# Stringybark Solar Farm Hydrology Assessment

**Stringybark Solar Farm Pty Ltd**

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# Initialisms and acronyms

| Abbreviation | Description |
|---|---|
| **ARI** | Average Recurrence Interval |
| **AEP** | Annual Exceedance Probability |
| **ARR** | Australian Rainfall and Runoff 2019 |
| **AHD** | Australian Height Datum |
| **DEM** | Digital elevation model |
| **ELA** | Eco Logical Australia |
| **HEC-RAS** | U.S. Army Corps of Engineers' HEC-RAS software package, Version 5.0.7 |
| **RFFE** | Regional Flood Frequency Estimates |
| **SEE** | Statement of Environmental Effects |

# Executive Summary

Eco Logical Australia Pty Ltd (ELA) has been engaged by Infinergy-Pacific to provide a preliminary hydrological assessment of existing and proposed conditions under potential 50%, 20%, 10%, 5%, 2% and 1% Annual Exceedance Probability (AEP) flood events for the proposed Stringybark Solar Farm near Armidale, New South Wales.

Hydrologic and hydraulic modelling was conducted using the U.S. Army Corps of Engineers' HEC-RAS software package. HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis for precipitation events with a storm duration of 1 hour.

A catchment area of approximately 1.6 $km^2$ drains through the proposed solar farm site area, which will cover an area of approximately 0.9 $km^2$. To facilitate the development, some vegetation removal associated with the construction of the solar array will be required at the northern end of the site, however this is not expected to affect local rainfall-runoff relationships. An increase in impervious area across the site of less than 0.5% (0.01 $km^2$), will similarly have minimal to negligible impact on rainfall-runoff relationships and hence negligible additional impact (<0.3% for the peak 1% Annual Exceedance Probability (AEP)) on potential flooding or flow velocities. This level of catchment change is within the error margins of the modelling and was not included within the 2D rain on grid analysis to determine flooded areas as the overall infiltration parameters on the site are not expected to change as a result of the development.

Preliminary modelling indicates that the only hydrological changes that will occur (as a consequence of the establishment of the proposed solar farm) would be minimal changes to flow characteristics within the existing drainage lines when compared to current conditions. The majority of the Site is not prone to flooding and there is no sheet flow. Within the drainage lines, modelling indicates the removal of farm dams within the drainage lines may result in localised changes in flow velocity. For example, for the 1 in 100 year flood event, with all existing dams removed from within the PV Array Area (as detailed in the SEE), the unmitigated peak flow leaving the Site would potentially increase from 28.6 $m^3/s$ to 31.6 $m^3/s$. The relatively small volumes of water predicted for the 1 in 100 year flood event, both pre- and post- development, reflect the small catchment area within which the Proposal is located. As such, the difference between pre and post-development flows is not considered to be significant.

Velocities in the primary flow paths are generally sufficiently low to avoid armour rock requirements in the channels up to the 1% AEP event. Some concentrated flow paths exhibit erosive forces in localised channel entrance areas. Regular maintenance activities, including sediment removal in internally draining areas and scour repairs at culvert inlets and outlets, would likely be required after significant flood events. The implementation of mitigation measures, such as drop structures and detention ponds, as outlined in *Managing Urban Stormwater: Soils and Construction* (the Blue Book), would be used to mitigate effects, resulting in negligible downstream impacts as a result of the Proposal.

Further detailed assessment should be undertaken as part of detailed design to refine the findings of this assessment and identify specific locations that may require stormwater management.

# 1. Introduction

Eco Logical Australia Pty Ltd (ELA) has been engaged by Stringybark Solar Farm Pty. Ltd. to conduct a preliminary hydrological assessment of existing and proposed conditions under potential 50%, 20%, 10%, 5%, 2% and 1% Annual Exceedance Probability (AEP) flood events for the proposed Stringybark Solar Farm (the Proposal) near Armidale, New South Wales.

This report describes the modelling approach for the development of potential flood depths, inundation extents and flow velocities under existing and proposed indicative conditions. As such, this modelling assessment should be considered preliminary and conservative as:

1. It incorporates an indicative design for the Site (**Figure 1-1**); and
2. Conditions and modelling parameterisation have been set up to provide a conservative assessment of hydrologic outcomes.

That is, modelling to refine results for the detailed design is likely to indicate reduced impacts (if any) compared to the results presented here.

Further flood modelling, undertaken post consent as part of detailed design, would be used to refine mitigation actions, such as inclusion of flood detention structures, to ensure potential off-site impacts are fully mitigated. These flood mitigation structures will be designed in accordance with relevant water management legislation to ensure that they do not unnecessarily retain water on site, to the detriment of downstream ecosystems and water users.

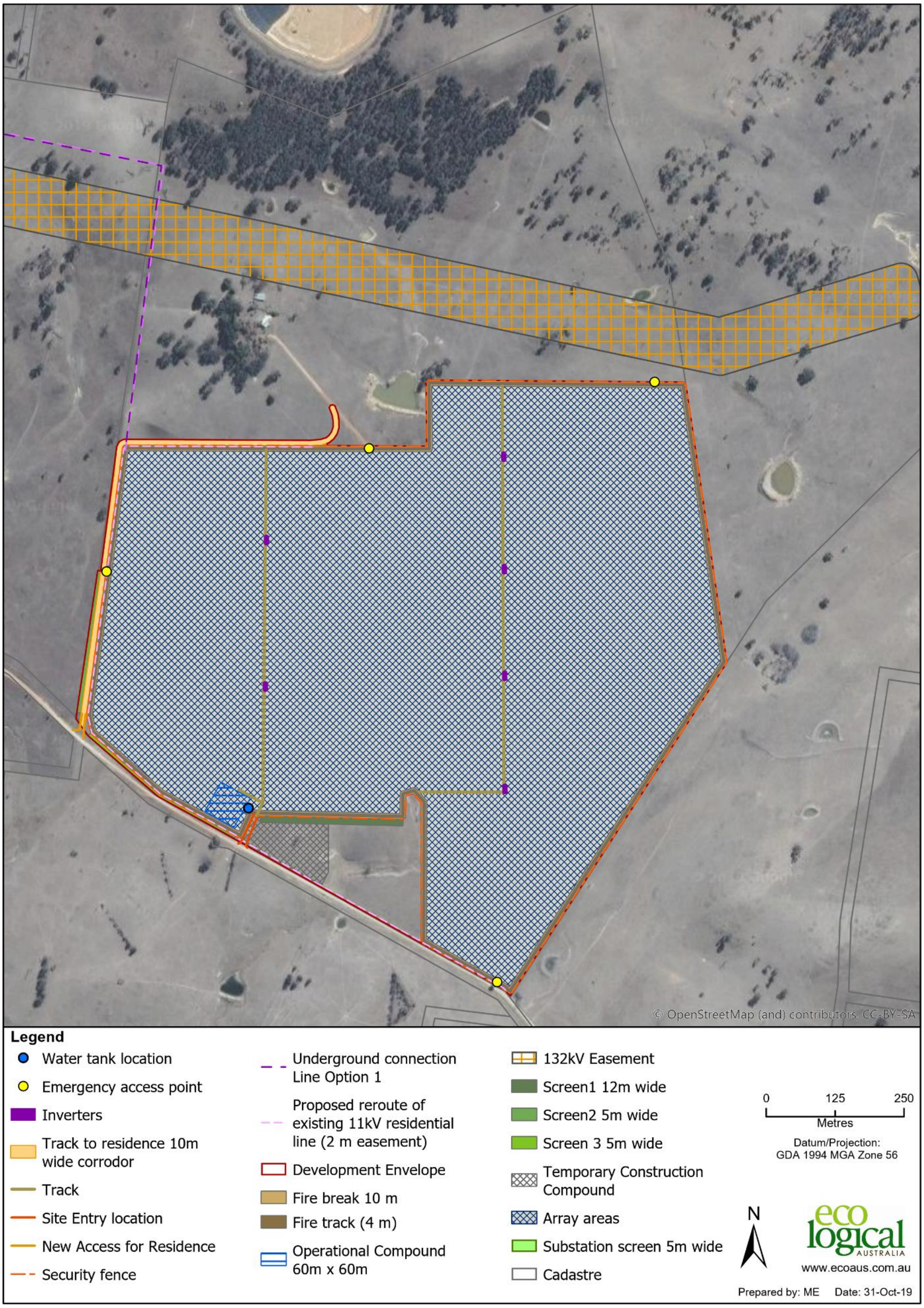


**Figure 1-1: Indicative Proposal considered for this hydrological assessment**

# 2. Model setup

This section outlines the hydrologic and hydraulic model setup for determining rainfall-runoff relationships and flow characterisation across the Proposal site. Hydrologic and hydraulic modelling was conducted for existing and proposed catchment conditions using the U.S. Army Corps of Engineers' HEC-RAS software package, Version 5.0.7 (USACE 2019). HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis for 50%, 20% 10%, 5%, 2% and 1% AEP precipitation events.

## 2.1 Catchments and drainage

The Proposal is intersected by local watercourses and overland flow paths that drain approximately 1.6 $km^2$ of contributing catchment area, including the Development Envelope. There are a number of on-site farm dams that capture drainage and reduce the erosion potential across the site under existing conditions. Under the proposed conditions formed access tracks, buildings, and inverters will be developed on the Site and the dams within the development area will be removed to accommodate solar panels.

**Figure 2-1** shows the contributing catchment area draining toward and through the Site, with indicative flow directions highlighting the principle entry and exit locations of drainage channels.

## 2.2 Inflow

Intensity-Frequency-Duration (IFD) rainfall information was sourced for the Site from the Bureau of Meteorology (BOM, 2016) on 1 October 2019 for coordinates 36.5678°S and 151.7853 °E. **Figure 2-2** shows the IFD curves for the defined 'frequent and infrequent' events (63.2% to 1% AEP), corresponding approximately to the 1 in 2 year to 1 in 100 year Average Recurrence Interval (ARI) events, respectively.

Based on the IFD data, a centrally loaded, nested frequency artificial storm (**Figure 2-3**) was developed for use in the hydraulic model, providing an unsteady time series inflow boundary condition. This frequency storm pattern is developed by placing the highest 1-minute-duration rainfall (highest intensity) in the centre of the storm and adding each increasing duration (with successively lower intensities) to the precipitation hyetograph.

Preliminary model runs were developed to determine the catchment response time, with a corresponding rainfall duration that produces the highest peak flow rates across the site. This initial catchment response assessment led to the adoption of a 1-hour synthetic storm, with the peak rainfall intensity occurring 30 minutes from the beginning of the simulation.

It should be noted that BoM IFD data vary for individual points in the catchment and areal reduction factors are typically applied to average the intensities across catchments. In this case, a conservative approach was taken, whereby no areal reduction factor was applied. This approach thus assumes that the highest point rainfall intensities occur across the entire catchment.

Initial and continuing losses of 11 mm and 3.9 mm/hour, respectively, were derived from the Australian Rainfall and Runoff (ARR) data hub. Regional Flood Frequency Estimates (RFFE) were developed (**Appendix A**) for comparison to rain-on-grid results. The rain-on-grid results show higher peak discharge rates than the RFFE approach – *see* **Section 3.1**. The rain-on-grid results are therefore considered to be conservative.

