Appendix A - Hydrology

Hydrology

A number of approaches have been used to establish an understanding of local hydrology and develop a hydrological model to inform analysis, and include:

- Review of flood studies previously completed for the Wimmera CMA
- Bespoke TUFLOW catchment model using contemporary techniques (ARR19)
- Comparison with regional flood equations.

Two flood studies were provided by the Wimmera CMA for review as follows:

- Memorandum- Regional Flood Mapping: Concongella Creek (Stage 1A) (Concongella Study)
- Upper Wimmera Flood Investigation Final Report Upper Wimmera Study

Concongella Creek

The Concongella Creek is located further west than the study area, and passes through the township of Stawell. The catchment topology and land use characteristics are similar to that of the study area and in that sense provide some useful comparative data.

The study sought to examine the use of two dimensional flood models for the purpose of estimating flood levels and included comparison with previous flood levels from earlier studies. Issues such as resolution of the two dimensional model and runtimes were tested and comparisons with other flood estimation methods were undertaken to make conclusions around suitableness of the approaches.

The study was undertaken in two main parts, looking at hydrology and then hydraulic processes.

Hydrology

Hydrology (i.e. how much water is in the system) was analysed using two main techniques: Regional Flood Frequency Estimation equations (using ARR1987 IFD inputs) and Flood Frequency Analysis (based on available gauge information).

Regional Flood frequency results were reported for a series of catchments ranging in size from 89km2 to 1968 km2 and results are summarised below.

The FFA analysis compared regional equation estimates of flow and those calculated from gauging records using the FLIKE software package and compared at two locations (Glenorchy and Navarre Road-Concongella Gauge).

In general, the FFA methods were found to report higher values, and the peak flow at the Navarre Road location was 246 cumecs, (approximately 50% higher). The study noted that the differences were within the expected bounds of error based on the length of gauging records.

Hydraulics

The second part of the study focussed on hydraulic analysis (i.e. how the water flows through the system) and was analysed using different resolution flood models developed using the TUFLOW software program and Direct Rainfall inputs.

Model results were tested against hydrology (peak flows) in the previous stage and rainfall loss parameters altered to 'calibrate' to known gauging locations. Values reported by the calibrated model were compared with flow estimates determined in the first stage.

The study concluded that the continuing losses increased for rarer storms, and generally Direct Rainfall method tended to overestimate flooding, but this became less pronounced for larger (rarer) rainfall events.

Finally, the report also considered the effect of model grid size (from 5 metre to 15 metre) and results indicate that finer grids produced higher flows that generally fell in the range of +/- 12% expected from the use of regional equations.

Upper Wimmera Flood Investigation Final Report

The Upper Wimmera flood investigation was prepared by WBM BMT consultants in 2014 and used a series of two-dimensional flood models to determine amongst other things flood extents in the Upper Wimmera River above Glenorchy.

Aspects of the report relevant to this study include two-dimensional model (TUFLOW) setup, calibration of flows against gauge data at various locations and comparison with estimates determined using Flood Frequency Analysis, estimates of peak flows and critical storm durations, and a model hydrograph.

Two locations upstream of the study area were of specific interest, the Wimmera River at Eversley and Mount Cole Creek at Crowlands, as these sites contribute flows that pass along the eastern boundary of our study area and key results are shown in Table A1.

Table A1- Upper Wimmera Flood investigation flow summaries

Location	**Area (km2)**	**1%AEP Peak flow (FFA) m3/sec**	**Critical event duration (RORB) (hours)**		
			AEP 1%	AEP 10%	AEP 20%
Wimmera River at Eversley	655	412	72	18	18
Mount Cole Creek at Crowlands	308	167	72	18	18

Catchment hydrology

The study area is bordered by the Wimmera River to the east, and it is expected that flows from the upper catchment will extend onto the floodplain and may have implications for the siting of infrastructure.

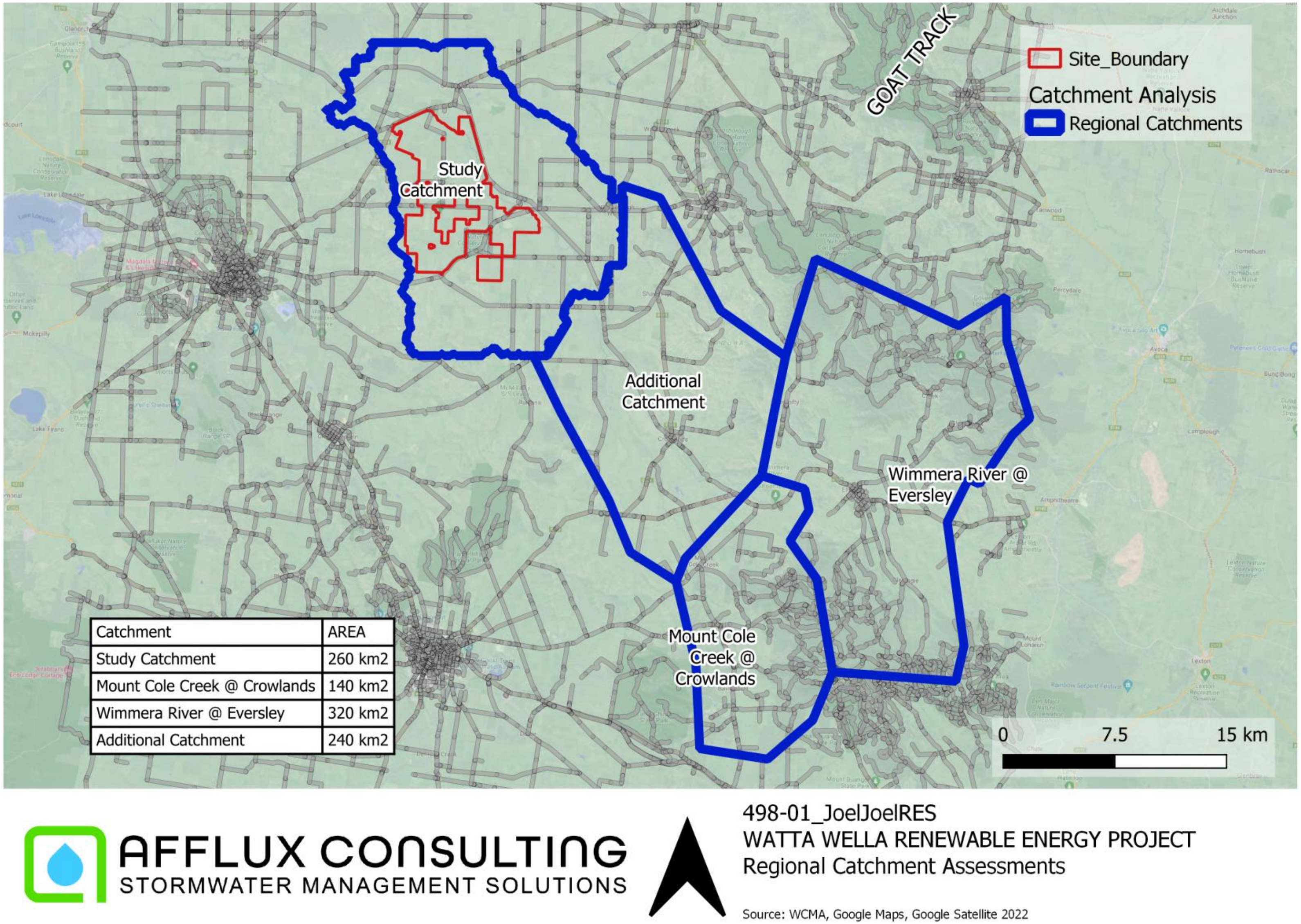
The terrain information supplied by RES does not extend to cover the upper catchment, and it is therefore proposed to introduce flows along the river channel at the upstream end of the model.

Peak flows values have been provided at two upstream locations and can be combined with an additional inflow from the 'additional catchment' that is located between these gauging stations and the catchment area covered by the terrain information provided for this study and are shown in Figure A1.

