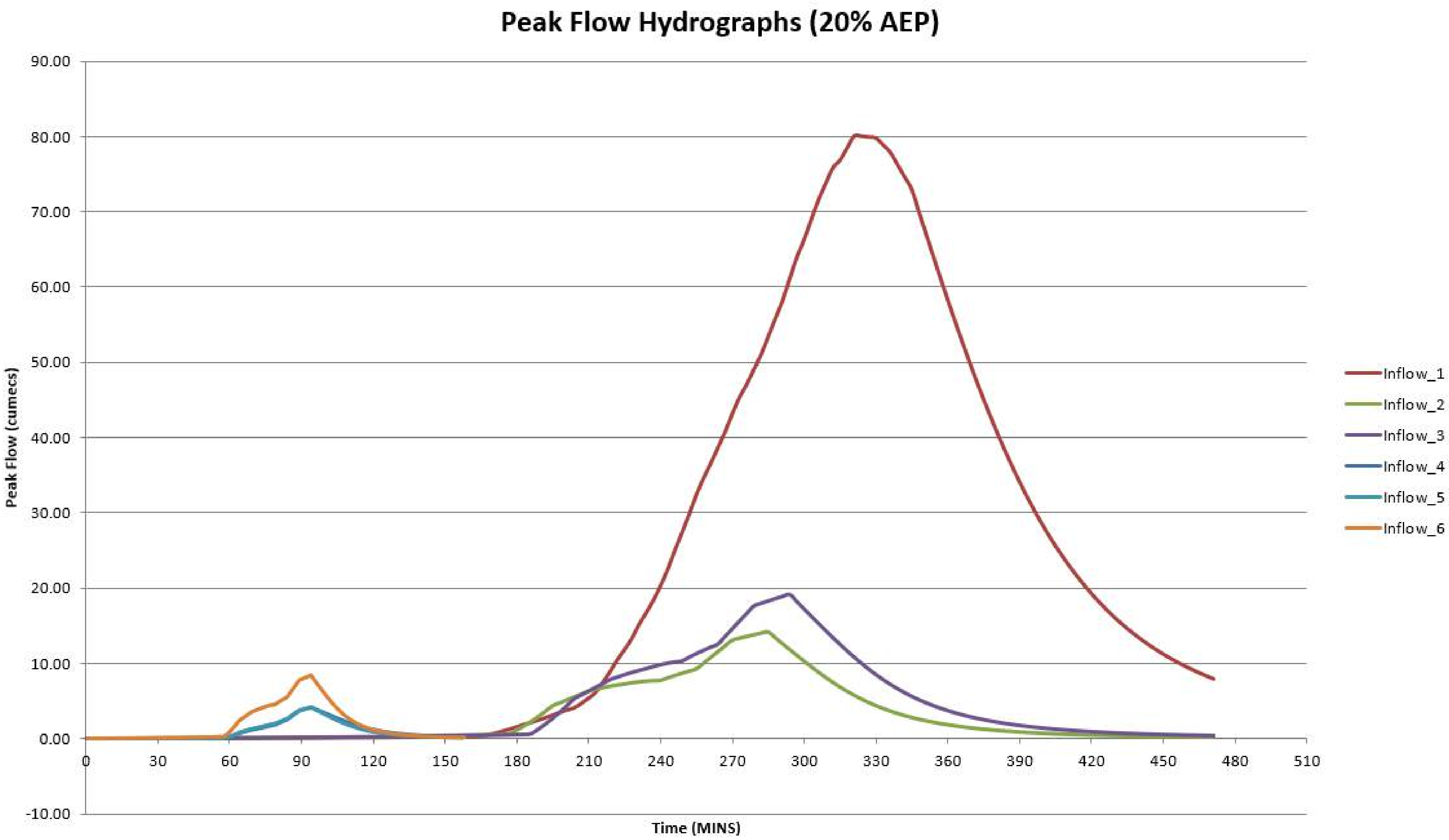
Peak Flow Hydrographs (2% AEP)
Peak Flow (cumecs)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0
30
60
90
120
150
180
210
240
270
300
330
360
Time (MINS)
Inflow_1
Inflow_2
Inflow_3
Inflow_4
Inflow_5
Inflow_6



Peak Flow Hydrographs (5% AEP)
140
120
100
80
60
40
20
0
-20
Peak Flow (cumecs)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
Time (MINS)
Inflow_1
Inflow_2
Inflow_3
Inflow_4
Inflow_5
Inflow_6



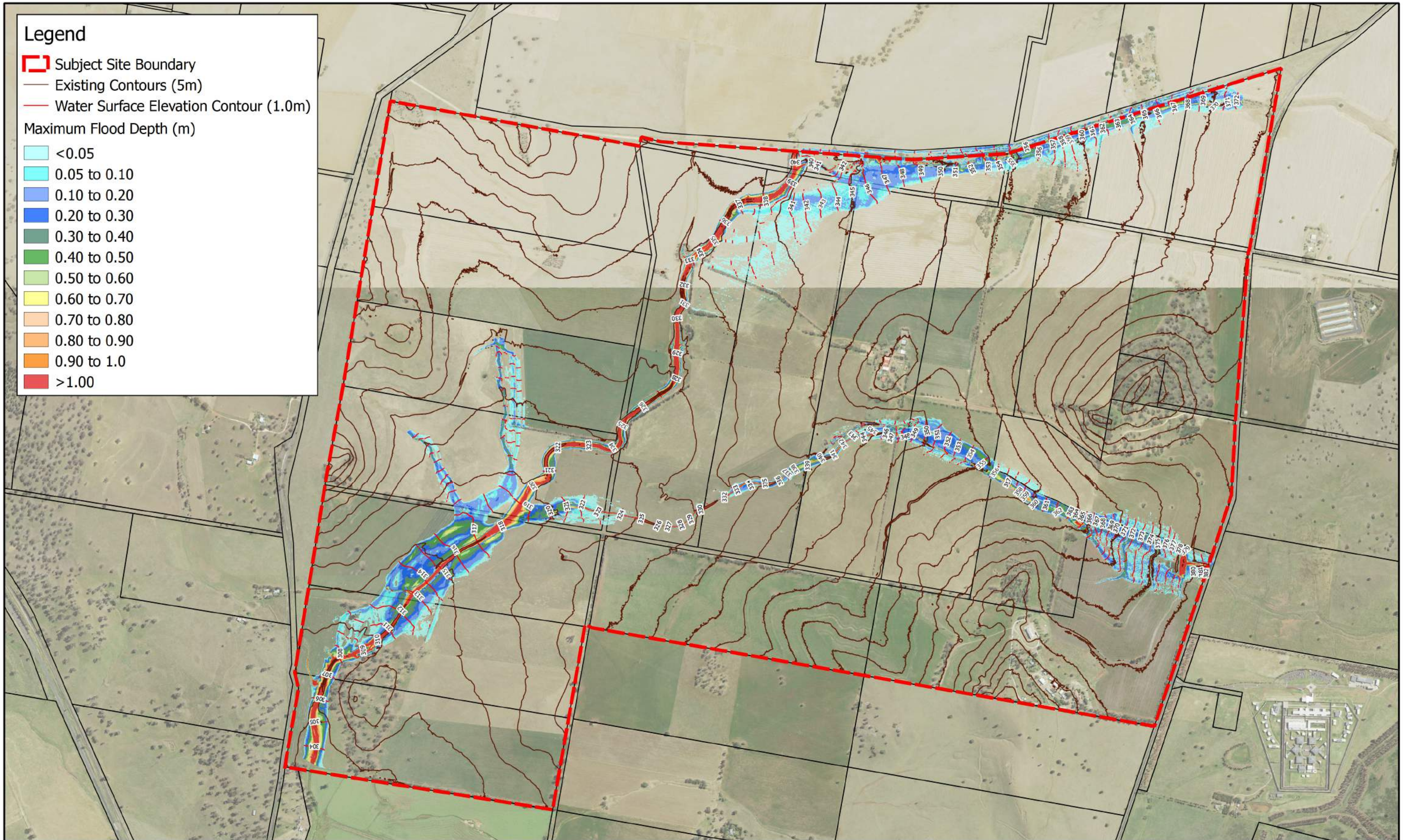
Peak Flow Hydrographs (10% AEP)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
Peak Flow (cumecs)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
Time (MINS)
Inflow_1
Inflow_2
Inflow_3
Inflow_4
Inflow_5
Inflow_6



