Appendix E: Flood modelling report

FINAL REPORT:

Wyalong Solar Farm Flood Modelling

October 2018

Document history

Revision:

Revision no.	03
Author/s	Paul Ollett Christopher Power
Checked	Greg Ellett
Approved	Christopher Power

Distribution:

Revision no.	02
Issue date	22/10/2018
Issued to	Cédric Bergé (ESCO Pacific)
Revision no.	01
Issue date	18/10/2018
Issued to	Cédric Bergé (ESCO Pacific)
Description:	Draft for comment, etc

Citation:

Please cite this document as:

Alluvium (2018), Wyalong Solar Farm Flood Modelling Report 03 by Alluvium Consulting Australia and Hydralinc for ESCO Pacific.

Acknowledgements:

We would like to acknowledge and thank the following people for their input in this review:

Cédric Bergé
Martina Gassner

Ref: 0418074_Wyalong_Solar_Farm_Flood_Modelling.docx

Contents

Figures

Tables

Acronyms and Glossary

Acronyms

AEP	Annual Exceedance Probability. The probability that a given rainfall total accumulated or peak flow rate for a given duration will be exceeded in any one year. See Table 1 for conversion to ARI.
AHD	Australian Height Datum
ARI	Average Recurrence Interval. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated or peak flow rate for a given duration. See Table 1 below for conversion to AEP.
ARR	Australian Rainfall and Runoff
CL	Continuing Loss
CRCCH	Cooperative Research Centre - Catchment Hydrology
CRCFORGE	Cooperative Research Centre - Focussed Rainfall Growth Estimation
DEHP	Department of Environment and Heritage Protection
DTM	Digital Terrain Model
DXF	Drawing Exchange Format
EA	Environmental Authority
GSDM	Generalised Short Duration Method
IFD	Intensity, Frequency, Duration
IL	Initial Loss
LiDAR	Light Detection And Ranging
ML	Megalitres
PMP	Probable Maximum Precipitation
WSE	Water Surface Elevation

Glossary

Alluvium	Alluvium Consulting Australia
WBNM	Hydrological modelling software package
TUFLOW	1D/2D Hydrodynamic modelling software package
XPSWMM	1D/2D Hydrodynamic modelling software package

In accordance with the Bureau of Meteorology guidance, the Annual Exceedance Probability (AEP) has been used in this report in preference to Annual Recurrence Interval (ARI) wherever possible. However, as ARI is used throughout the ACARP criteria for assessing hydraulic parameters of channels, it is necessary to use ARI for this component of work.

As shown in Table 1, ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP. However, for higher probability events (e.g. the 2 year ARI) the corresponding AEP is an awkward percentage (39%).

To reduce confusion, the following approach has been adopted when using ARI and AEP:

- ARI has been used for the smaller (higher probability) storm and flood events up to the 50 year which are considered in the hydraulic assessment of stream parameters.

- For higher magnitude (lower probability) events the AEP has been adopted for the discussion of flood risk.

Table 1. ARI to AEP conversion table

ARI (yrs)	AEP	AEP (%)
2	0.393	39
5	0.181	18
10	0.095	10
20	0.049	5
50	0.020	2
100	0.010	**1**
200	0.005	**0.5**
500	0.002	**0.2**
1000	0.001	**0.1**
2000	0.0005	**0.05**

1 Introduction

Alluvium Consulting Australia Pty Ltd (Alluvium) has been commissioned by ESCO Pacific to undertake a flood study to inform an Environmental Impact Study (EIS). The EIS is required as a part of ESCO Pacific's planned solar farm at Wyalong, near West Wyalong, NSW (Figure 1 and Figure 2 – see the Project Area).

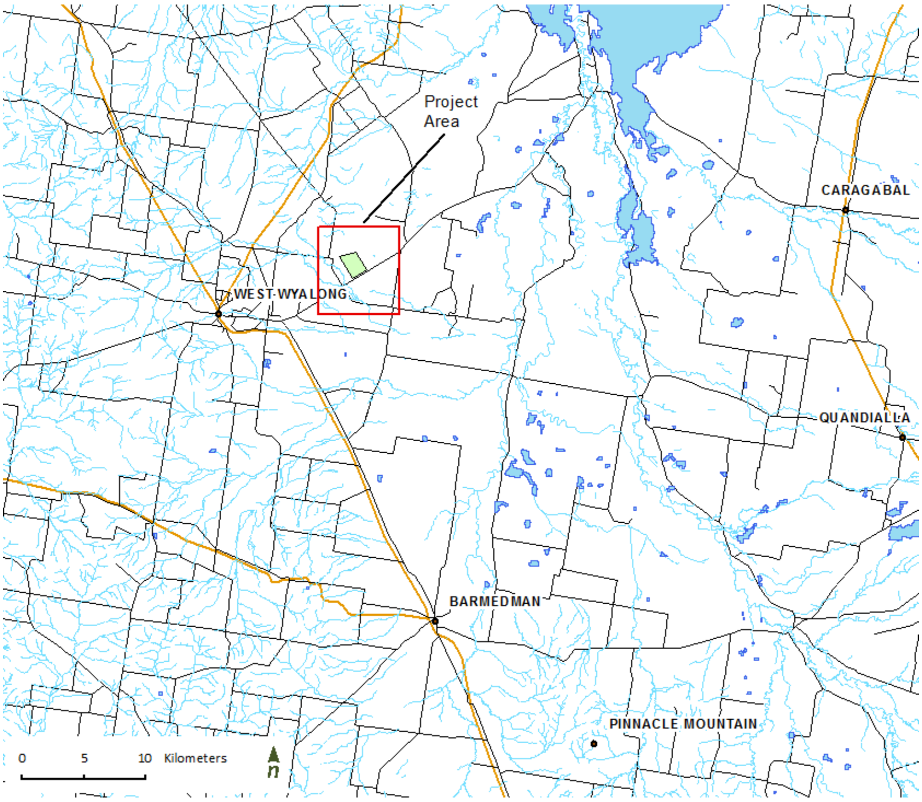


Figure 1. *Locality Plan of the proposed Study Area.*

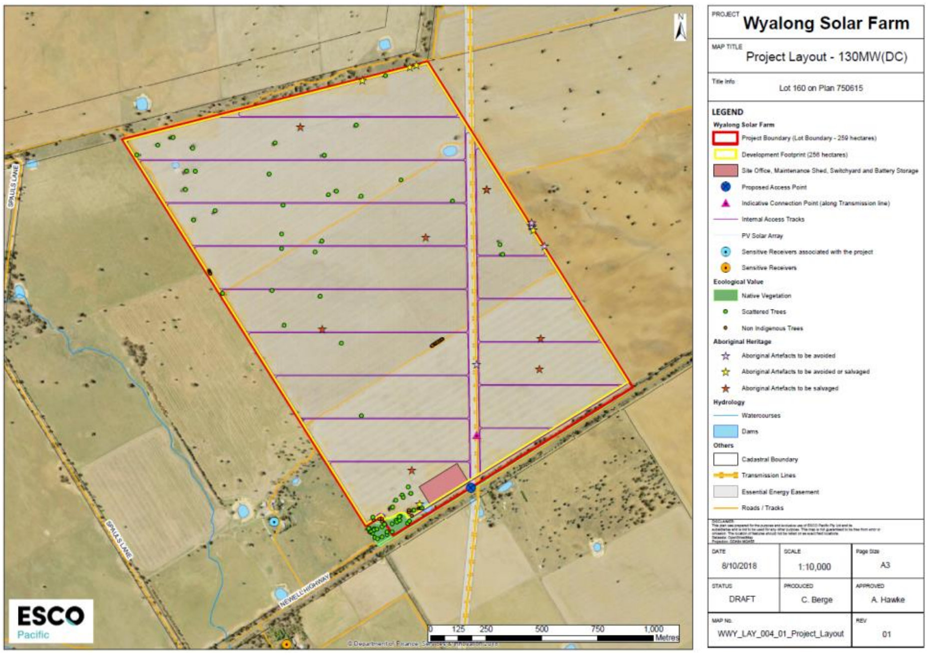


Figure 2. *Proposed ESCO Pacific Solar Farm – "Project Area" (Note: layout is conceptual in nature)*

2 Flood Modelling

2.1 Overview

The NSW Office of Environment and Heritage (OEH) has requested a Flood Study to assess several criteria pertaining to flood immunity, floodplain impacts, safety and emergency management in relation to the proposed Project Area. This investigation has been undertaken in order to support an EIS for the initial Project Area precinct of the Wyalong Solar Farm. Specific responses to the full tabulated criteria are included in Section 5 below, and the modelling methodology which underpins those responses is outlined in Section 2.3.

The proposed Project Area plus the upstream catchment has a total area of over 170 km^2 (17,000 ha). The level of assessment for the methodology takes a minimalist approach to the flood study, as it is believed the Project Area is of low risk (both its own internal infrastructure and impacts to neighbouring property). This status is due to the Project Area's generally high elevation (Figure 3), and the nature of the assets (panels mounted on posts above ground).

The availability of previous flood studies is discussed in section 2.2 below.

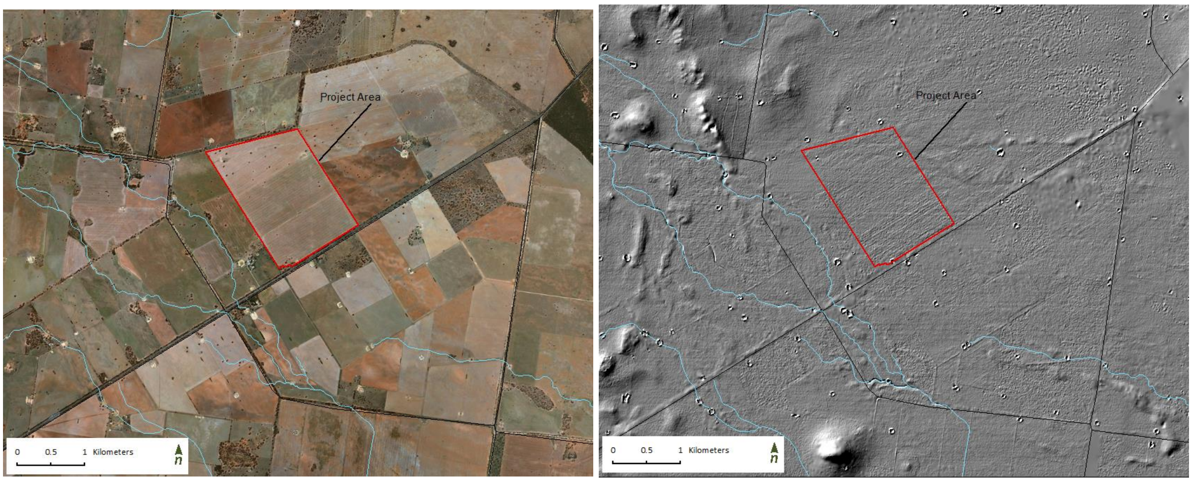


Figure 3. *(LEFT) Aerial with the extents of the Project Area (red). (RIGHT) Digital Elevation Model (dark grey = high; light grey = low)*

The following events were simulated in the assessment with their rationale discussed in Section 2.3:

- 5% [1:20] AEP: to plan road and drainage / cross drainage infrastructure for the Project Area
- 1% [1:100] AEP: to determine flood immune locations and levels for main buildings such as the Operation and Maintenance (O&M) Building and other medium risk infrastructure
- 0.1% [1:1000] AEP: to determine flood immune locations and levels for high risk infrastructure such as the Project Area switch yard.