Flow generated in the 'additional catchment' has been proportioned using a weighted average of the two upstream gauged catchments.

The Upper Wimmera flood study provides peak flows for a series of return periods from 1% AEP to 20% AEP. Inflow values for events outside this range have been interpolated from plotted results shown in Figure A2.

The adopted hydrograph from the Upper Wimmera catchment studies is shown in Figure A3. Flow hydrographs for other areas will be proportionally scaled to match peak flows derived from interpolated results and applied over durations of between 15 and 20 hours as indicated and used as inputs to overlay on a local direct rainfall model for the study area.



Catchment	AREA
Study Catchment	260 km2
Mount Cole Creek @ Crowlands	140 km2
Wimmera River @ Eversley	320 km2
Additional Catchment	240 km2

Figure A1- Catchment delineation and relation to other studies

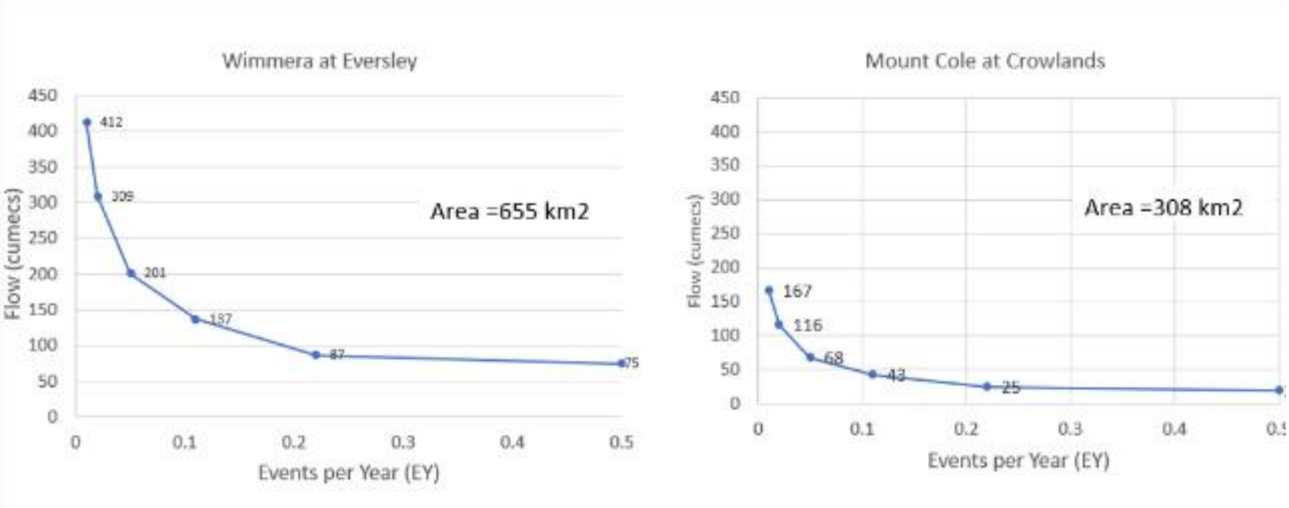


Figure A2- Upper catchment flows

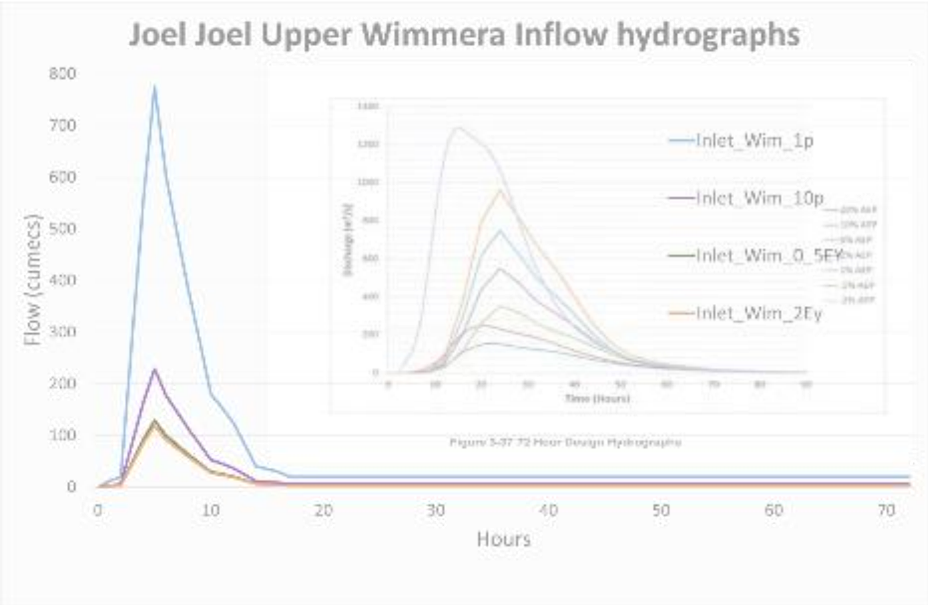


Figure A3- Adopted hydrographs

Implications for model development

The remainder of this study will focus on developing a two dimensional flood model using the software package TUFLOW and using this to prepare estimates of flood parameters across the study area and implications for infrastructure.

From the review of the above reports there are a number of key conclusions that can be drawn and used to inform our modelling approach, which are summarised as follows:

- Direct Rainfall is a valid approach that can be used to model impacts on an individual catchment. Higher resolution models (5 metre grid) are able to reasonably replicate flows expected from the use of empirical and statistical methods.
- Initial and continuing losses can vary depending on the return period; however, these generally fall within a range as indicated in Table A2 (below), and that continuing loss seems to increase with rarer events.
- Critical event durations and peak flows can be used to estimate catchment flows.
- Typical runoff parameters are described (i.e. for catchment roughness).
- Terrain data collected by the client for the localised study area is likely to be of higher vertical resolution than that used of other studies and should be used in preference where available.

Table A2- Loss parameters from flood studies

Loss Parameter	0.5% AEP	1% AEP	10% AEP	20% AEP
Initial Loss (mm)	15- 25	15- 25	15- 25	15- 25
Continuing Loss (mm)	2.25	2.5- 4.0	1.5- 2.5	1.5- 2.0

Appendix B - Flood Mapping

Hydraulic Assessment

A hydraulic assessment methodology has been developed to ensure the best available data inputs are used, ensure model runtimes and data generation is manageable and generally meet the requirements of ARR2019.

Client supplied terrain data does not extend to cover the Upper Wimmera catchment, and as such it is not possible to use Direct Rainfall modelling for these reaches. Assessment of these areas and indicative flows have been determined through the Hydrology method described elsewhere in this report.

A hybrid approach using Direct Rainfall for the local catchment and hydrological methods for the broader catchment is therefore the preferred approach.

The strategy is broadly outlined as follows:

1. Stage 1 Model. Coarse resolution (20 metre grid) TUFLOW model developed for local catchment for purpose of determining critical storm. This involves Direct Rainfall model runs for ensemble storms up to 72 hours and analysis to determine critical event duration and applicable temporal pattern (i.e. Mean event).
2. Stage 2 Model. High resolution (5 metre) TUFLOW model with Direct Rainfall input of critical event for local catchment, combined with (different) critical event inputs from upstream catchment.

Assessment have been undertaken for each of the identified recurrence intervals with a focus on assessing local catchment behaviour and interactions within the Project area for differing critical durations as follows:

- 1% AEP. Critical duration is determined at the interface with the solar farm and Landsborough Road. This has been selected as the solar farm is considered to be the asset class most affected by flooding, its proximity to the Wimmera River and the likely influence of a hydraulic control (bridge) across the River. The storm thus determined will be used to assess a range of impacts against a standard 1%AEP event as described in Planning ordinance
- 10% AEP and 39.35% AEP. Critical durations have been determined within the Project sub area and are generally considered more applicable for impacts on project elements due to the likely increased intensity of rainfall events in shorter duration storms.

This hybrid approach reflects the observations in the regional catchment strategy that intensification of rainfall is a likely threat. From a technical viewpoint increased intensity is likely to result from shorter duration events (such as thunderstorms) and the approach therefore reflects the practical realities of the catchment.