Peak Flow Hydrographs (20% AEP)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Peak Flow (cumecs)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
Time (MINS)
Inflow_1
Inflow_2
Inflow_3
Inflow_4
Inflow_5
Inflow_6

APPENDIX E

Pre-Development Flood Mapping



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WELLINGTON NORTH SOLAR PLANT

FIGURE 1.1

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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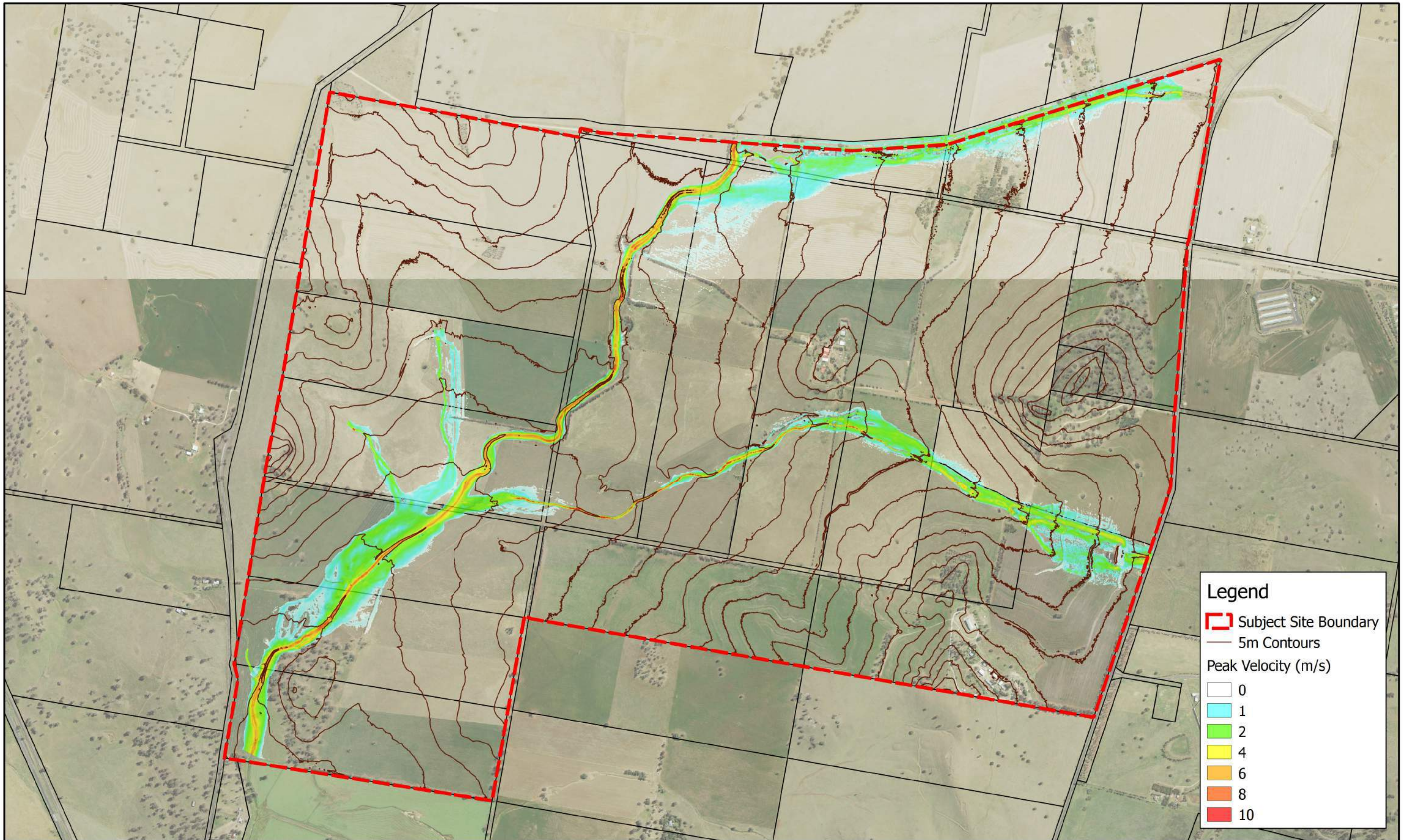

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200 0 200 400 600 m
Scale 1:15,000 at A3

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FIGURE 1.2

PRE-DEVELOPMENT 1% AEP PEAK VELOCITY

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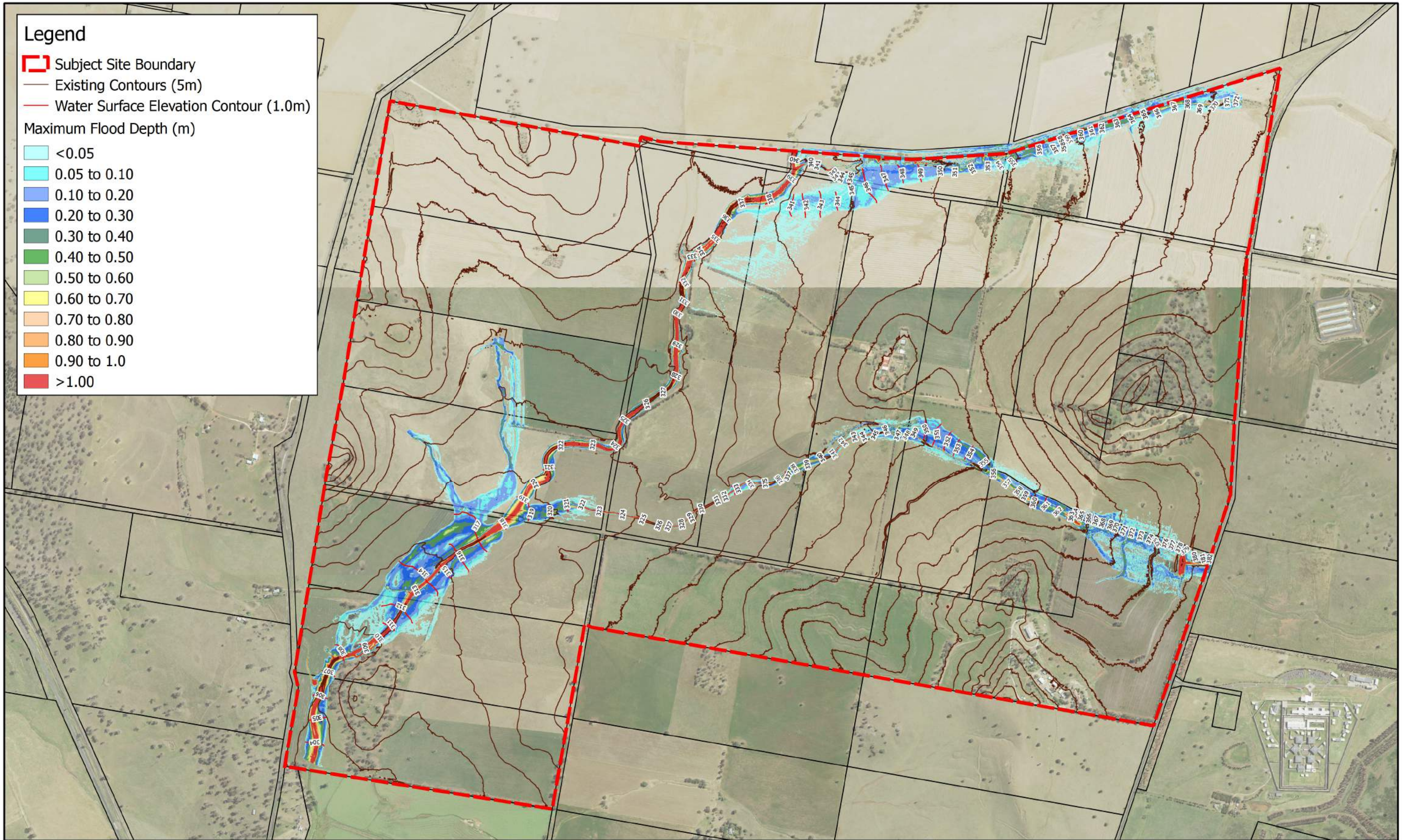