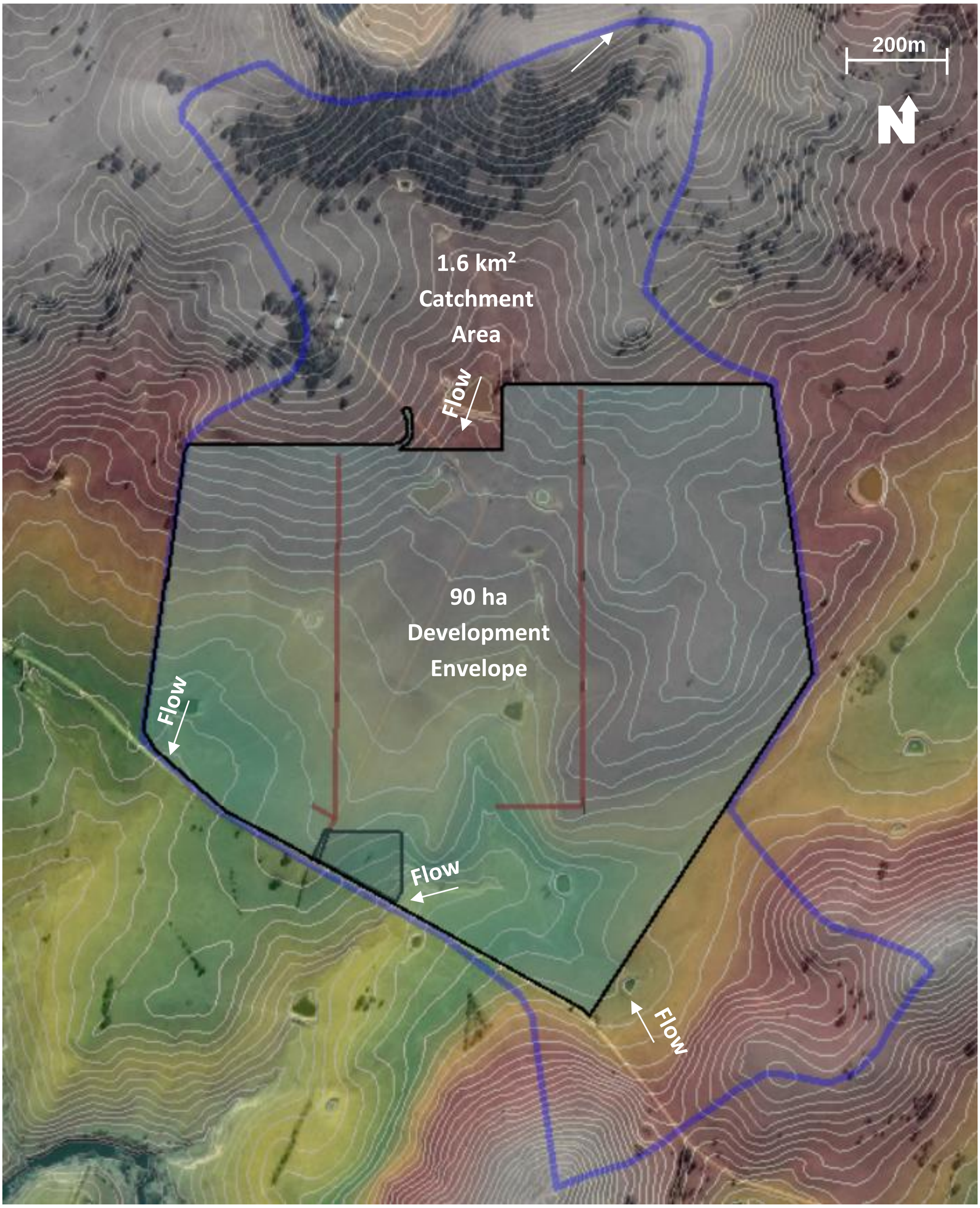


**Figure 2-1 Stringybark Solar Farm contributing catchment area**

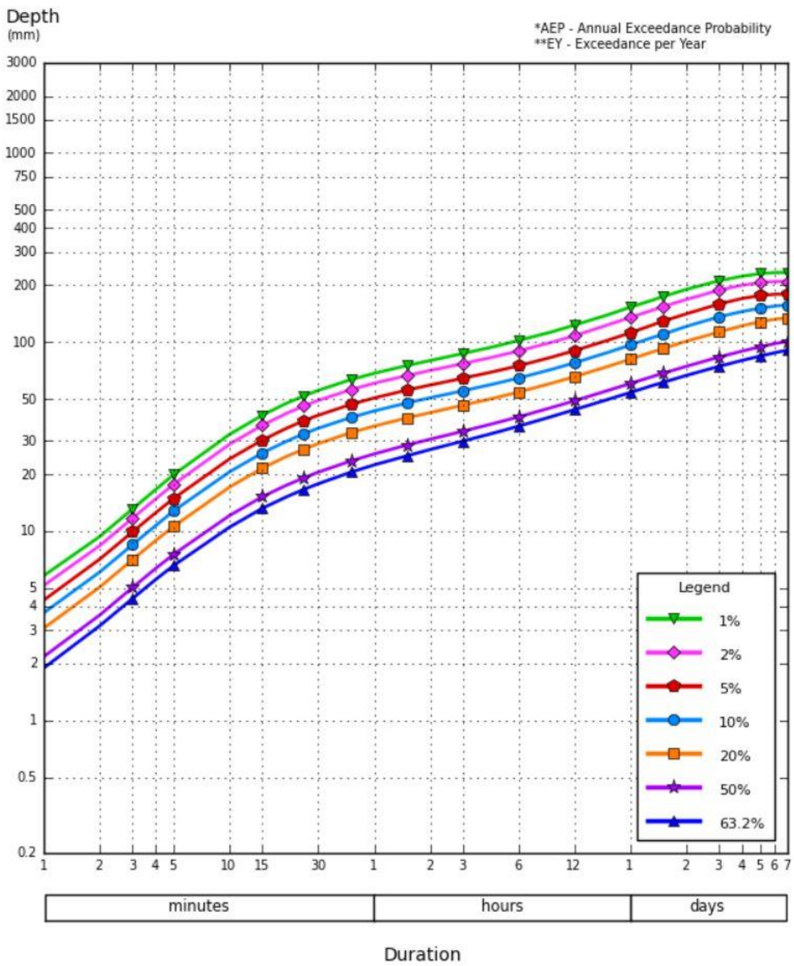


**Figure 2-2 BoM IFD data for frequent, infrequent, and rare design rainfalls**

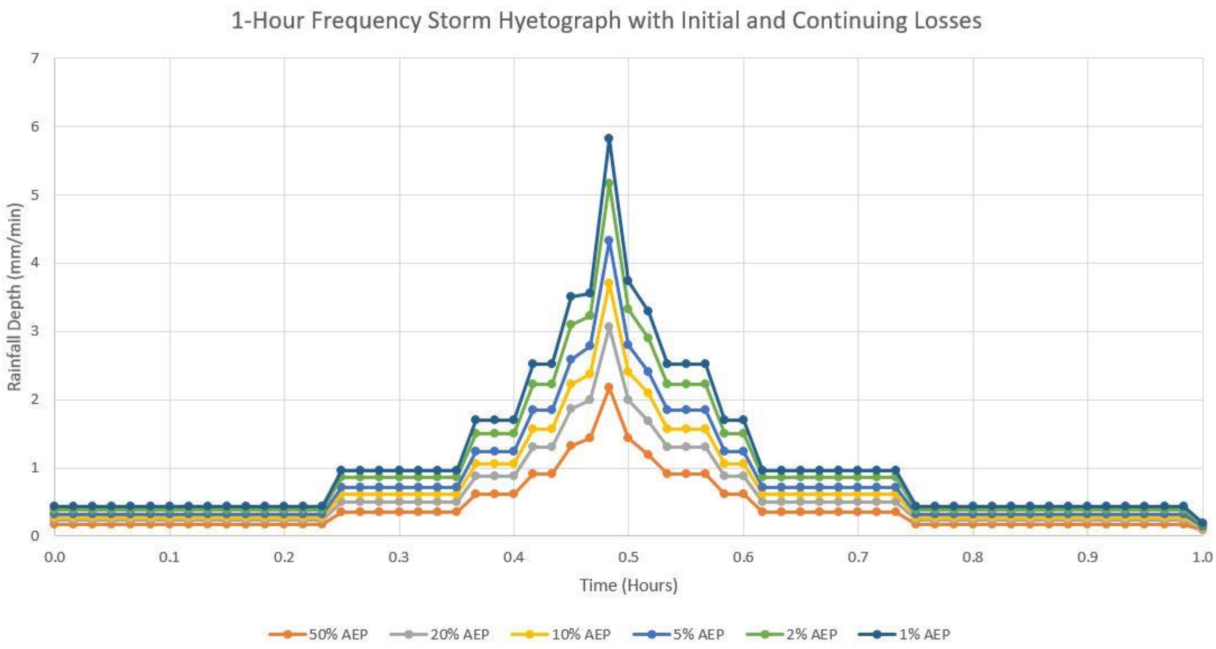


**Figure 2-3 Frequency storm values applied to 2D flow area**

## 2.3 Outflow

The downstream outlet was set to a normal depth boundary condition, using a uniform bed slope of 0.1% as the estimated energy slope, as measured from the available terrain data.

## 2.4 Terrain

The modelled terrain is based on 2-metre by 2-metre resolution raster grid digital elevation model (DEM) data compiled from Geoscience Australia's elevation foundation database combined with local 50 cm site DEM data. A smoothing process was applied where the two datasets were joined to provide a smoother transition between the two DEM surfaces. An additional terrain surface was developed for the proposed condition with farm dams removed.

## 2.5 Computational Mesh

A two-dimensional (2D) flow area was delineated in HEC-RAS to coincide with the catchment boundary. The downstream boundary of the 2D flow area was extended downstream of the Site boundary in order to capture any backwater effects if evident. The modelled 2D flow area covers an area of approximately 2 $km^2$. A computational mesh spacing of 10 metres by 10 metres was applied across the catchment, varying to 5 metres by 5 metres in the vicinity of the site. HEC-RAS recognises the sub-grid terrain resolution within individual computational cells, and the flow transfer calculations between individual grid cells account for the geometry of the underlying surface at the terrain resolution of up to 50-cm by 50-cm where applicable across the site area. Break lines were delineated along creek channels, roadways, drains, and bunds to align cell faces along crest and channel thalweg alignments.

## 2.6 Roughness

A roughness coefficient of 0.08 was uniformly applied to the 2D flow area. This roughness value exceeds typical channelised roughness recommendations but is more appropriate for use in a rain-on-grid analyses due to the relatively shallow sheet flow depths across the catchment.

A range of Manning's roughness coefficients was applied to the model as a sensitivity analysis, with coefficients ranging from 0.06 to 0.12, to account for potential differences arising from the highly variable flow depths, vegetation coverage and uncertainties in the modelled area considering the lack of calibration data. Water surface levels were found to be relatively non-sensitive to the roughness coefficient, with predicted depth changes of approximately 5-10% corresponding to a 20% decrease in roughness.

## 2.7 Hydraulic Structures

No culverts, bridges, or other hydraulic structures were included within the modelled area.

## 2.8 Computational Settings

An adaptive computational time step was applied based on a maximum Courant Number of 3.0 as recommended in the HEC-RAS user manual, resulting in an average adopted time step of approximately 5 seconds. The Full Momentum equation set was adopted in order to account for the varying flow directions. Mass balance errors and water surface elevation convergence errors were checked for model stability and to confirm that imbalances remained below reasonable thresholds for model stability (in this case within 0.2% for mass balance and within 1 cm for water surface elevation convergence). A 2-

hour simulation window was applied to capture peak discharges and allow the flood peaks to propagate through the model.

Default threshold depths were decreased by one order of magnitude in order to capture the flow transfer effects of direct precipitation sheet flow across the catchment.

Except where otherwise noted, other program defaults have been applied to all remaining coefficients, options, tolerances and model settings.

## 2.9 HEC-RAS Model Summary

**Table 2-1** summarises the model parameters used for the selected HEC-RAS model runs.

**Table 2-1: Summary of model parameters**

| Model Parameter | Value |
|---|---|
| **Inflow** | Nested 50%, 20%, 10%, 5%, 2% and 1% AEP frequency storm excess precipitation hyetographs |
| **Outflow** | Normal depth slope of 1.3 to 2.5% |
| **Simulation window** | 2 hour |
| **Computational time step** | 2-5 seconds |
| **Computational mesh grid** | 5 metres to 10 metres |
| **Roughness** | 0.04 – 0.10 |
| **Equation set** | Full momentum |
| **DEM grid resolution** | 0.2 metres – 2 metres |

# 3. Hydraulic Results

## 3.1 Peak discharge

**Figure 3-1** through **Figure 3-4** show indicative hydrographs immediately downstream of the site based on rain-on-grid estimations for existing and proposed conditions. Peak discharge is tabulated for the different events in **Table 3-1**, under existing (dam) and proposed (no dam) landscape conditions. Note that the no dam conditions only removes dams currently within the Development Envelope.

**Table 3-1: Peak outflow (off-site) discharge from the prominent discharge outlets under indicated rainfall return events**

| Stringybark peak outflow discharge ($m^3/s$) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2-year | | 5-year | | 10-year | | 20-year | | 50-year | | 100-year | |
| | Dam | No Dam | Dam | No Dam | Dam | No Dam | Dam | No Dam | Dam | No Dam | Dam | No Dam |
| **West Outlet** | 0.6 | 1.0 | 1.9 | 2.1 | 3.0 | 3.2 | 4.3 | 4.6 | 6.0 | 6.4 | 7.8 | 9.4 |
| **Central Outlet** | 1.6 | 2.7 | 4.2 | 5.9 | 7.1 | 9.2 | 10.7 | 12.9 | 15.7 | 17.2 | 20.8 | 22.1 |