It should be noted that the hydraulic assessments do not include analysis for climate change. Currently, climate change is not an explicit requirement for consideration under the Planning Overlays, however as a practical outcome this can be addressed through the design phase by increasing design flows by a suitable multiplier or using conservative loss estimates.

Model Setup

A flood model for the site and surrounds was constructed using the TUFLOW HPC model, and the general setup remains the same for all recurrence intervals.

The general model setup is shown in Figure B1 which indicates the extent of the TUFLOW model, and location of key inputs such as rainfall and upstream flows.

Lidar extent and Manning's roughness map can be seen in Figure B2. For clarity, a Mannings Roughness of 0.06 has been applied to the waterways, and all road reserves set at 0.02 with all other areas set at 0.035. A slope boundary has been set at the northern end of the model based on the general terrain slope.

Given the vertical difference and linear between the Project area and the model boundary the slope boundary approach is considered satisfactory as it assists in model stability. Tailwater effects at the lower boundary is extremely unlikely to offer any influence on flood conditions in any critical area.

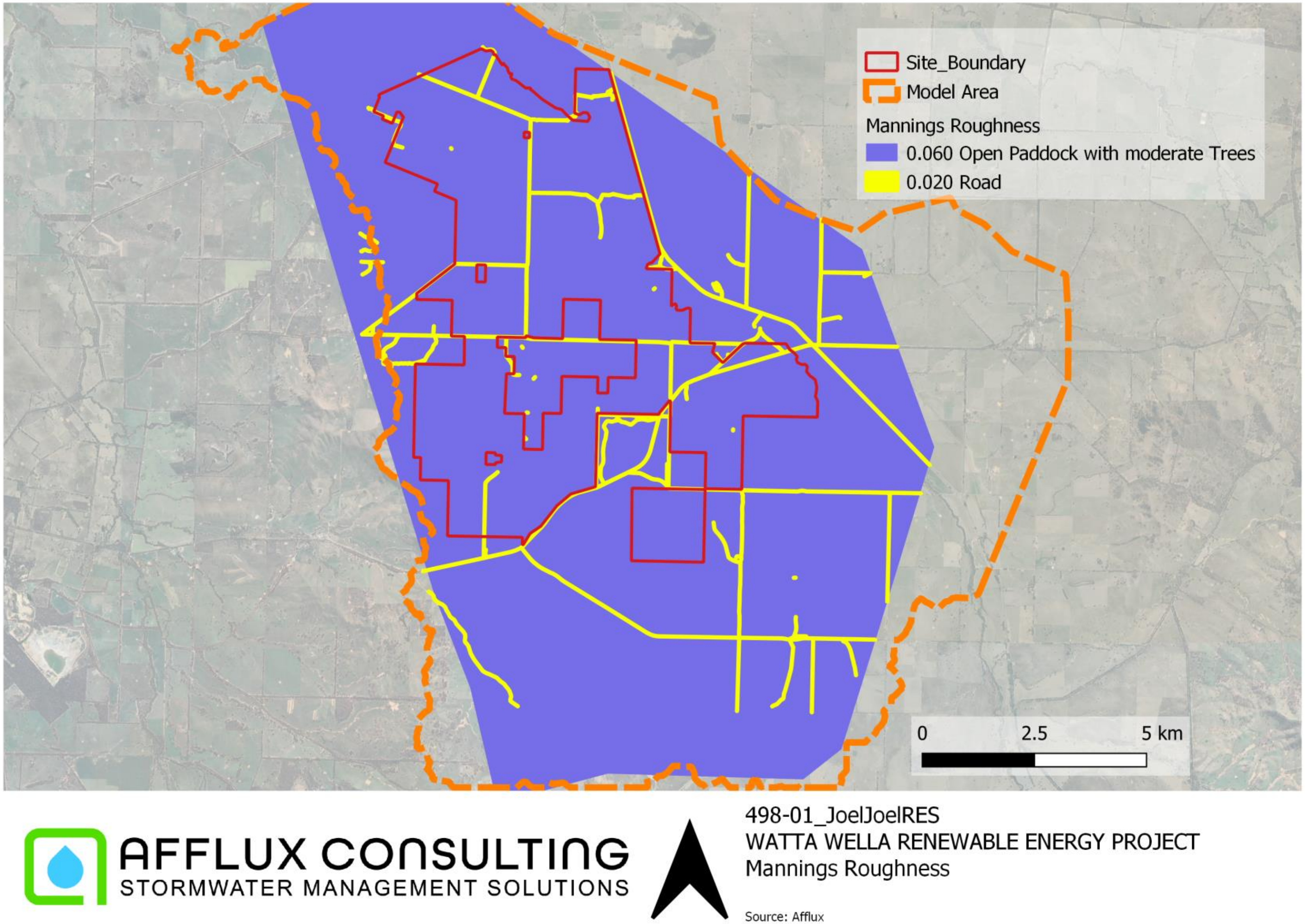


Figure B1- Manning Roughness

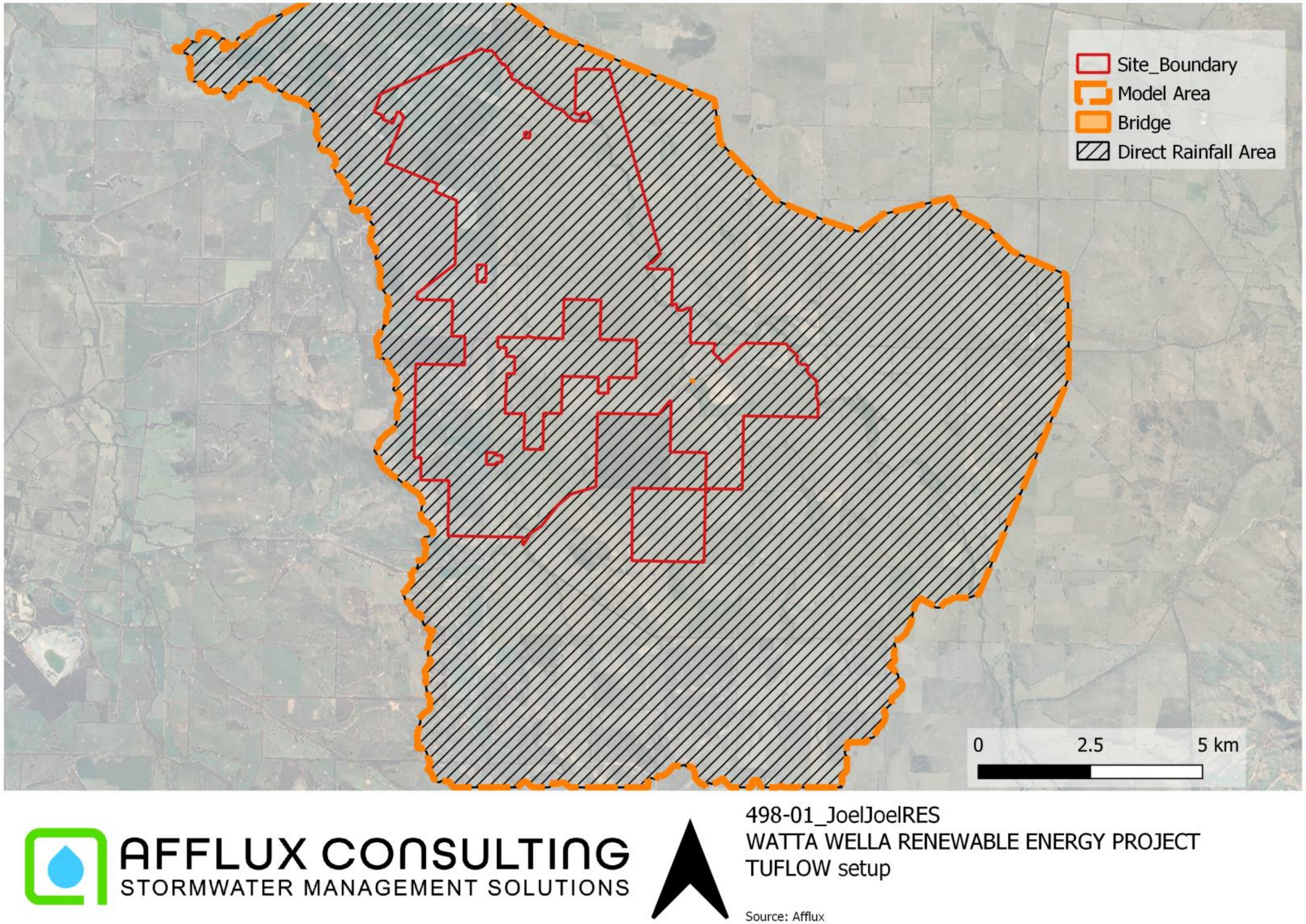


Figure B2- TUFLOW rainfall application area

Direct Rainfall

Direct Rainfall can be used to simulate both the catchment hydrology and hydraulic capacity of the area. The Direct Rainfall methodologies are useful for understanding critical time of concentration and temporal pattern behaviour for small catchments and have a distinct advantage over traditional hydrological approaches in that they are able to respond to the terrain model to determine the direction of flow.

They are also useful in the implementation of ARR19 which requires the assessment of a full suite of storms though a catchment.

Storm event parameters and expected losses were extracted from ARR datahub website in early 2021 (1% AEP) and mid 2022 (10 % and 39.35 %AEP) for a range of storm durations as indicated below.

Model losses were extracted at the same time and are summarised in Table B1. While losses were downloaded they were not used for shorter duration storms as it was found that initial losses dominated, to the detriment of runoff generation. As such, it was decided to use no losses and consequently overestimate runoff generated as a conservative approach.