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FIGURE 2.1

PRE-DEVELOPMENT 2% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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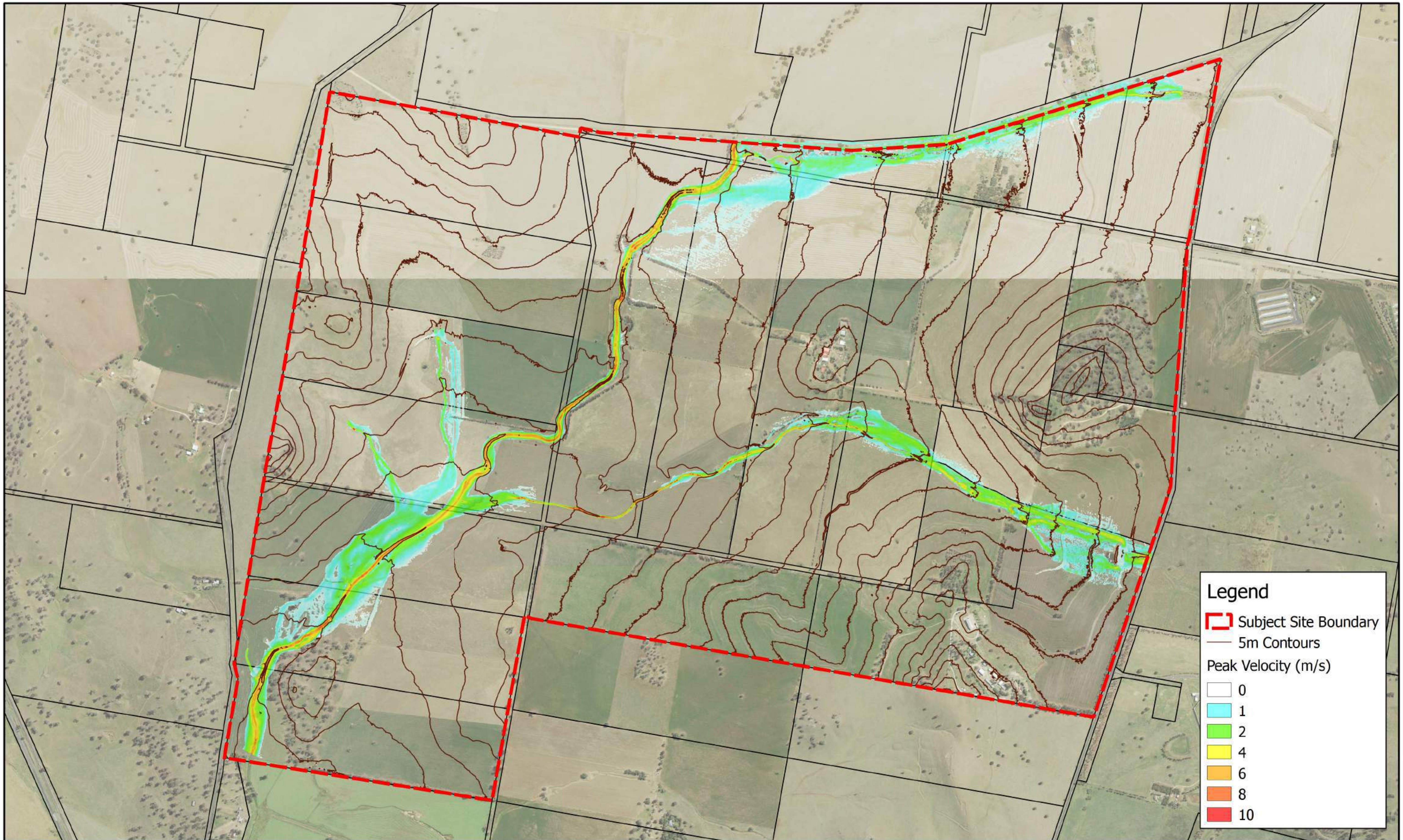

