Premise

TERRAIN SOLAR

Marulan Solar Farm

HYDRAULIC ASSESSMENT

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14 March 2022

DOCUMENT AUTHORISATION					
Revision	**Revision Date**	**Report Details**			
1	12/03/2021	Draft Report			
2	14/03/2022	Hydraulic Assessment Report			
Prepared By		**Reviewed By**		**Authorised By**	
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ABBREVIATIONS

Abbreviation	Definition
Annual Exceedance Probability (AEP)	The probability of a flood event occurring in any year expressed as a percentage
Australian Rainfall and Runoff (ARR)	National guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia
Digital Terrain Model (DTM)	Digital Terrain or Elevation Model
Light Detection and Ranging (LiDAR)	Remote light sensing to measure ranges
Metres, Australian Height Datum (m AHD)	Elevation from the Australian Height Datum reference
Regional Flood Frequency Estimation (RFFE)	Model for transferring flood characteristics information from a group of gauged catchments to a particular location of interest
Two-Dimensional Unsteady Flow Model (TUFLOW)	A suite of advanced 1D/2D/3D computer simulation software for flooding, urban drainage, coastal hydraulics, sediment transport, particle tracking and water quality
Watershed Bounded Network Model (WBNM)	Event based hydrologic model for calculating flood hydrographs

1. INTRODUCTION

Premise Australia Pty Ltd (here within referred to as "Premise") has been commissioned by Terrain Solar to undertake a Hydraulic Assessment for the proposed Solar farm in the suburb of Carrick, New South Wales. The proposed development as part of "Marulan Solar Farm", consists of construction of a solar farm, grid connection, access and substation on farmland.

This hydraulic assessment includes an analysis of pre-development site conditions to establish the base runoff characteristics, and quantification of the potential impacts associated with the proposed development.

Refer to **Figure 1** below for a Road Map Image of the site and its locality.

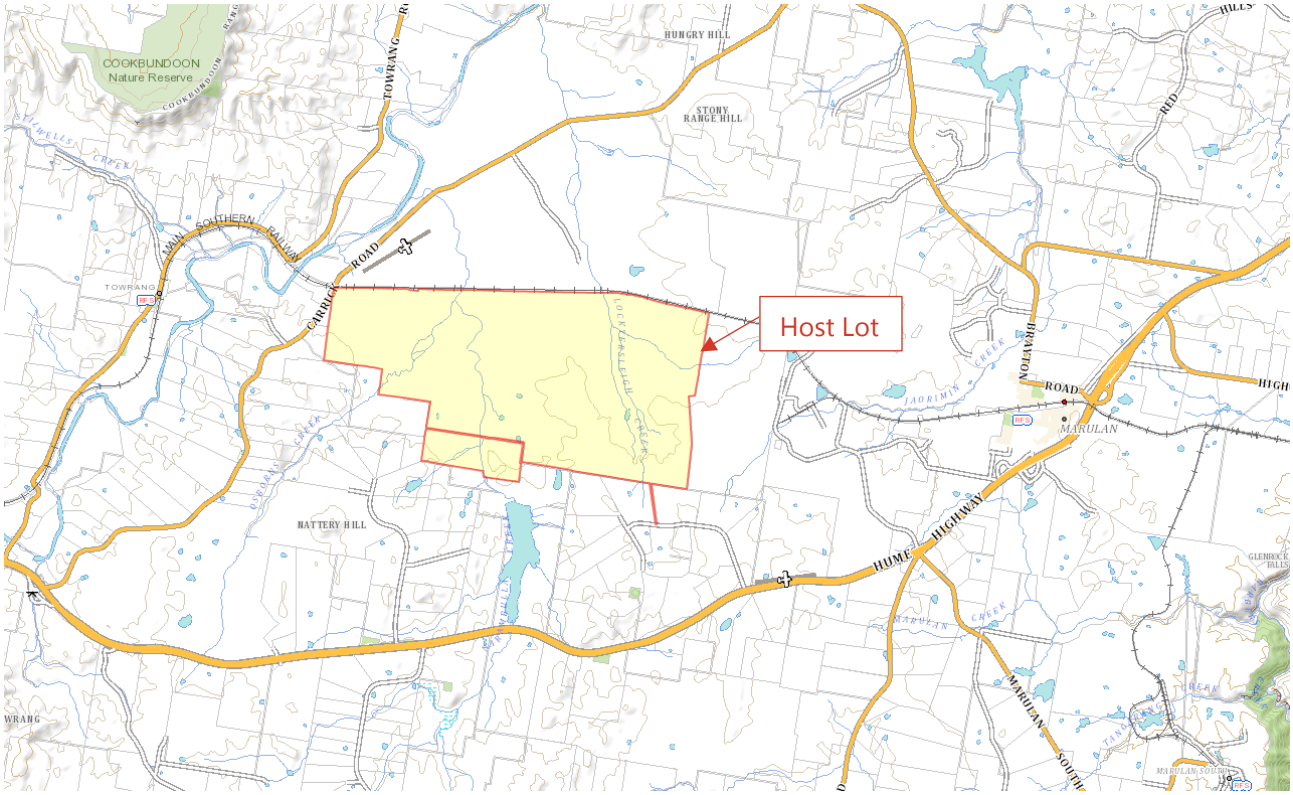


Figure 1 – Road Map (Source: NSW Six Maps)

2. SITE CHARACTERISTICS

2.1 Site Location

The subject site is located on Lot 55 in DP1141136 at 154 Munro Road in Carrick, in the Goulburn Mulwaree Government Area (LGA), in NSW. The subject site has Carrick Road to the west and Munro Road to the south. The total area of the site is approximately 1400.4302 hectares with the proposed solar farm area at approximately 9.43 hectares. **Figure 2** shows an aerial view of the existing land for site locality details.

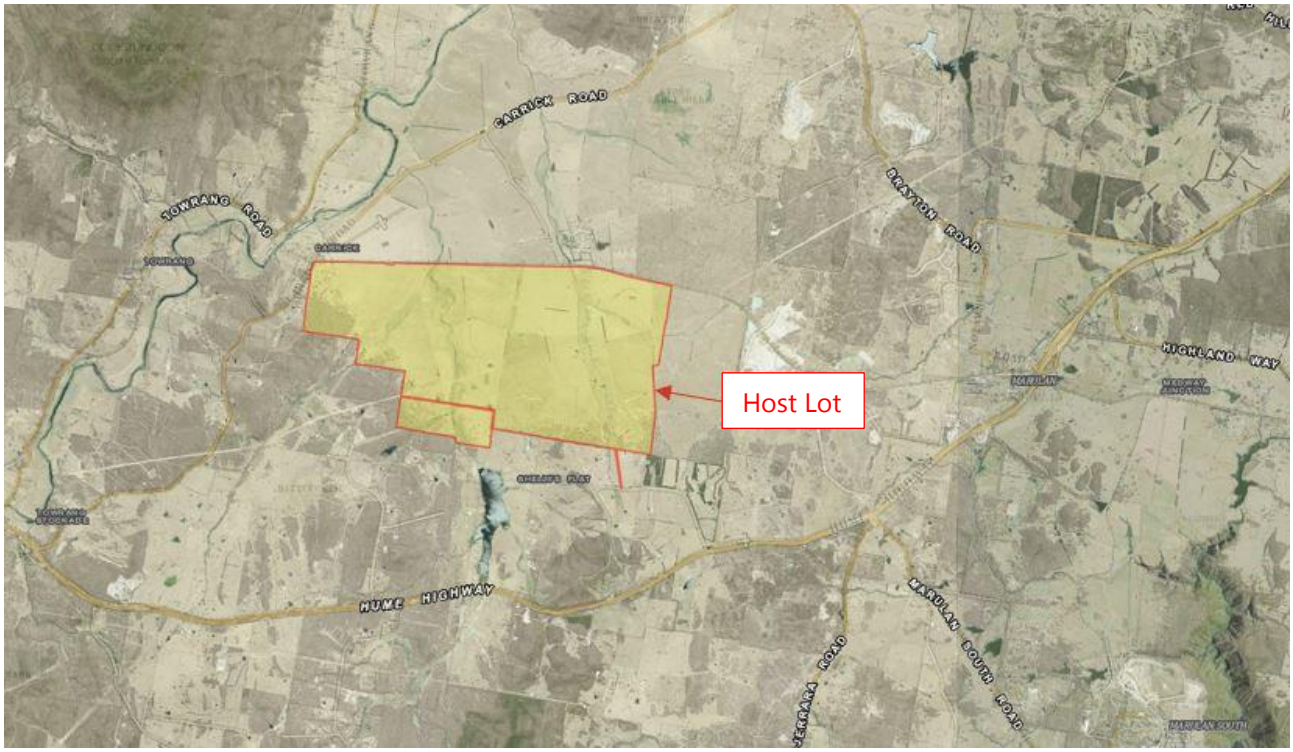


Figure 2 - Aerial Image of Site Location (Source: NSW Six Maps)

2.2 Topography

Based off the topography, drainage of the subject site is generally as follows:

- Topography ranges from 703.591m AHD to 654.597m AHD;
- The site has a small ridge that traverses the site from south to north;
- The proposed solar farm location is on a small ridge;
- The site generally drains in a north direction to Wollondily River.

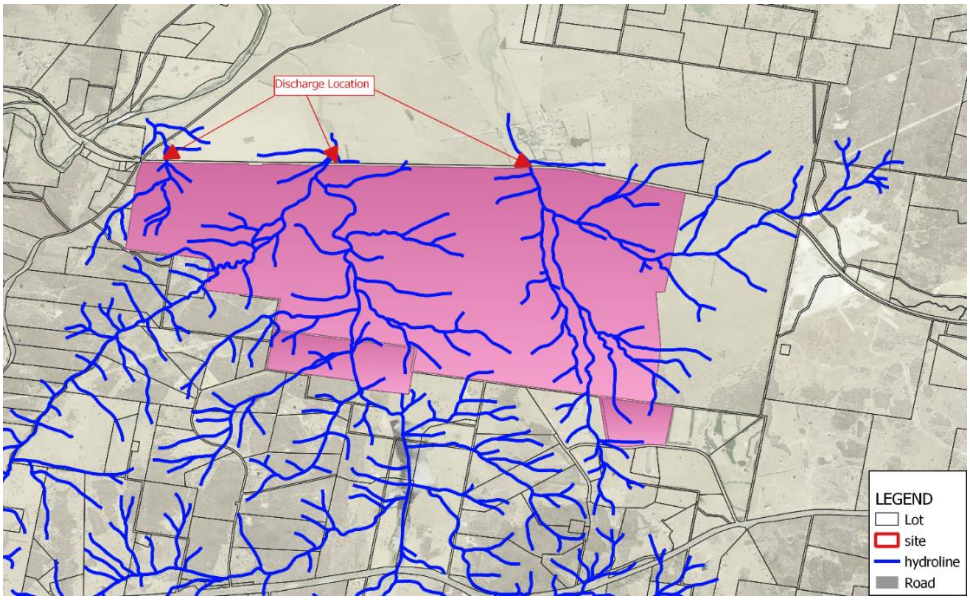


Figure 3 - Discharge Location

3. PROPOSED DEVELOPMENT

It is proposed that the "Marulan Solar Farm", consists of construction of a solar farm with grid connection, access from Munro Road, and substation with battery energy storage system on the existing farmland. The proposed development layout is shown below and in **Appendix A** of this report.