Given the dominance of rural land, the loss model used was applied uniformly across all model runs for longer events as it was unlikely that the influence of impervious surfaces would make any significant difference.

Table B1- Model loss parameters

Storm Return Period	Storm Duration	Losses	Used in Model
39.35% AEP	10min 20min 30min 60min 90min 120min 180min	IL: 3.7- 3.9 mm CL: 4.7 mm/h IL: 7.4- 7.8 mm CL: 4.7 mm/h IL: 11.1- 11.7 mm CL: 4.7 mm/h IL: 22.3- 23.4 mm CL: 4.7 mm/h IL: 21.6- 22.4 mm CL: 4.7 mm/h IL: 21.2- 22.5 mm CL: 4.7 mm/h IL: 23.1- 24.2 mm CL: 4.7 mm/h	No
10% AEP	10min 20min 30min 60min 90min 120min 180min	IL: 3.8- 4.0 mm CL: 4.7 mm/h IL: 7.5- 8.0 mm CL: 4.7 mm/h IL: 11.3- 11.9 mm CL: 4.7 mm/h IL: 22.6- 23.9 mm CL: 4.7 mm/h	No

		IL: 21.9- 23.0 mm CL: 4.7 mm/h IL: 22.0- 22.8 mm CL: 4.7 mm/h IL: 22.5- 23.7 mm CL: 4.7 mm/h	
1% AEP	1hr 3hr 6hr 12hr 24hr 30hr and longer	IL: 24.1 mm CL: 4.7 mm/h IL: 20.0 mm CL: 4.7 mm/h IL: 21.4 mm CL: 4.7 mm/h IL: 22.5 mm CL: 4.7 mm/h IL: 24.4 mm CL: 4.7 mm/h IL: 25 mm CL: 4.7 mm/h	Yes

1.1. 1% AEP flood modelling

The 1% AEP (Annual Exceedance Probability) flood discharge for the site was estimated following ARR 2019 (Australian Rainfall and Runoff, 2019) processes and included a Direct Rainfall methodology for the local catchment.

Events modelled are shown in Table B2 with losses discussed previously.

Table B2- Events modelled in TUFLOW

		Temporal Pattern No.									
Storm Duration		**TP1**	**TP2**	**TP3**	**TP4**	**TP5**	**TP6**	**TP7**	**TP8**	**TP9**	**TP10**
	3hr	X	X	X	X	X	X	X	X	X	X
	12hr	X	X	X	X	X	X	X	X	X	X
	24hr	X	X	X	X	X	X	X	X	X	X
	30hr	X	X	X	X	X	X	X	X	X	X
	36hr	X	X	X	X	X	X	X	X	X	X
	48hr	X	X	X	X	X	X	X	X	X	X
	72hr	X	X	X	X	X	X	X	X	X	X

A time to concentration map was formed to identify a critical storm event for the catchment and is shown in Figure B3 and Figure B4. The 24 hour event was selected as it corresponded to a the solar farm location along the interface with Landsborough Road and close to the centre of the study area, as being indicative of storms impacting the site. Temporal pattern 5 was selected for further analysis, and closely corresponds to the identified temporal pattern of the 24 hour storm close to where Six Mile Creek crosses under Landsborough Road.

This storm configuration was carried forward a series of finer resolution models to plot impacts for a variety of storm events.

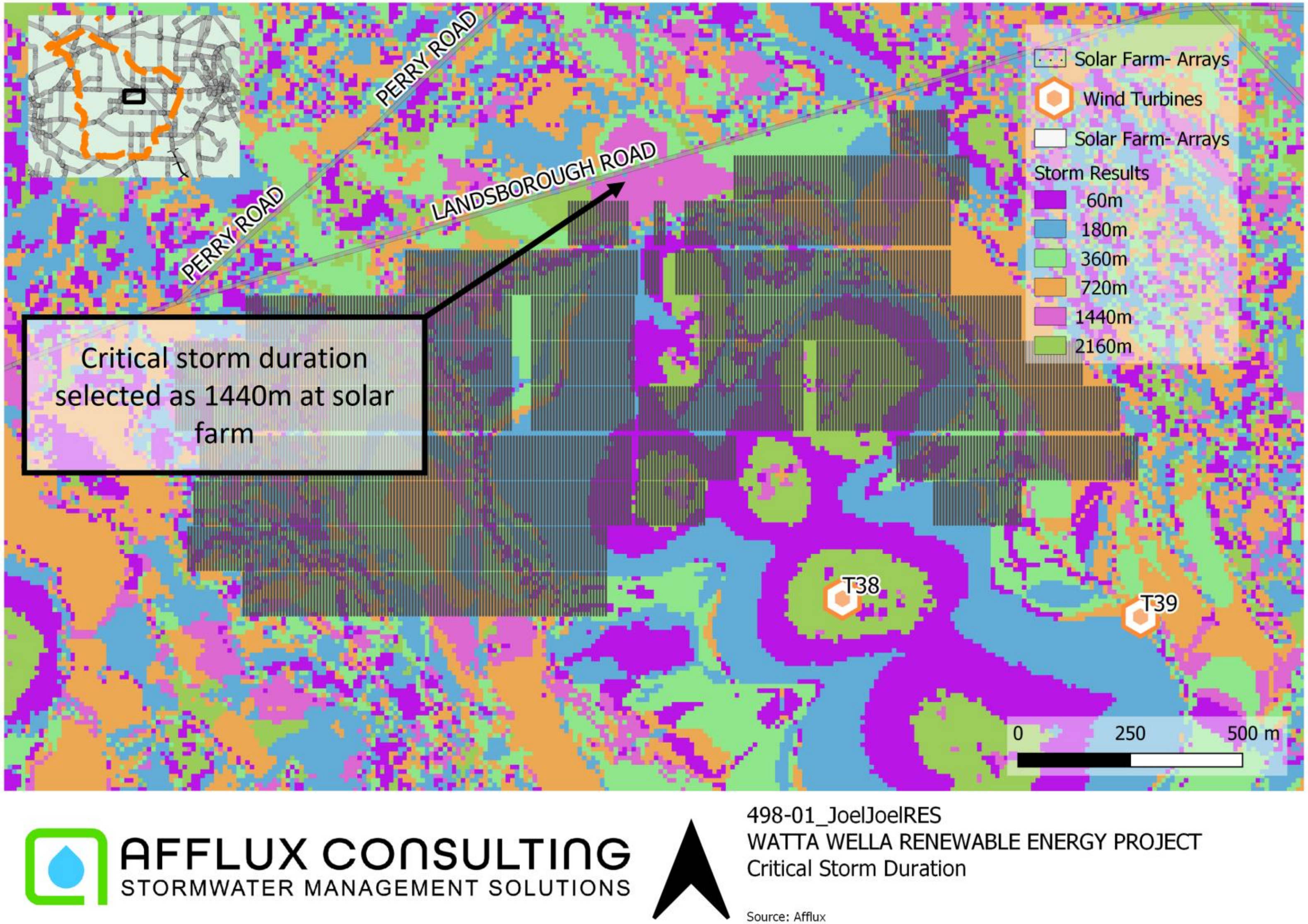


Figure B3- Direct rain results (20 metre grid)- Selection of critical event duration