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FIGURE 2.2

PRE-DEVELOPEMNT 2% AEP PEAK VELOCITY

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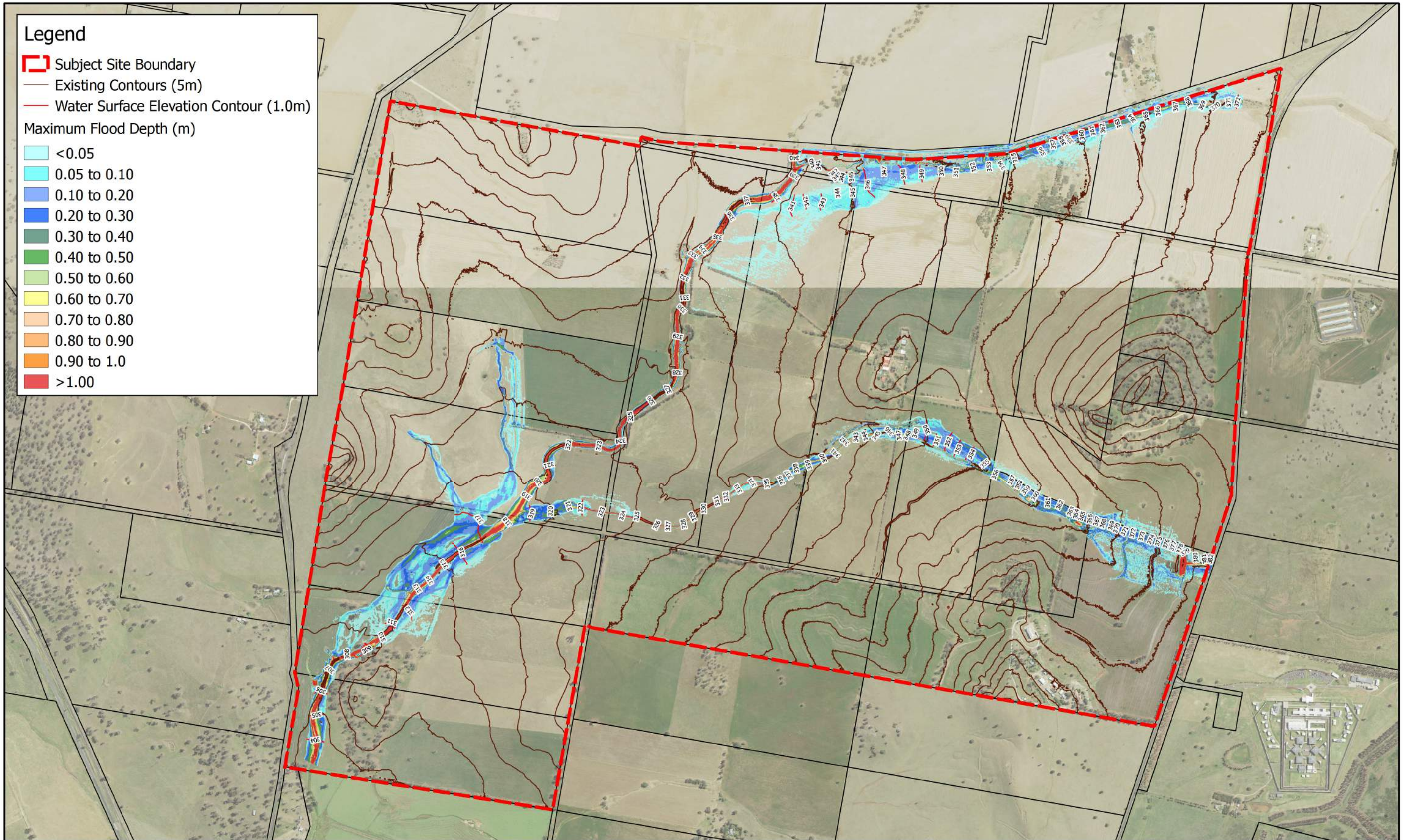

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FIGURE 3.1
PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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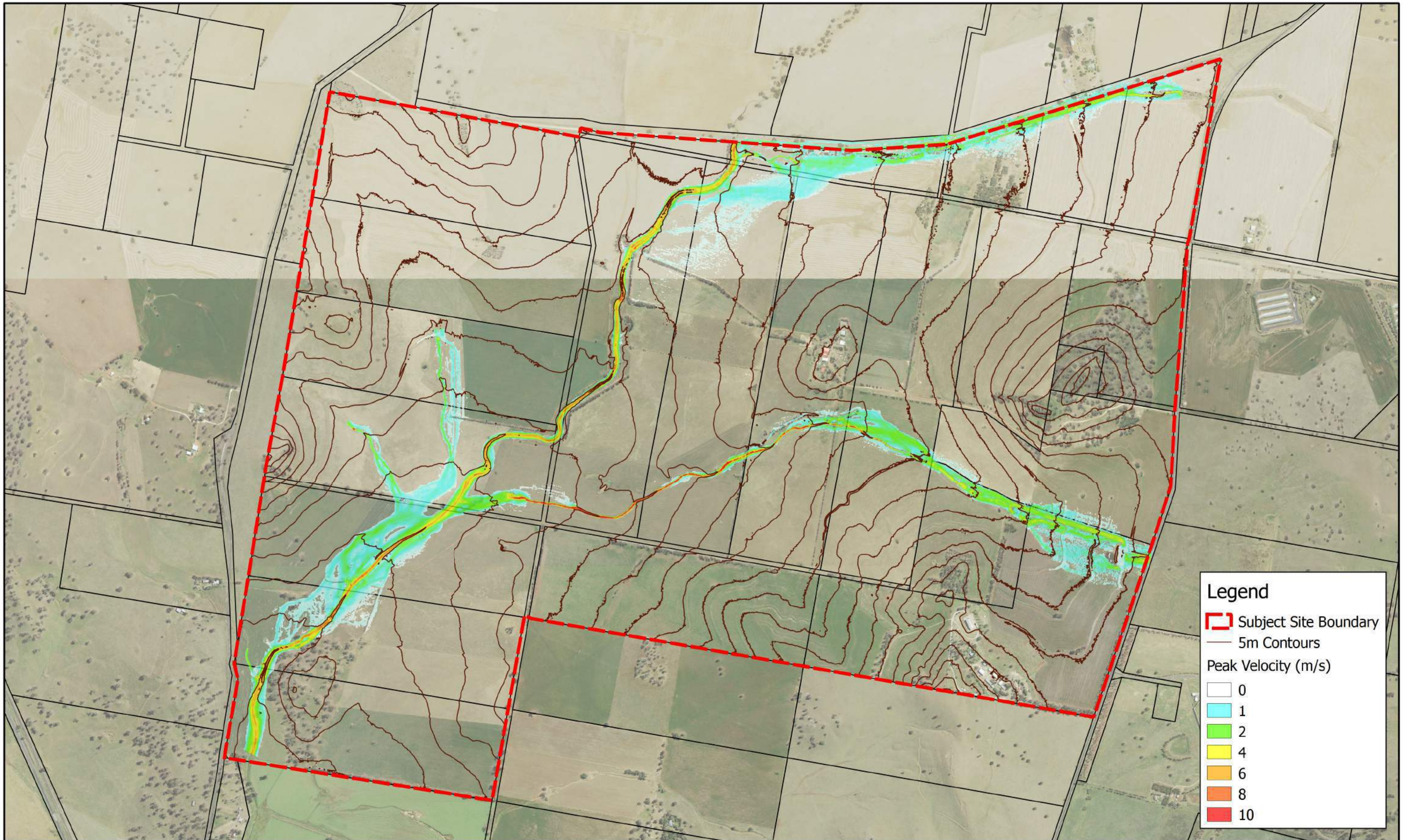