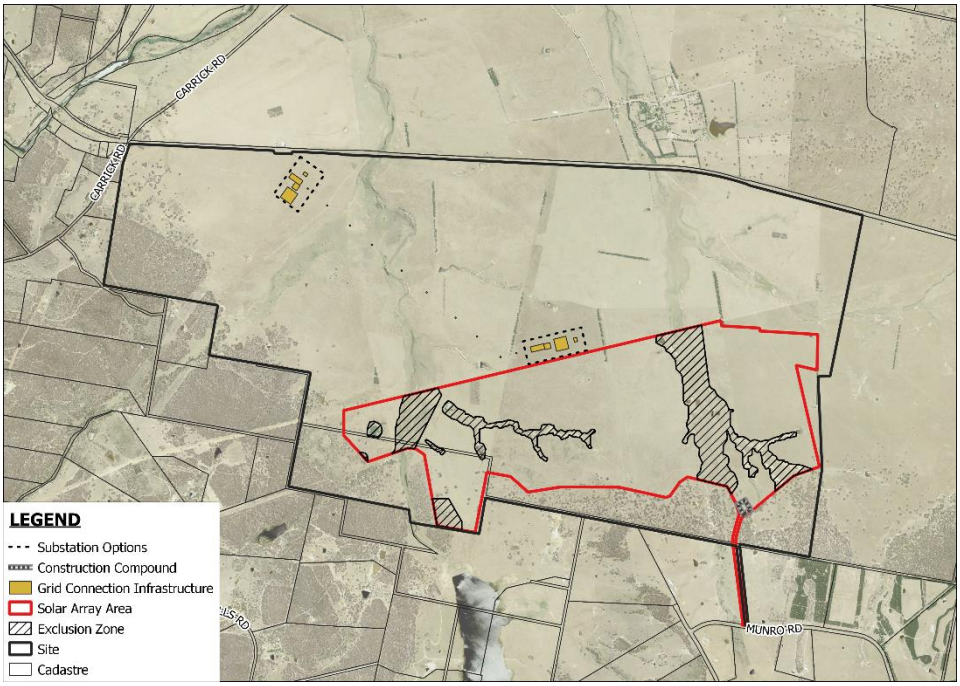


Figure 4 – Proposed Development Layout

4. DATA

Data in the preparation of this report, information about the site was gathered from the following sources:

- Detailed Survey prepared by Premise dated 11/01/2021;
- 5m Aerial LiDAR sourced from Geosciences Australia (data files dated September 2014);
- Development footprint provided by Terrain Solar
- River gauge data by the Australian Bureau of Meteorology; and
- Aerial Imagery by NSW Spatial Services' Six Maps (Accessed on 19th January 2021).

5. FLOOD RISK ASSESSMENT

5.1 Hydrologic Assessment

Hydrologic modelling was undertaken using the runoff-routing software, WBNM (version 2017) to determine the peak discharge hydrographs from the catchment. The resultant hydrographs are used as inflows in the detailed hydraulic model (refer **Section 5.1.3**).

The hydrologic modelling considers only one scenario where the land use for the site and external catchments are determined as per the latest aerial imagery (Existing Case).

5.1.1 MODEL PARAMETERS

Figure 5 below details the existing site catchment plan (also included in **Appendix B**).

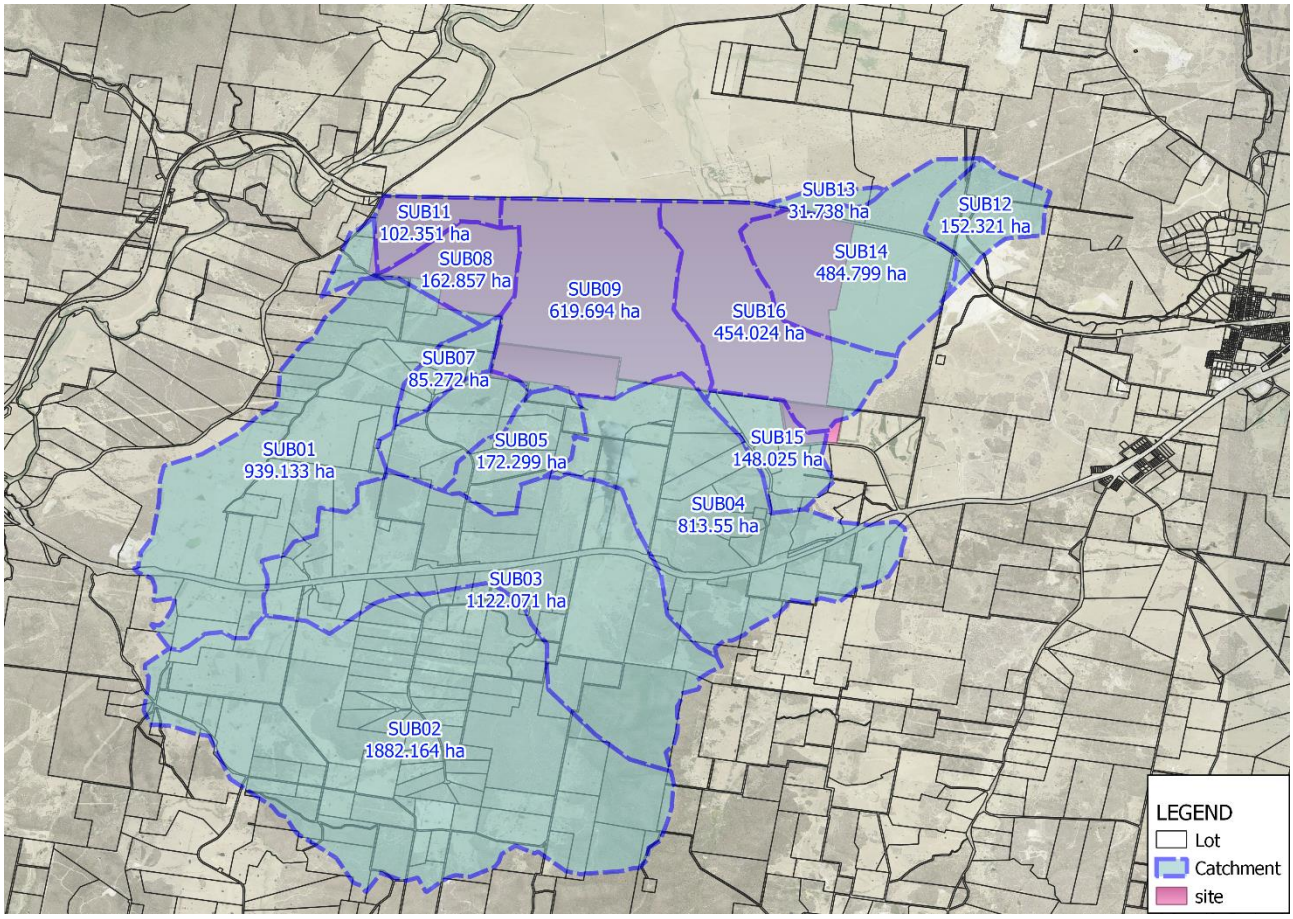


Figure 5 – WBNM Model - Existing Catchment Extent

To determine the fraction impervious (f_i) in the pre-development scenario sub-catchments, aerial photography analysis of the site has been undertaken to estimate the percentage of impervious regions.

A summary of the existing site catchment parameters is contained in **Table 1**

Table 1 - WBNM Model – Existing Catchment Parameters

Catchment	Area (ha)	Fraction Impervious (*fi*)
Sub01	1093.368	20.00
Sub02	1882.164	20.00
Sub03	1122.071	20.00
Sub04	816.892	20.00
Sub05	172.299	20.00
Sub06	171.476	20.00
Sub07	85.272	20.00
Sub08	162.857	20.00
Sub09	619.694	20.00
Sub10	39.227	20.00
Sub11	102.351	20.00
Sub12	152.321	20.00
Sub13	31.738	20.00
Sub14	484.799	20.00
Sub15	148.025	20.00
Sub16	454.024	20.00

The below details the WBNM parameters adopted for all events and temporal patterns:

- Pervious Initial Loss (mm) – 11.0
- Pervious Continuing Loss (mm/hr) – 2.9
- CL adjusting with 0.4
- Probability Neutral Burst Initial Loss for NSW
- Lag Parameter – 1.5

The losses are based on NSW Government Office of Environment and Heritage's report "Review of ARR design Inputs for NSW – Final Report" dated February 2019 (undertaken by WMA Water) and ARR website page "NSW Specific Data Info".

The WBNM hydrological model was analysed for the 10-minute to 72-hour for the full spectrum of temporal patterns for the 1% AEP storm events. It was determined that the critical event is the 720-minute duration, and the mean temporal pattern was 8.

The peak flow results produced from WBNM were compared against the Rational Method and the Regional Flood Frequency Estimation (RFFE) model from the ARR2019 website.

5.1.2 CATCHMENT DISCHARGE COMPARISON

The peak discharges for the development site provided by the hydrologic model for the 1% AEP events were compared to RFFE model results to ensure reasonable model outputs. The results of this comparison are provided in **Table 2**.

Table 2 – 1% AEP Peak Discharge Comparison

Sub Catchment	ARI Design Event Peak Flow (m^3/s)	
	WBNM	RFFE
Total	105.5	141

A comparison of the hydrologic model results and RFFE show that the hydrologic model results are within a reasonable limit of the RFFE, with the lower confidence limit for the 1% AEP event identified as 53.4m^3/s. The difference can be attributed to the hydrologic model having additional consideration of individual catchment characteristics and runoff routing, which is omitted from the RFFE.

5.1.3 RESULTS

The peak flow rates predicted for each sub-catchment is presented in **Table 3** below. These peak inflows (and their respective hydrographs) have simultaneously been utilised as the inflow boundaries in the hydraulic modelling portion of this assessment.

Table 3 – Hydrologic Peak Flow Rate Results

Sub Catchment	AEP Design Event Peak Flow (m^3/s)
Sub01	50.352
Sub02	78.064
Sub03	51.413
Sub04	39.829
Sub05	11.442
Sub0	11.398
Sub07	6.472
Sub08	10.935
Sub09	55.079
Sub10	3.404
Sub11	8.37
Sub12	10.361
Sub13	2.847
Sub14	26.217
Sub15	10.125
Sub16	48.18
Sub17	105.492

5.2 Hydraulic Assessment

A hydraulic assessment was undertaken to determine the flood extent levels over the Site to ensure the switching station has suitable flood immunity. The assessment was undertaken utilising TUFLOW, a two dimensional (2D) fully dynamic hydraulic modelling package (version 2020-01-AB).