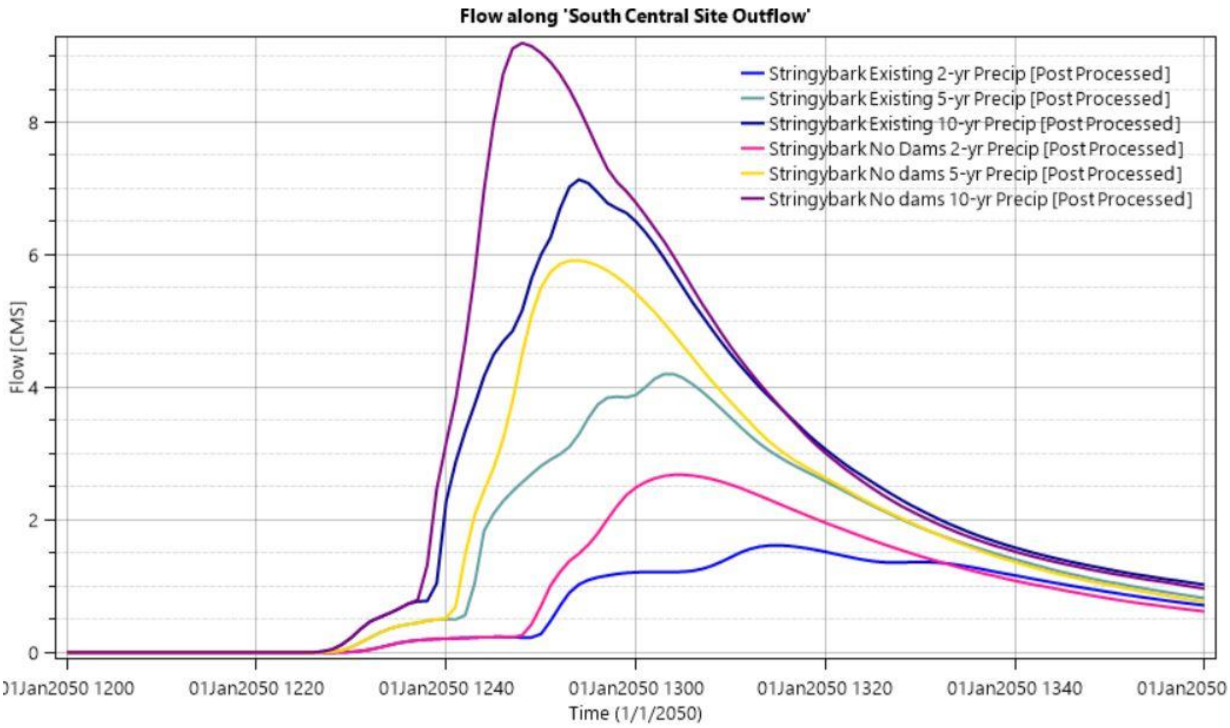

**Figure 3-1 2-year, 5-year, and 10-year outflow hydrographs for central channel**

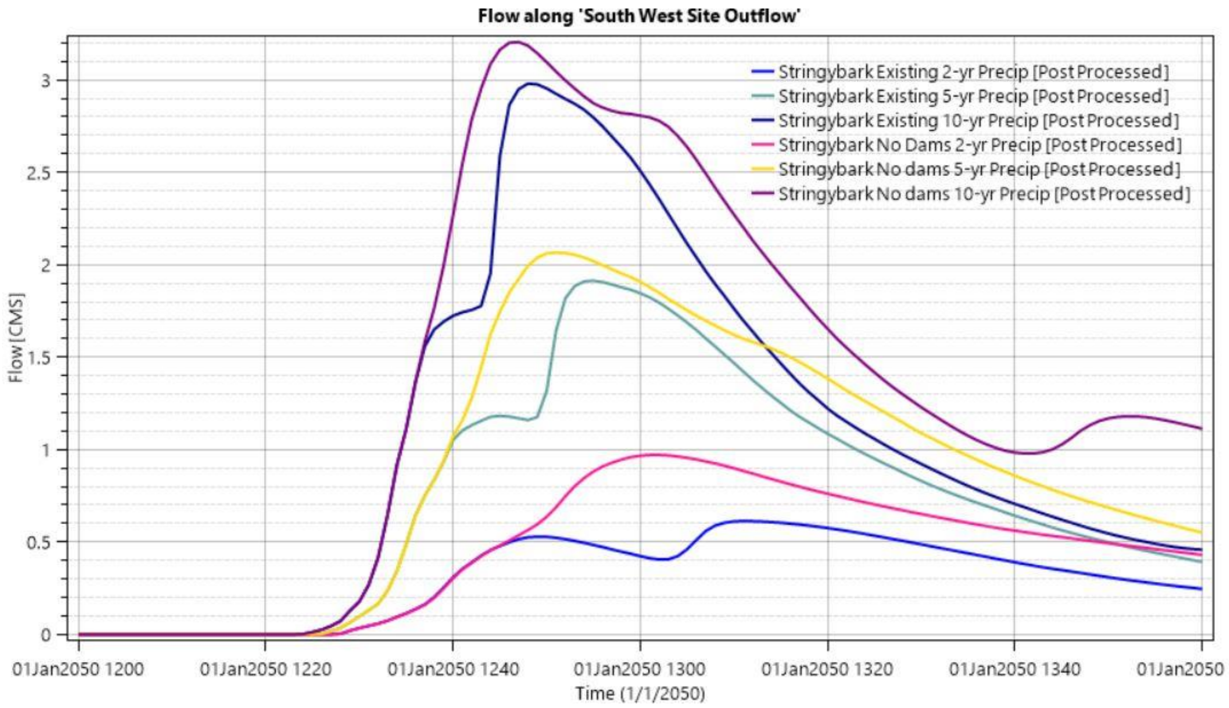


**Figure 3-2 2-year, 5-year, and 10-year outflow hydrographs for western channel**

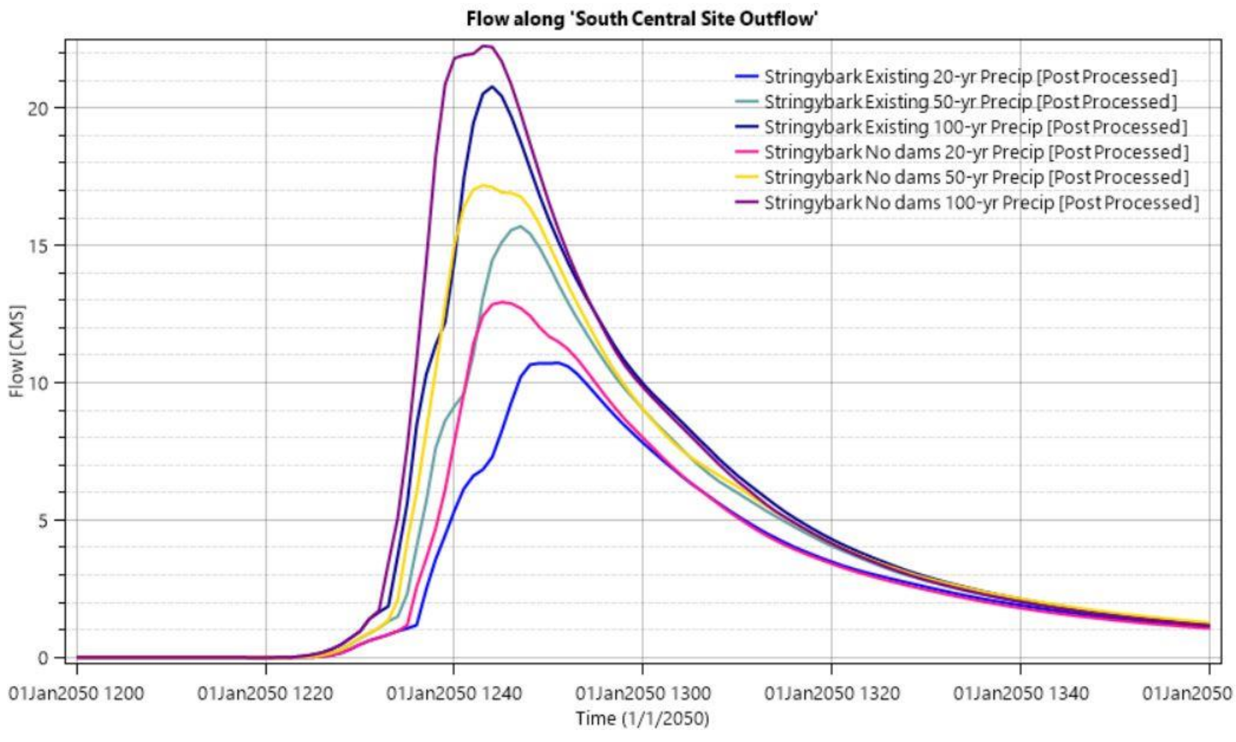

**Figure 3-3 20-year, 50-year, and 100-year outflow hydrographs for central channel**

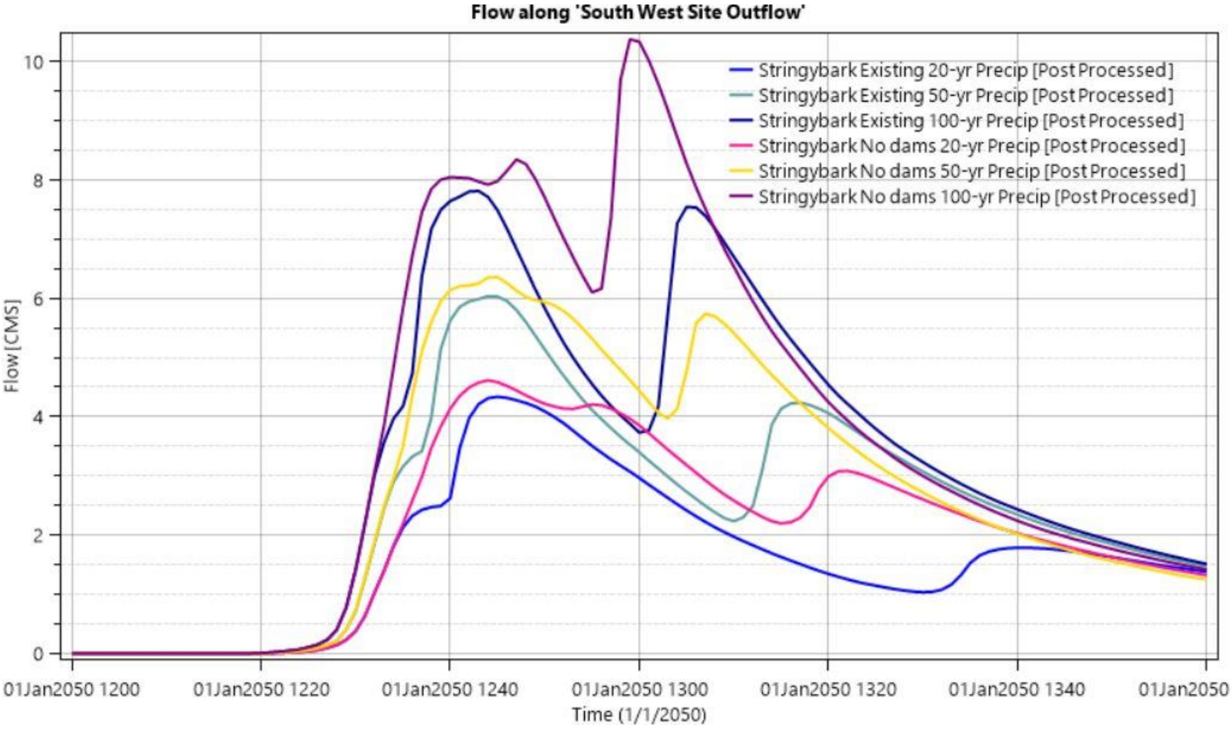


**Figure 3-4 20-year, 50-year, and 100-year outflow hydrographs for western channel**

**Table 3-2** shows the RFFE results for comparison with the HEC-RAS model results. The table shows that the rain-on-grid results overestimate flow compared to the RFFE results, emphasising the conservative nature of this modelling assessment. In the absence of calibration data, the rain-on-grid results are applied in accordance with the approach outlined above (**Section 2**).

**Table 3-2: RFFE results**

| AEP (%) | HEC-RAS rain-on-grid ($m^3/s$) | RFFE Discharge ($m^3/s$) | RFFE 5th Percentile Confidence Limit ($m^3/s$) | RFFE 95th Percentile Confidence Limit ($m^3/s$) |
|---|---|---|---|---|
| 50 | 2.1 | 0.6 | 0.3 | 1.5 |
| 20 | 5.9 | 1.5 | 0.7 | 3.2 |
| 10 | 9.9 | 2.3 | 1.1 | 5.2 |
| 5 | 14.8 | 3.4 | 1.5 | 7.8 |
| 2 | 21.3 | 5.3 | 2.2 | 12.7 |
| 1 | 28.1 | 7.0 | 2.8 | 17.7 |

## 3.2 Peak flow depths, velocities and shear stress

**Figure 3-5** through **Figure 3-12** show the maximum flow depths and velocities under the six modelled scenarios (50%, 20%, 10%, 5%, 2% and 1% AEP). The inundation figures show areas where flow depths exceed 5 cm and velocity figures have areas where velocities exceed 2 m/s shown in red. Flow depths within the watercourses across the site are generally less than 50 cm in events up to the 1% AEP.