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FIGURE 3.2

PRE-DEVELOPMENT 5% AEP PEAK VELOCITY

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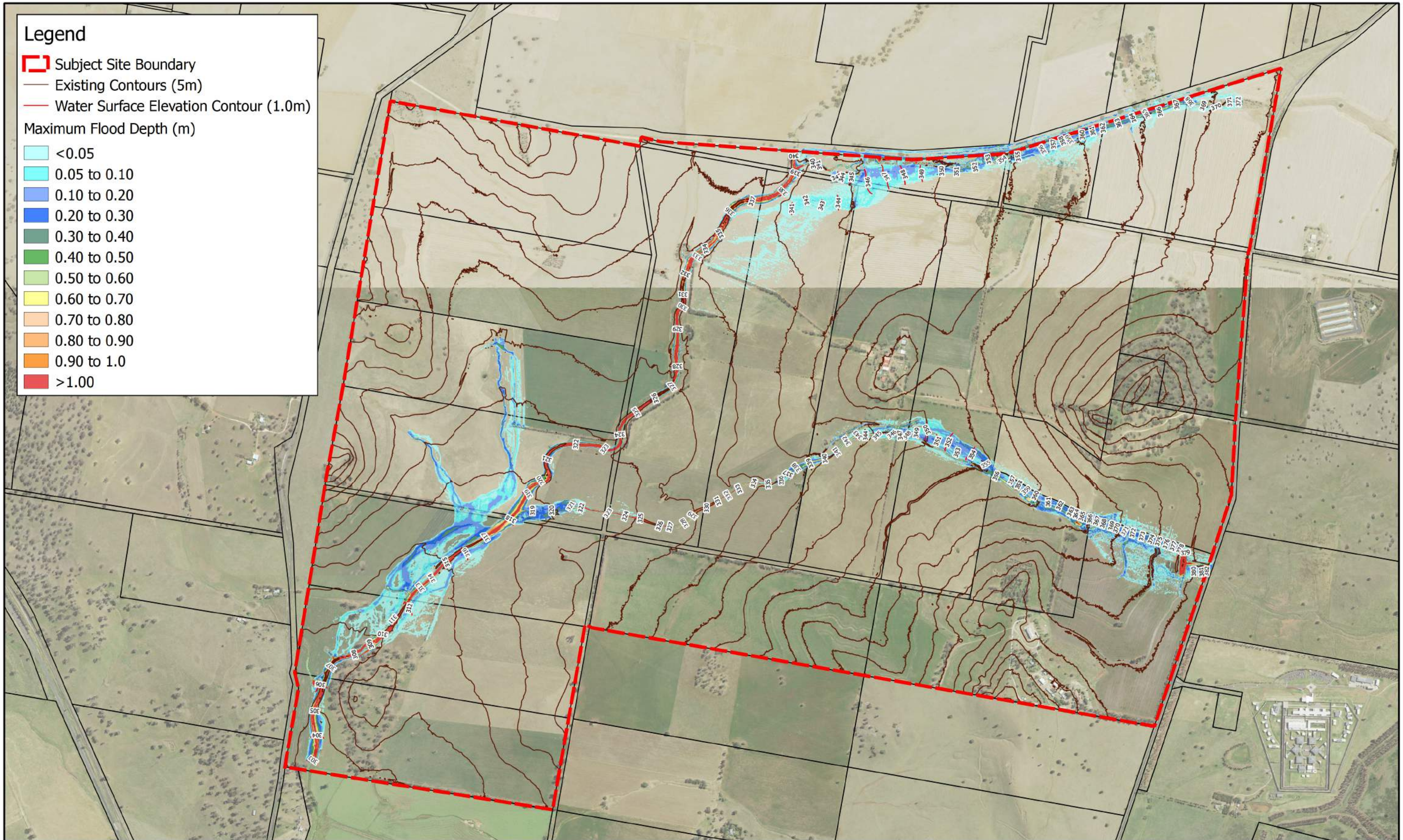

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FIGURE 4.1

PRE-DEVELOPMENT 10% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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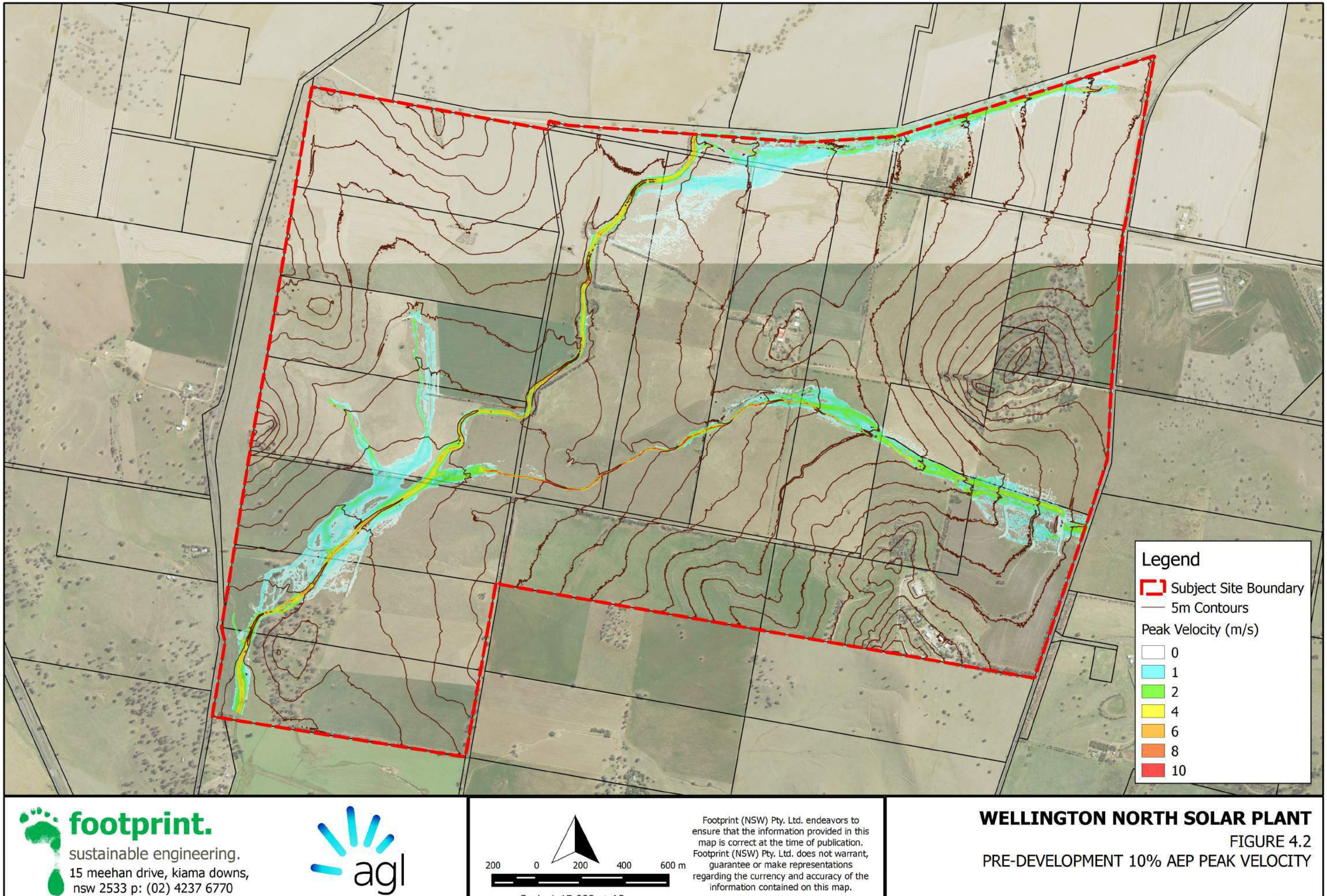