The following scenarios have been considered:

- **Pre-development Case** – assumes the catchment and site are in an existing condition; and
- **Post-development case –** includes the proposed solar arrays.

The following sections detail the TUFLOW model parameters adopted and results.

5.2.1 MODEL SETUP

The pre-development case has the following model parameters:

- The existing case model topography was constructed utilising detailed site survey and LiDAR data.
- The post-development topography was updated to include the proposed development as per the layout in Appendix A.
- Appendix B contains the topographic maps used in the hydraulic modelling.
- Grid cell size is 5m.
- No structures were modelled.
- The roughness was based on current aerial imagery that was obtained from NSW Six Maps website (assessed in April 2020). The Manning's n' roughness values used within this model are shown in Table 4 below and Appendix B contains the roughness used in the hydraulic modelling.

Table 4 – Manning's n

Tuflow Material ID	Landuse	Manning's n
1	Pasture/Paddock	0.035
2	Roads	0.015
5	Average Grass	0.045
6	Dense Vegetation	0.08
8	Solar Area	0.08

- The inflow boundary conditions for the model are design storm inflows from the WBNM model, detailed in **Section 5.1** above. The source inflows were modelled using Rainfall on grid within TUFLOW. Refer **Figure 6** below and Appendix B for model layout.
- A normal-depth rating curve was adopted for the downstream boundary condition.

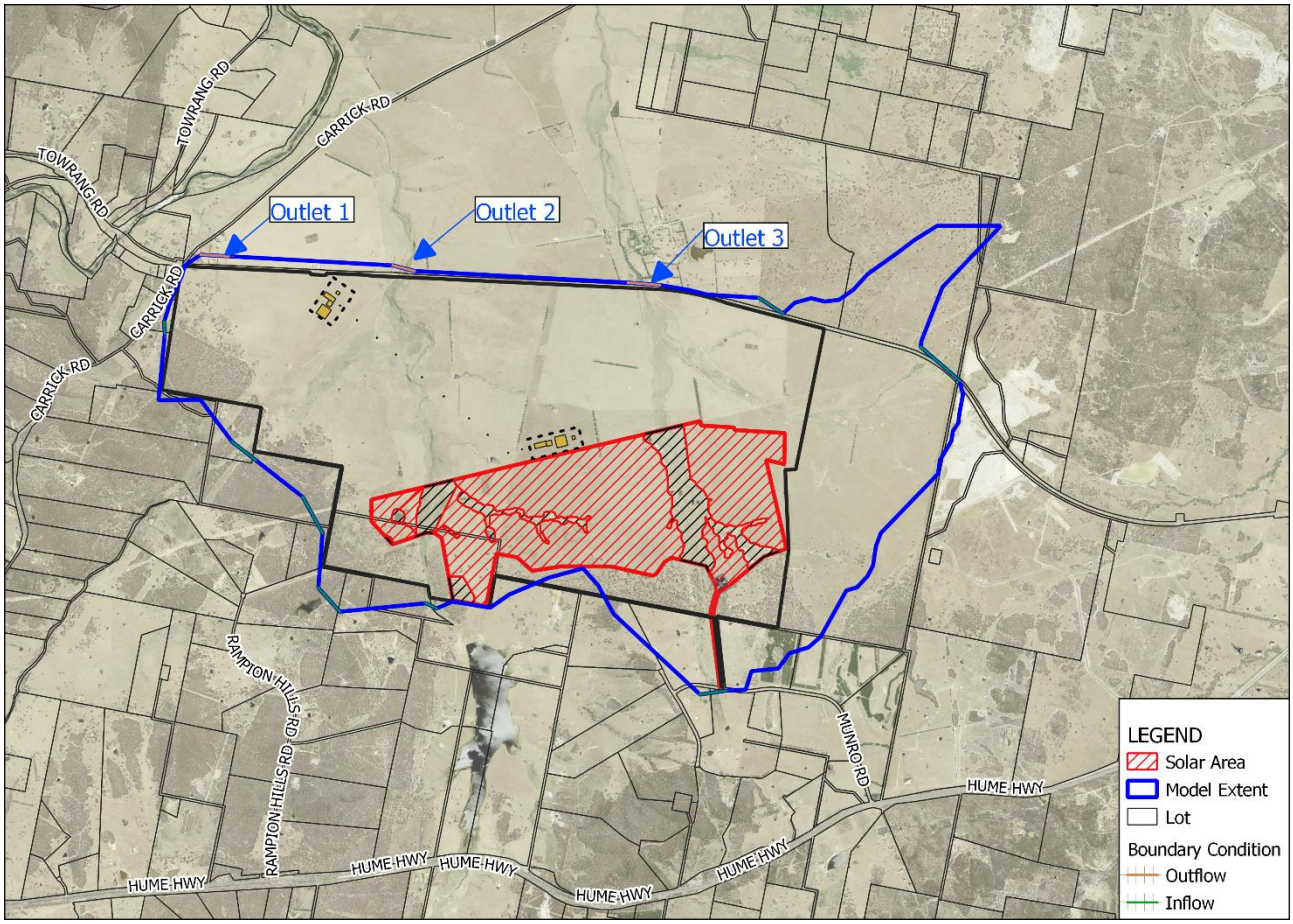


Figure 6 – TUFLOW Boundary

The post-development case is based on the pre-development case with the following modifications to account for the proposed works:

- The post-development topography was updated to include the proposed solar array as per the development footprint investigation area in **Appendix A**.
- The solar panel array is located outside of identified 'exclusion' zones that are restricted by existing flow paths, infrastructure and environmental value areas.
- Two (2) proposed locations for the substation have been identified as outside of land constrained by flooding and have consequently not been included explicitly in the hydraulic model.

5.2.2 HYDRAULIC RESULTS

The results from the modelling are in the following Appendices:

- **Appendix D** – Pre-development 1% AEP Flood Maps (depth, velocity, elevation and hazards);
- **Appendix E** – Post-development 1% AEP Flood Maps (depth, velocity, elevation and hazards).
- **Appendix F** – 1% AEP Flood Impact Map

The predicted peak discharge results from the hydraulic assessment are presented in **Table 5** below.

Table 5 – Predicted Peak Discharge – 1% AEP Event

Location	Discharge (m^3/s)		
	Pre	Post	Impact
Outlet 1	6.1429	5.8764	-0.2665
Outlet 2	77.0314	50.6153	-26.4161
Outlet 3	54.3847	49.0936	-5.2911

The results show that the proposed solar farm is predicted to not cause external impacts in terms of water surface levels and peak discharges.

The results show that the proposed location of the proposed solar array and access from Munro Road are suitable in terms of flooding constraints. Typically, areas with a high flood depth and velocity are considered to be inappropriate for solar panel installation. The locations where the overland flow path exceeds depth and velocity values expected to be high risk for infrastructure have been identified as 'exclusion' areas in the development layout, and the probability of erosion and scour is expected to be minimal.

Both options for the proposed substations are located outside of the 1% AEP extent and are considered appropriate in terms of flood hazard.

6. CONCLUSION

This Hydraulic Assessment has been prepared to provide the impact of the proposed Marulan Solar Farm, Carrick, New South Wales on flood levels, velocities and discharge. The assessment included hydrologic assessment to determine inflows to the hydraulic model. The hydraulic modelling showed that there are no impacts external to the site.

The modelling also indicates that no mitigation measures (such as a detention basin) are required. The proposed location of the solar panels and access are within the bounds of low flooding risk (depths less than 0.9m and velocities less than 1m/s). The locations identified for the substation are outside of the 1% AEP flood extent. As discussed in **Section 5.2.2**, the infrastructure is located outside of areas with high flow depth and velocity, and the risk of erosion or scour is considered to be minimal.

7. QUALIFICATIONS

Our analysis and overall approach have been specifically catered for the requirements of Terrain Solar and may not be applicable beyond this scope. For this reason, any other third parties are not authorised to utilise this report without further input and advice from Premise.

Premise has relied on the following information as outlined in the Data Section of this Report.

While Premise's report accurately assesses peak flows from design storms in accordance with current industry standards and guidelines and the use of regional flood gauge, future observed flows may vary from that predicted. For these reasons appropriate freeboards should be adopted.

8. REFERENCES

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, *"Australian Rainfall and Runoff: A Guide to Flood Estimation"*, Commonwealth of Australia (Geoscience Australia), 2016, Canberra.

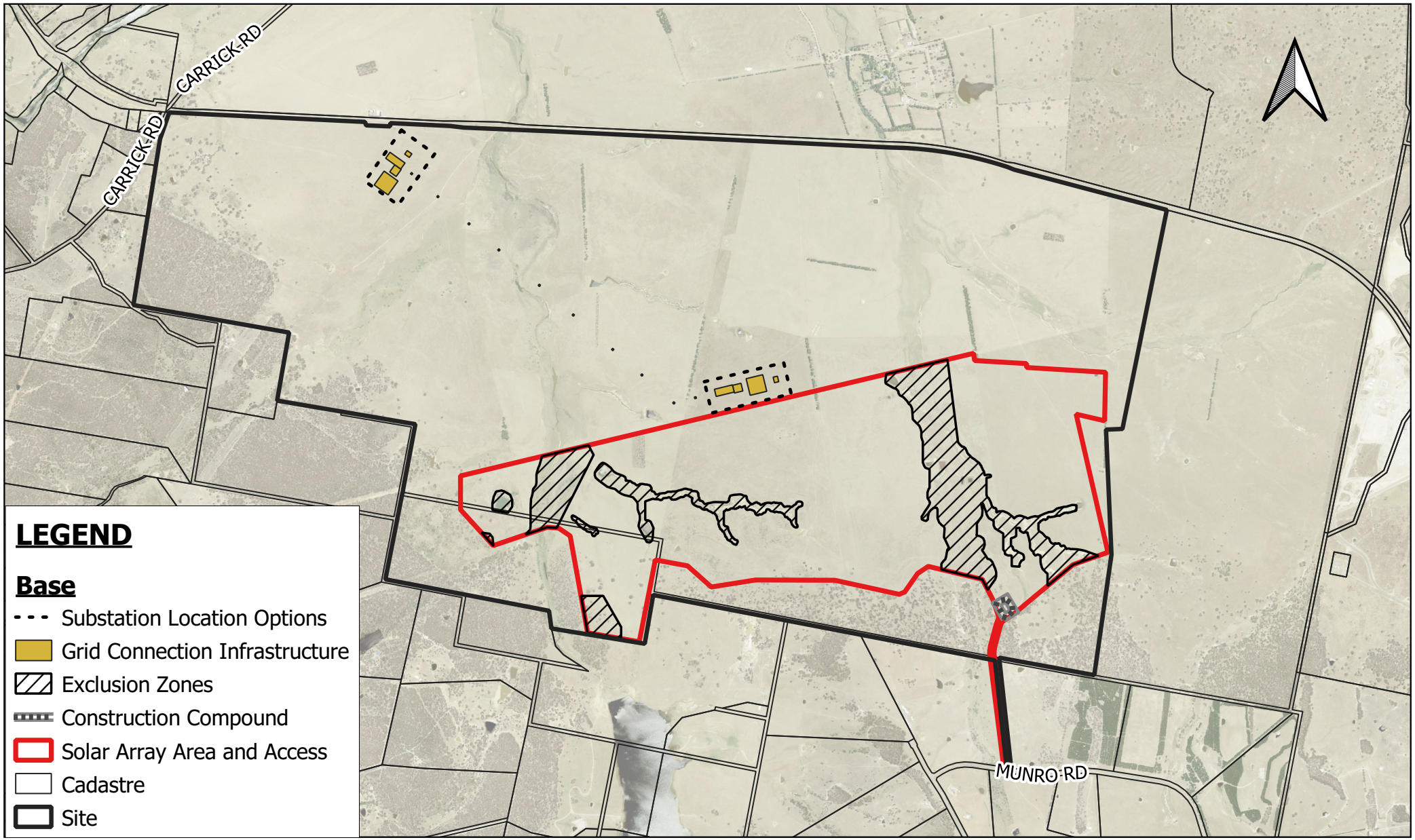
Bureau of Meteorology, 2016 IFDs – Rainfall Data. Available at: http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016