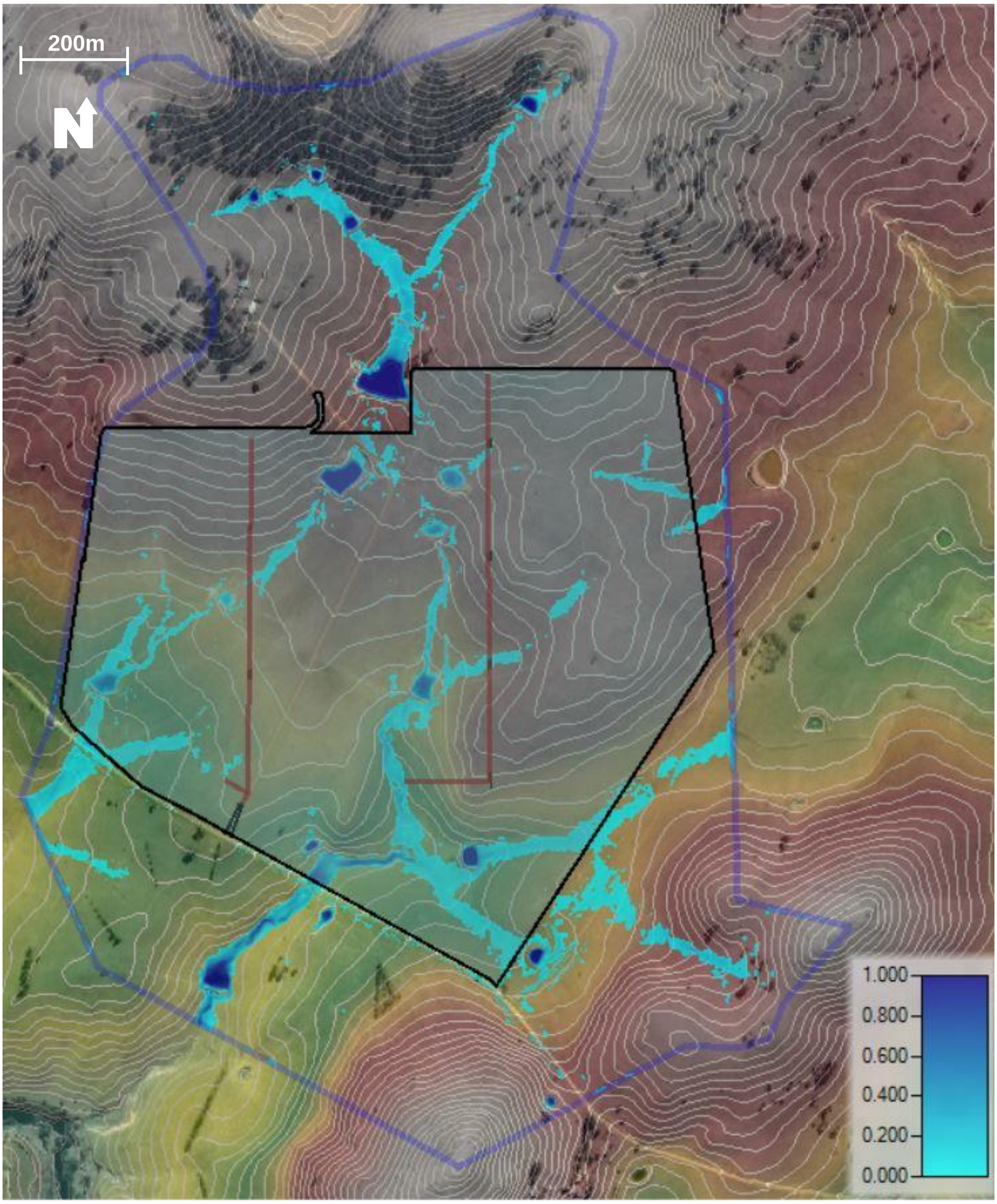


**Figure 3-5 10% AEP Existing Conditions Maximum Flow Depths**

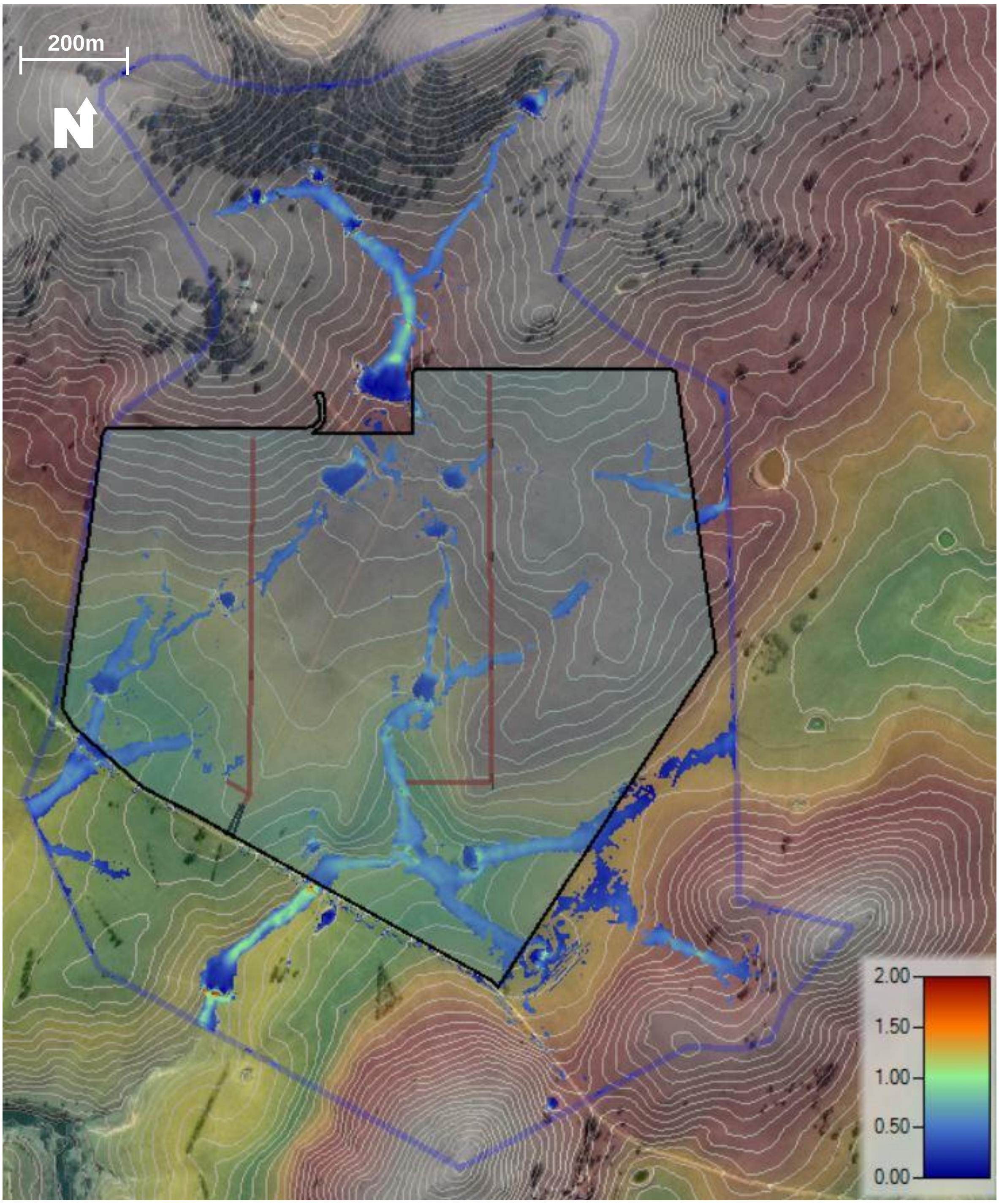


**Figure 3-6 10% AEP Existing Conditions Maximum Velocities**

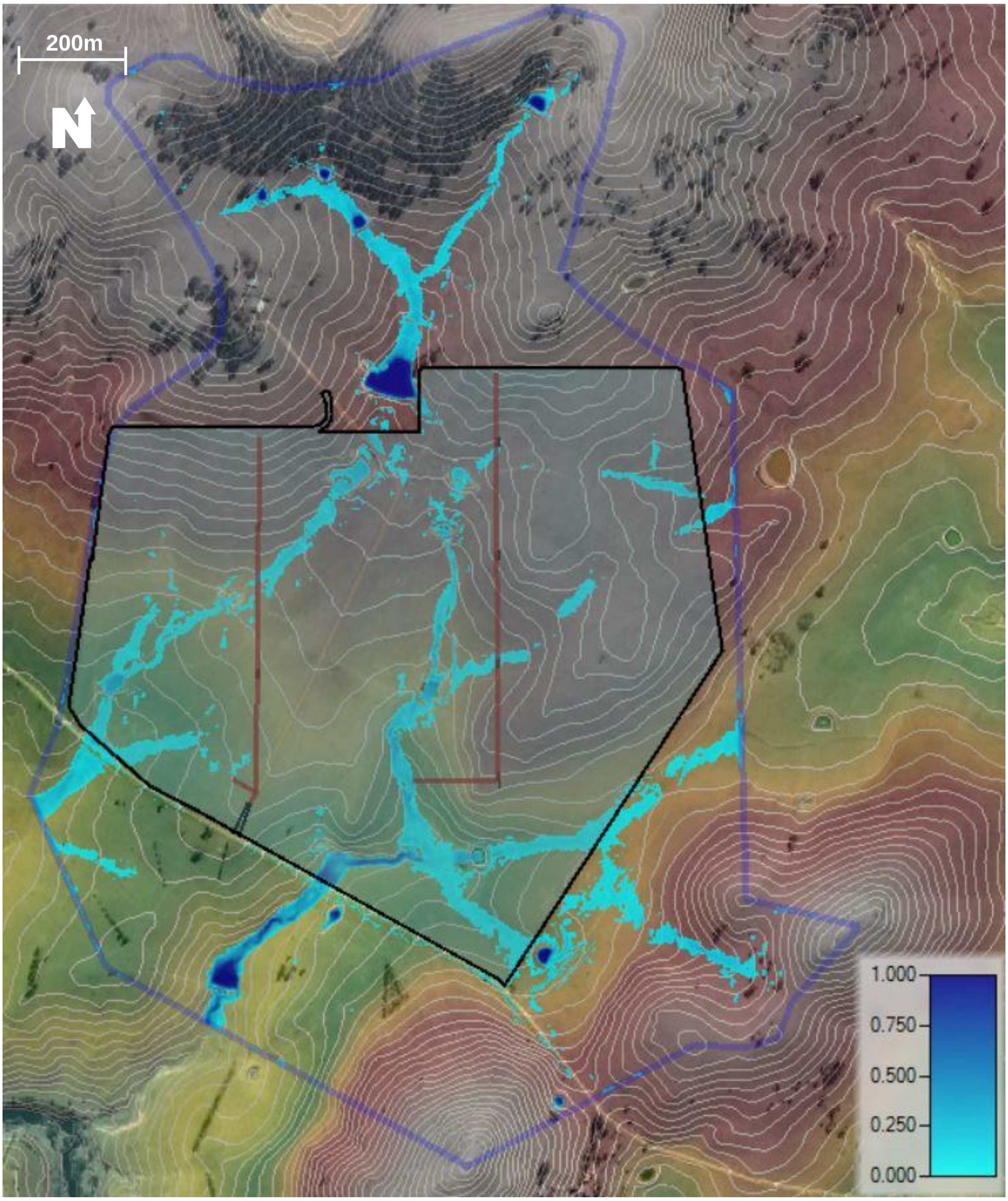


**Figure 3-7 10% AEP Proposed Conditions Maximum Flow Depths**

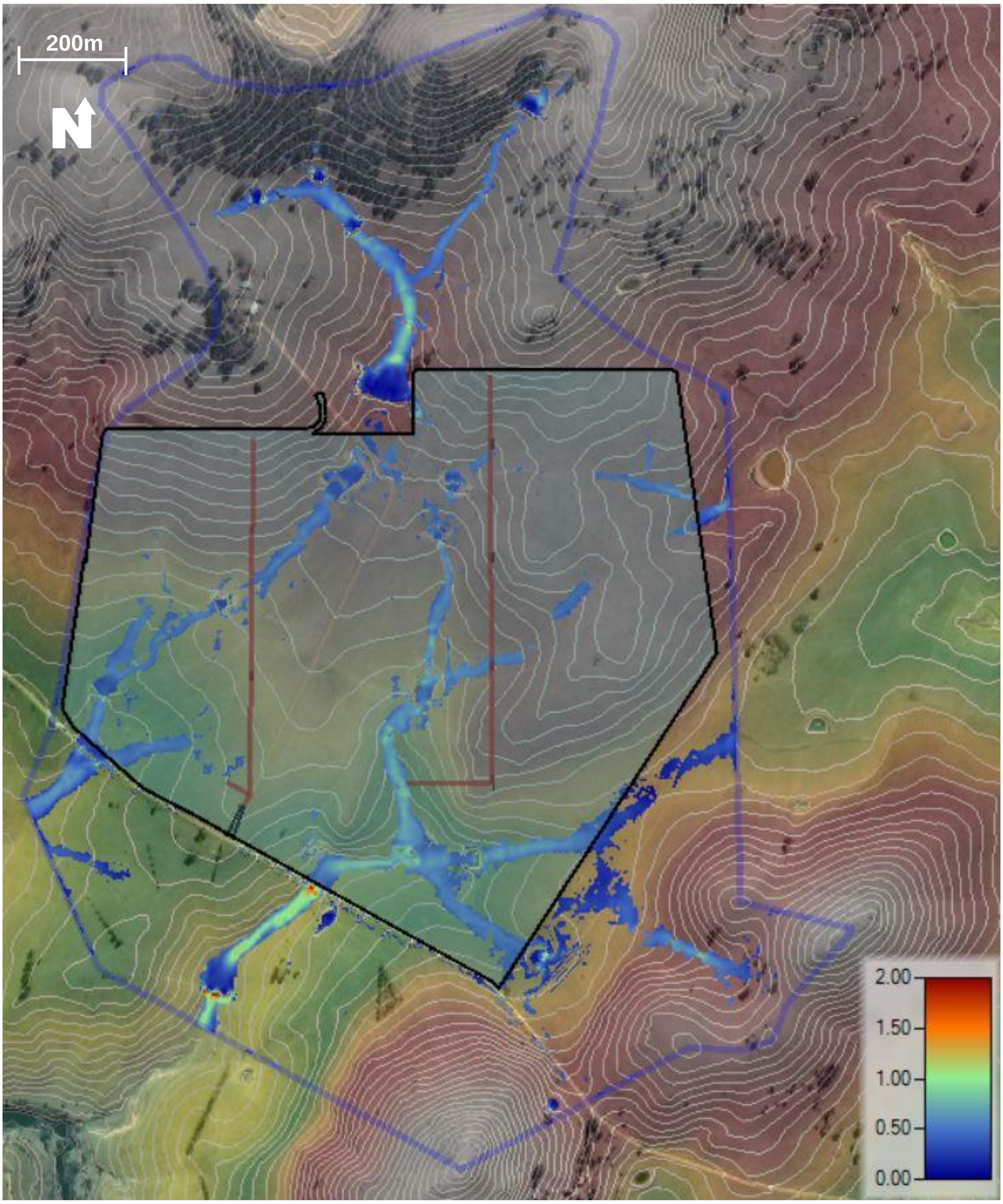


**Figure 3-8 10% AEP Proposed Conditions Maximum Velocities**

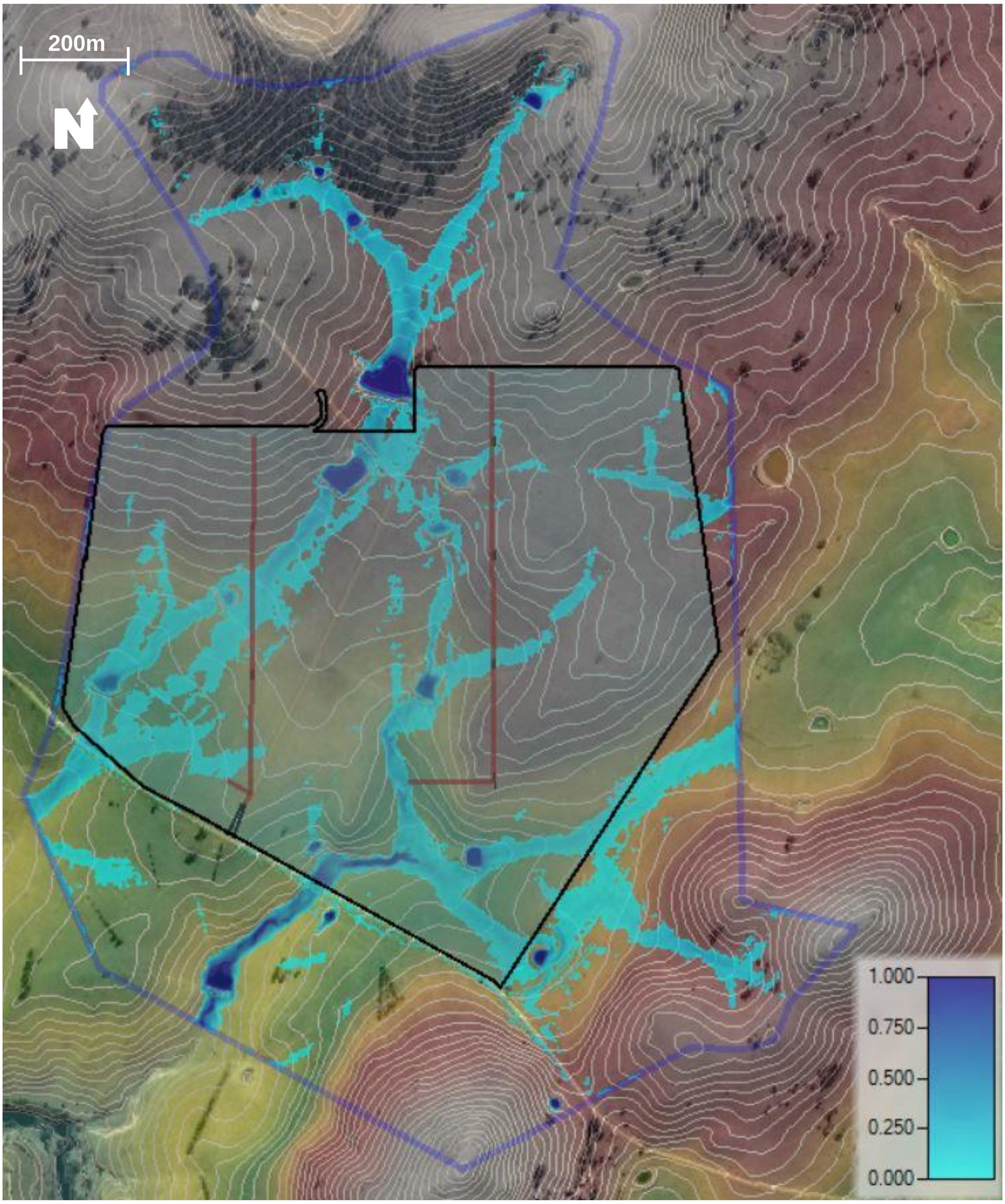


**Figure 3-9 1% AEP Existing Conditions Maximum Flow Depths**

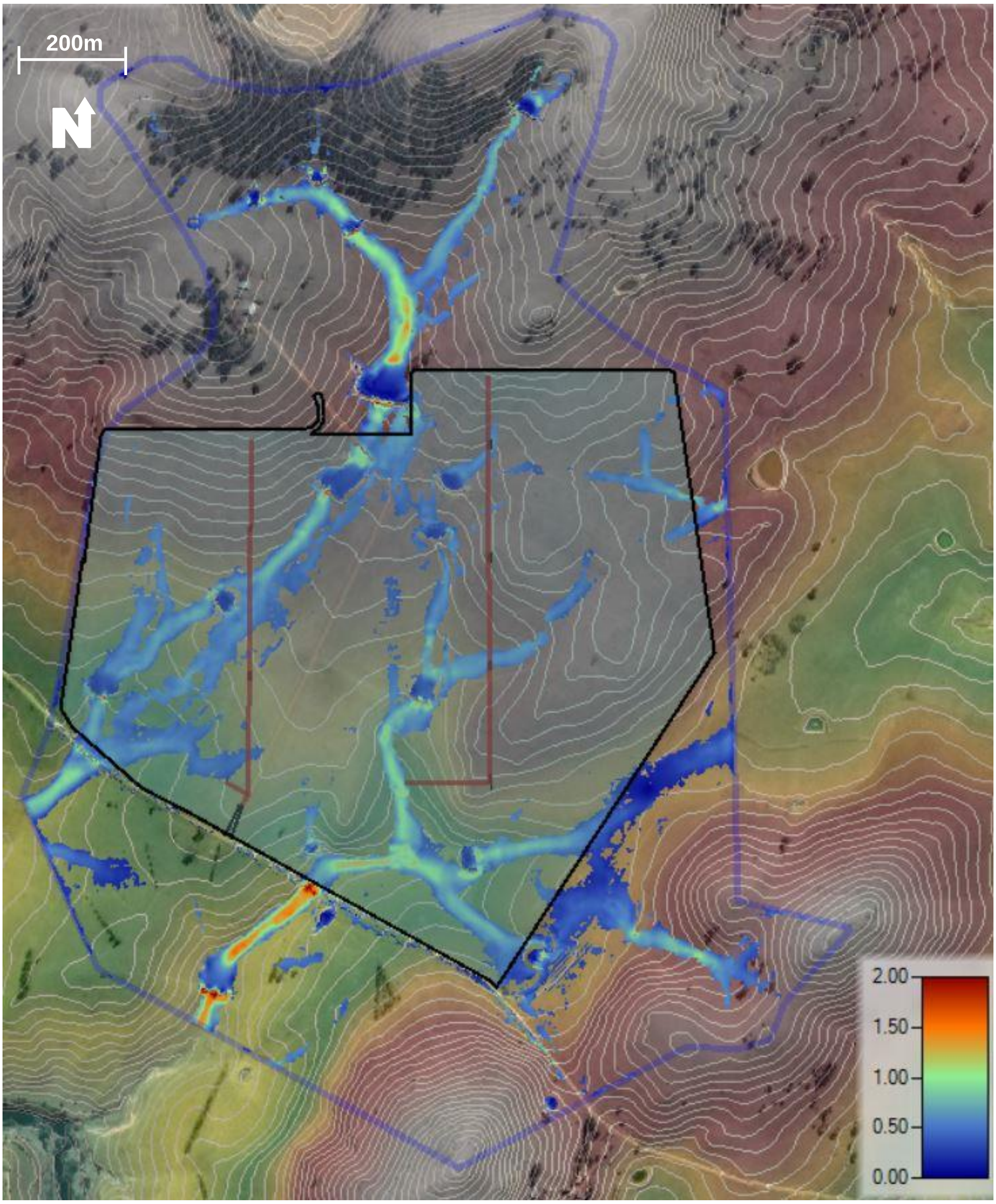


**Figure 3-10 1% AEP Existing Conditions Maximum Velocities**

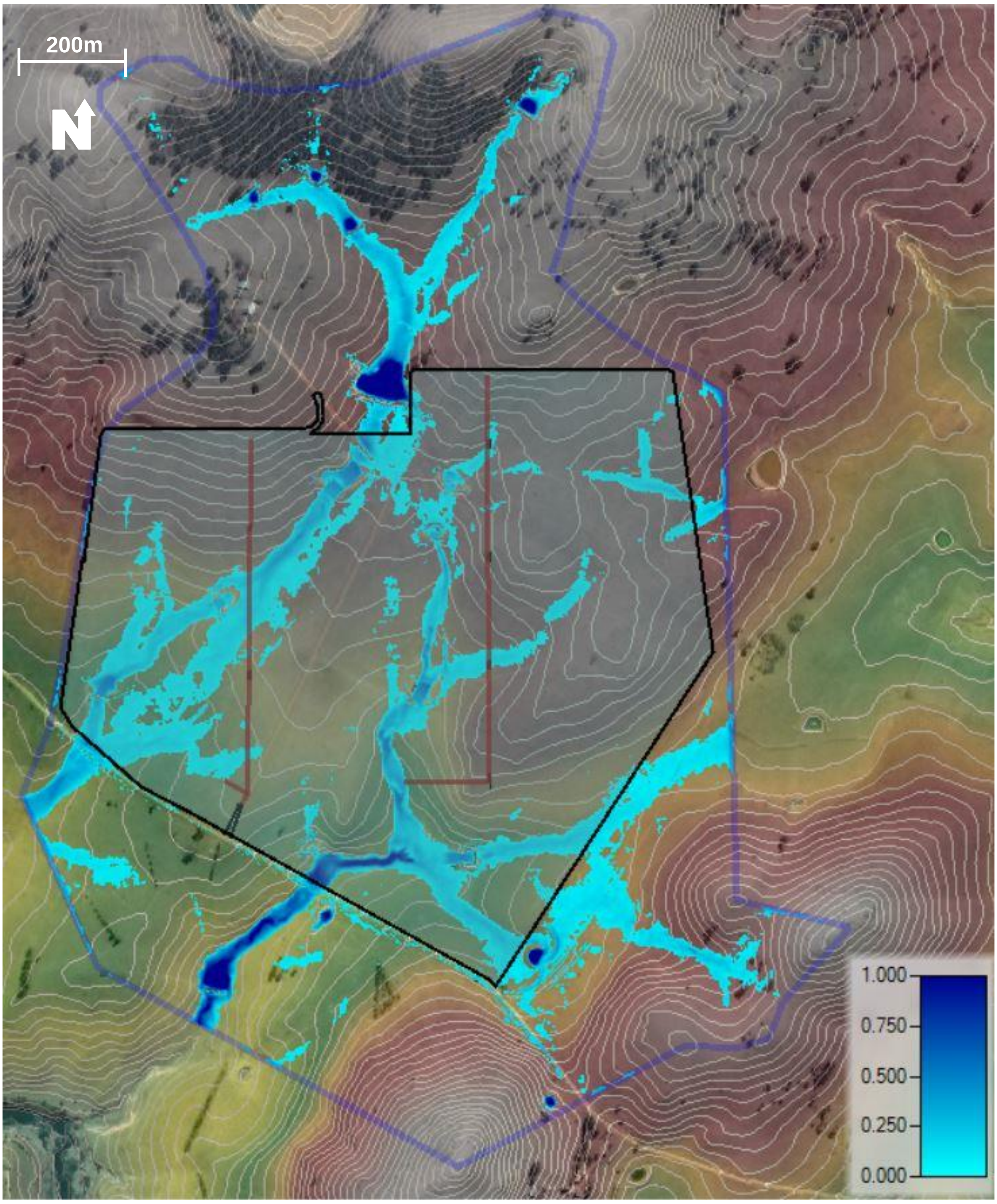


**Figure 3-11 1% AEP Proposed Conditions Maximum Flow Depths**

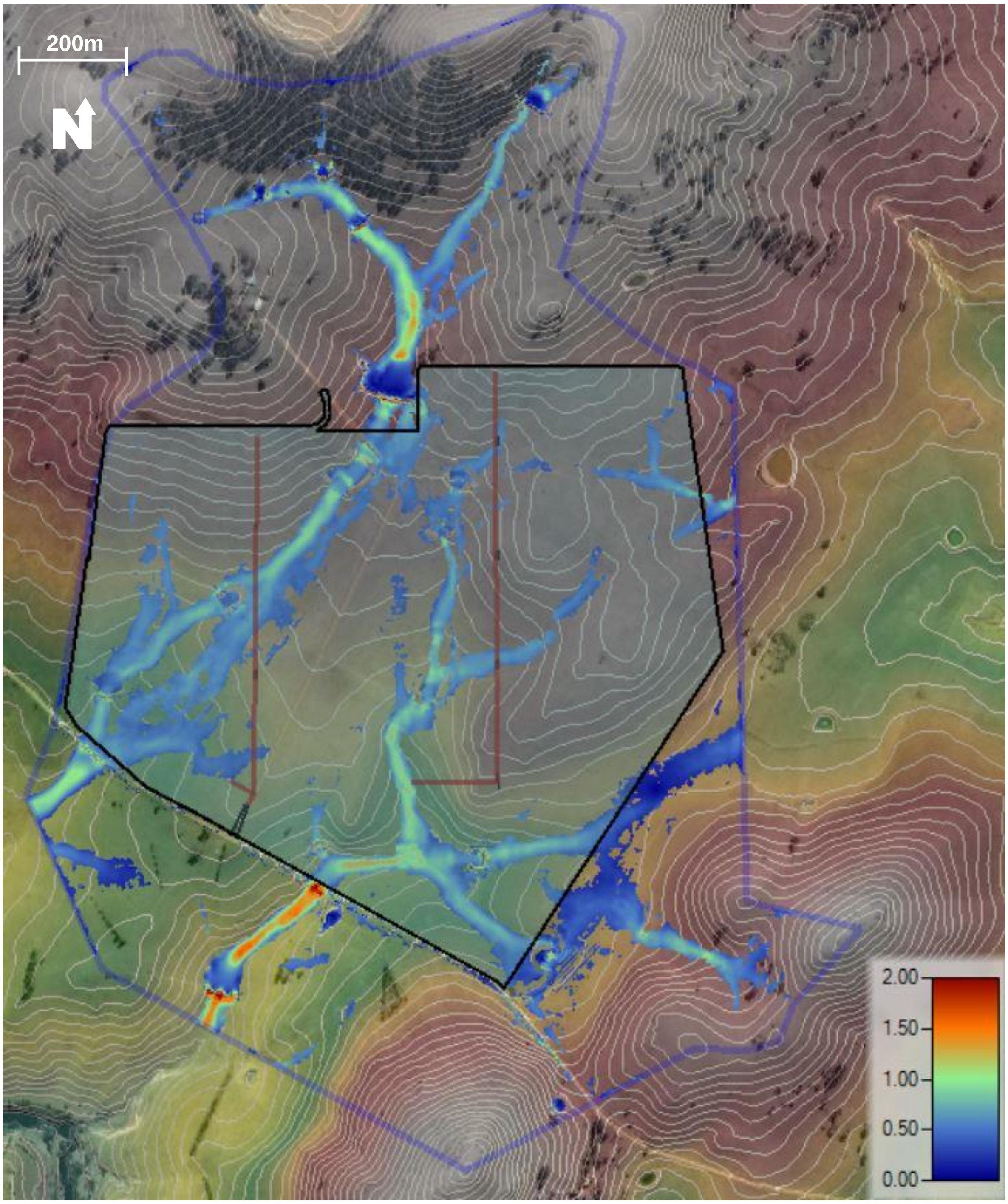


**Figure 3-12 1% AEP Proposed Conditions Maximum Velocities**

**Figure 3-13** and **Figure 3-14** show the differences between the existing Site conditions and the Proposed Conditions in maximum depths for the 10% AEP and 1% AEP, respectively. The primary differences in maximum depths for both the 10% AEP and 1% AEP flood events occur near the dams. Where dams have been removed, the ponded depths decrease and the sheet flow depths downstream of the dams increase.

As expected, the dams have a proportionally larger effect on smaller flows, so the depth differences in the downstream channels in the 1% AEP flood are less than in the 10% AEP flood. The maximum increase in peak flow depth in the downstream channels in the 10% AEP event is 100 mm.