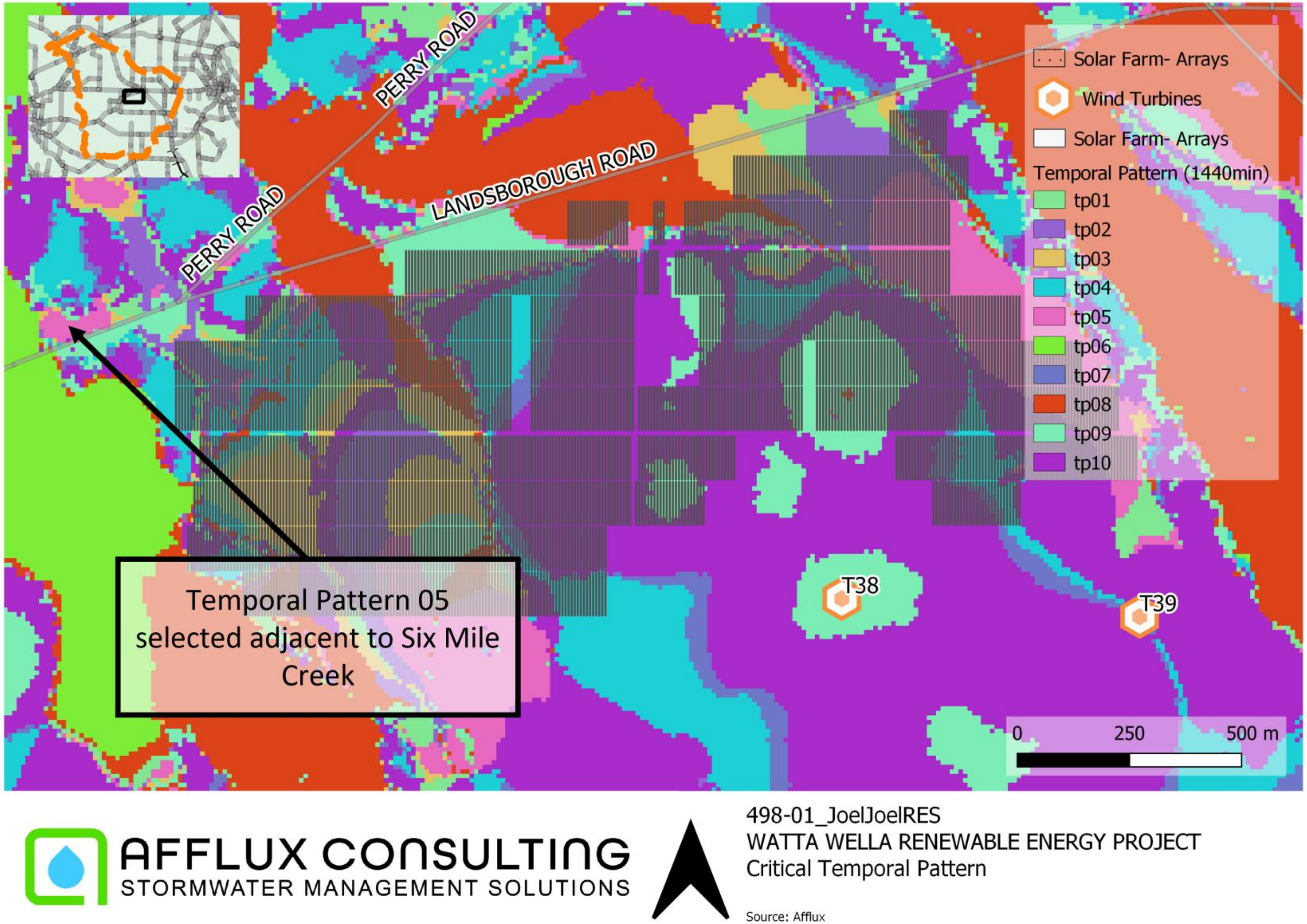


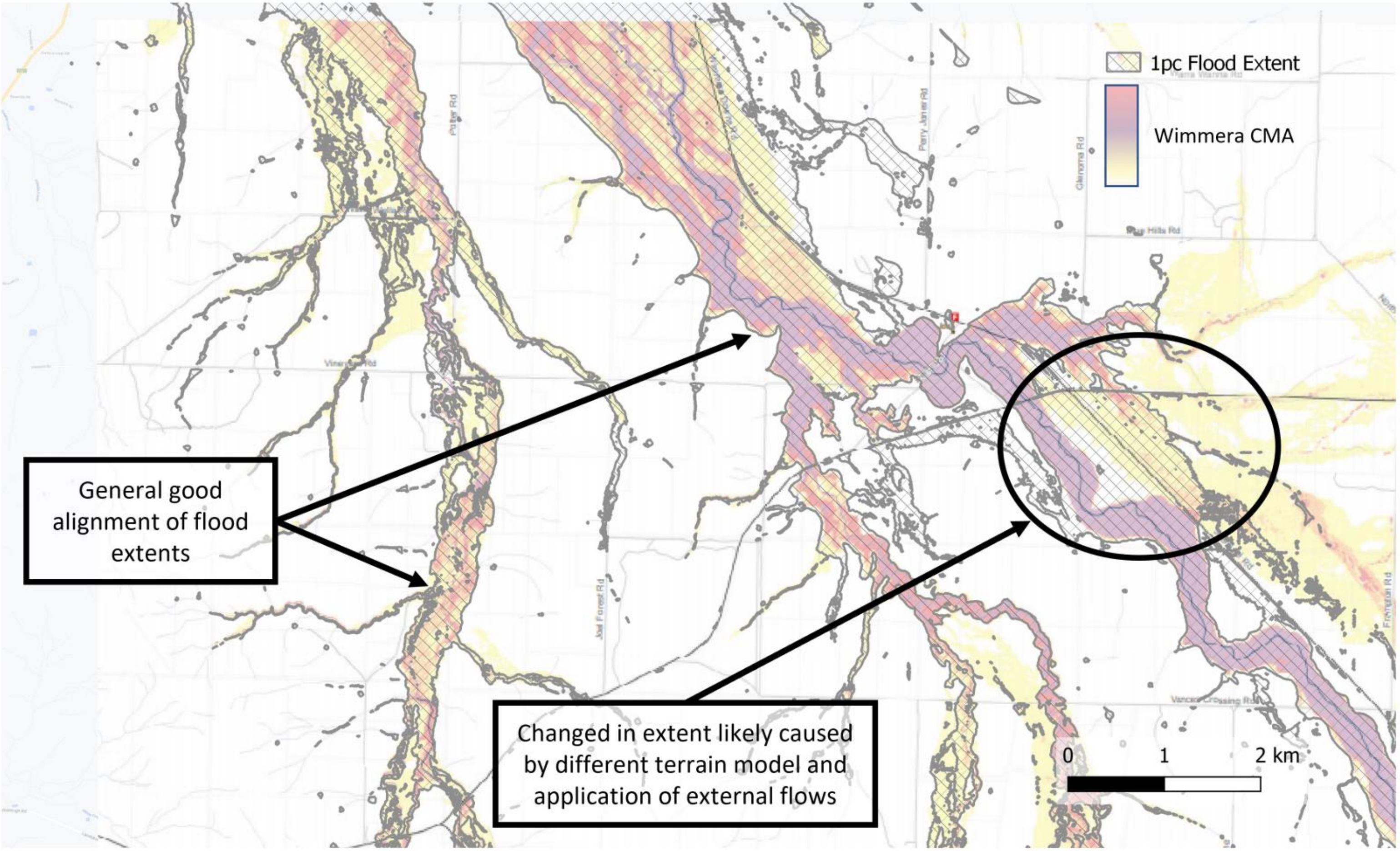
Figure B4- Direct Rain results (20 metre grid)- Selection if temporal pattern for critical event

Calibration of Stage 1 results

The results obtained through the Stage 1 ROG modelling were compared with regional flood results published on the Wimmera CMA website for the local model and are shown in Figure B5. As much of the solar farm is located within the localised catchment it was more important that the ROG approach is calibrated and the results show a high degree of correlation in areas where flows are well developed (i.e. along creek channels).