WMA Water for NSW Government Office of Environment and Heritage, February 2019 "Review of ARR design Inputs for NSW – Final Report"

Cook, L. M. and R. H. McCuen. 2013. "Hydrologic Response of Solar Farms." Journal of Hydrologic Engineering 18:536–4

APPENDIX A

PROPOSED SITE PLAN



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Proposed Site Layout

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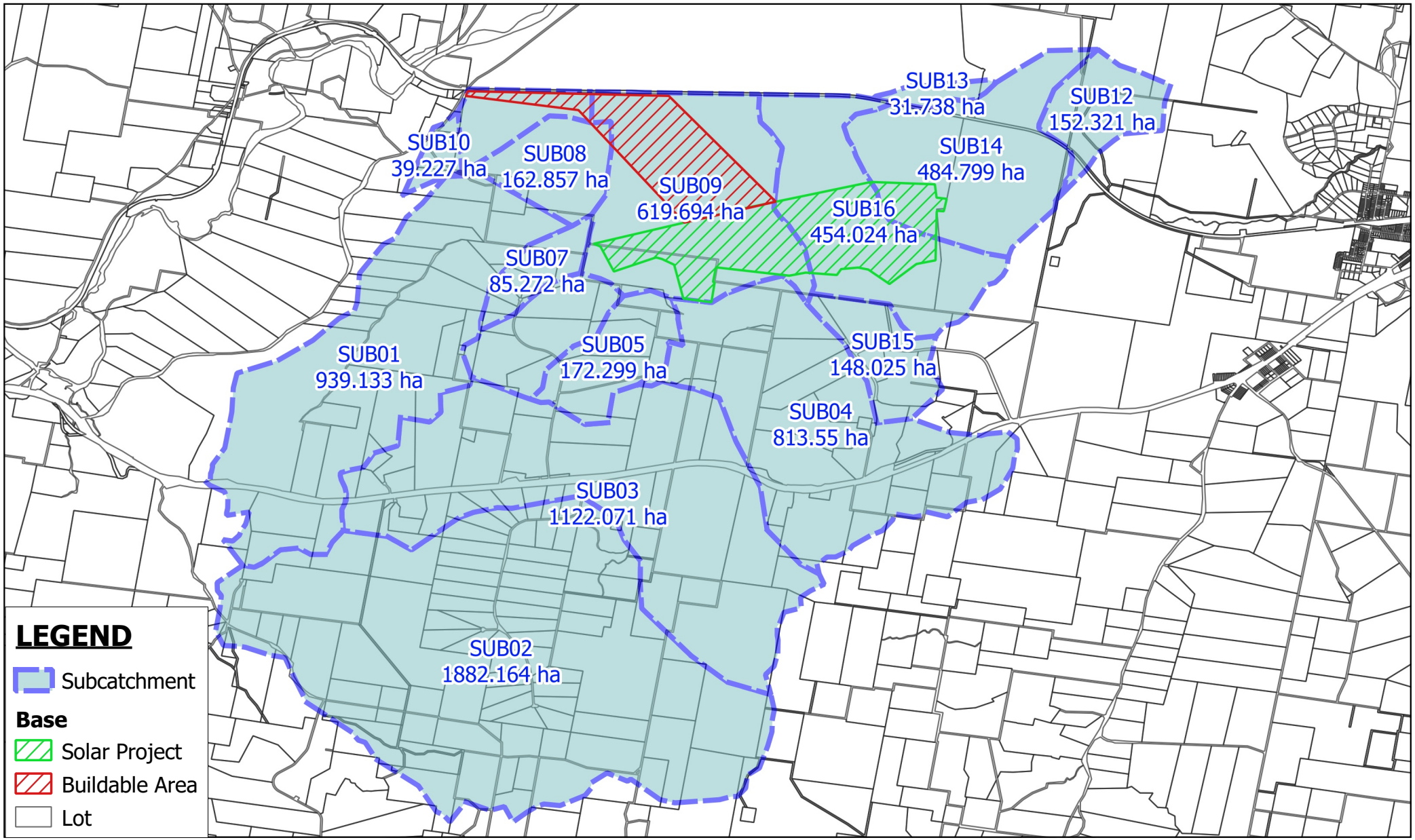
APPENDIX B

WBNM CATCHMENT PLAN AND RFFE SUMMARY



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WBNM HYDROLOGIC CATCHMENTS

Jan 2021

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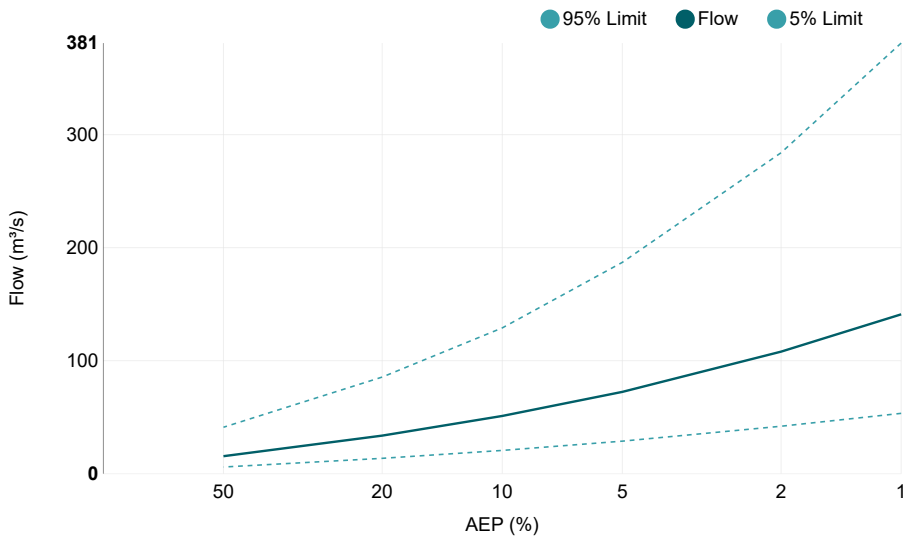
Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	15.5	5.91	41.1
20	33.7	13.6	85.5
10	51.1	20.6	129
5	72.4	28.8	187
2	108	42.0	284
1	141	53.4	381

Statistics

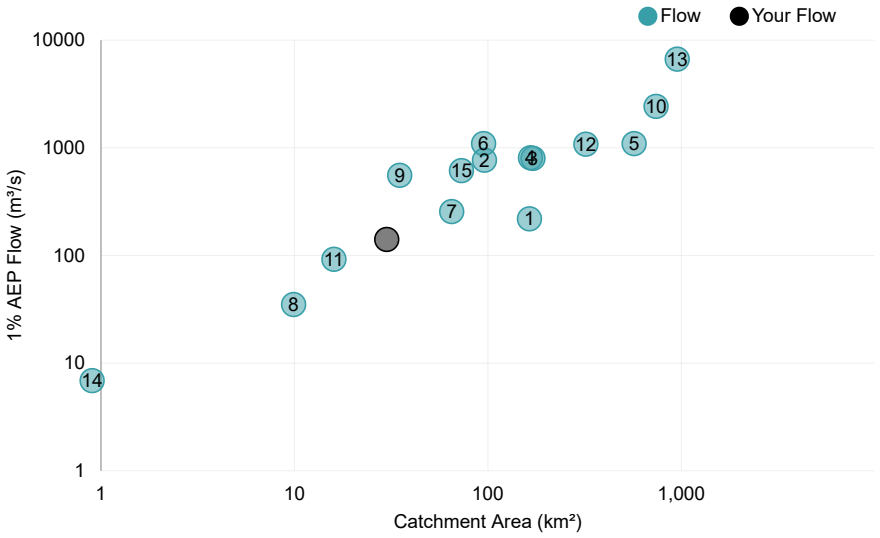
Variable	Value	Standard Dev
Mean	2.478	0.648
Standard Dev	0.890	0.167
Skew	0.098	0.027

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

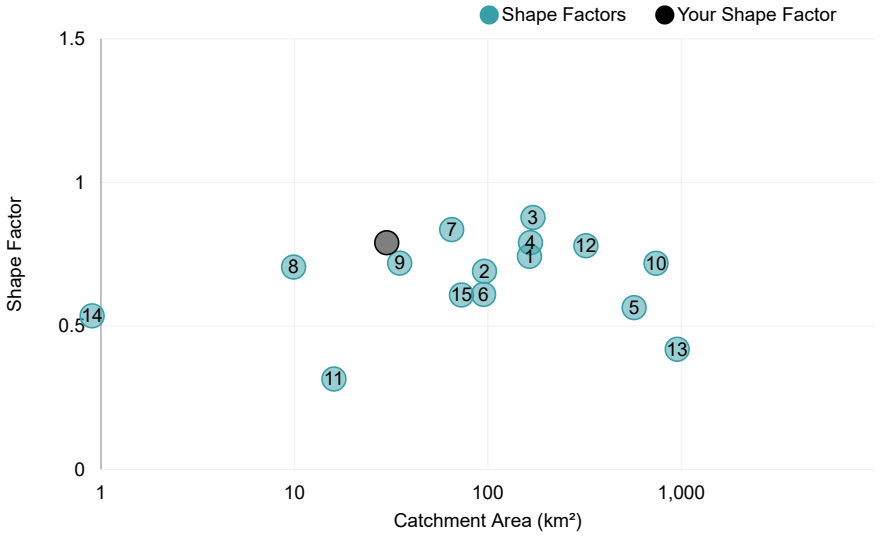
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