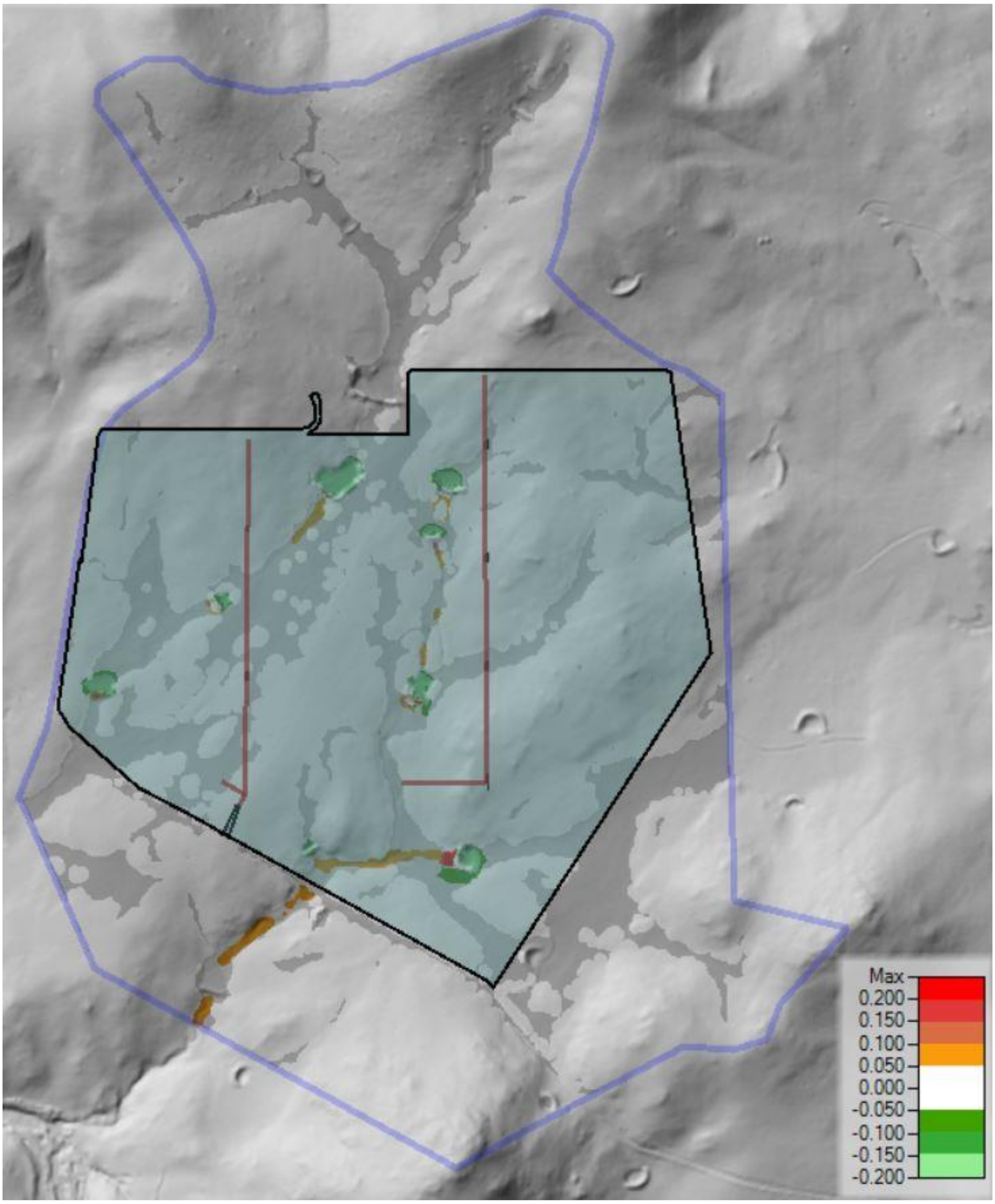


**Figure 3-13 10% AEP Maximum Flow Depth Difference**

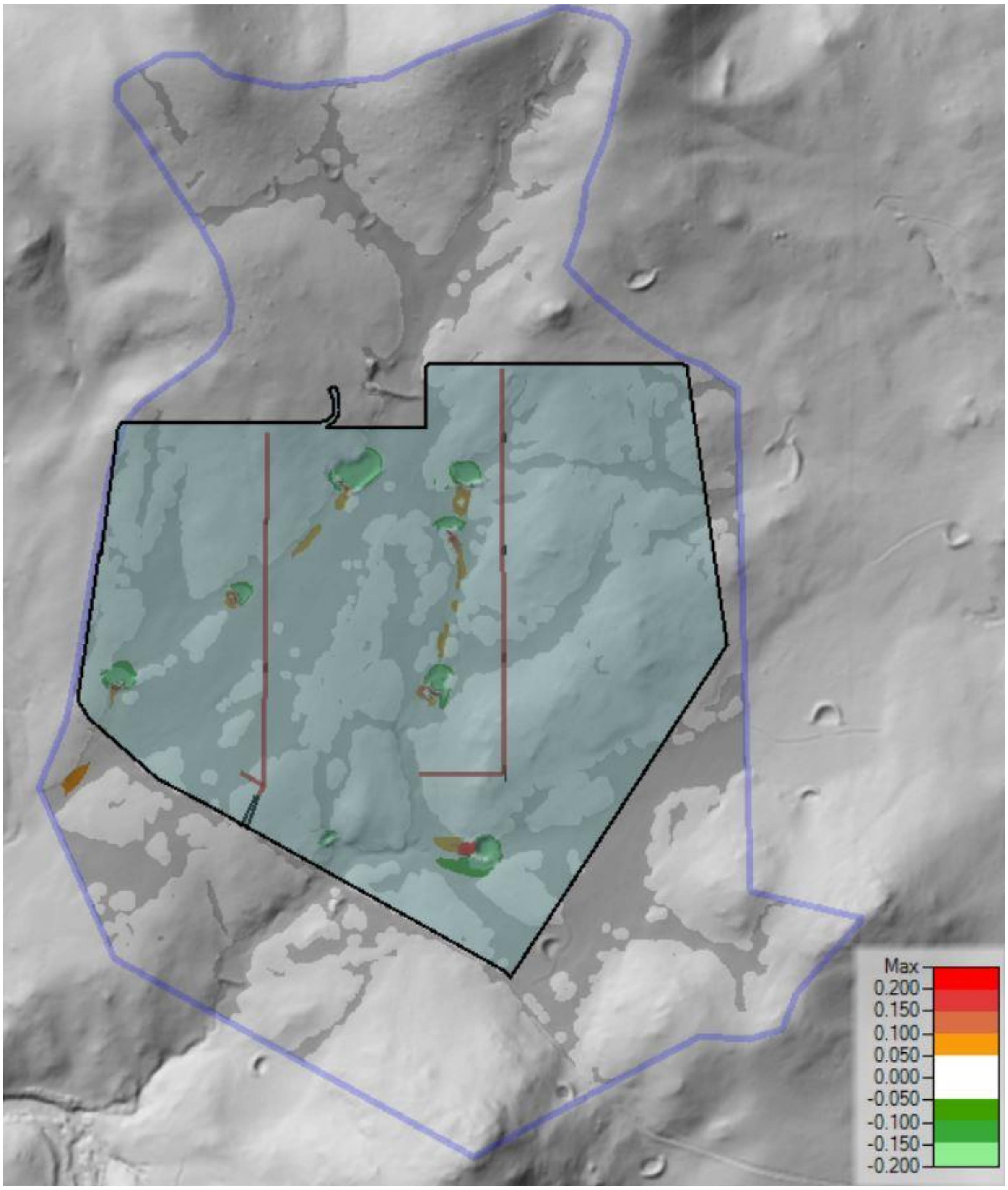


**Figure 3-14 1% AEP Maximum Flow Depth Difference**

Maximum reductions in water surface elevations occur at the removed dams. The maximum reductions amount to the total active storage height of each of the dams.

Should onsite management of these changes in depths be required to be managed as part of the design, the fact that these are occurring for higher recurrence interval events (i.e. 10% as opposed to 1%), readily allows stormwater management measures (such as drop structures or downstream sediment basins) to be implemented to mitigate the effects.

## 3.3 Proposed Features

The piles of the solar panels do not obstruct a significant proportion of active flow conveyance and therefore do not affect flood levels at the Site. Other changes, however, have potential to affect flood levels. The removal of farm dams and the inclusion of tracks, for example, will change runoff patterns, flow directions, and peak discharge rates. Increased area of impervious land may also affect flood characteristics, and this has been investigated as part of the modelling process.

Solar panel placement is not expected to impact on rainfall-runoff characteristics of the catchment. Although rainfall may be intercepted by the surface of the solar panels before hitting the ground, this has little effect on rainfall energy and due to the relatively sparse spacing of the proposed tracking solar arrays (minimum row spacing of 5.5m, *see* Section 4.1.5 of the SEE), the intercepted rainfall is spread over a relatively large area for infiltration. Further minimising local impacts is the fact that the PV panels track the sun throughout the day and hence will distribute runoff across a broader footprint. Given the large vegetated surface area below each panel and between rows that will absorb rainfall and minimise runoff potential, it is considered that surface water runoff velocities associated with the PV panel array are no more likely to generate erosion and sedimentation than the existing land management processes associated with the Site.

The limited vegetation removal associated with the construction of the solar array does not comprise a significant portion of the contributing catchment area and is thus not expected to affect local rainfall-runoff relationships. The overall infiltration parameters on the site are therefore not expected to change significantly as a result of the Proposal.