The Stage 1 modelling results show water extent that is more extensive in some areas but it is expected that slight differences in extent are attributable to tolerances on the underlying terrain and will be further refined through subsequent modelling.

As the Wimmera River receives flow from a much larger catchment calibration to a local Direct Rainfall model was not required.



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498-01_JoelJoelRES
WATTA WELLA RENEWABLE ENERGY PROJECT
1% AEP Extents and comparison with Previous flood reporting
Source: Afflux, Wimmera CMA, Google Maps 2022

Figure B5- Comparison of TUFLOW Stage 1 results with regional flood modelling

10% and 39.35% AEP flood modelling

While eth 1%AEP storm is the ‘headline’ event that is normally used for Planning assessment, there is a possibility that high intensity and shorter duration storms could have a range of impacts, and to allow full suite of assessments using a traditional risk assessment framework as discussed in Appendix C additional storms were selected for analysis.

The 10% and 39.35%AEP (Annual Exceedance Probability) flood discharge for the site was estimated following ARR 2019 (Australian Rainfall and Runoff, 2019) processes and included a Direct Rainfall methodology for the local catchment.

Events modelled are shown in Table B3 with no losses as discussed previously.

It was opted to not include a full suite of ensemble runs, largely to ensure efficient model run times. The judicious selection of three ensembles provides an assessment of front and end loaded events, and the exclusion of model losses is expected to account for minor differences across all ensembles.

Table B3- Events modelled in TUFLOW

		Temporal Pattern No.									
Storm Duration		**TP1**	**TP2**	**TP3**	**TP4**	**TP5**	**TP6**	**TP7**	**TP8**	**TP9**	**TP10**
	10min	X				X					X
	20min	X				X					X
	30min	X				X					X
	60min	X				X					X
	90min	X				X					X
	120min	X				X					X
	180min	X				X					X

A time to concentration map was formed to identify a critical storm event for the catchment as determine at the site downstream boundary

The one hour event and Temporal Pattern 5 was selected as the most 'dominant' pattern affecting infrastructure locations across the Project area, and as discussed previously conservative loss estimates will assist in ensuring the final flows are able to adequately inform design.

As with the rarer events, this storm configuration was carried forward a series of finer resolution models to plot impacts for a variety of storm events.

It was not considered necessary to calibrate these results for a variety of reasons which include:

- The Direct Rainfall methodology differs from regional hydrology approaches; as such it is unlikely that a truly comparative basis exists
- The model used updated and expected higher resolution terrain information than was available for earlier studies. Any comparison would then highlight as much a difference in terrain information than actual flooding
- In areas where the topography is characterised as inclined, the model resolution is expected to be satisfactory to delineate flow paths between ridge lines and high ground
- Notwithstanding, buffers can be applied around infrastructure items and flood extents to assess the potential for flood impacts to occur in the 'grey' area caused by the model sampling resolution. This provides an acceptable level of robustness in analysing risk.

Stage 2 Modelling

Stage 2 Modelling was undertaken using a higher resolution grid (i.e. 5 metres) and introducing upstream flows into the Wimmera River channel as discussed previously.

In addition, a bridge was included in the model at the point where the Seven Mile Creek passes under Landsborough Road as this was considered to be a local flow control that could influence tailwater back into the solar farm area.

Stage 2 modelling parameters are summarised in Table B4 below.

Table B4- TUFLOW model parameters and Quality Assurance checks

Model setup and outputs (summary)		
Inflow Boundaries	Approximately 6.5 kilometre upstream of site within Wimmera River Channel	Flow based on analysis of upper catchment analysis of hydrology and critical event
Outflow Boundaries	Approximately 4.5 kilometre downstream of site	Fixed head boundary (140 metre AHD) and approximately 60 metres below terrain levels along lowest interface with Project area
Grid Size	5.0	High resolution model to characterise flow across land.
Time Step	Initial time step of 10 seconds (2d)	Reasonable time step for selected grid size. The HPC model uses adaptive time steps to account for various control parameters monitored during model run time.
Model run duration	Varies between 2 and 3 times event duration (i.e. 3 hour storm runs for 9 hours, 72 hour storm runs for 144 hours)	Allows sufficient time for peak flows to pass through the site.
Model Solver	TUFLOW HPC	2020-01-AA-iDP-w64
Model Topography	Client supplied Photogrammetry	Adopted as the basis of model.
Quality Assurance		
Mass Balance	~0% (all final runs)	Mass balance indicates model stability and representativeness of physical conditions. As per Melbourne Water modelling guidelines this should ideally be less than 1%.
Adaptive Timestep changes	Nil	Timesteps are adapted automatically by the TUFLOW engine based on control number rations calculated during model runs and are used to ensure model stability. No timestep changes have been reported for any model runs

Results

Direct Rainfall results have been filtered to remove the first 20 millimetres of runoff. Shallow runoff occurring at less than the vertical resolution of terrain model can lead to misleading results by overestimating flooded area.

Typically filtering is undertaken at 20 millimetre or 50 millimetre depths, and 20 millimetre has been used in this analysis.

A likely flood extent has been inferred from the filtered results and in addition to depth filtering, isolated areas of flooding up to 200m^2 have been removed as modelling artefacts in order to assist with identification of major flow paths that are more likely to be critical for determining impacts on and from infrastructure.

The resultant flood extent has been further extended by a 30 metre buffer distance to allow an assessment of impacts (i.e. for risk assessment purposes) which is considered conservative, but will ensure a robust process that should allow minor changes in design layout in response to site and ground conditions.

Flood model results for all recurrences and higher resolution runs are provided in Appendix D.

All results show Depth, Water Surface Elevation and Velocity results. The shorter duration events also include additional Bed Shear Stress information to assist with an understanding of erosion potential.

For analysis of results there are a number of areas where flood impacts against infrastructure occurs (within a 50 metre flood extent buffer), and these are summarised in Table B5

Smaller plots (i.e. A4 in size) which are centred on these areas are included as Appendix E.