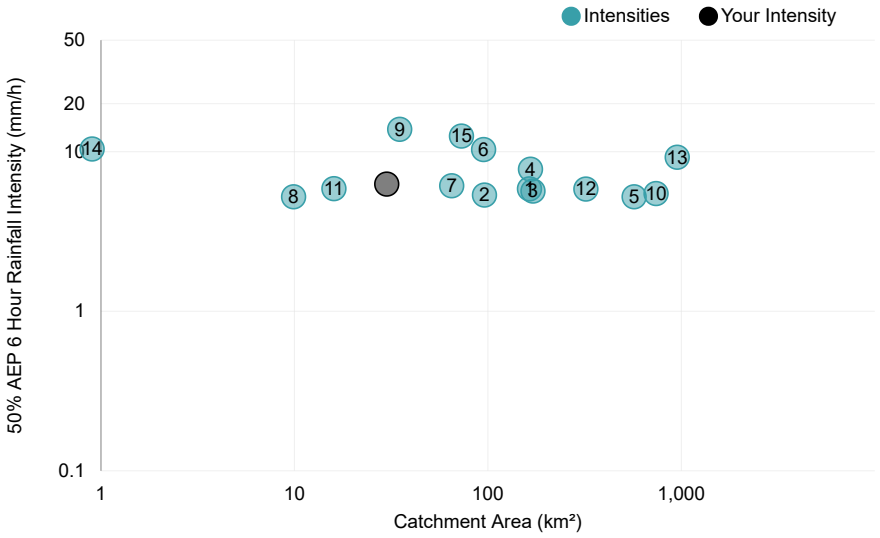
1% AEP Flow vs Catchment Area



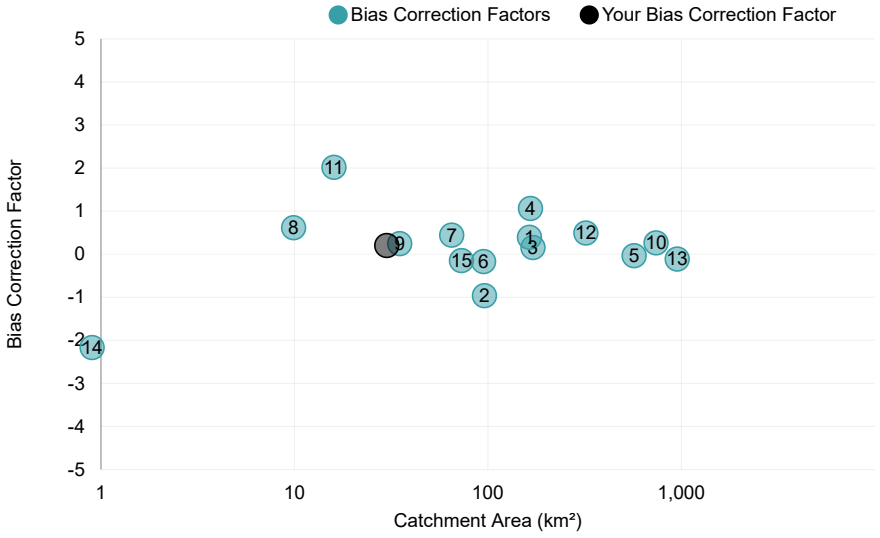
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



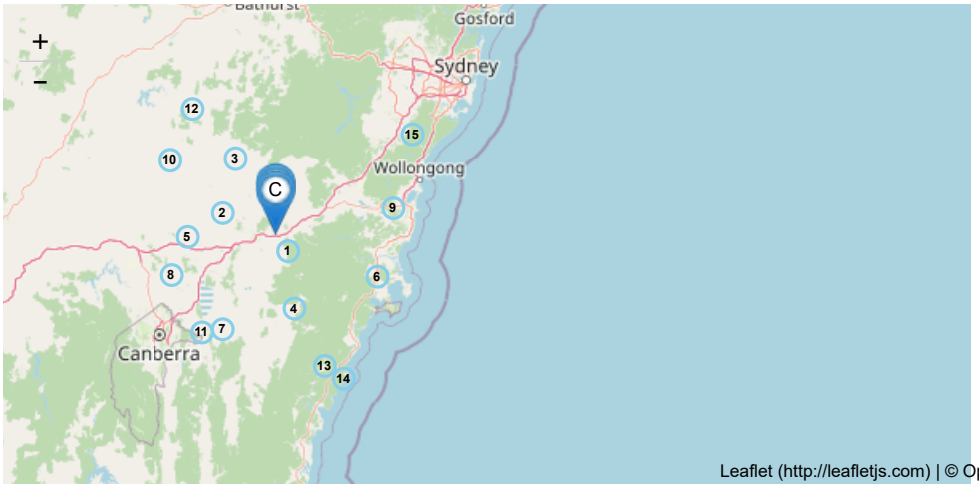
Download

TXT Nearby JSON

Input Data

Input Data

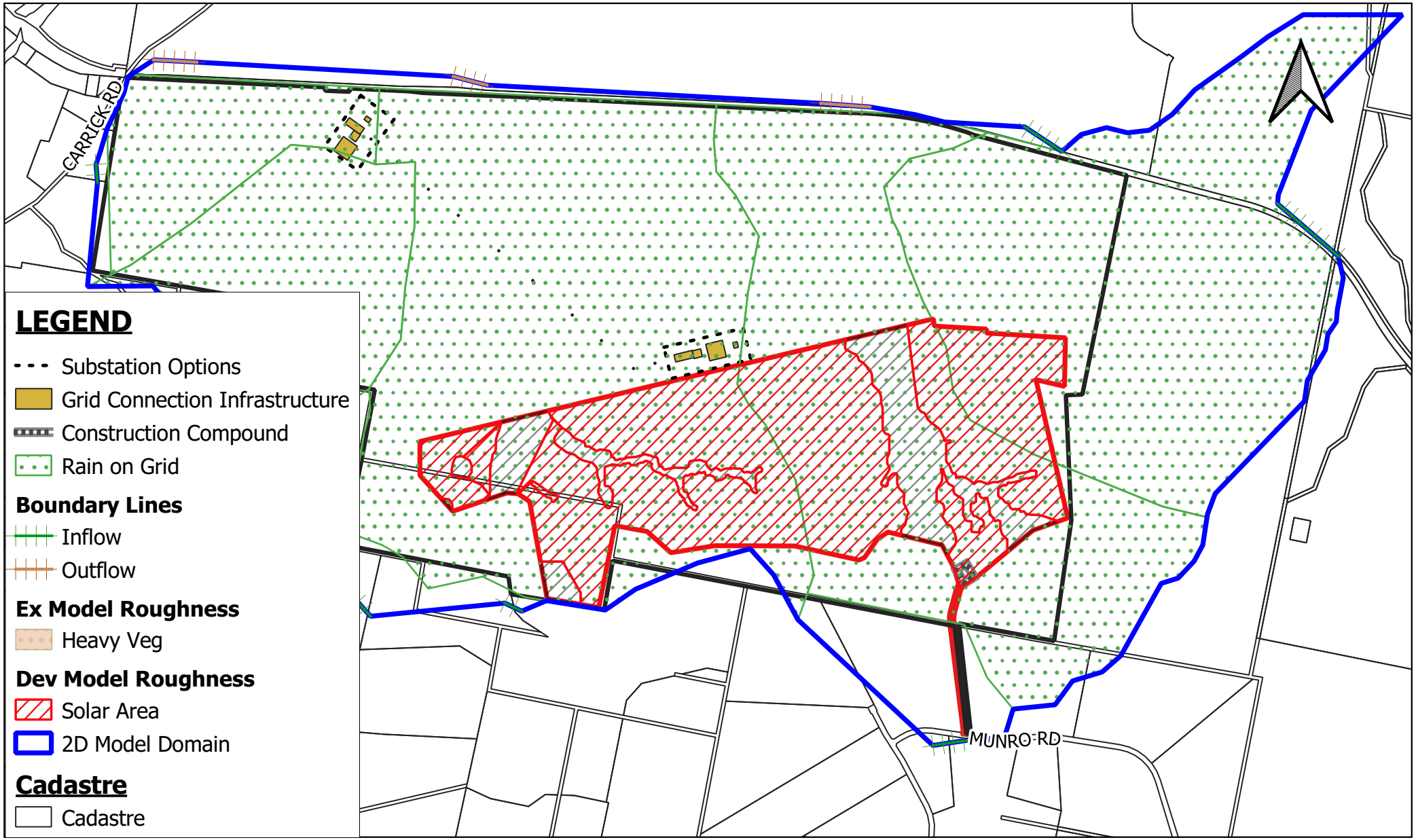
Date/Time	2021-01-31 00:34
Catchment Name	Catchment1
Latitude (Outlet)	-34.69245
Longitude (Outlet)	149.90391
Latitude (Centroid)	-34.73131
Longitude (Centroid)	149.90505
Catchment Area (km^2)	30.0
Distance to Nearest Gauged Catchment (km)	16.14
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.266813
2% AEP 6 Hour Rainfall Intensity (mm/h)	12.714906
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.79
Interpolation Method	Natural Neighbour
Bias Correction Value	0.202



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).

APPENDIX C

HYDRAULIC MODEL PLANS (TUFLOW)



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TUFLOW Hydraulic Model Setup

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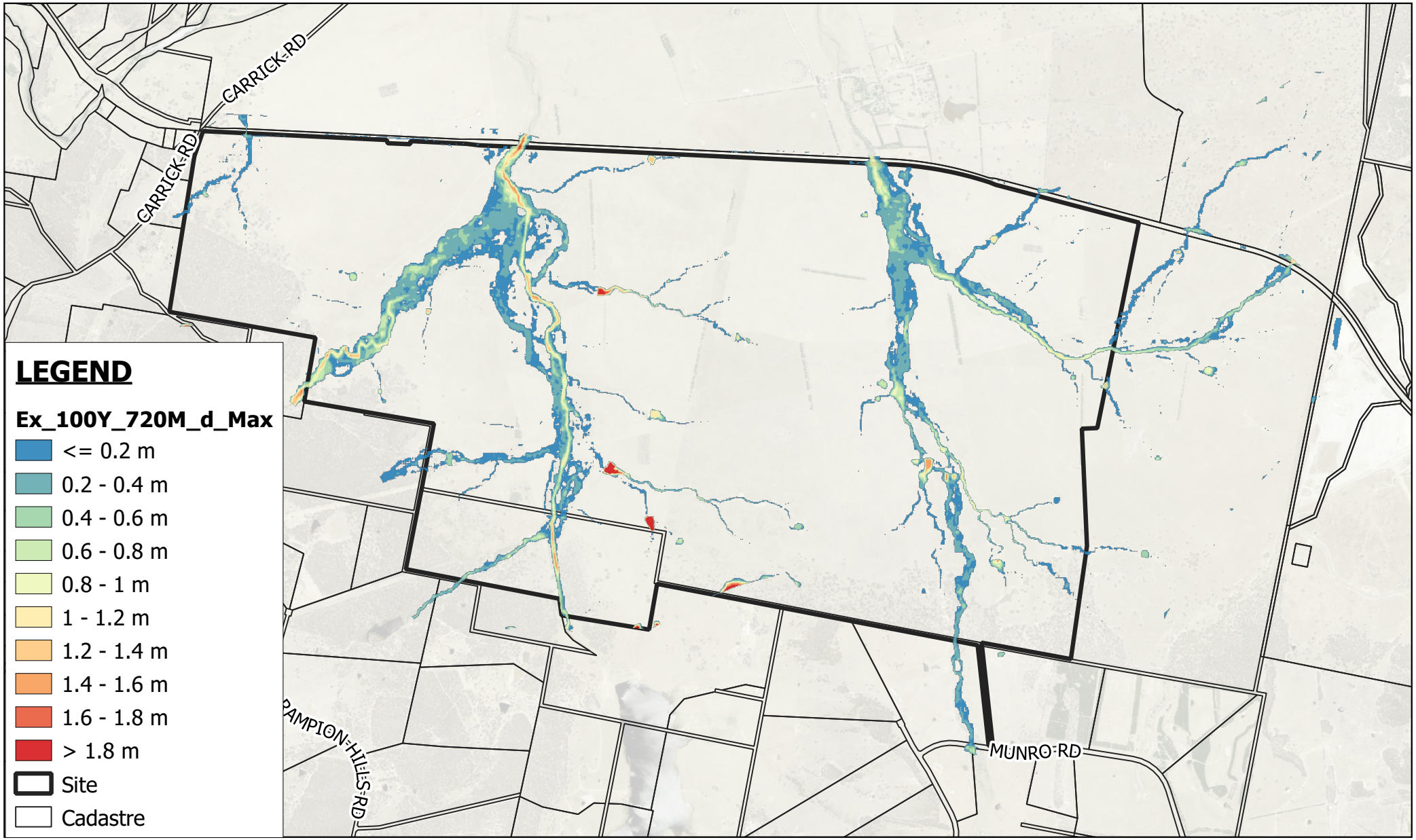
APPENDIX D