2.2 Previous flood studies

- The nearest flood study[1] is for Ungarie, NSW, located 40 km northwest of the Project Area. The report does not include flood modelling for West Wyalong and the Project Area.
- A search of the NSW Planning Portal, Six Maps, Bland LEP, NSW Flood Data Portal and a general search online did not result in any flood-related mapping for the Project Area and surrounding areas.

[1] http://www.blandshire.nsw.gov.au/sites/default/files/for_comments/DRAFT%20Ungarie%20Flood%20Study%20Report.pdf

2.3 Environment and Heritage (OEH) Assessment Criteria

The NSW Office of Environment and Heritage (OEH) in previous correspondence requested a Flood Study to assess several criteria in relation to the proposed Project Area (see the specific responses to the full tabulated criteria in Section 5). The criteria refer to principles in the NSW Government Floodplain Development Manual (FDM, 2005), and the application of these were applied as follows.

Definitions & Interpretation:

Flood prone land: 'land susceptible to flooding by the PMF event'.

> Interpretation: technically any land can experience a Probable Maximum Precipitation event. However the context in the FDM (2005) is with respect to floodplain development, and as there are no significant creeks or rivers in the vicinity of the Project Area, which experiences predominantly overland sheet flow, the Project Area is not considered "flood prone" or to be located on a "floodplain". A classification of "contributing watershed" for the Project Area may be a more appropriate definition.

Flood planning area: 'the area of land below the FPL and thus subject to flood related development controls'.

> Interpretation: there currently are no flood planning levels (FPLs) for the Project Area or surrounding areas, and therefore the Project Area is not part of a flood planning area.

Hydraulic categorisation:

- *Flood storage area: 'those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity of flood impacts by reducing natural flood attenuation'.*
- *Floodway areas: 'those areas of the floodplain where a significant discharge or water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels'.*

> Interpretation: within the context of river and creek flooding, and floodplain management, the Project Area is located in the overland sheet flow or contributing watershed upper areas of the catchment. The Project Area does not reside within the flood storage or flood conveyances elements of a floodplain.

Flood hazard: 'a source of potential harm or a situation with a potential to cause loss'.

> Interpretation: the nature of "flood hazard" is typically quantified as the product of flow depth x flow velocity and is relevant to any aspect of runoff, including overland sheet flow, stormwater, drainage, and floodplains. Therefore the "flood hazard" levels are applicable to this assessment.

Flood surface: the maximum water surface, exposed to the atmosphere, expressed as a level normally to the Australian Height Datum (m. AHD) or sometimes local Port datum. (Definition created for purposes of discussion).

> Interpretation: the flood surface of overland sheet flow can still possess significant depth and flood hazard, and therefore is relevant for the Project Area planning and setting of infrastructure levels.

Modelled Flood Magnitudes: The OEH criteria request discussion around the 5% AEP (20yr ARI), 1% AEP (100yr ARI), 0.5% AEP (200yr ARI) and 0.2% AEP (500yr ARI). At the early stages of the investigation, it was found that due to the "overland sheet flow" nature of flooding in this upper watershed, differences between the 1%, 0.5% and 0.2% AEP events were quite small, less than 100mm. Therefore, due to some of the significant high risk infrastructure proposed for the Project Area, and to prudently examine the impacts of a greater flood magnitude, the 0.5% and 0.2% AEP events were replaced by the more severe 0.1% (1000yr ARI) event. The average 1% AEP (100yr ARI) depth across the Project Area was 250mm, and 350mm for the 0.1% AEP (1000 year ARI).

2.4 Survey and digital elevation model

LiDAR survey was obtained for the catchment at 1 km^2 tiles and joined to form an overall Digital Elevation Model (DEM) of 5 m resolution (Figure 4 and Figure 5). The tiles were obtained from the Geoscience Australia website (2018).

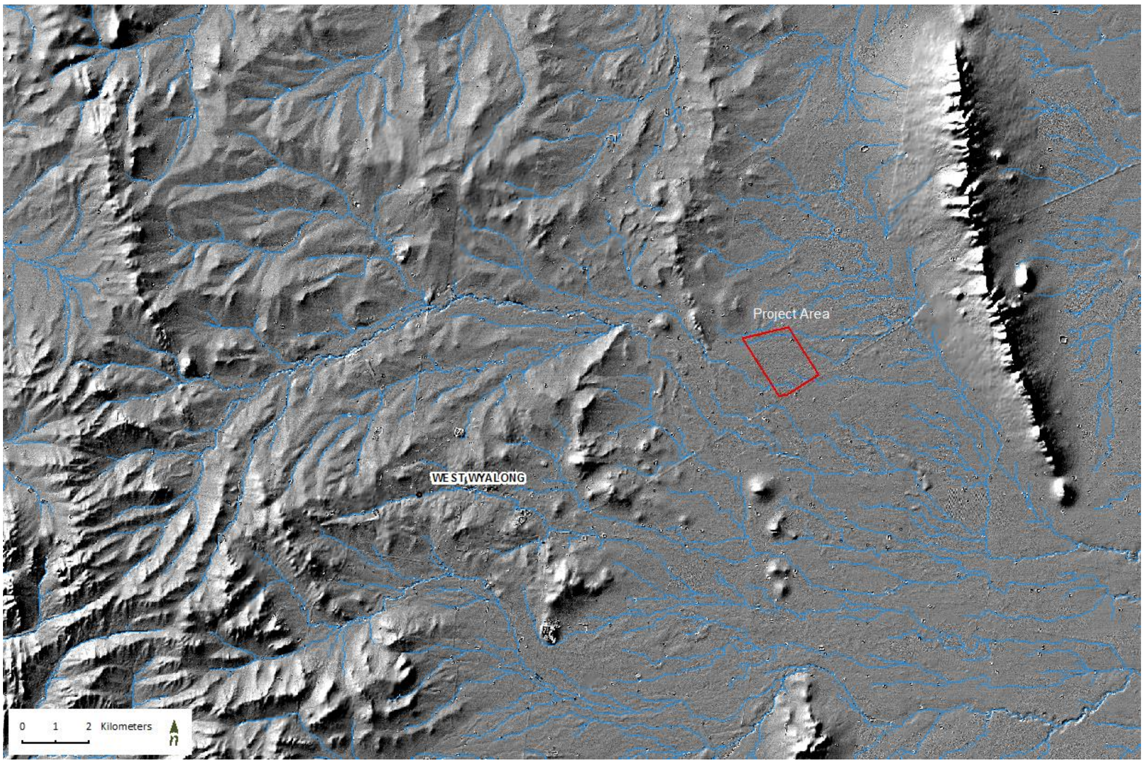


Figure 4. *The DEM and streamlines over the Project area*

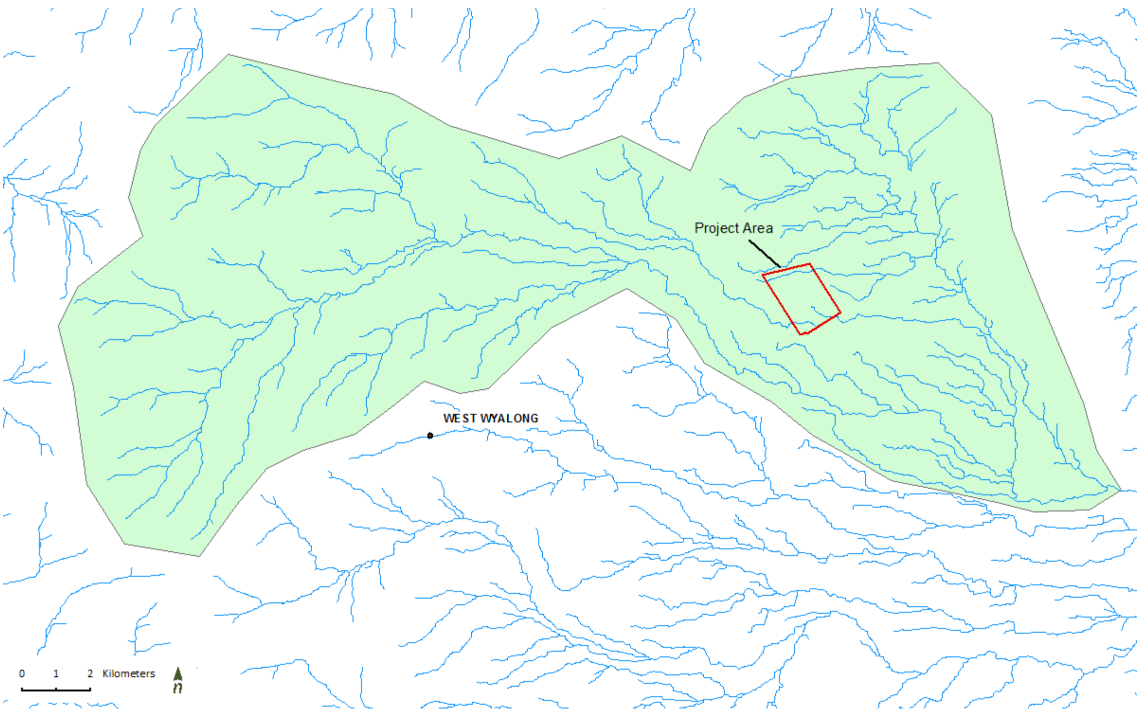


Figure 5. *The catchment and streamlines near and over the project area*

2.5 Hydraulic Model Build

The flood models were built using the above DEM, using the 2-dimensional TUFLOW software. A "regional" flood model was constructed incorporating the large catchment area upstream of the Project Area, utilising a cell size of 20m in order to establish riverine and or creek flooding conditions. A "local" flood model was also built at a finer cell size of 5m, incorporating the immediate catchment area upstream, to establish localised drainage and overland flow across the proposed solar farm. See Figure 6 below for the regional and local model coverages.