The additional impervious area related to the proposed access tracks, buildings, inverters and hardstand areas (approximately 9,647$m^2$) amounts to approximately 0.5% of the total catchment area. The effect of this change to impervious land area on peak runoff values would be an increase of 0.3% in peak discharge flows. This is considered negligible in the context of the runoff from this catchment and within the certainty limits of the modelling thereof.

The figures shown above (**Figure 3-5** through **Figure 3-12**) can therefore be considered to be representative of peak depths for both the existing conditions and for proposed future conditions under full solar farm development.

# 4. Discussion and Recommendations

Preliminary hydrological modelling for the proposed Stringybark Solar Farm shows that the majority of the Site is not prone to flooding, with little sheet flow. Within drainage lines, modelling indicates the proposed concept design results in some potential for increased depth and flow velocities.

The removal of farm dams and the construction of additional impervious surfaces are predicted to increase peak discharge rates at the downstream site extent by approximately 10%. Based on the predicted velocities and flood extents, the Proposal's solar arrays and associated infrastructure are unlikely to significantly affect downstream erosion or sedimentation. Some scour protection within the Site may be warranted where concentrated flow paths enter defined drainage channels.

Velocities in the primary flow paths are generally sufficiently low to avoid armour rock requirements in the channels up to the 1% AEP event. Some concentrated flow paths exhibit erosive forces in localised channel entrance areas. Regular maintenance activities, including sediment removal in internally draining areas and scour repairs at culvert inlets and outlets, would likely be required after significant flood events.

It should be noted that velocities (generally <2 m/s) within the watercourses are generally below tabulated thresholds for armour rock (**Table 4-1**). That is, below a level that might be expected to require protection. Some localised mitigation through rock protection, however, may be warranted in the immediate vicinity of any culvert outfalls within the Site, where flow is concentrated. Such mitigation measures (if any) would be determined following further hydrological modelling as part of detailed design.

**Table 4-1: Design of rock slope protection (from Table 3.11, Austroads 2013, Table 5.1, MRWA 2006)**

| Velocity (m/s) | Class of rock protection (tonne) | Section thickness, *T* (m) |
|---|---|---|
| < 2 | None | – |
| 2.0–2.6 | Facing | 0.50 |
| 2.6–2.9 | Light | 0.75 |
| 2.9–3.9 | ¼ | 1.00 |
| 3.9–4.5 | ½ | 1.25 |
| 4.5–5.1 | 1.0 | 1.60 |
| 5.1–5.7 | 2.0 | 2.00 |
| 5.7–6.4 | 4.0 | 2.50 |
| > 6.4 | Special | – |

The presence of the solar panels, however, does not increase erosion. Although rainfall may be intercepted by the surface of the solar panels before hitting the ground, this has little effect on rainfall energy and due to the relatively sparse spacing of the proposed tracking solar arrays (minimum row spacing of 5.5m, see Section 4.1.5 of the SEE (ELA, 2019)) the intercepted rainfall is spread over a relatively large area for infiltration. Further minimising local impacts is the fact that the PV panels track the sun throughout the day and hence will distribute runoff across a broader footprint than would be the case if a fixed array was installed. This results in a large vegetated surface area below each panel and between rows that will absorb rainfall and minimise runoff potential.

The additional impervious area related to the proposed roadways, tracks, inverters and hardstand areas amount to approximately 0.5% of the total catchment area. The effect of this change to impervious land area on peak runoff values would be an increase of 0.3%. This is considered negligible in the context of the runoff from this catchment and within the certainty limits of the modelling thereof. This change would be easily mitigated through the application of appropriate stormwater management measures developed during detailed design.

Preliminary modelling indicates that the establishment of the Proposal would result in minimal changes to flood characteristics within the existing drainage lines. When compared to current conditions, the unmitigated peak flows leaving the Site are predicted to increase from 28.6 $m^3/s$ to 31.6 $m^3/s$ for the 1% AEP flood event. The implementation of mitigation measures, such as drop structures and detention ponds, as outlined in *Managing Urban Stormwater: Soils and Construction* (the Blue Book), would be used to mitigate any effects, resulting in negligible downstream impacts as a result of the Proposal.

Based on the preliminary modelling results, the following are recommended as part of detailed design:

1. Peak flow rates and hydrographs are confirmed for the appropriate AEP events (through implementation of an appropriate rainfall-runoff model, such as RORB or XP-RAFTS)
2. Flow depth and velocity calculations are re-assessed to aid design of any standard stormwater infrastructure required to manage changes (if any) in runoff rates.

The former allows assessment of the degree of any mitigation management measures that may be required, whilst the latter will provide locations where such measures may be needed.

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# Appendix A ARR data hub and RFFE results



**ATTENTION:** This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

## Australian Rainfall & Runoff Data Hub - Results

### Input Data

| | |
|---|---|
| Longitude | 151.785 |
| Latitude | -30.568 |
| **Selected Regions (clear)** | |
| River Region | show |
| ARF Parameters | show |
| Storm Losses | show |
| Temporal Patterns | show |
| Areal Temporal Patterns | show |
| BOM IFDs | show |
| Median Preburst Depths and Ratios | show |
| 10% Preburst Depths | show |
| 25% Preburst Depths | show |
| 75% Preburst Depths | show |
| 90% Preburst Depths | show |
| Interim Climate Change Factors | show |
| Probability Neutral Burst Initial Loss (./nsw_specific) | show |
| Baseflow Factors | show |

# Data

## River Region

| | |
|---|---|
| **Division** | South East Coast (NSW) |
| **River Number** | 6 |
| **River Name** | Macleay River |
| **Shape Intersection (%)** | 100.0 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v1 |

## ARF Parameters

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

| Zone | a | b | c | d | e | f | g | h | i | Shape Intersection (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| East Coast North | 0.327 | 0.241 | 0.448 | 0.36 | 0.00096 | 0.48 | -0.21 | 0.012 | -0.0013 | 100.0 |

## Short Duration ARF

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

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v1 |

https://data.arr-software.org 2/10

## Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

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

| | |
|---|---|
| **Storm Initial Losses (mm)** | 11.0 |
| **Storm Continuing Losses (mm/h)** | 3.9 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v1 |

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

| | |
|---|---|
| **code** | ECsouth |
| **Label** | East Coast South |
| **Shape Intersection (%)** | 100.0 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v2 |

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

| | |
|---|---|
| **code** | ECsouth |
| **arealabel** | East Coast South |
| **Shape Intersection (%)** | 100.0 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v2 |

## BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-30.5677500397&longitude=151.785267932&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |

## Median Preburst Depths and Ratios

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

| min (h)\AEP(%) | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|
| 60 (1.0) | 0.6 (0.023) | 1.3 (0.035) | 1.7 (0.039) | 2.1 (0.042) | 1.8 (0.029) | 1.5 (0.022) |
| 90 (1.5) | 0.6 (0.020) | 0.7 (0.018) | 0.8 (0.017) | 0.9 (0.016) | 0.9 (0.014) | 1.0 (0.013) |
| 120 (2.0) | 1.7 (0.055) | 2.0 (0.046) | 2.1 (0.042) | 2.3 (0.039) | 1.7 (0.024) | 1.3 (0.016) |
| 180 (3.0) | 0.3 (0.010) | 0.4 (0.008) | 0.4 (0.007) | 0.4 (0.006) | 0.9 (0.012) | 1.3 (0.014) |
| 360 (6.0) | 1.0 (0.025) | 1.6 (0.029) | 2.0 (0.030) | 2.3 (0.031) | 3.7 (0.041) | 4.7 (0.046) |
| 720 (12.0) | 0.0 (0.000) | 0.6 (0.009) | 1.0 (0.013) | 1.4 (0.015) | 6.2 (0.057) | 9.8 (0.080) |
| 1080 (18.0) | 0.0 (0.000) | 0.3 (0.004) | 0.5 (0.006) | 0.7 (0.007) | 9.2 (0.075) | 15.5 (0.111) |
| 1440 (24.0) | 0.0 (0.000) | 0.2 (0.003) | 0.4 (0.004) | 0.6 (0.005) | 9.6 (0.071) | 16.3 (0.107) |
| 2160 (36.0) | 0.0 (0.000) | 0.2 (0.002) | 0.3 (0.003) | 0.4 (0.003) | 3.0 (0.020) | 5.0 (0.029) |
| 2880 (48.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.3 (0.002) | 0.5 (0.003) |
| 4320 (72.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2018_v1 |
| **Note** | Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged. |

## 10% Preburst Depths

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

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

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2018_v1 |
| **Note** | Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged. |



## 25% Preburst Depths

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

| min (h)\AEP(%) | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|
| 60 (1.0) | 0.0 (0.000) | 0.0 (0.001) | 0.1 (0.001) | 0.1 (0.001) | 0.0 (0.001) | 0.0 (0.000) |
| 90 (1.5) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 120 (2.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 180 (3.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 360 (6.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 720 (12.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 1080 (18.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.1 (0.001) | 0.2 (0.001) |
| 1440 (24.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.8 (0.006) | 1.4 (0.009) |
| 2160 (36.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 2880 (48.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |
| 4320 (72.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2018_v1 |
| **Note** | Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged. |



## 75% Preburst Depths

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

| min (h)\AEP(%) | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|
| 60 (1.0) | 10.4 (0.406) | 9.6 (0.268) | 9.1 (0.211) | 8.6 (0.171) | 12.9 (0.213) | 16.1 (0.236) |
| 90 (1.5) | 10.4 (0.366) | 11.0 (0.276) | 11.3 (0.238) | 11.7 (0.210) | 10.2 (0.154) | 9.2 (0.122) |
| 120 (2.0) | 12.9 (0.421) | 13.2 (0.313) | 13.5 (0.266) | 13.7 (0.232) | 12.9 (0.183) | 12.3 (0.154) |
| 180 (3.0) | 7.3 (0.215) | 10.0 (0.217) | 11.9 (0.215) | 13.7 (0.213) | 15.7 (0.204) | 17.2 (0.198) |
| 360 (6.0) | 16.5 (0.410) | 19.0 (0.350) | 20.7 (0.321) | 22.3 (0.297) | 29.1 (0.324) | 34.1 (0.336) |
| 720 (12.0) | 10.3 (0.210) | 14.9 (0.227) | 18.0 (0.231) | 20.9 (0.232) | 37.7 (0.349) | 50.3 (0.410) |
| 1080 (18.0) | 8.0 (0.145) | 10.4 (0.140) | 12.0 (0.136) | 13.5 (0.132) | 35.4 (0.289) | 51.9 (0.373) |
| 1440 (24.0) | 0.5 (0.008) | 4.4 (0.054) | 6.9 (0.072) | 9.4 (0.084) | 26.6 (0.197) | 39.5 (0.259) |
| 2160 (36.0) | 0.4 (0.005) | 4.8 (0.052) | 7.7 (0.070) | 10.5 (0.082) | 16.7 (0.108) | 21.3 (0.123) |
| 2880 (48.0) | 0.0 (0.000) | 3.1 (0.030) | 5.1 (0.042) | 7.0 (0.050) | 8.1 (0.048) | 8.8 (0.047) |
| 4320 (72.0) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 0.0 (0.000) | 2.9 (0.016) | 5.1 (0.024) |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2018_v1 |
| **Note** | Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged. |



## 90% Preburst Depths

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

| min (h)\AEP(%) | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|
| 60 (1.0) | 30.9 (1.208) | 28.6 (0.796) | 27.1 (0.627) | 25.6 (0.506) | 44.6 (0.736) | 58.8 (0.860) |
| 90 (1.5) | 37.1 (1.302) | 37.0 (0.933) | 37.0 (0.777) | 36.9 (0.664) | 50.1 (0.754) | 60.0 (0.799) |
| 120 (2.0) | 40.8 (1.335) | 63.0 (1.488) | 77.6 (1.532) | 91.7 (1.550) | 72.9 (1.031) | 58.7 (0.736) |
| 180 (3.0) | 25.5 (0.757) | 36.0 (0.777) | 42.9 (0.777) | 49.5 (0.770) | 95.0 (1.237) | 129.1 (1.486) |
| 360 (6.0) | 33.6 (0.836) | 45.4 (0.835) | 53.2 (0.825) | 60.7 (0.810) | 85.7 (0.956) | 104.5 (1.029) |
| 720 (12.0) | 23.9 (0.489) | 38.3 (0.583) | 47.7 (0.615) | 56.9 (0.631) | 78.9 (0.730) | 95.4 (0.778) |
| 1080 (18.0) | 30.1 (0.545) | 38.9 (0.525) | 44.7 (0.509) | 50.3 (0.492) | 89.1 (0.727) | 118.1 (0.850) |
| 1440 (24.0) | 14.7 (0.243) | 20.9 (0.258) | 25.1 (0.260) | 29.0 (0.259) | 61.3 (0.455) | 85.5 (0.561) |
| 2160 (36.0) | 16.5 (0.241) | 23.2 (0.252) | 27.7 (0.252) | 32.0 (0.249) | 41.6 (0.270) | 48.7 (0.280) |
| 2880 (48.0) | 0.7 (0.010) | 10.0 (0.099) | 16.1 (0.134) | 22.0 (0.156) | 27.1 (0.161) | 31.0 (0.163) |
| 4320 (72.0) | 0.0 (0.000) | 4.9 (0.043) | 8.1 (0.060) | 11.2 (0.071) | 32.2 (0.171) | 47.9 (0.227) |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2018_v1 |
| **Note** | Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged. |