PRE-DEVELOPMENT 1% AEP FLOOD MAPS



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1% AEP Peak Flood Depth - Existing Case

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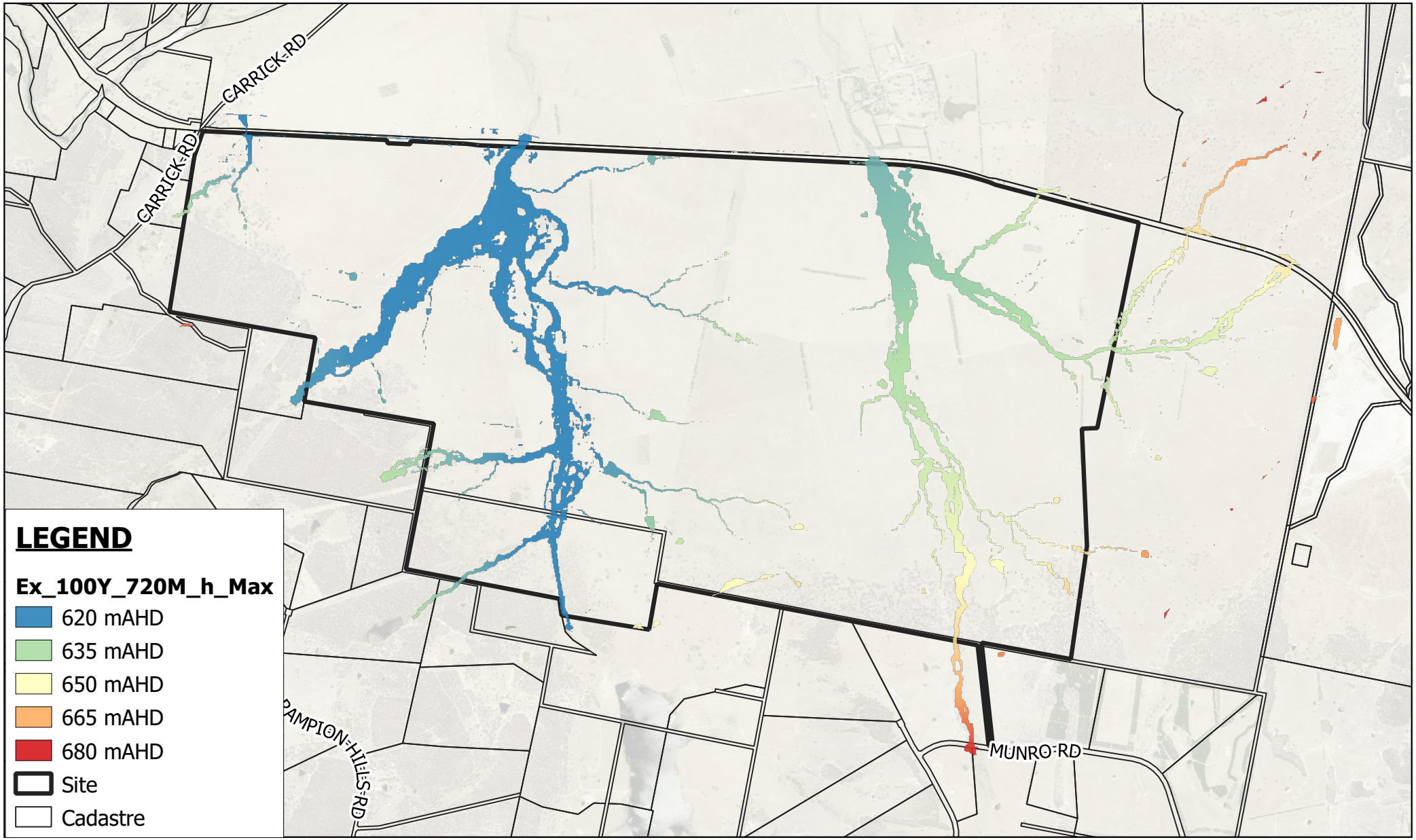

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1% AEP Peak Flood Elevation - Existing Case

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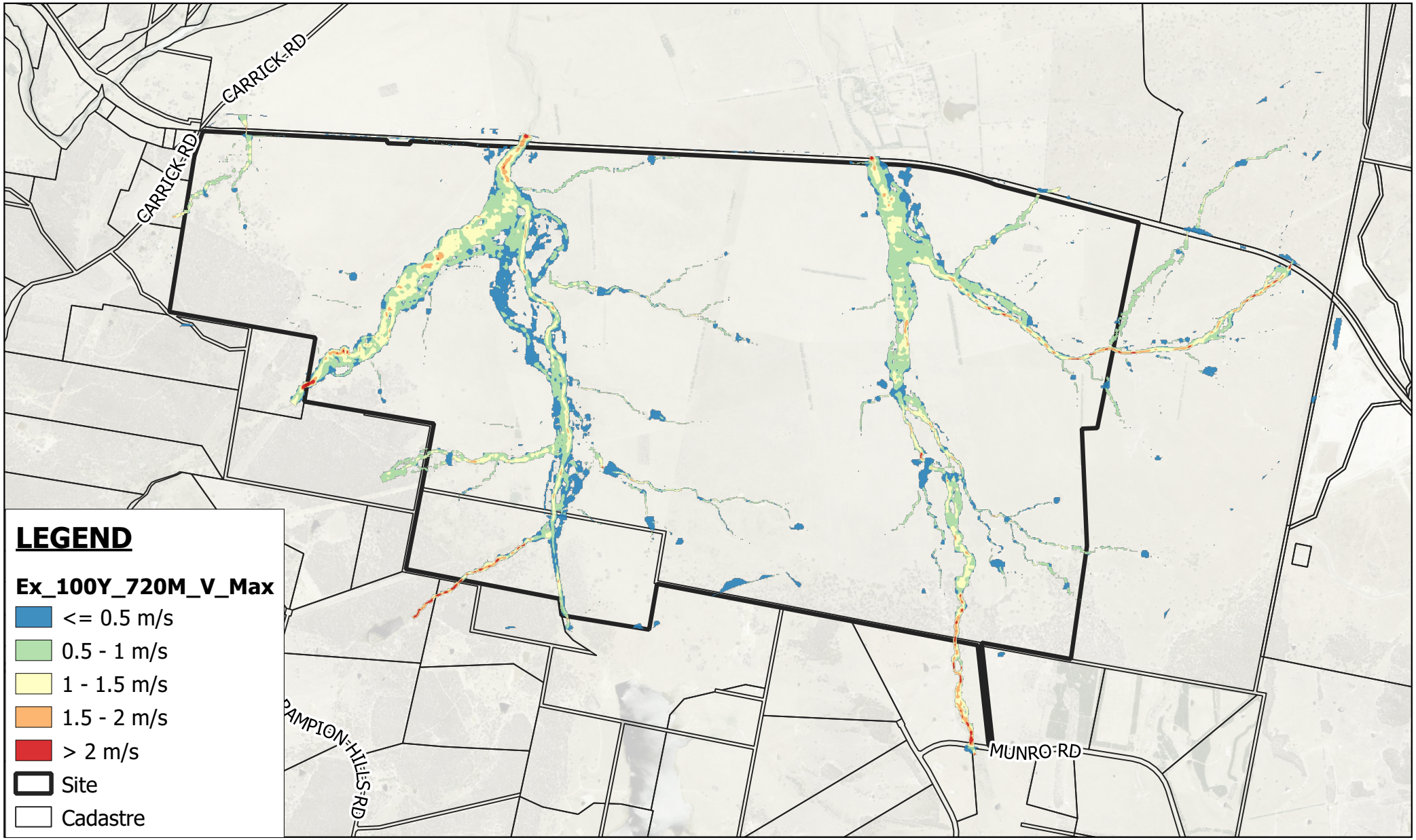

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1% AEP Peak Flood Velocity - Existing Case