In both models the Direct Rainfall Method (DRM) was employed, where design rainfall is applied directly to every cell within the model area. The direct rainfall method was calibrated (discussed in the Hydrological Section below) and a final catchment-wide Manning's 'n' value of 0.07 adopted. The parameters from the regional model calibration were applied to the local model, and grids of flood surface, depth, velocity and hazard calculated for both the regional and local models for the 0.1% AEP (1:1,000yr), 1% AEP (1:100yr) and 5% AEP (1:20 yr) events. It was found in all cases that the regional model results were always more conservative and therefore only the regional model results were adopted for planning purposes.

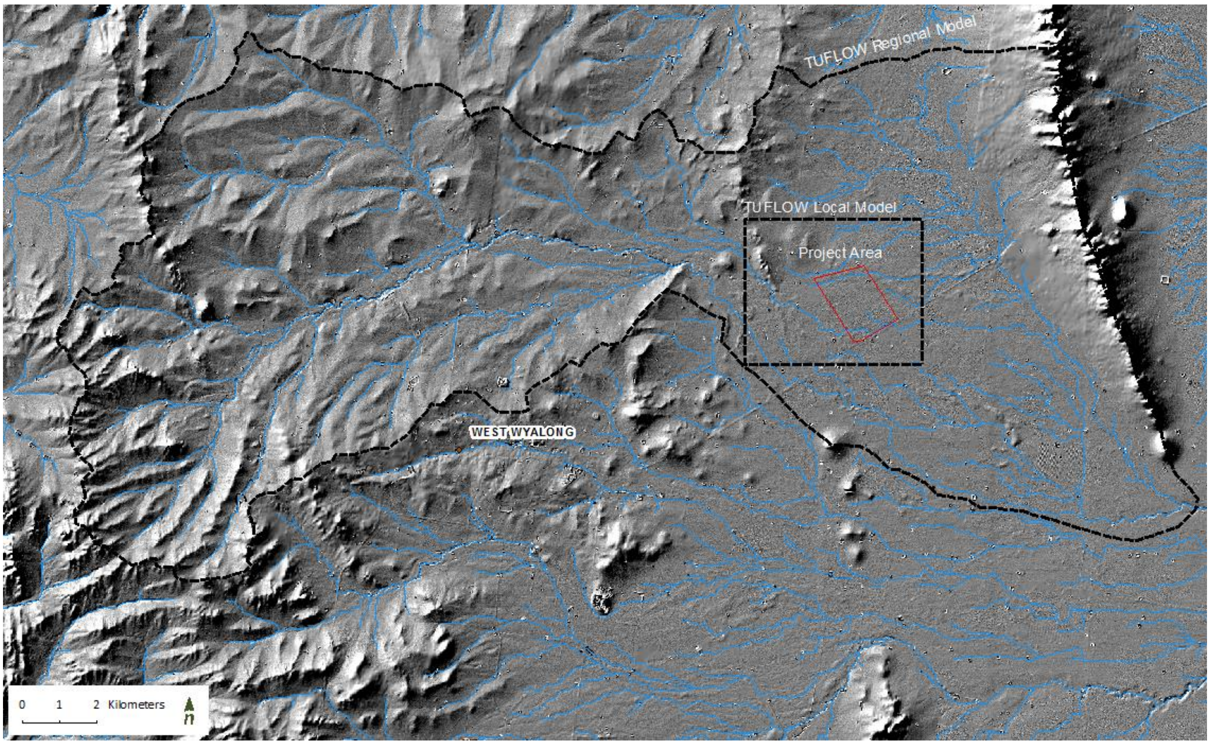


Figure 6. *Extent of the 2D TUFLOW model with nominal streamlines*

2.6 Hydrological Estimation

To determine the design discharges two hydrological methods were utilised to determine which was more conservative. The first was the new Regional Flood Frequency Estimation Method (RFFEM) (more details contained in Attachment B) in the Australian Rainfall and Runoff 2016 (ARR16) literature, and a full hydrological model was constructed using the WBNM software.

The WBNM model was broken down into 27 sub-catchments, each having an average area of 10 km^2 and total area of 270 km^2. The standard routing parameters recommended for ungauged catchments were used: C = 1.6 for catchment routing and R = 1.0 for natural-channel routing. The discharge results of the WBNM and RFFEM, measured at the downstream extent of the regional model, are shown in Table 1 and are in close agreement. The TUFLOW DRM model was run iteratively varying Manning's 'n' until agreement was obtained with the

RFFEM and WBNM methods. The maximum flood depths from this process are tabulated in Table 2 and illustrated in Figure 7.

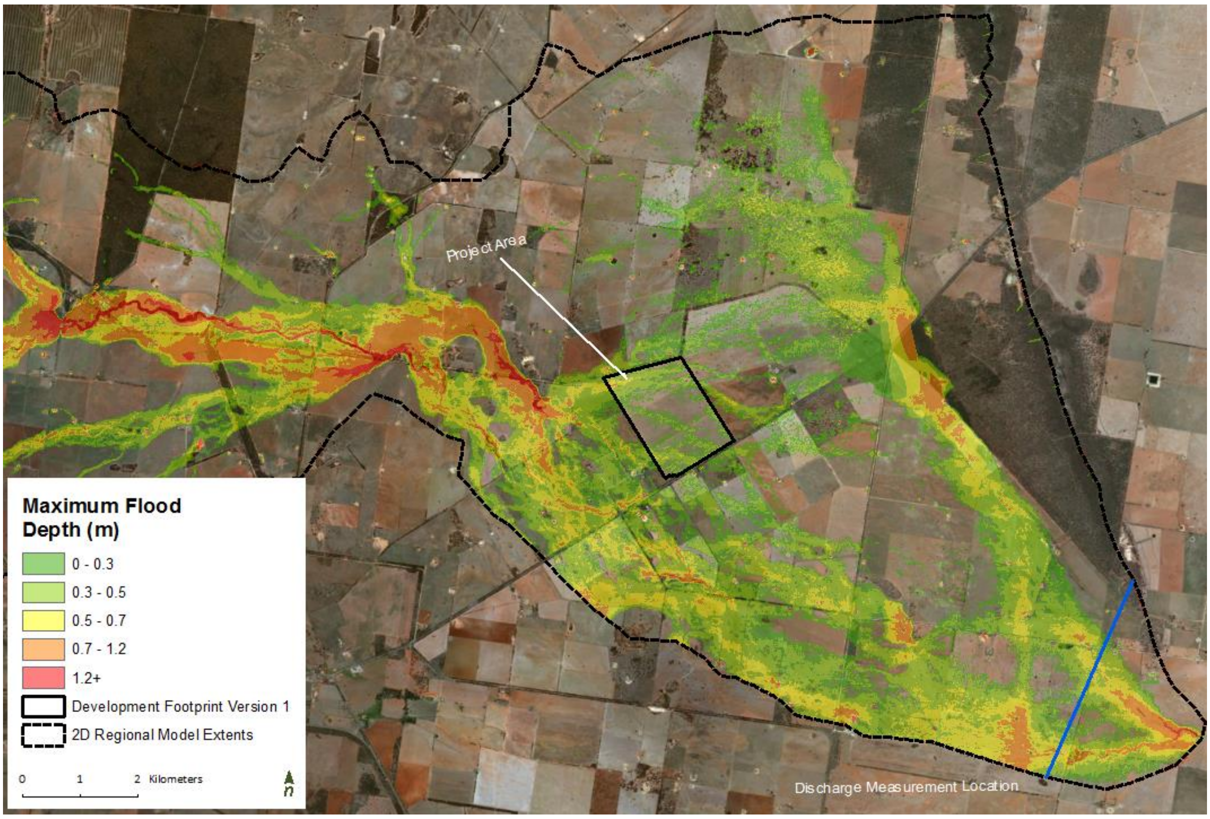


Figure 7. *Discharge Measurement Locations (Note: layout is conceptual in nature)*

Table 2: Discharge Estimates

Model	1% AEP [1:100 years]	Units
Catchment Area	270	(km^2)
RFFEM	237	m^3/s
WBNM	256	m^3/s
TUFLOW DRM	285	m^3/s

2.7 Flood and Hazard Mapping of Results

An estimation of the flooding hazard was achieved by multiplying the maximum flood depths and velocities at each timestep of the flood model of the 100-year ARI event (1% AEP), yielding Figure 8. The flood hazard values may be used for development planning, and there is a variety of guidance in the literature. The guidance produced by Scenic Rim Regional Council (Queensland) in Table 3 below is quite useful as it provides additional guidance on flood free access requirements for various types of vehicles, as well as evacuation distances for key facilities during flood events.

Based on the categories of flood risk given by Figure 8 the majority of the Project Area has a low flood risk with the exception of the dams and a western portion of the Project Area, which are at a medium to extreme level. If the dams were to be filled in to match surrounding ground level this hazard category may be reduced. Detailed maps of flood inundation and flood hazard are given in Attachment A.

Table 3. Low Hazard Evacuation Routes (Scenic Rim Regional Council, 2017)

Criteria	Degree of Flood Hazard			
	Low	**Medium**	**High**	**Extreme**
Wading ability	If necessary children and the elderly could wade. (Generally, safe wading velocity depth product is less than 0.25).	Fit adults can wade. (Generally, safe wading velocity depth product is less than 0.4).	Fit adults would have difficulty wading. (Generally, where wading velocity depth product is less than 0.6.)	Wading is not an option.
Evacuation distances	<200 metres	200-400 metres	400-600 metres	>600 metres
Maximum Flood Depths	<0.3 metres	<0.6 metres	<1.2 metres	>1.2 metres
Maximum Flood Velocity	<0.4 metres per second	<0.8 metres per second	<1.5 metres per second	>1.5 metres per second
Typical means of egress	Sedan	Sedan early, but 4WD or trucks later.	4WD or trucks only in early stages, boats or helicopters	Large trucks, boats or helicopters.