Table B5- Flood results impacting infrastructure

Infrastructure Classification	Identification/ location	Interaction with flooding			Description/ Outcome
		1% AEP	10% AEP	39.35% AEP	
Wind turbines (no impact)	T1- T11, T13- T17, T20- T28, T30- T39, T41- T46	Nil	Nil	Nil	All lie outside buffer. No risk assessment required
Wind turbines (potential impact within buffer)	T12	Yes	Yes	No	Pad located on fringe of flood extent. Turbine located within buffer extent
	T18	Yes	Yes	No	Pad located on fringe of flood extent. Turbine located within buffer extent
	T19	Yes	No	No	Pad located on fringe of flood extent. Turbine located within buffer extent
	T29	Yes	Yes	No	Pad located on fringe of flood extent. Turbine located within buffer extent
	T40	Yes	Yes	No	Pad located on fringe of flood extent. Turbine located within buffer extent
	T47	Yes	Yes	Yes	Pad and turbine located within confluence of stream flows

Solar arrays	General	Yes	Yes	Yes	Western, eastern and frontage along Landsborough Road located within flood and buffer extent. Modelled flood extents through majority of solar farm have not been identified in Overlay. Impacted area reduces for smaller storms
Solar farm-buildings	General	Yes	Yes	Yes	Eight inverter station located to east, west and frontage along Landsborough Road located within flood and buffer LSIO extent. Modelled flood extents through majority of solar farm have not been identified in the LSIO. This reduces to four buildings for smaller events
Solar farm-access tracks	General	Yes	Yes	Yes	2.7 kilometres of track located to east, west and frontage along Landsborough Road located within flood and buffer extent. Modelled flood extents through majority of solar farm have not been identified in the LSIO This reduces to 1 kilometre and coincides with smaller events
Battery storage	General	Yes	Yes	Yes	Flooding occurs along defined channel running centrally through battery storage. Flood modelling confirms LSIO extent The area impacted is similar in all storm events
Reticulation (no impact)	General	No	No	No	93 kilometres of proposed reticulation not located in flood impacted areas
Reticulation (potential impact within buffer)	General	Yes	Yes	Yes	12.6 kilometres of reticulation located in flood areas. Individual lengths range from around 50 metres to 2.3 kilometres. All cable reticulation proposed to be underground. Impacted lengths increase to 18 kilometres for smaller events (due to the distribution of shorter events in upper catchment)
Access tracks	General	Yes	Yes	Yes	7.5 kilometres of access tracks located in flood areas. The majority of

					individual lengths range from 50 metres to 2.3 kilometres. Impacted lengths reduce to 7.1 kilometres for smaller events. Hazard classifications can be applied to roads to assist in determining risk classification. For access track segments. the majority are classified as Hazard Class 2 - suitable vehicular traffic (excluding small vehicles). Identified areas will require additional attention through design or access limitations to ensure they remain safe.
Ancillary items	General	Yes	Yes	Yes	A number of ancillary items intersect with floodway buffer; however it should be noted these may also include a buffer around works areas etc. Identified areas may require additional detail to design and operational use to ensure that impacts on waterways are avoided.

Appendix C

Flood Risk Assessment

A Flood Risk Report is required under **Clause 44.03** (Floodway Overlay) of the Planning Scheme as a formal method to respond to impacts from potential flooding, particularly in circumstances where a Floodplain Development Plan is not in place.

Floodplain Development Plans are described in the Guidelines as enabling "*the council and local floodplain management authority to include specific local requirements in the planning scheme'*. Upon review of publicly accessible information and after discussions with the Wimmera CMA we are of the view that no such plan exists for the Project area, and a Flood Risk Report is appropriate.

The Risk Assessment methodology follows a standard process of hazard definition, likelihood of occurrence and severity of consequence, specifically with regard to the process of gaining approval, and mitigation responses will be offered to reduce risk to acceptable threshold (i.e. timely permit approval able to be achieved).

Appendix E provides a range of Maps showing the various buffers and planning layers that have been used to underpin the risk assessment.

At this stage in the Project lifecycle details of how the facility should be constructed or operated have not been fully determined and assessed, however for most infrastructure classes there are some obvious requirements that have been captured in a final summary table.

Definitions used in the risk assessment of each hazard are identified below and summarised in Table C1 and Table C2 with Table C3 providing assessment categories (risk ratings).

Table C1- Frequency of occurrence

Definition of Frequency	Description
High	The facility/ infrastructure item is impacted by flood waters encroaching within a 30m buffer for the 39.35% AEP and/ or 10% AEP Event
Medium	The facility/ infrastructure item is impacted by flood waters encroaching within a 30 metre buffer for the 1% AEP Event
Low	The facility/ infrastructure item is not impacted by flood waters

Table C2- Severity of consequence

Definition of Severity	Risk to operations	Risk to floodplain
High	Excessive floodwaters likely to compromise function	Floodplain impacts (e.g. afflux) that extend beyond Project boundary and unlikely to be managed through agreements
Medium	Floodwaters impact, with only minor depth that can be managed by freeboard or design parameters (e.g. to mitigate erosion)	Floodplain impacts (e.g. afflux) contained within Project boundary and able to be managed with landholder agreement with respect to individual land parcels
Low	No interaction with floodwaters	No interaction with floodwaters

Table C3- Application of risk ratings

		Severity of consequence			Mitigation Required
		High	Medium	Low	
Frequency	High	5	4	3	Y/N
	Medium	4	3	2	
	Low	4	2	1	

Hazard identification

A range of hazards have been identified and are described below.

Hazards that may impact on approvals and operation which have been assessed are described below and generally address the requirements of the LSIO and FO under the Planning Scheme:

- Flood depth impacting operation: This is generally taken to imply that the Project infrastructure item becomes 'wet' under a flood modelling scenario.
- Excessive hazard conditions: This is taken to imply that flood conditions exceed hazard thresholds that include a combination of depth, velocity and velocity depth product.
- Afflux at property boundary: This implies that the existing surface water levels experienced within any individual land holding in the Project area or at the Project boundary and beyond are increased due to the Project.
- Erosion: This is taken to imply that the velocity or bed shear levels exceed an acceptable threshold value. For the purpose of assessment bed shear stress will be used as an indicator.
- Pollution of waterways.
- Riparian encroachment.

Further information on how hazards will be assessed is provided in the sections below.

Flood depth

Floodwaters impact on various infrastructure items at a range of depths, but generally can be classified as low. The largest depths reported within the Project area, fall within the solar farm area along the Landsborough Road frontage, with a maximum depth of around 500 millimetres associated with lower lying land.

Where floodwaters exist, it is typical to provide a freeboard allowance to be added to the flood depth and underlying terrain level to provide a construction level at each specific location.

For areas where there are floodwater impacts, an appropriate construction level has been stipulated to achieve the requirements of the Wimmera CMA for 300 millimetres freeboard. Given the scale of the project these are reported on 50 metre spacings and some interpolation may be required for specific locations.

Based on the freeboard levels being achieved, risk can be reduced to low providing other considerations are taken into account and appropriate weather and waterproof protection is used for electrical connection falling within these zones.

Hazard assessment

The Flood hazard categories as outlined by the Australian Emergency Management Institute in 2014 have been selected for assessment of risk to roads and accessways and is shown in Figure C1.

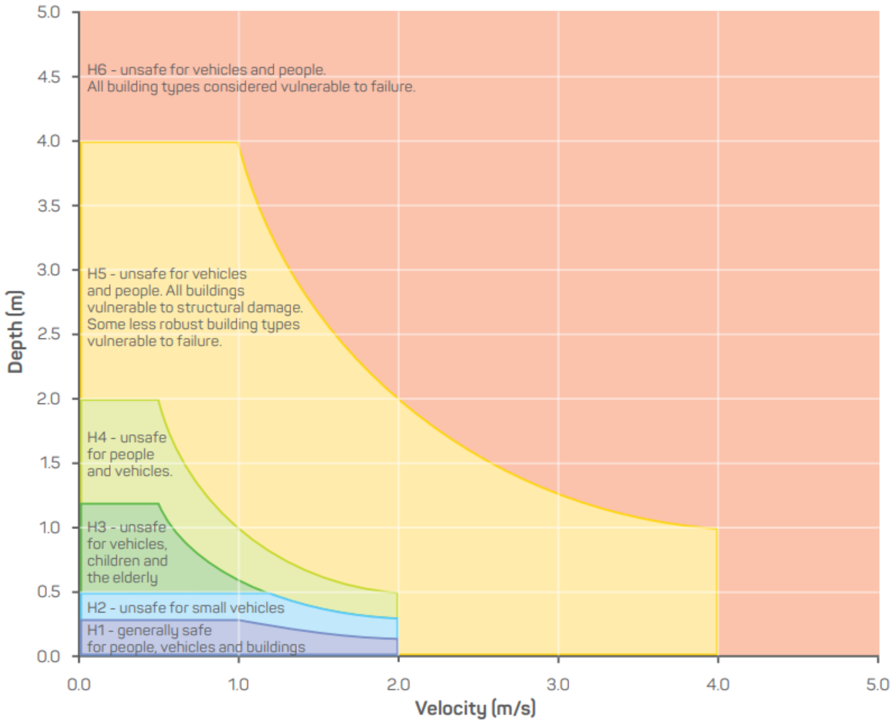

Figure C1- Hazard classifications

Given the Project setting it is expected that site access will be limited to authorised personnel and traffic, and it is anticipated that larger vehicles (trucks, 4WD) will be mainly used throughout the Project life. As such Hazard Class 2 is considered suitable for the project purposes.