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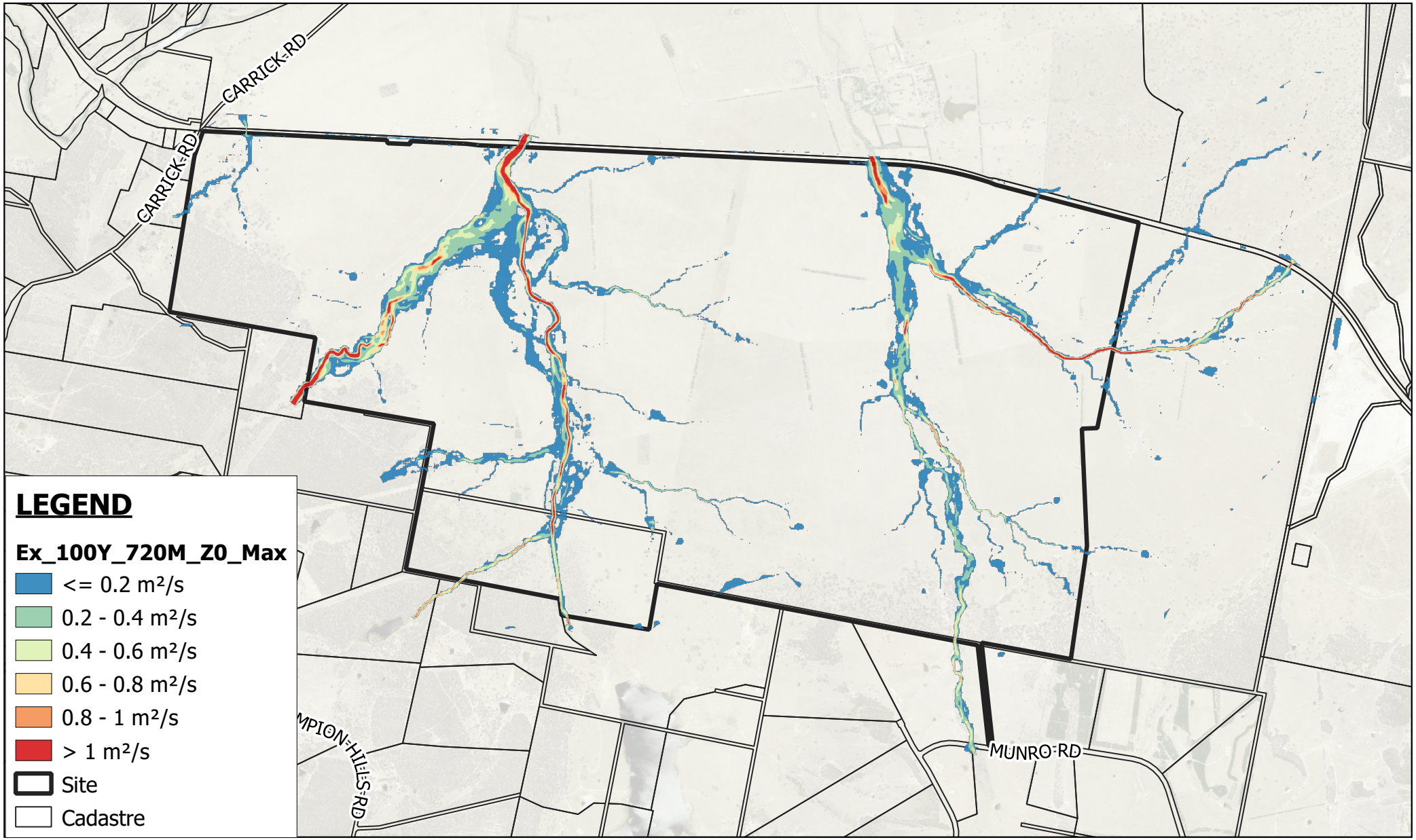

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1% AEP Peak Flood Hazard - Existing Case

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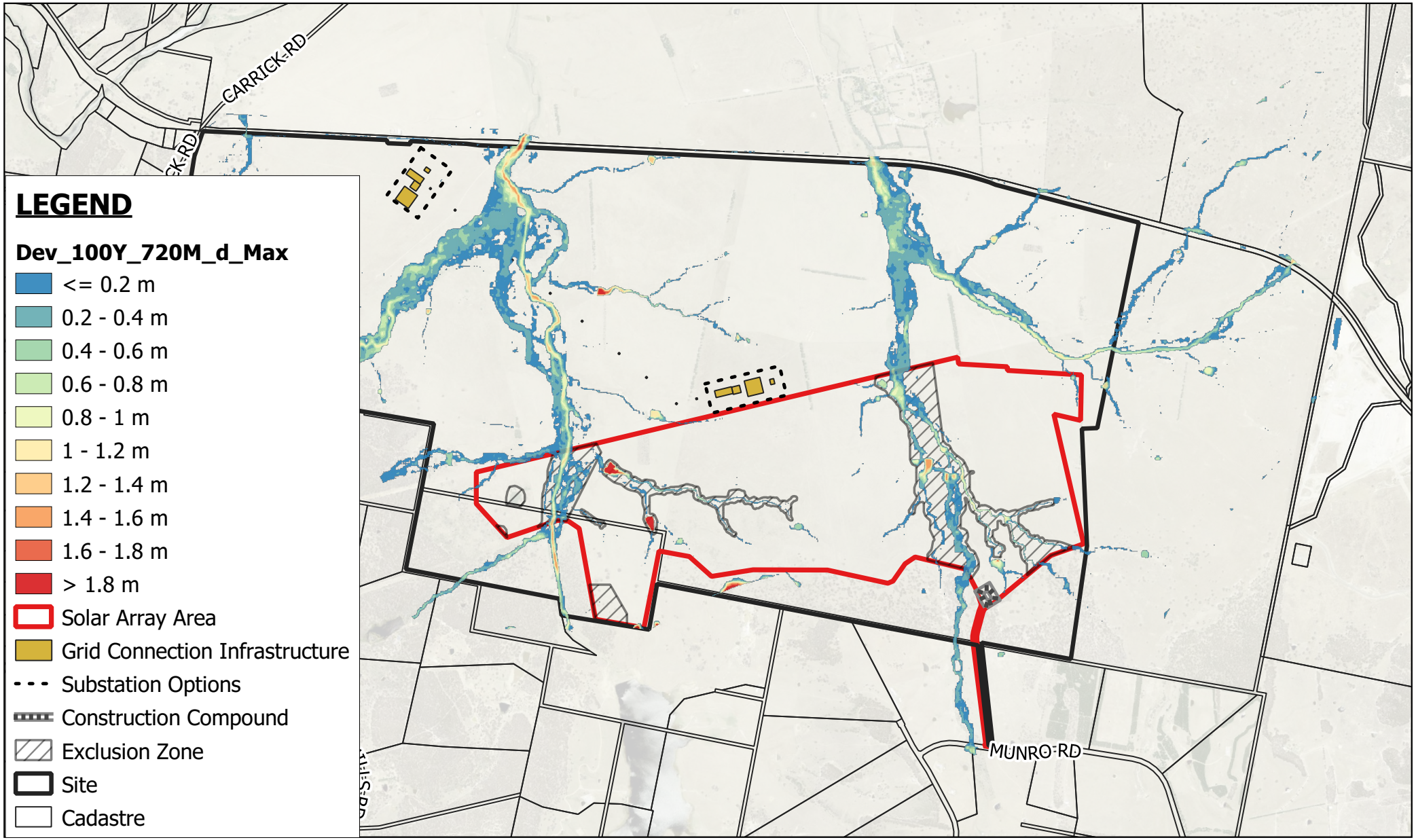
APPENDIX E

POST-DEVELOPMENT 1% AEP FLOOD MAPS



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1% AEP Peak Flood Depth - Developed Case

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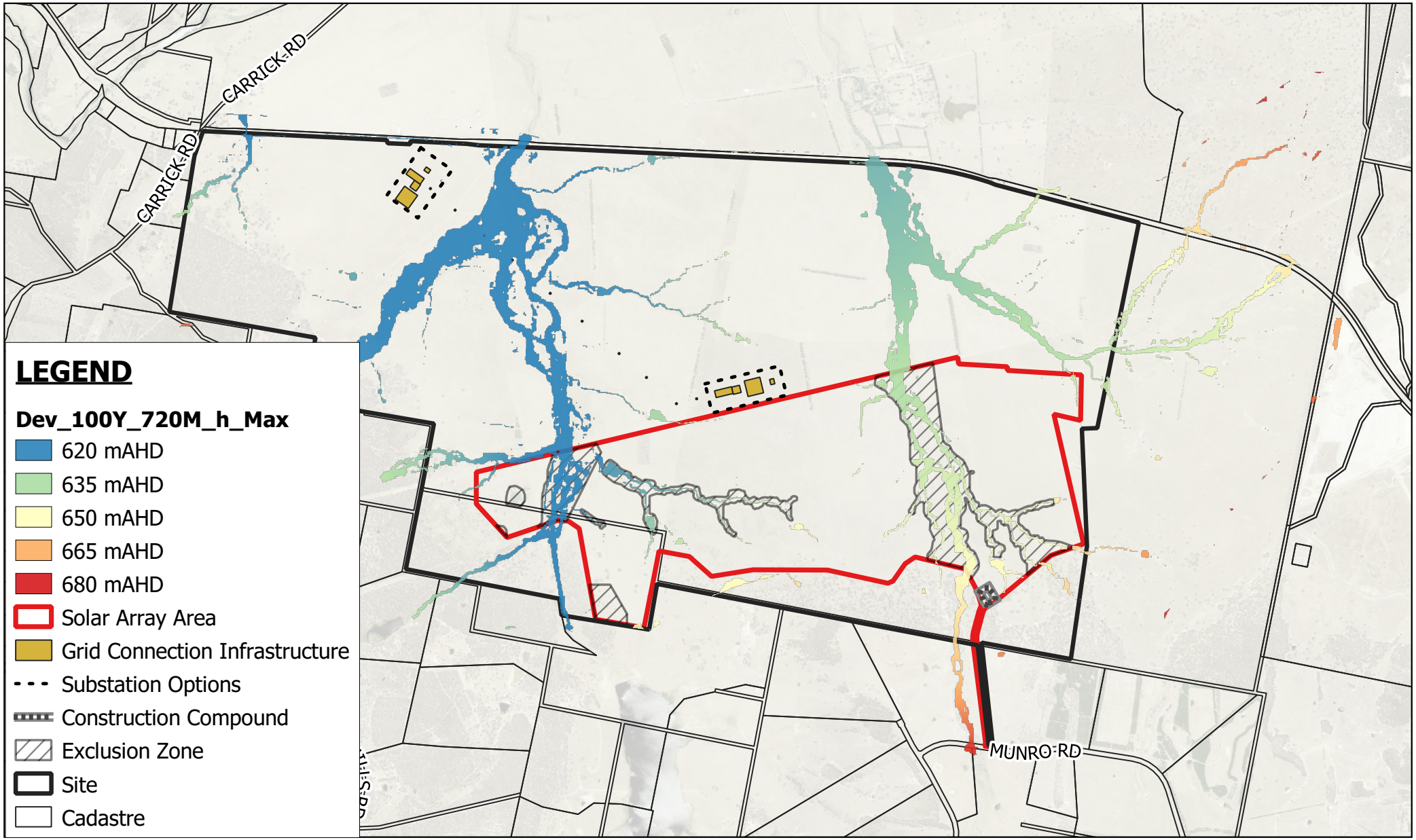