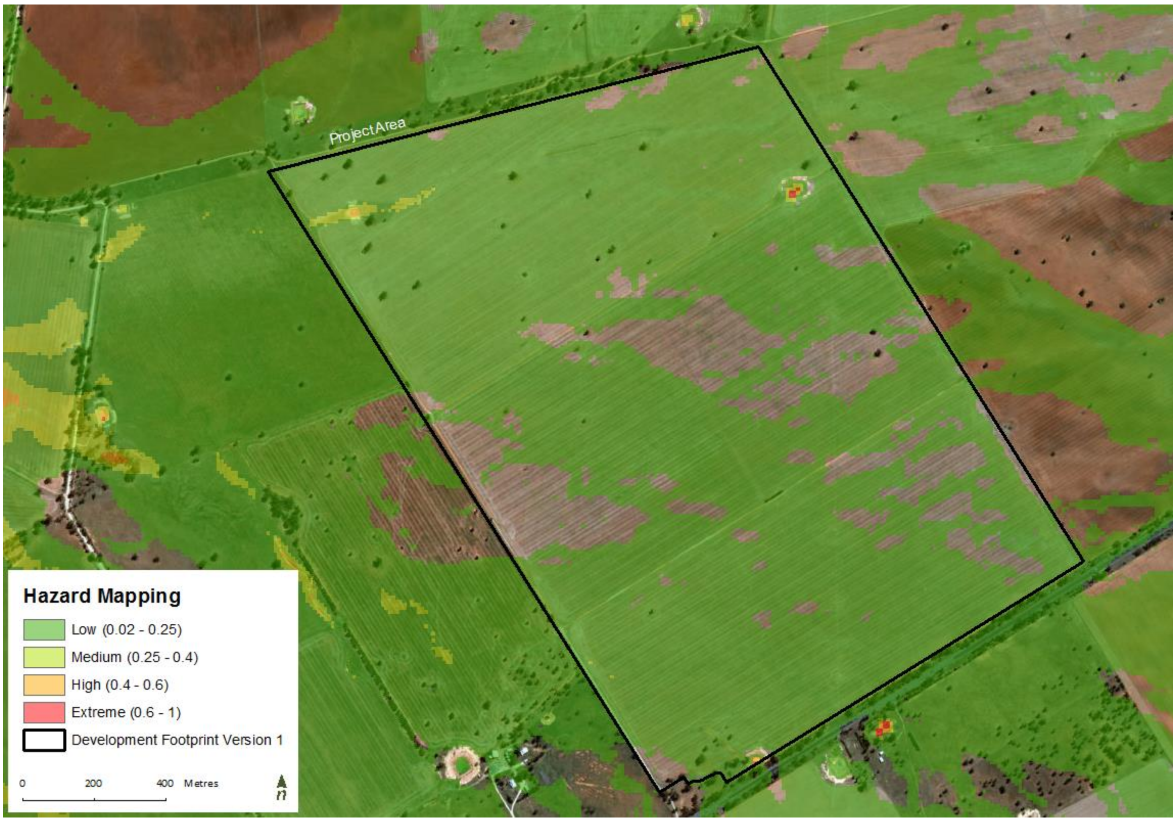


Figure 8. *Hazard mapping (D x V product) of the Project Area for the 1% [1:100 ARI] AEP. (Note: the footprint is conceptual in nature)*

3 Potential flood impacts due to the Solar Farm

Generally, there are two potential impacts a solar farm could have on flooding and runoff external to the Project Area.

- Impacts on riverine flood levels due to the Project Area obstructing flow.
- Impacts on flood levels due the Project Area producing extra runoff.

3.1 Runoff Obstruction (blockage) due to the Solar Farm

The results of the flood modelling showed that runoff through and adjacent to the proposed solar farm Project Area was shallow and of an overland nature. Significant creek or riverine flooding did not develop due to the flat nature of the terrain and relatively low runoff volumes. Therefore, the impacts of the solar farm obstructing the very shallow overland flow observed in the catchment would be negligible.

3.2 Increased Runoff due to the Solar Farm

In terms of the Project Area and associated panels generating additional local stormwater runoff a literature review was initially conducted on this topic and a number of references sourced and reviewed. The references and their summaries are as follows:

AECOM, 2012. County of San Diego. Preliminary Hydrology and Drainage Study for Tierra Del Sol Solar Farm.

- Potential for 5% increase in runoff discharges due to impervious areas.
- To be mitigated by infiltration trenches.

Cook and McCuen, 2013. Journal of Hydrologic Engineering, ASCE. Hydrologic Response of Solar Farms.

- The solar panels themselves do not have a significant effect on catchment runoff.
- If the runoff characteristics of the final ground cover under the panels is increased (increased impervious area or decreased roughness) then runoff may increase significantly.

Water Solutions, 2017. Lower Wonga Solar Q1 Renewable Energy Generation Facility Flood Study.

- There are no expected changes to the runoff volumes, peaks, or times to peak for flood events in the catchment due to all the additional surface area of solar panels provided the surface coverage is maintained.
- Considered that a healthy cover of vegetation will ensure similar levels of infiltration as currently experienced at the Project Area.

It may be concluded that so long as the Project Area vegetation conditions are maintained to pre-developed conditions, and that impervious areas are not increased substantially, additional runoff from the Project Area is unlikely to occur. Small increases in imperviousness are unlikely to increase peaks due to hydrograph timing effects. However, without specific details on the layout and structures to be built, conclusions at the Solar Farm the impact can only be inferred.

4 Flood Emergency Management

4.1 Severe Weather Warnings

The Bureau of Meteorology has a range of severe weather warning systems appropriate for use in the operation of the solar farm. It is recommended that operations staff have access to the following facilities for early severe weather warnings:

- The "**BOM Weather**" application provides severe weather warnings, summaries listed by State, and live updates. Other information provided by the application such as radar and forecasts is also useful.
- The BOM "**RSS feeds**" (Really Simple Syndication) is an information system which provides the latest weather information and may be issued any time. RSS feeds has a Land Warning feed for NSW, which can provide up-to-date information as soon as it becomes available to desktop and mobile devices. See: http://www.bom.gov.au/rss/

During heavy weather warnings, ABC Radio announce information on flood affected areas and road closures. Radio and BOM information should be reviewed frequently for potential major flooding and road closures.

4.2 Notification of Staff at Risk from flooding

Facility members and visitors can be notified of potential flooding, road and facility closure via several mechanisms:

1. Staff severe weather applications (above)
2. "Group Text" (message) notification via mobile phone, sent to all members;
3. Group email;
4. Individual telephone notifications.

4.3 Evacuation Route

ESCO Pacific is to plan the evacuation routes, taking into account zones of high flood hazard shown in Appendix A.

4.4 Consultation

Local Government

As the Project Area is largely free from regional riverine flooding, and as flood warning times are significant, consultation has presently not been undertaken directly with Council officers or staff. Staff are not required to be present at the Project Area O&M facility during large flood events.

State Emergency Services (SES)

As noted above the Project Area is largely free from regional riverine flooding, and as flood warning times are significant, consultation has presently not been undertaken directly with the State Emergency Service (SES). The assessment confirms that early flood warning, evacuation time, and flood evacuation routes are realistically achievable for the Project Area, without placing additional burden on SES staff.

4.5 Flood Emergency Management Procedures

At this point in time, it is not considered warranted to produce detailed Emergency Management Procedures for flood emergency. However, it is proposed that detailed Emergency Management procedures be developed in due course, covering but not limited to the following.

Roles and Responsibilities
It is noted that further details and specific procedures need to be developed for the Project Area, and this report clearly lays the foundation for these procedures and demonstrates that flood warning and evacuation of the Project Area is realistically achievable. The initial requirement for the procedures will need to identify roles and responsibilities:

1. Who has legal responsibility for the maintenance and implementation of the Flood Emergency Management Plan;
2. The specific roles and responsibilities of the business owner or facility manager;
3. Whether there are Flood Duty Officers on-site and their roles and responsibilities;
4. Roles and responsibilities of all facility users including public and members.

Procedures for Before, During and After a Flood
Flood emergency management procedures and training will be crucial for staff and management working at the facility, but also a formalised induction will be required for new members. The development of future WHS Procedures (recommended to be undertaken by a WHS specialist), Staff Training and Inductions should include at a minimum but not be limited to:

1). At all times

1. Annual testing (e.g., drills) of FEMP procedures, including annual review and update;
2. Adequate resourcing of the FEMP, including designated trained flood duty officers;
3. Staff and club member induction accreditation;
4. Monitoring of weather conditions and warnings, weather forecasts;
5. Create and annually update the emergency contact list;
6. Ensure all equipment and resources to implement the FEMP are available and in working order.

2). When a flood is likely

1. The FEMP manager monitors the official warnings, selected response triggers and warning system;
2. Facility occupants are notified of the possibility of flooding and reminded of actions and procedures should an emergency response be required;
3. If early evacuation is the selected response action, the selected means of transport is provided, and evacuation occurs before cut off time;
4. If sheltering in place is the selected response action stocking or food and medications is undertaken by occupants according to the maximum possible duration of isolation;
5. Other resources are brought in as required by the FEMP;
6. Movable objects are secured, and chemicals lifted above PMF level;
7. Outdoor activities are suspended;
8. Safety equipment is checked.

3). During a Flood

1. The FEMP manager monitors the official warnings, response triggers and warning system;
2. Evacuations cease, and no one leaves the premises until all clear is given by emergency services;
3. Members who are not on the premises at the time are notified not to try and reach the premise;

4. FEMP manager provides regular updates on the situation to members.

4). After a Flood

1. Check the building structural integrity before evacuees can return to the premises (a qualified structural engineer may be required);
2. Check the safety and function of services before evacuees can return to the premises;
3. Organise a safe clean-up;

Review the FEMP to account for lessons learnt.

5 NSW OEH Flood Assessment Criteria

Criteria	Response
13. The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: • Flood prone land (i.e., any land below the PMF) • Flood planning area, the area below the flood planning level (i.e., Designated Flood Level incorporating asset risk) • Hydraulic categorisation (floodways and flood storage areas) • Flood Hazard	[Item 13] Refer to Section 2.3 of the report and Appendix A for the flood event mapping. Only the flood inundation and hazard categories are appropriate for the Project Area.
14. The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% Annual Exceedance Probability (AEP), 1% AEP flood levels and the probable maximum flood, or an equivalent extreme event.	[Item 14] Refer to Section 2.3 for events modelled. The PMF event is normally mapped to identify "Flood Prone Land" in the context of a floodplain, and therefore was not required for the Project Area which experiences "overland sheet flow".
15. The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios: Current flood behaviour for a range of design events as identified in 10 above. This includes the 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	[Item 15] Refer to Section 2.3 for events modelled. In consultation with ESCO, it is proposed that significant earthworks are generally not required for the Development Area or solar panel installations. Roads planned within the Development Area are to be designed to ensure overland flow is not re-directed. Building and infrastructure pads will not be positioned within concentrated overland flow. The development will not adversely increase or re-direct flooding at neighbouring properties.
16. Modelling in the EIS must consider and document: a. The impact on existing flood behaviour for a full range of flood events including up to probably maximum flood. b. 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, hazards and hydraulic categories. c. Relevant provisions of the NSW Floodplain Development Manual 2005.	[Item 16 a] The events, 4.9% AEP (1:20yr), 1% AEP (1:100yr) and 0.1% AEP (1:1000yr) event were simulated, however simulation of a PMF is not warranted for overland sheet flow where impacts are negligible. See Section 2.3 for further discussion. [Item 16 b] No impacts due to overland sheet-flow nature of flooding, and also no increase in runoff (see Section 3). [Item 16 c] Impacts and flood hazard low, floodplain storage preserved.