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FIGURE 4.2

PRE-DEVELOPMENT 10% AEP PEAK VELOCITY

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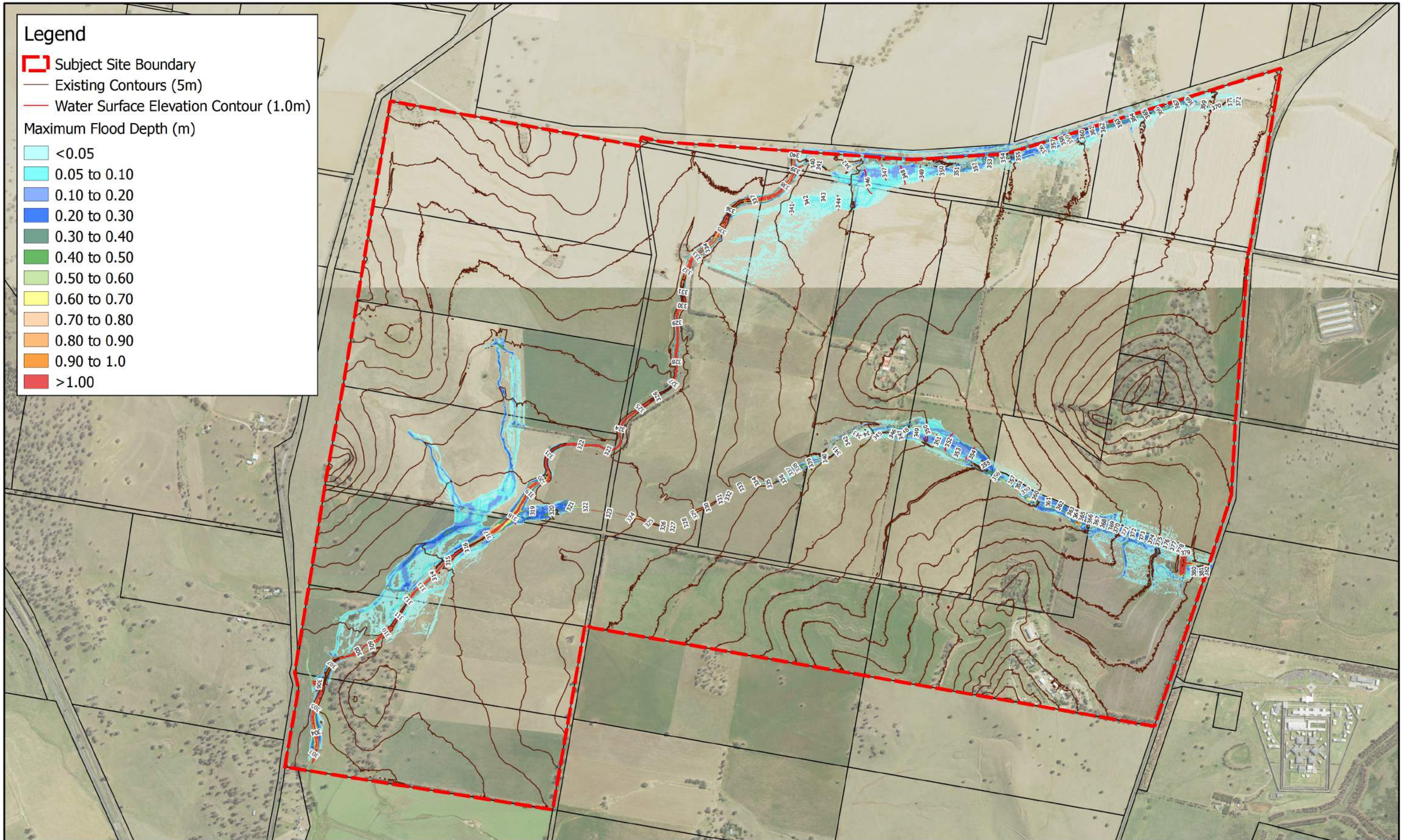

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FIGURE 5.1

PRE-DEVELOPMENT 20% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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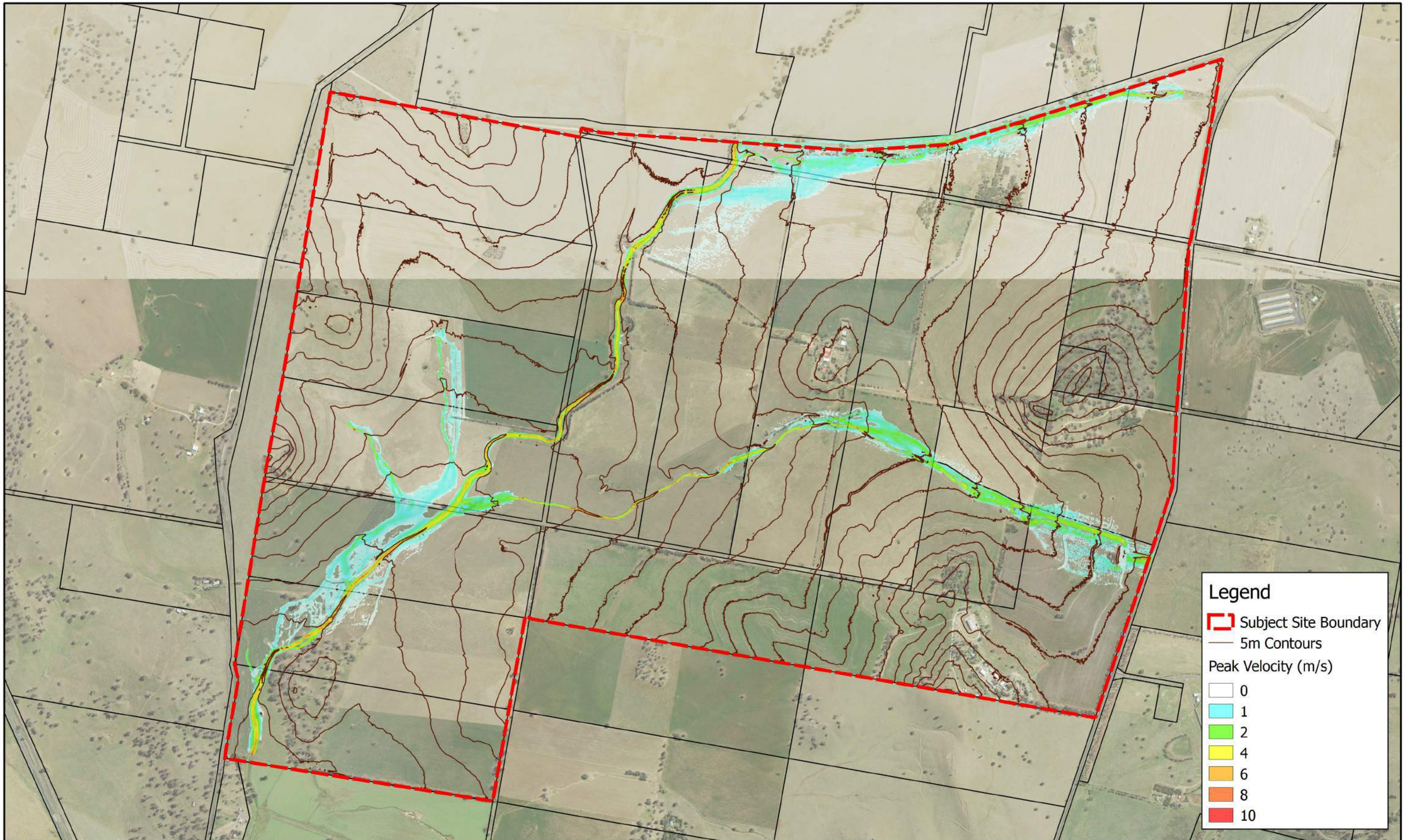