## Interim Climate Change Factors

| | RCP 4.5 | RCP6 | RCP 8.5 |
|---|---|---|---|
| **2030** | **0.869 (4.3%)** | 0.783 (3.9%) | **0.983 (4.9%)** |
| **2040** | **1.057 (5.3%)** | 1.014 (5.1%) | **1.349 (6.8%)** |
| **2050** | **1.272 (6.4%)** | 1.236 (6.2%) | **1.773 (9.0%)** |
| **2060** | **1.488 (7.5%)** | 1.458 (7.4%) | **2.237 (11.5%)** |
| **2070** | **1.676 (8.5%)** | 1.691 (8.6%) | **2.722 (14.2%)** |
| **2080** | **1.810 (9.2%)** | 1.944 (9.9%) | **3.209 (16.9%)** |
| **2090** | **1.862 (9.5%)** | 2.227 (11.5%) | **3.679 (19.7%)** |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2019_v1 |
| **Note** | ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website. |

## Probability Neutral Burst Initial Loss

| min (h)\AEP(%) | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|
| **60 (1.0)** | 5.3 | 4.7 | 4.8 | 4.8 | 4.8 | 2.1 |
| **90 (1.5)** | 5.4 | 4.7 | 4.9 | 4.9 | 5.1 | 2.3 |
| **120 (2.0)** | 5.1 | 4.3 | 4.7 | 4.3 | 4.7 | 1.9 |
| **180 (3.0)** | 6.0 | 4.9 | 5.0 | 4.6 | 4.3 | 2.1 |
| **360 (6.0)** | 5.3 | 4.2 | 4.9 | 4.1 | 4.6 | 1.5 |
| **720 (12.0)** | 6.0 | 4.6 | 5.2 | 4.3 | 4.1 | 1.8 |
| **1080 (18.0)** | 6.4 | 5.1 | 5.6 | 4.9 | 3.9 | 1.8 |
| **1440 (24.0)** | 7.7 | 5.9 | 6.1 | 5.2 | 3.9 | 2.1 |
| **2160 (36.0)** | 7.8 | 6.2 | 6.3 | 5.5 | 5.8 | 2.2 |
| **2880 (48.0)** | 9.5 | 6.9 | 7.0 | 6.5 | 8.1 | 2.7 |
| **4320 (72.0)** | 9.9 | 8.7 | 8.8 | 9.5 | 8.2 | 2.9 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |

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

## Baseflow Factors

| | |
|---|---|
| **Downstream** | 8692 |
| **Area (km2)** | 1074.194944 |
| **Catchment Number** | 8491 |
| **Volume Factor** | 0.11808 |
| **Peak Factor** | 0.018092 |
| **Shape Intersection (%)** | 100.0 |

## Layer Info

| | |
|---|---|
| **Time Accessed** | 27 October 2019 11:38PM |
| **Version** | 2016_v1 |

Download TXT (downloads/8a9be18a-d07a-4845-ba25-ed40ef404e14.txt)

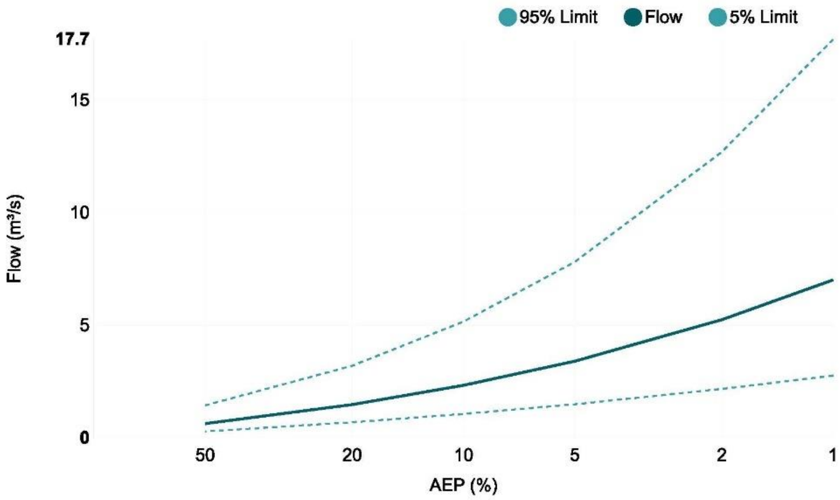
Download JSON (downloads/c8324506-4031-4773-b164-d7d0768af204.json)

Generating PDF... (downloads/ad35a08a-900a-4b28-8e09-5f910a33f9ea.pdf)



# Results | Regional Flood Frequency Estimation Model




| AEP (%) | Discharge (m³/s) | Lower Confidence Limit (5%) (m³/s) | Upper Confidence Limit (95%) (m³/s) |
|---|---|---|---|
| 50 | 0.640 | 0.290 | 1.45 |
| 20 | 1.49 | 0.700 | 3.21 |
| 10 | 2.34 | 1.07 | 5.17 |
| 5 | 3.41 | 1.50 | 7.82 |
| 2 | 5.25 | 2.18 | 12.7 |
| 1 | 7.02 | 2.77 | 17.7 |

## Statistics

| Variable | Value | Standard Dev |
|---|---|---|
| Mean | -0.392 | 0.524 |
| Standard Dev | 0.995 | 0.201 |
| Skew | 0.101 | 0.028 |



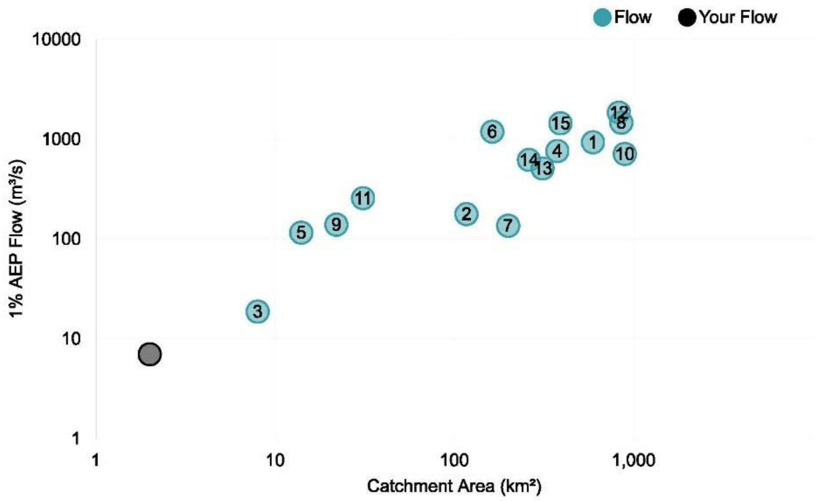
Note: These statistics come from the nearest gauged catchment. Details.

**Correlation**

| | | |
|---|---|---|
| 1.000 | | |
| -0.330 | 1.000 | |
| 0.170 | -0.280 | 1.000 |

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

## 1% AEP Flow vs Catchment Area

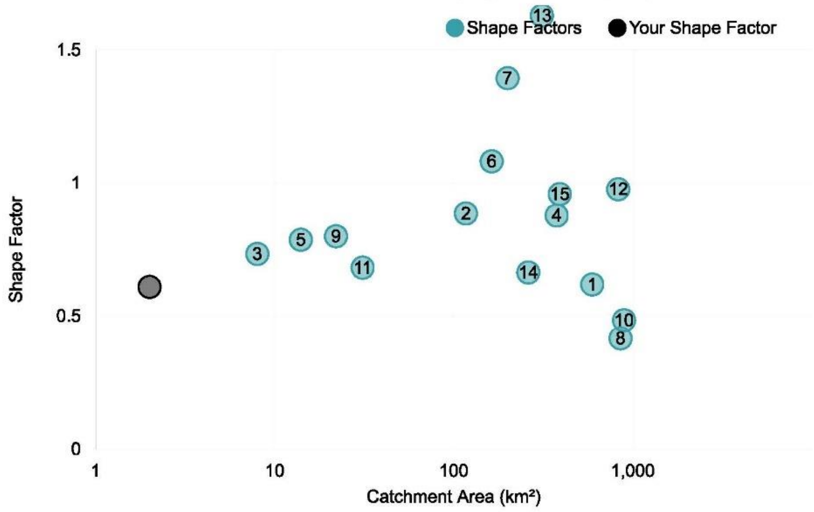



## Shape Factor vs Catchment Area

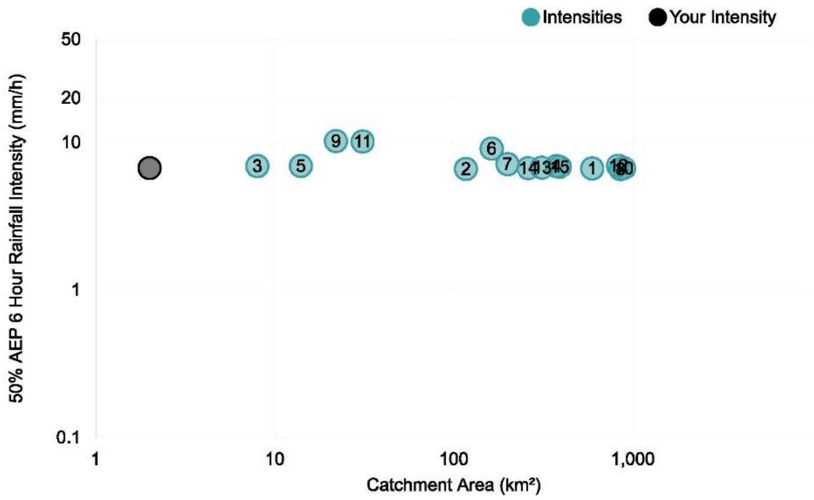


10/27/2019 Results | Regional Flood Frequency Estimation Model

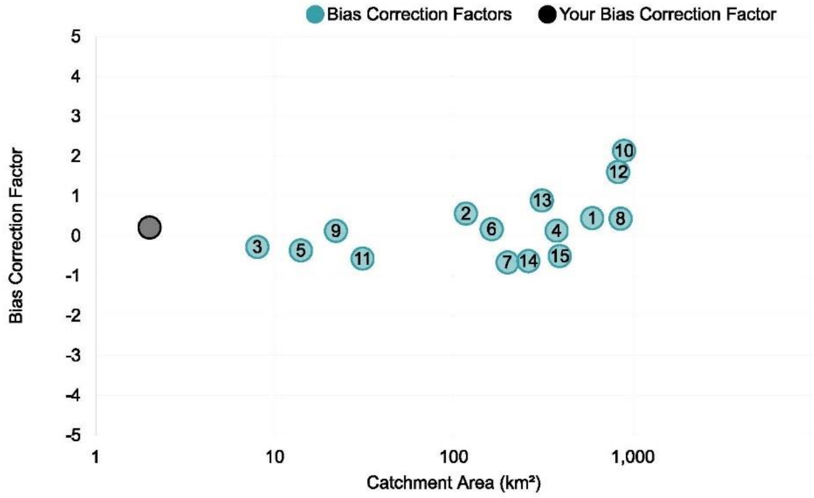



# Intensity vs Catchment Area




https://rffe.arr-software.org 3/6

# Bias Correction Factor vs Catchment Area




# Download

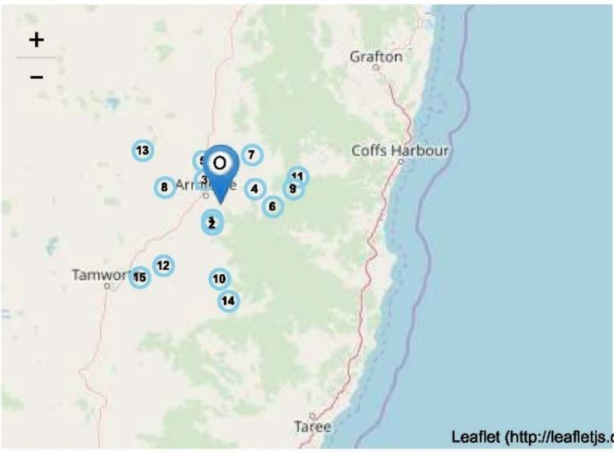
TXT Nearby JSON

**Input Data**

| | |
|---|---|
| Date/Time | 2019-10-27 23:50 |
| Catchment Name | Stringybark |
| Latitude (Outlet) | -30.574093 |
| Longitude (Outlet) | 151.781386 |
| Latitude (Centroid) | -30.567232 |
| Longitude (Centroid) | 151.785712 |
| Catchment Area ($km^2$) | 2.0 |
| Distance to Nearest Gauged Catchment (km) | 13.61 |
| 50% AEP 6 Hour Rainfall Intensity (mm/h) | 6.706799 |

**Input Data**

| | |
|---|---|
| 2% AEP 6 Hour Rainfall Intensity (mm/h) | 14.931342 |
| Rainfall Intensity Source (User/Auto) | Auto |
| Region | East Coast |
| Region Version | RFFE Model 2016 v1 |
| Region Source (User/Auto) | Auto |
| Shape Factor | 0.61 |
| Interpolation Method | Natural Neighbour |
| Bias Correction Value | 0.212 |

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

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