17. The EIS must assess the impacts 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.	[Item 17 a] Flooding was overland sheet flow in nature. No impacts on neighbouring properties due to flow obstruction (blockage) or increased imperviousness (see Section 3).
b. Consistency with Council Floodplain Risk Management Plans. c. Consistency with any Rural Floodplain Management Plans. d. Compatibility with flood hazard of the land.	[Item 17 b-d] No flood studies or management plans were identified for the Project Area. Flood hazard is very low thus compatible with most developments.
e. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	[Item 17 e] Solar farm does not alter floodplain characteristics and is an appropriate development for the nature of flooding experienced (overland sheet flow), see section 2.7 for details.
f. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	[Item 17 f] The development site will not alter beneficial inundation of the floodplain well downstream.
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. h. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.	[Item 17 g] Not due to the solar farm itself, however this issues also to be addressed in construction planning. Riparian vegetation or river banks or water courses are not present in the Project Area [Item 17 h] No flood emergency management issues. Refer to Section 4 on emergency management. SES and Council will be provided with a copy of this report.
i. Whether the proposal incorporates specific measures to manage risk to life from flooding. These matters are to be discussed with the SES and Council. 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 SES.	[Item 17 i] The Risk to life from flooding is low, however some emergency management recommendations are made to assist transport away from the Project Area. Refer to Section 4 on emergency management. SES and Council will be provided with a copy of this report [Item 17 j] Recommendations made in Section 4. The 0.1% AEP (1000yr ARI) event was simulated as a proxy to the PMF. Refer to Section 4 on emergency management. SES and Council will be provided with a copy of this report [Item 17 k] No impacts are expected. See Section 3.
k. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	

6 Conclusions & Recommendations

This investigation has been undertaken in order to support an EIS for the initial Project Area precinct of the Wyalong Solar Farm, having a total precinct area of approximately 255 ha. The NSW Office of Environment and Heritage (OEH) has requested a Flood Study to assess several criteria pertaining to flood immunity, floodplain impacts, safety and emergency management. Response is made to individual criteria in Section 5, being underpinned by the main body of this assessment.

Local catchment (or overland flow) flood modelling was undertaken for the Project Area to provide guidance on the planning of internal infrastructure and to assess the external impacts of the Project Area. Riverine or Creek flooding was not identified by the investigation.

Flood emergency management was investigated in detail, including such elements as severe weather warnings and river flood levels (early warning), notification of staff, communication protocols and sources of up to date information, evacuation, and emergency management procedures.

In responding to specific OEH Flood Assessment Criteria in Section 5, the following conclusions were made in general:

a) Flood prone areas have been mapped, appropriate flood planning levels identified, and hydraulic hazard categories identified. Medium to high risk infrastructure in the Project Area should have a high level of flood immunity and be elevated above appropriate designated flood levels (including a freeboard allowance).

b) The Project Area will have no impact on flooding due to flow obstruction or blockage. The Project Area earthworks do not include any infilling or depletion of floodplain storage. The Project Area is not expected to increase runoff, provided developed case vegetationb and land cover provides similar levels of infiltration and retardance. Recommendations on the level of flood immunity required in the detailed design of infrastructure should be undertaken by civil designers in consultation with ESCO Pacific.

c) The Project Area is not expected to have any impact on existing community emergency management arrangements and is not expected to place any burden on Council or SES staff. Consultation with Council and SES was not considered to be warranted at this point in the assessment, however will be undertaken on development of internal WH&S procedures at a later date. Normal emergency management procedures are to be employed with respect to flooding. Flood warning times are reasonable, and staff are not required to be on-site during flood conditions.

d) The Project Area experiences shallow overland sheet flow, low hazard ratings, and is not expected to sustain flood damages during major flooding. Social and economic consequences due to the impact of flooding on the Project Area are expected to be negligible.

RECOMMENDATION: In summary, the findings of this Flood Study demonstrate that the Project Area solar development should meet OEH's recommended policies and assessment criteria, as impacts on the surrounding floodplain are considered to be negligible or NIL. Furthermore, risk to human life and infrastructure is considered to be low during large floods, and no additional burden is placed on Council or State Emergency Services staff.

With respect to flooding, construction of the facilities (for example, O&M Building, Switchyard and Battery Storage Area) could be positioned anywhere along the transmission line provided they are located outside or elevated sufficiently above overland flood zones. Buildings and other infrastructure are not to be located in concentrated overland flow and must have sufficient freeboard above an appropriate designated flood level. If located within flood zones, facilities should be suitably designed to address for example (but not limited to) flood immunity, erosion, structural, and safety issues. At some locations staff may need to cross one or more overland flow paths when vacating the Project Area. Vehicle crossings will need to be provided to allow safe entry and egress, and designed to appropriate standards and safety criteria.

7 References

AECOM, 2012, County of San Diego, “*Preliminary Hydrology and Drainage Study for Teirra Del Sol Solar Farm*”, sourced from: https://www.sandiegocounty.gov/content/dam/sdc/pds/ceqa/Soitec-Documents/Final-EIR-Files/Appendix_3.1.5-1_PreliminaryHydrologyDrainageStudy_TDS.pdf

Beatty & Macknick & McCall and Braus, “*Native Vegetation Performance under a Solar PV Array at the National Wind Technology Center*”, ESCO Associates Inc, National Renewable Energy Laboratory, sourced from: *https://www.nrel.gov/docs/fy17osti/66218.pdf*

Cook and McCuen, 2013. Journal of Hydrologic Engineering, ASCE. Hydrologic Response of Solar Farms.

Edalat, Mohammad Masih, "*Remote sensing of the environmental impacts of utility-scale solar energy plants*" (2017). UNLV Theses, Dissertations, Professional Papers, and Capstones. 3075.

Geoscience Australia website, 2018, “*ELVIS - Elevation and Depth - Foundation Spatial Dat*a”, sourced from http://elevation.fsdf.org.au/, 02/18/2018.

Joshua Eggleton and Darren Lyons, 2016, “*Ungarie Flood Study R.N20477.001.03 Draft Report for Public Exhibition*”, BMT WBM, sourced from: *http://www.blandshire.nsw.gov.au/sites/default/files/for_comments/DRAFT%20Ungarie%20Flood%20Study%20Report.pdf*

NSW, 2005, “*New South Wales Floodplain Development Manual. Department of Infrastructure*”, Planning and Natural Resources. New South Wales Government, April 2005.

Scenic Rim Regional Council, 2017, “*Temporary Local Planning Instrument 01/2017 (Flood Hazard)*”, Scenic Rim Regional Council, sourced from: *http://www.scenicrim.qld.gov.au/documents/44179689/44249160/Certified%20Temporary%20Local%20Planning%20Instrument%20adopted%206%20November%202017.pdf*

Water Solutions, 2017, “*Lower Wonga Solar Q1 Renewable Energy Generation Facility Flood Study*”, source: https://www.gympie.qld.gov.au/documents/40033667/0/Flood%20Study.pdf

Attachment A
Flood Modelling Mapping

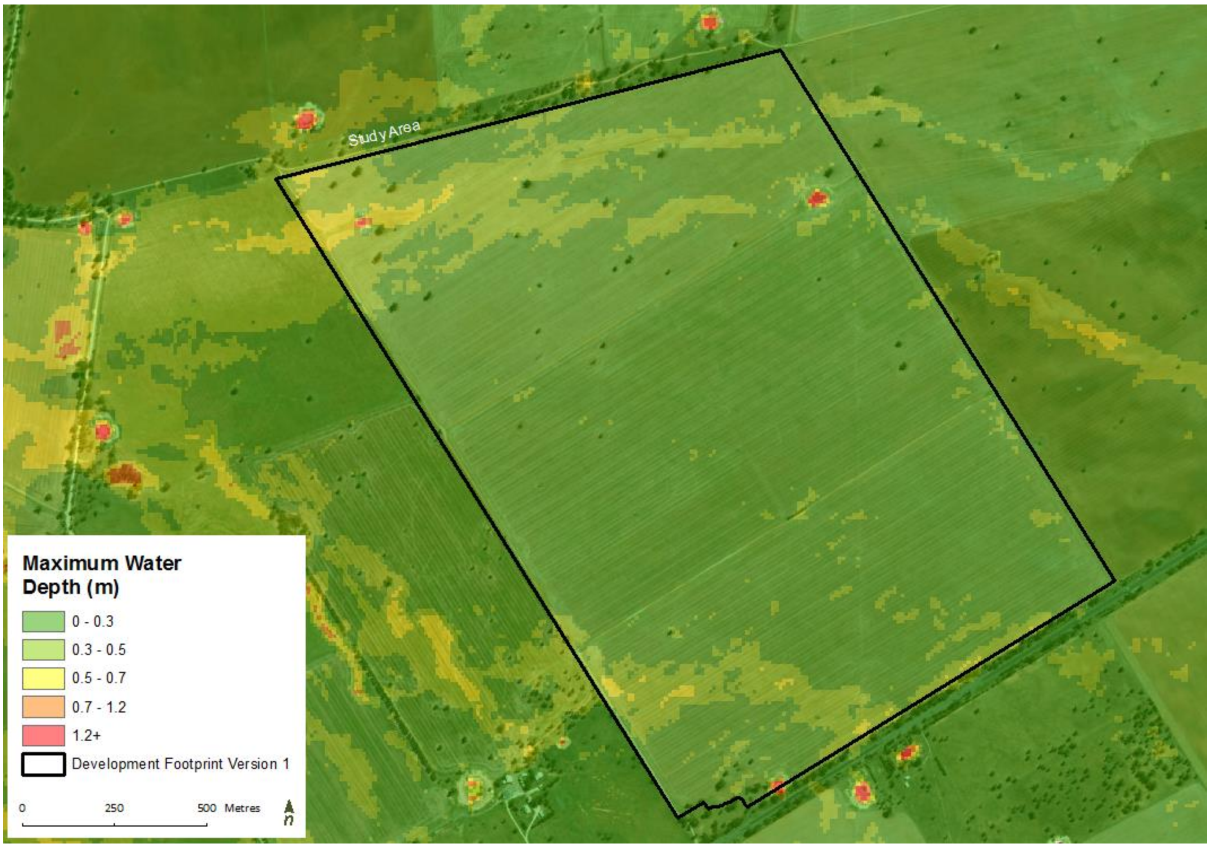


Figure 9. *4.9% AEP (20 year ARI) Flood Inundation Project Area (Note: layout is conceptual in nature)*