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FIGURE 5.2

PRE-DEVELOPMENT 20% AEP PEAK VELOCITY

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APPENDIX F

Post Development Flood Mapping

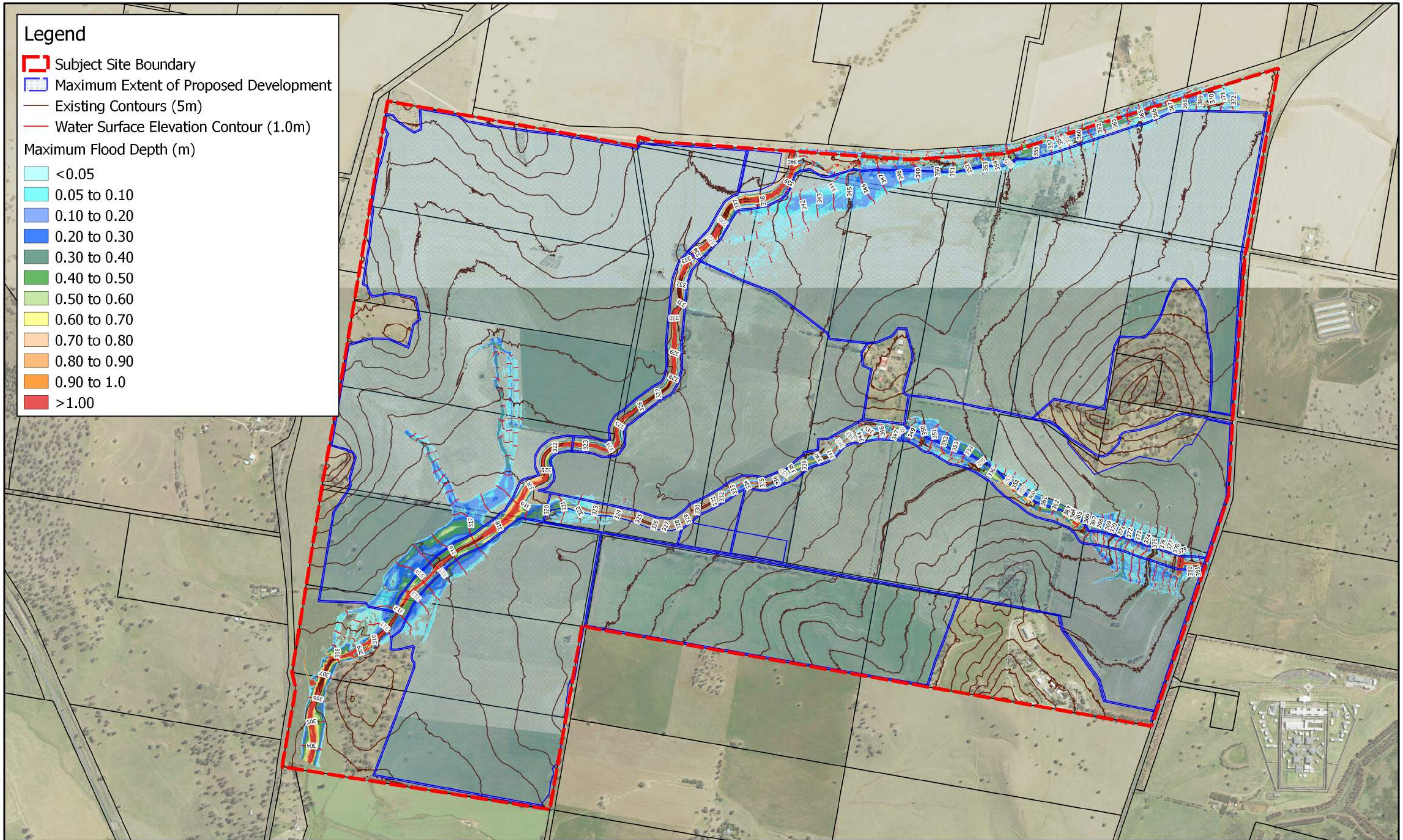

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FIGURE 6.1

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

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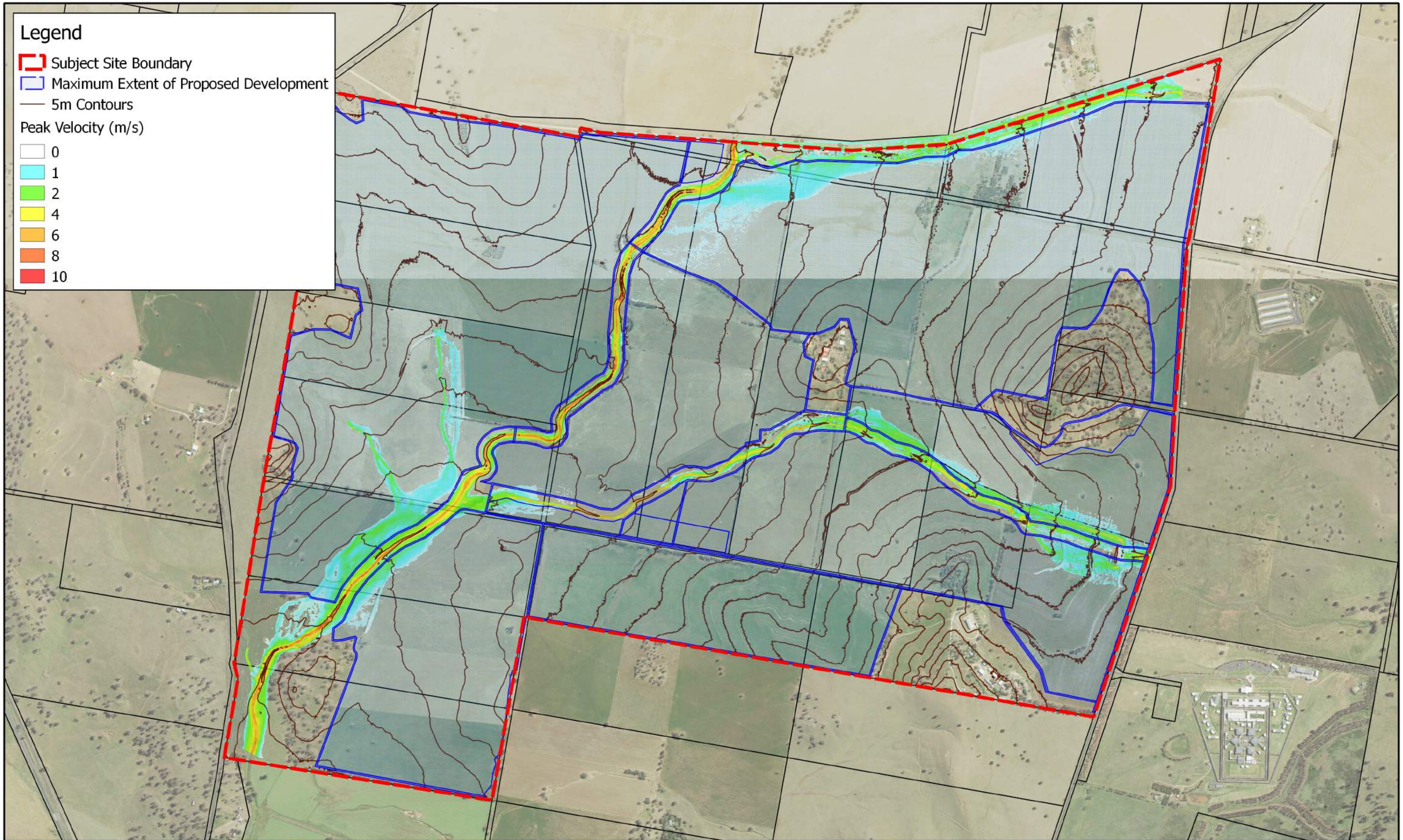