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MARULAN SOLAR FARM

1% AEP Peak Flood Elevation - Developed Case

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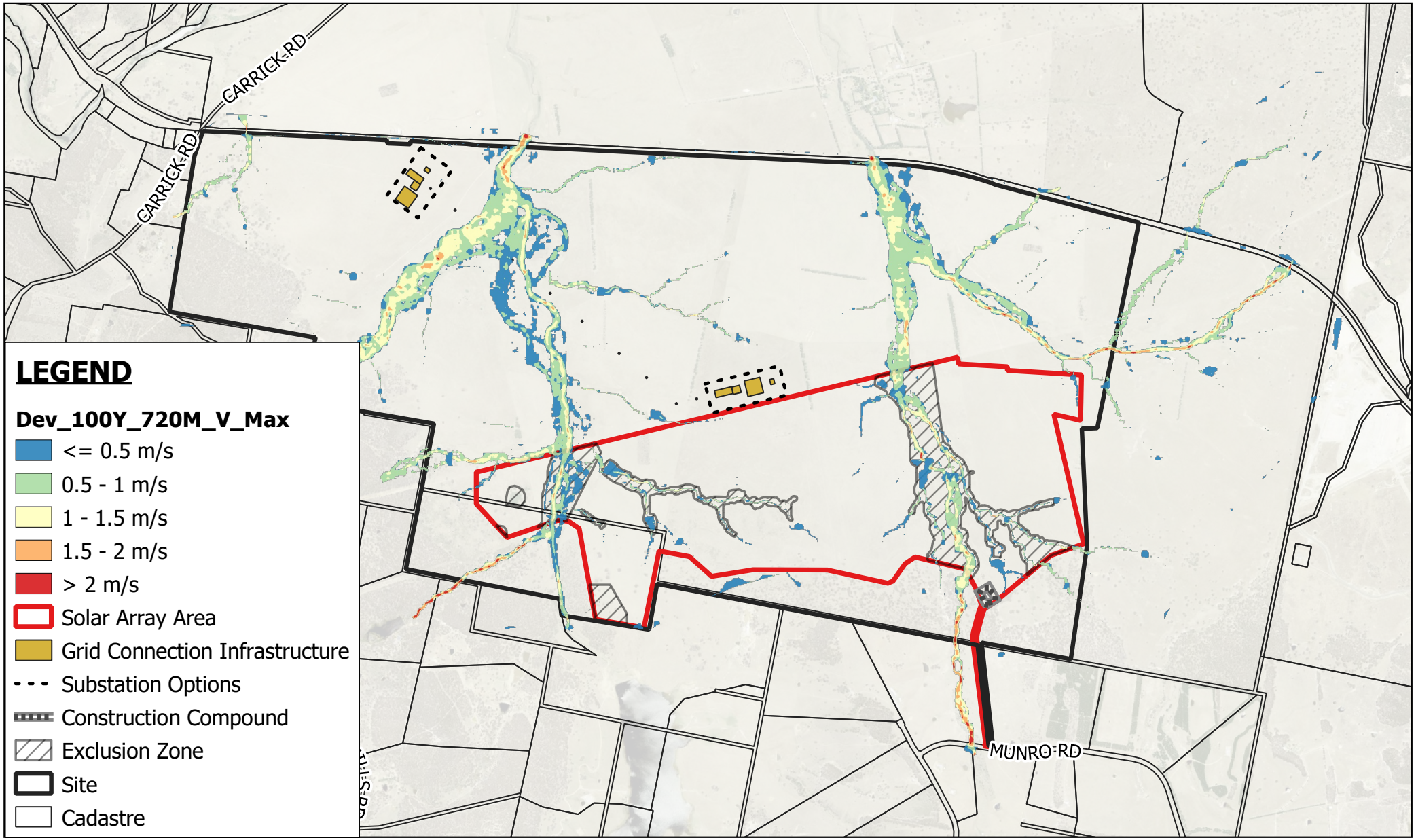

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1% AEP Peak Flood Velocity - Developed Case

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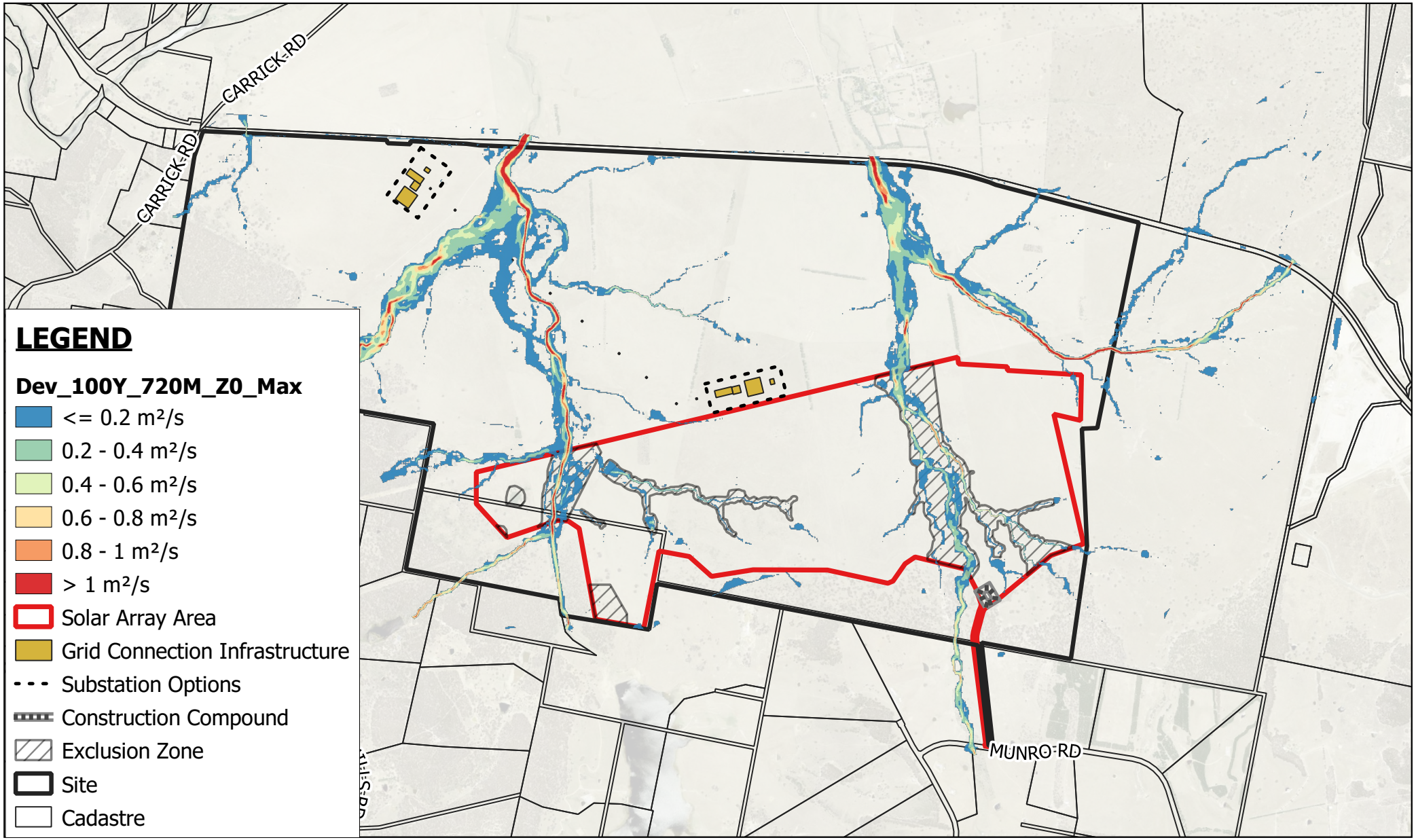

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1% AEP Peak Flood Hazard - Developed Case

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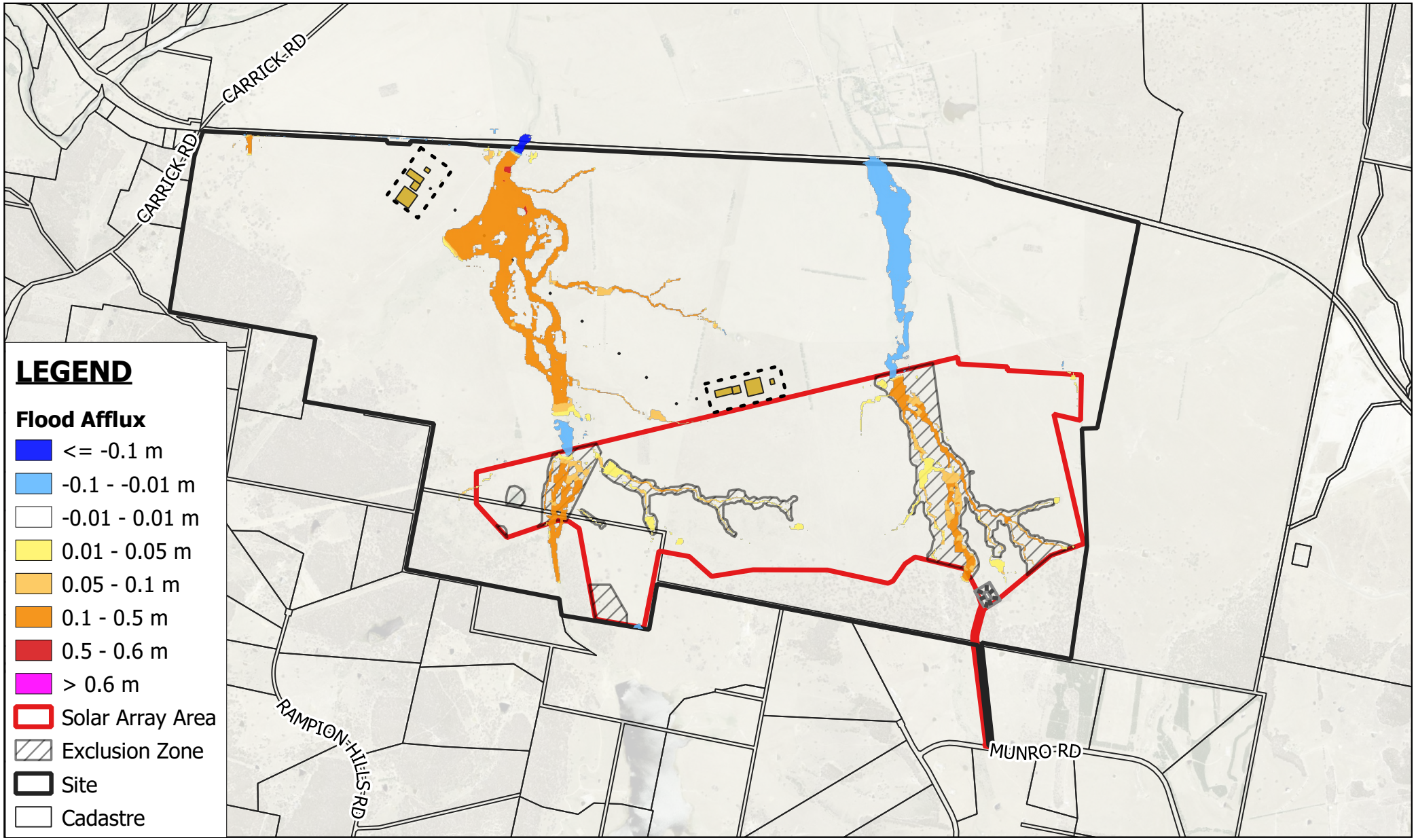
APPENDIX F

1% AEP FLOOD IMPACT MAP



Premise

0 1000 2000 m

Scale 1:32,000

21.03.2022

TERRAIN SOLAR

MARULAN SOLAR FARM

1% AEP Flood Impact

Mar 2022

GEO-0100

F001