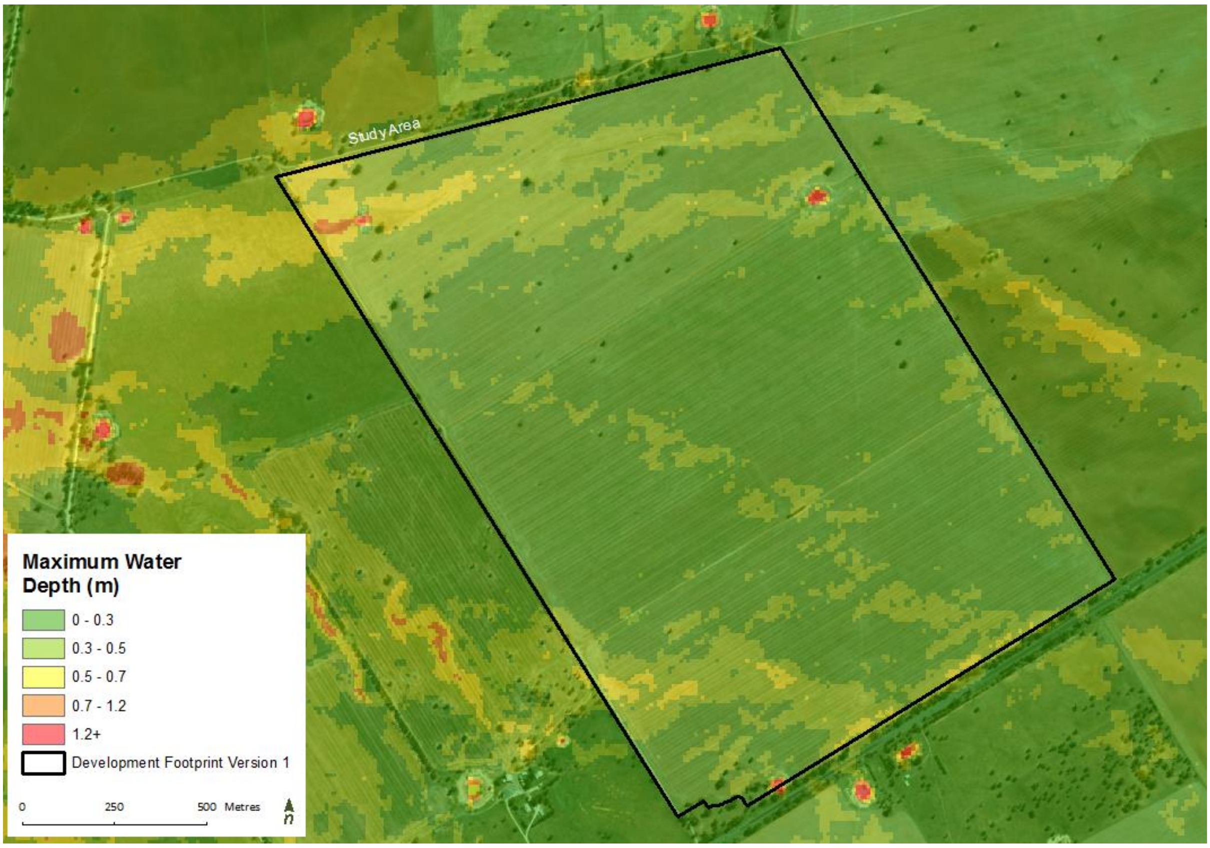


Figure 10. *1% AEP (100 year ARI) Flood Inundation Project Area (Note: layout is conceptual in nature)*

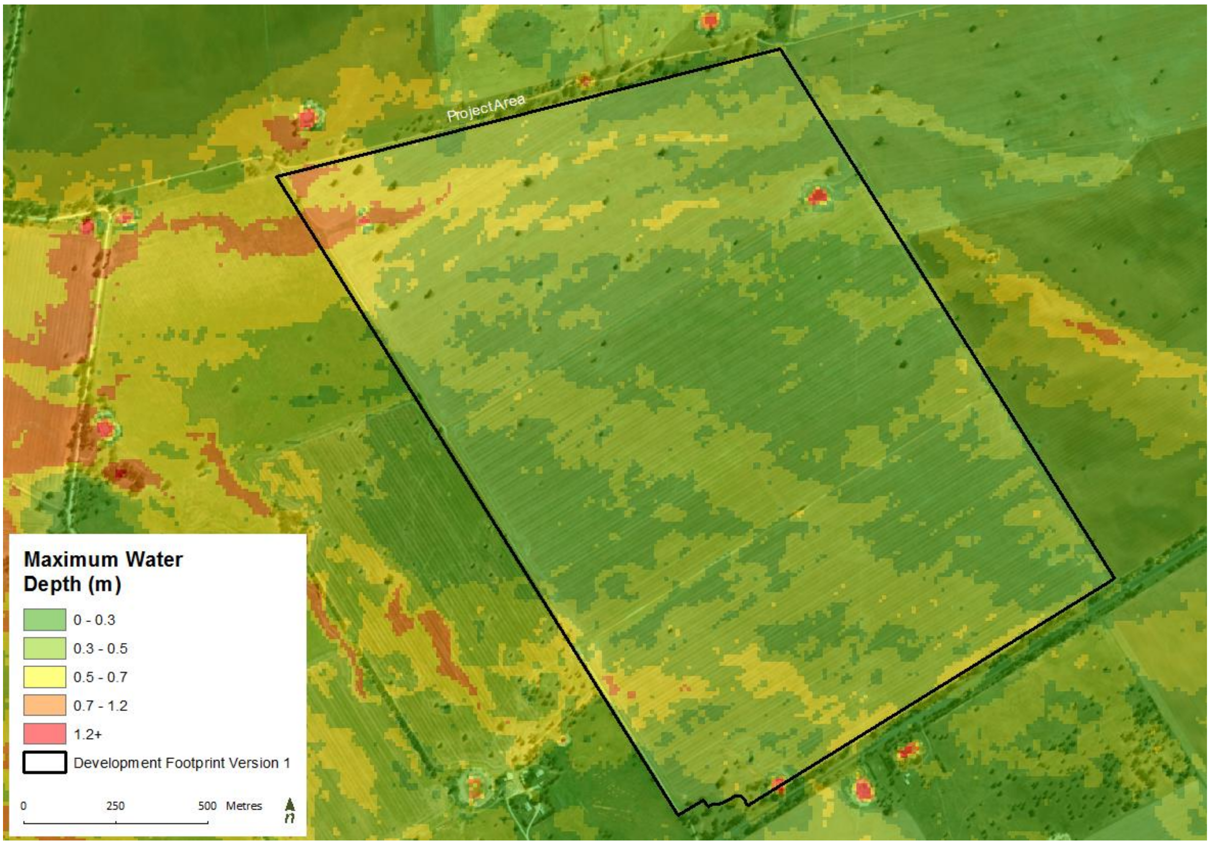


Figure 11. *0.1% AEP (1000 year ARI) Flood Inundation Project Area (Note: layout is conceptual in nature)*

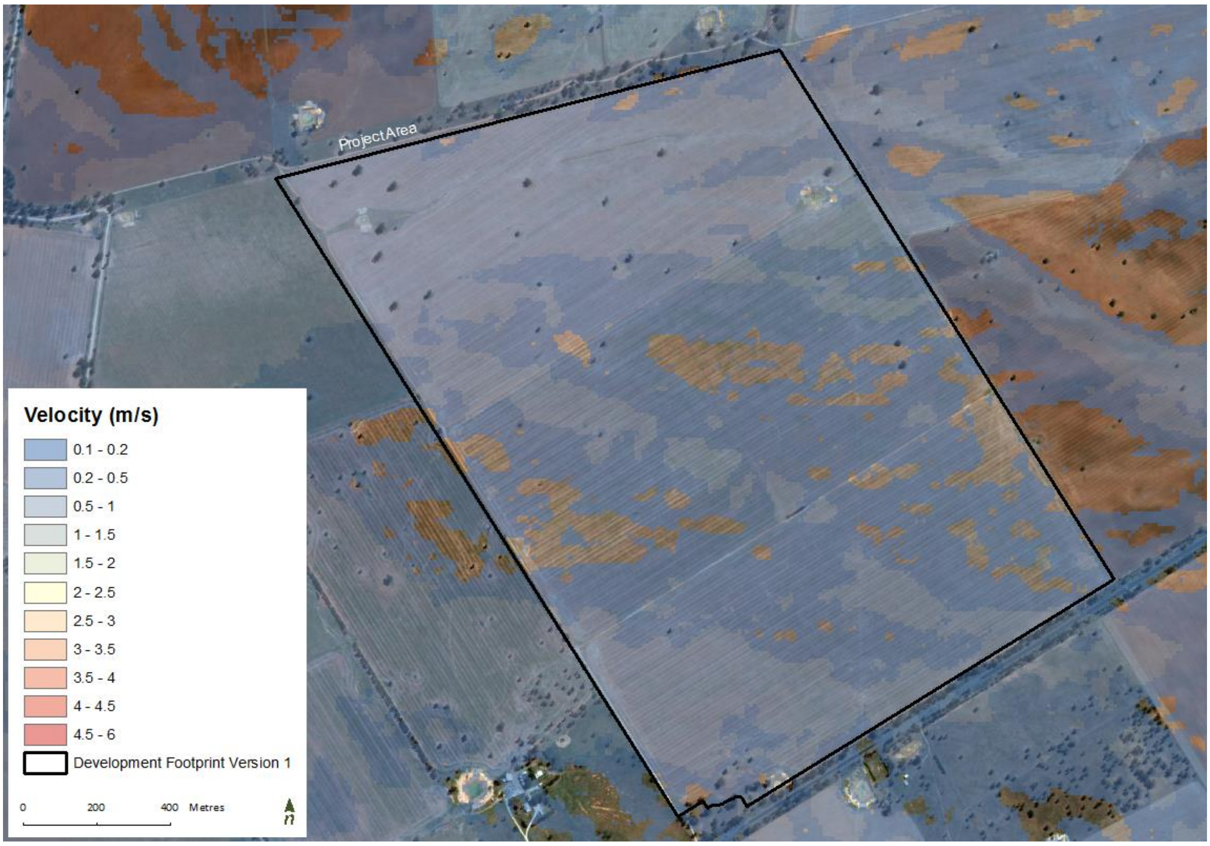


Figure 12. *4.9% AEP (20 year ARI) velocity in the Project Area (Note: layout is conceptual in nature)*