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FIGURE 6.2

POST DEVELOPMENT 1% AEP PEAK VELOCITY

Rev 3 - 18 MAY 2018

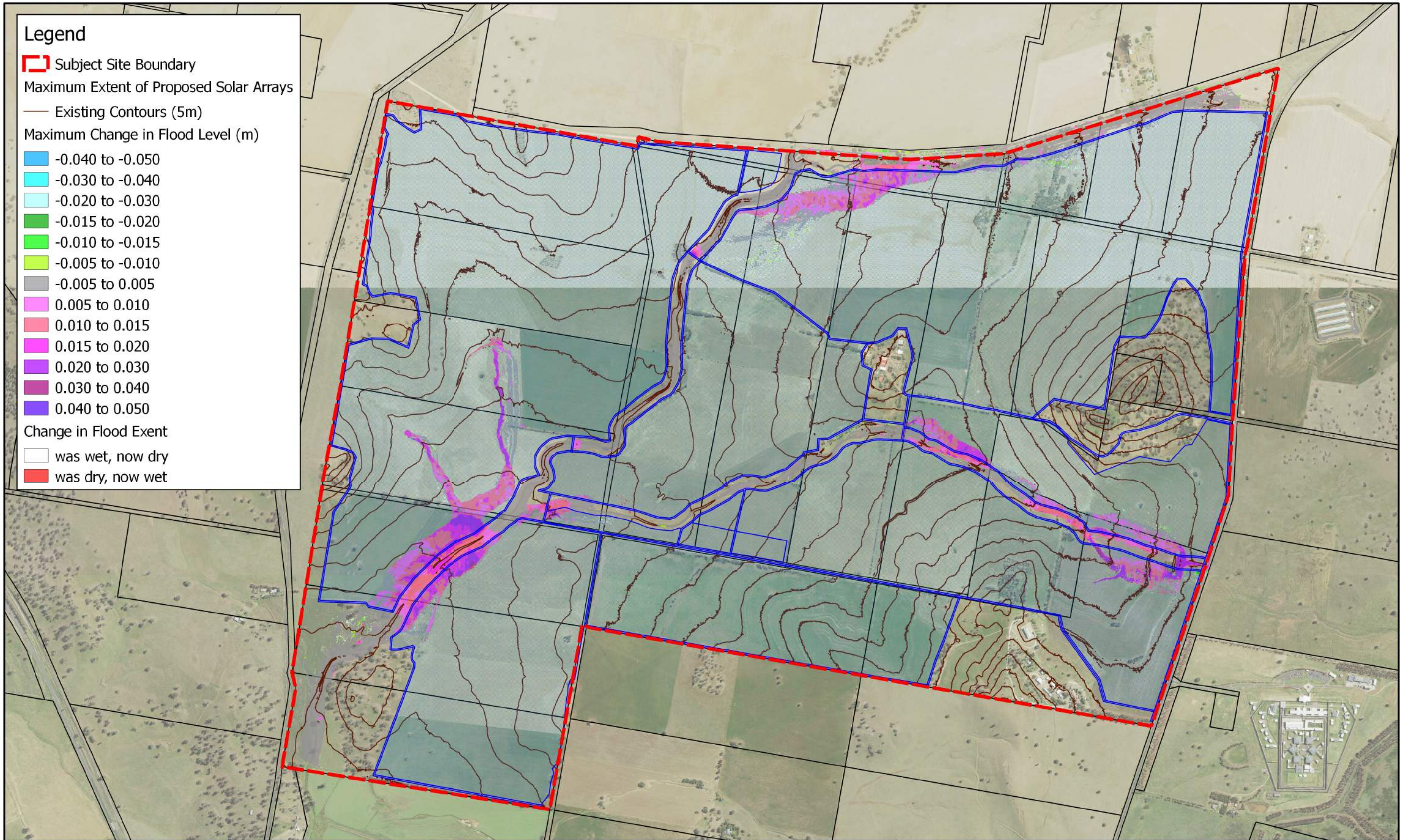

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FIGURE 7.1

IMPACT OF PROPOSED DEVELOPMENT ON PEAK FLOOD LEVELS IN 1% AEP EVENT

Rev 2 - 21 MAY 2018

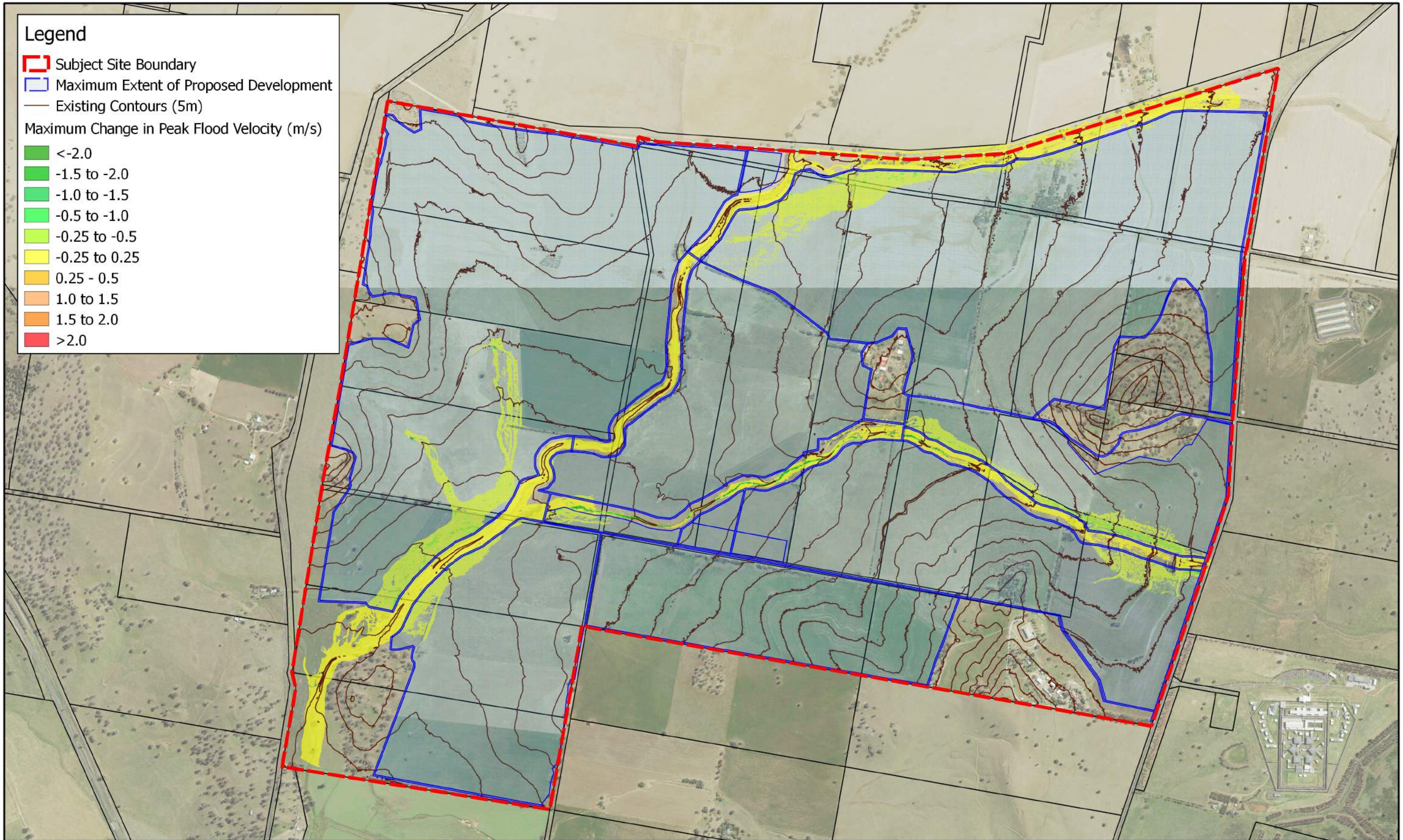

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FIGURE 7.2

IMPACT OF PROPOSED DEVELOPMENT ON PEAK FLOOD VELOCITIES IN 1% AEP EVENT

Rev 1 - 21 MAY 2018