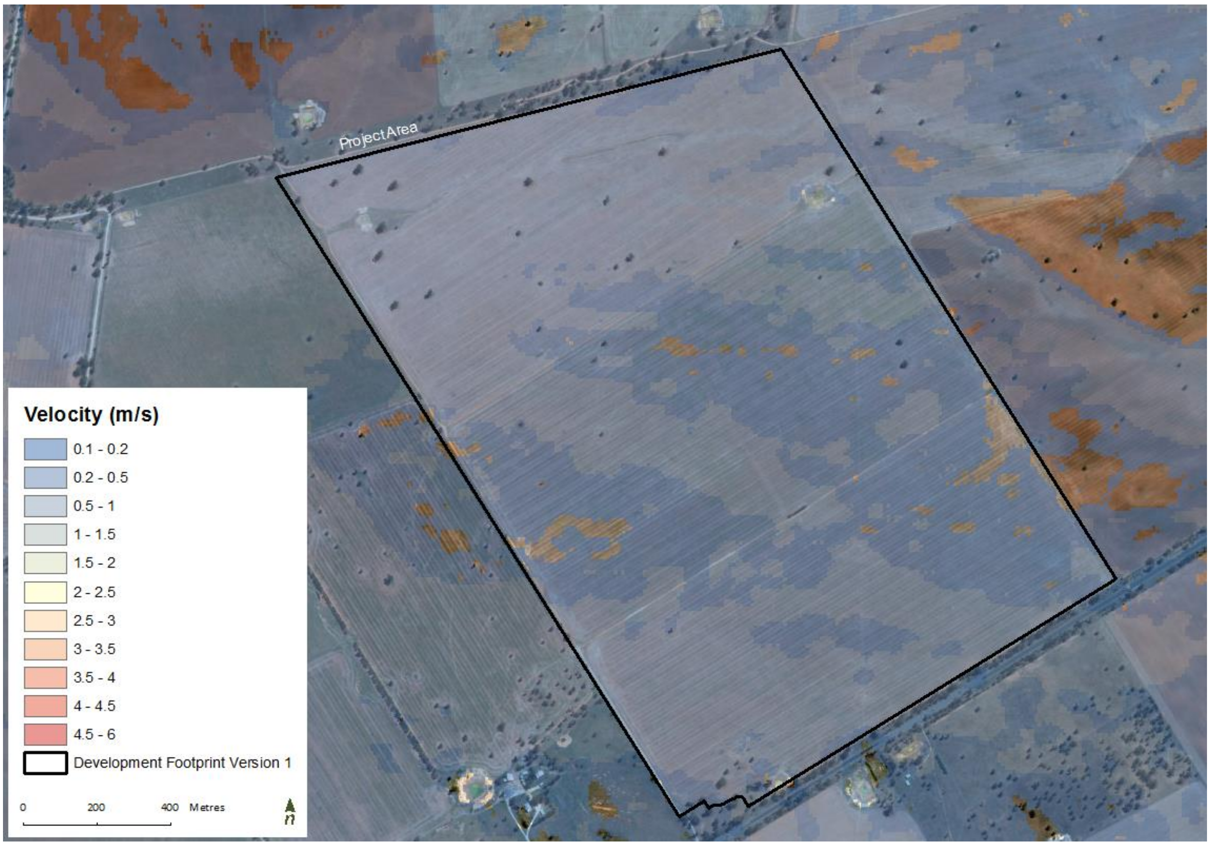


Figure 13. *1% AEP (100 year ARI) velocity in the Project Area (Note: layout is conceptual in nature)*

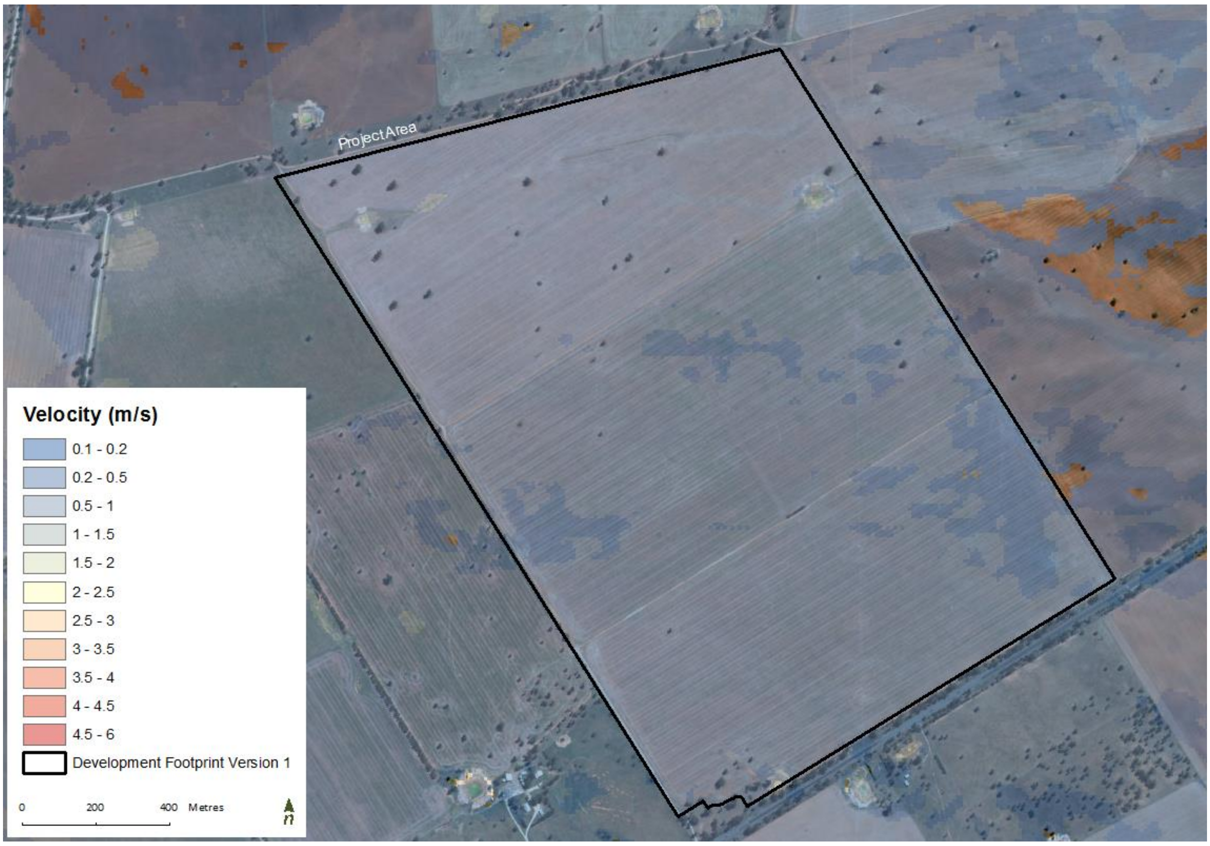


Figure 14. *0.1% AEP (1000 year ARI) velocity in the Project Area (Note: layout is conceptual in nature)*

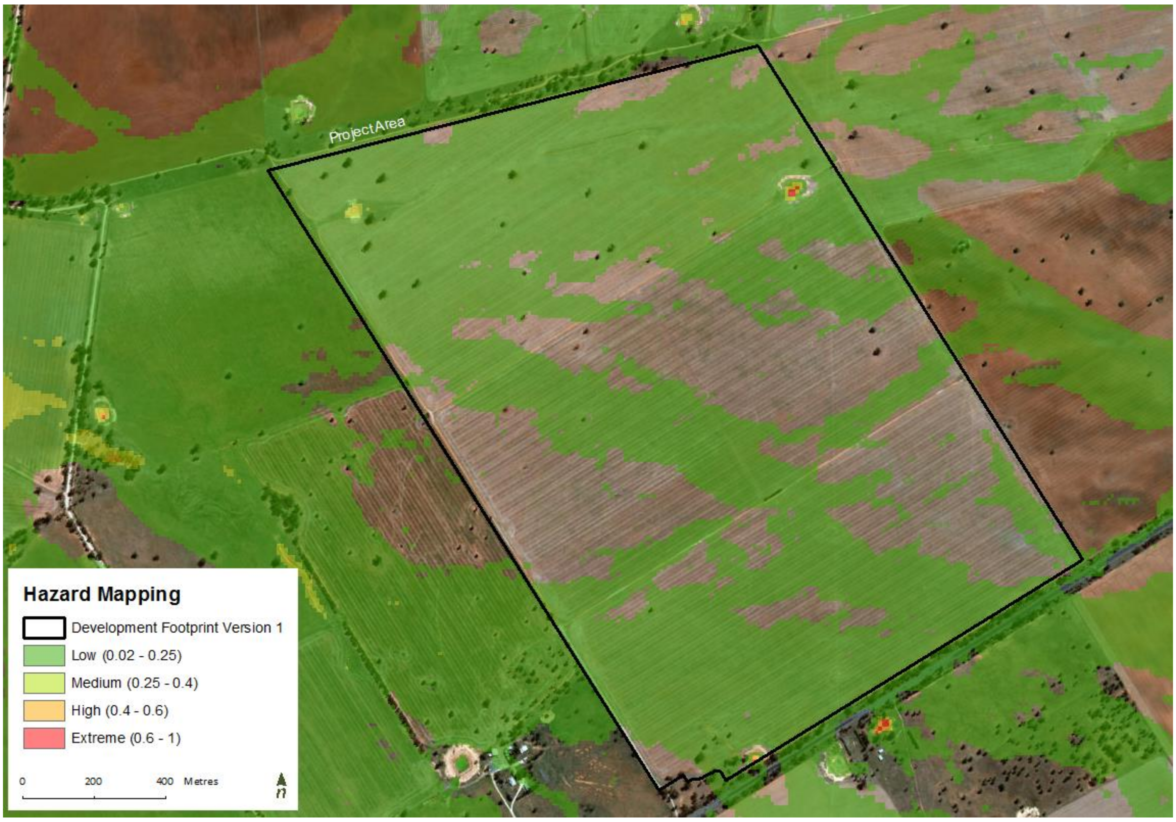


Figure 15. *Hazard mapping (D x V product) of the Project Area for the 4.9% [1:20 ARI] AEP. (Note: the footprint is conceptual in nature)*

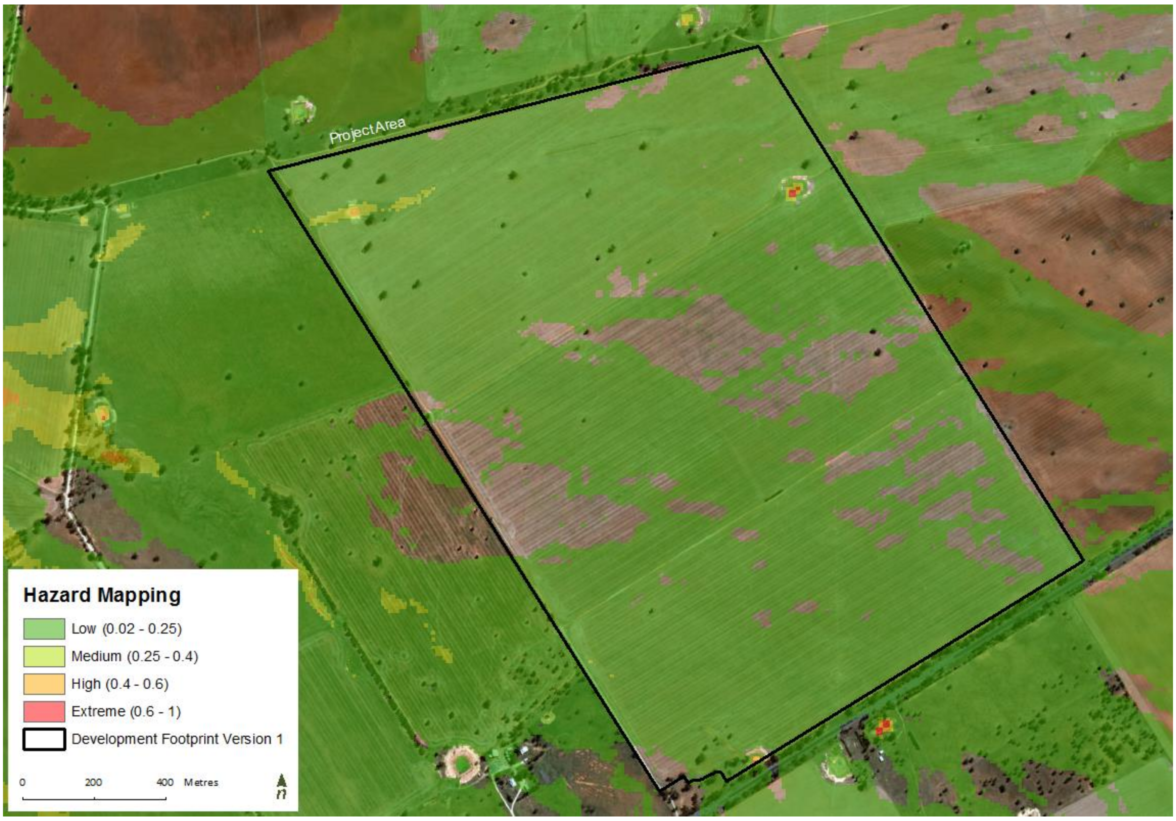


Figure 16. *Hazard mapping (D x V product) of the Project Area for the 1% [1:100 ARI] AEP. (Note: the footprint is conceptual in nature)*

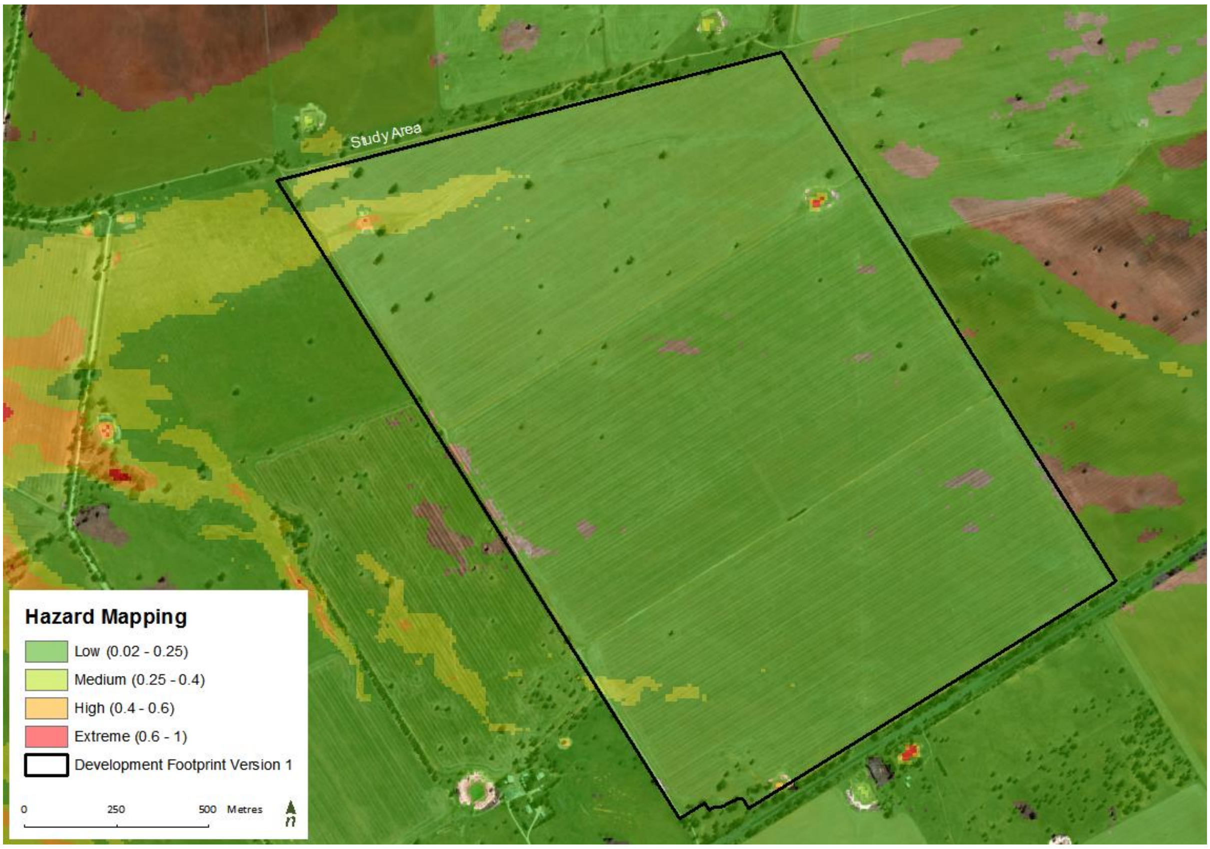
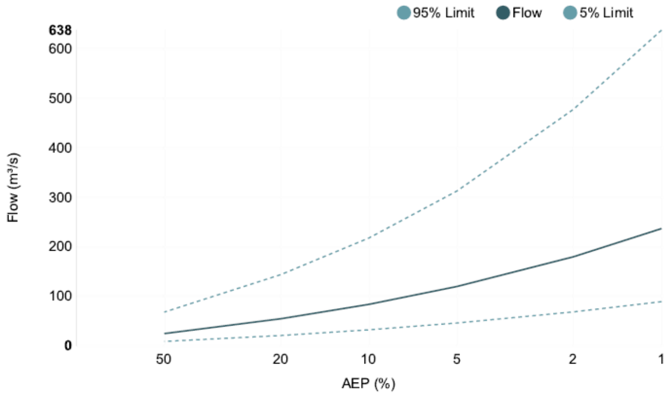


Figure 17. *Hazard mapping (D x V product) of the Project Area for the 0.1% [1:1000 ARI] AEP. (Note: the footprint is conceptual in nature)*

Attachment B
Regional Flood Frequency Estimation Model 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	24.8	9.00	68.3
20	54.8	20.9	144
10	83.9	32.4	218
5	120	46.2	313
2	180	68.7	478
1	237	89.3	638

Statistics

Variable	Value	Standard Dev
Mean	3.318	0.577
Standard Dev	0.905	0.121
Skew	0.124	0.026

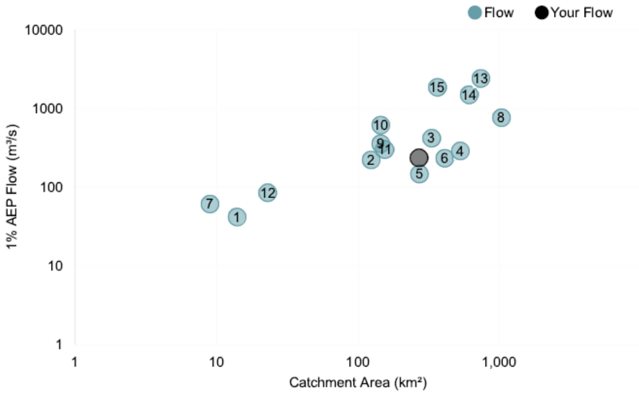
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

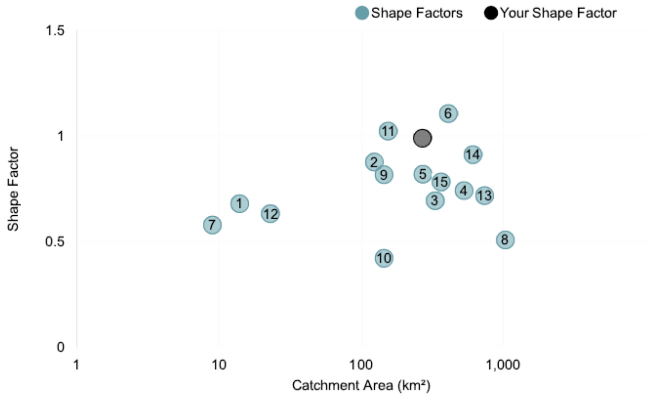
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

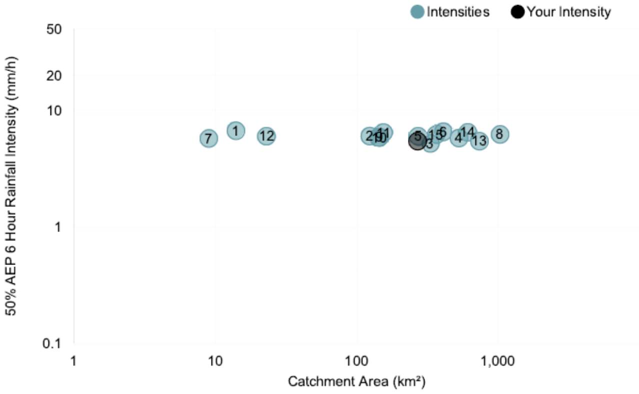
1% AEP Flow vs Catchment Area



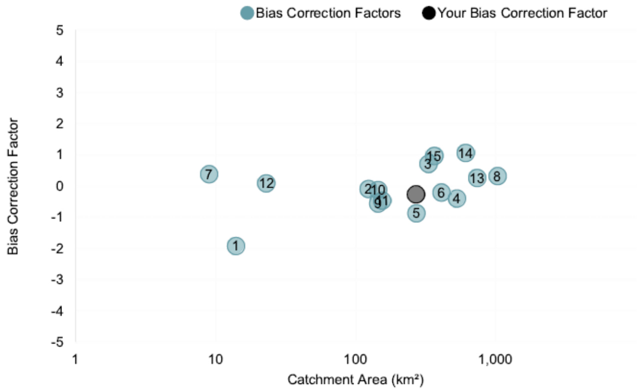
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

TXT PDF Nearby JSON

Input Data

Input Data

Date/Time	2018-10-13 21:05
Catchment Name	Catchment1
Latitude (Outlet)	-33.93622688
Longitude (Outlet)	147.4143747
Latitude (Centroid)	-33.88784228
Longitude (Centroid)	147.2476469
Catchment Area (km^2)	270.0
Distance to Nearest Gauged Catchment (km)	94.76
50% AEP 6 Hour Rainfall Intensity (mm/h)	5.473841
2% AEP 6 Hour Rainfall Intensity (mm/h)	12.786106
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.99
Interpolation Method	Natural Neighbour
Bias Correction Value	-0.261

Leaflet (http://leafletjs.com) | © OpenStreetMap (http://osm.org/copyright) contributors

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)