Where higher hazard exists, there will need to be additional measures included to manage risk.

Afflux assessment

Afflux potential has been divided up based on infrastructure class. Reticulation located underground is not expected to cause afflux condition.

Afflux has been assessed through modelling using pre and post flood conditions, supported by a qualitative assessments depending on the nature of infrastructure.

Larger infrastructure items include hardstand areas associated with turbines, buildings and inverter pads associated with the solar farm and the Battery Storage area. It is assumed that the turbines are located above the associated hardstand pads.

These perimeters of these larger infrastructure items have been used to modify the terrain by adding an additional 1.5 metres to the underlying terrain to effectively raise these above existing ground surface. Based on the size of these items a 10 metre grid modelling grid was adopted to achieve a balance between computational times and the ability to assess impacts based on the size of the various infrastructure items.

Once run, the results for pre and post development conditions were compared to identify areas where water level had increased or decreased, and areas that changes from being dry to wet and vice versa, Typically an allowance of 30-50 millimetres is allowed for changes in depth as determined at the nearest downstream property boundary is considered acceptable for flood plain assessments.

Wind turbines

Afflux at property boundary. Afflux assessment requires 'before' and 'after' assessment of flood conditions and generally requires that the resolution of the model and the infrastructure that may impact the flood is suitably matched, and may require the use of a 'downscaled' model. Under the Planning Scheme, afflux is a consideration for rarer storm events.

Afflux is levels were found to be localised and associated with the turbines and associated pads which were identified as falling within the flood extents. Only the 1% AEP has been used for assessment of afflux as this aligns with planning requirements and is generally seen to be conservative. There were no reported instances of afflux impacts being experienced beyond the property boundary for any parcel of individual parcel of land or the project as a whole. Therefore, based on the adopted criteria the afflux impact is assessed to be low, and where localised afflux is identified it should be possible to address this through individual landholder agreements.

Afflux maps are provided in Appendix F.

Solar farm

The solar farm area is impacted by both local catchment runoff and potential overflow from the Wimmera River in larger events. The water flows along both edges of the entire solar farm area and inundated regions are formed when water is trapped by Landsborough Road which crosses the floodplain.

A bridge located along the Wimmera Road alignment and across the Six Mile Creek are the primary mains through which water is relieved from the area. From an assessment of terrain there is potential for water to become ‘trapped’ behind the road in a range of flood events, with an increasing area of coverage for longer duration storms.

While it is possible to set levels to ensure that the solar arrays, building and electrical connections are set at levels 300 millimetres above flood level there may be further operational implications that need to be considered from an access perspective.

It is not expected that the solar arrays (which will be built on poles embedded into the ground and raised above flood levels) will have any noticeable afflux impositions for the broader floodplain,

This this may not be the case for buildings and inverter areas which are currently shown on plans as being up to 60 metres wide and located perpendicular to the predominant flow direction. These items at this size has been explicitly tested through the pre and post event modelling, and while afflux was observed it was localised and did not extend beyond the adjacent property boundary. Advice from the design team is that these building layouts are conservatively oversized and any reduced building size would present even lower risk. As water level differences are maintained within property boundaries these can be addressed by landholder agreement.

Afflux plots for the solar farm are provided in Appendix F.

For buildings and inverter pads the application of 300 millimetre freeboard above indicated flood level will be required, and it would be advisable to pay extra care to electrical connections in these zones.

Roads

Afflux potential for access roads will be variable, and largely dependent on the final nature of construction and is summarised as follows:

- For roads constructed at or close to existing grade it is unlikely that any afflux will entail.
- Roads that are raised and perpendicular to flow direction, afflux effects are likely to occur on the upstream side. As such, it will be the individual landholder that would experience the effect, and it

is expected this will be negotiated by agreement. It is likely that any road improvements would provide possible benefit to the landholder and would factor in the agreement discussions.

- Raised roadways are likely to provide for flow conveyance (e.g. culverts or forded crossings) and the specific design of these should take into account the nature of discharge. It is expected that the design of these features would be aligned with existing flow paths and potentially reduce downstream afflux in larger events.

We have reviewed the requirements of the Works on Waterways permits which will require that sufficient conveyance is maintain under any road structure located close to a defined waterway as such to limit the likelihood of afflux.

On the basis of these analysis is it expected that afflux risks can be considered as low for the purpose of approval, and the Works on Waterways permit process provides a mechanism so that specific issues are addressed through design.

Battery Storage

The battery storage straddles an overland flow path and has the potential to create localised afflux impacts as confirmed by analysis.

Options are available to mitigate afflux at this location and can be refined through design and include:

- Localised afflux can be managed through agreements with landholder
- Location of specific battery installations to allow overland flow path to operate unhindered and avoid any afflux impacts
- Provision of drainage to divert runoff through/ around the battery storage. If existing overland flow rates can be maintained afflux will be reduced
- Provide an alternate flow path. Modelling indicates that if the battery storage provides an obstruction to flow runoff will find a new pathway to the south west and re-join the channel below.

Afflux plots for the battery storage are provided in Appendix F.

Erosion potential

Erosion potential is a function of various aspects including soil, runoff characteristics and vegetation. Shear resistance thresholds are provided in Figure C2 for various vegetation covers.

It is not possible to determine the actual risk posed through erosion based on information provided for review, however using a threshold of 100N/m^2 (for short grass cover) the 10% AEP results have been filtered to determine areas of increased risk.

The analysis indicates that the higher shear stress areas located away from infrastructure items, are mainly associated with either larger watercourses or higher catchment areas where slopes are greater.

On the basis of this analysis, erosion potential associated with the facility is considered low, however care should be taken when designing individual items to avoid unnecessarily concentration flows which may then lead to issues occurring.

There is a small risk that access to sunlight for ground covers under the solar farm may limit the viability of vegetation if these were to be in permanent shadow. Advice from the design team indicates that the solar arrays will be able to track the sun as it transits the sky, and as such there is expected to be reasonable sunlight to support ground cover vegetation.

Title	Maximum shear stress resistance thresholds for herbaceous vegetation in gully initiation studies
Vegetation type	**Threshold erosion data (N/m^2)**
Aquatic (swampy) vegetation	105
Tussock and sedge	240
Disturbed tussock and sedge	180
Bunch grass 20-25 cm high	184
Bunch grass 2-4 cm high	104
Bunch grass	80-170*
Bermuda grass	110-200*
Buffalo grass, Kentucky bluegrass	110-200*
Notes	* These ranges summarise data for a variety of soil types/hillslopes.

Figure C2- Shear Stress resistance- typical values for vegetation types

1.2. Pollution

While the main focus of this report is on flood impacts it is expected that the potential for water pollution will need to be managed in and around waterways.

The use of buffer distances for assessment of flood risk provides an initial protection against fugitive emissions from works, and equipment storage areas and further detail will need to be developed through the various construction phases (such as through a construction management plan). Protection against sediment runoff through erosion, and materials handling techniques are considered the appropriate response to limit risk from specific works areas.

In this report these risks have been primarily associated with ancillary areas, but is equally applicable to specific constructions works (such as laying foundations and erecting wind turbines).

1.3. Riparian encroachment

Riparian buffers support waterway health by filtering catchment pollutants (such as sediment), providing habitat for various ecological communities and supporting stream bank stabilisation.

Riparian buffers are generally characterised into three general zones which include the stream channel, a core riparian zone and vegetated setback and are shown conceptually in Figure C3.

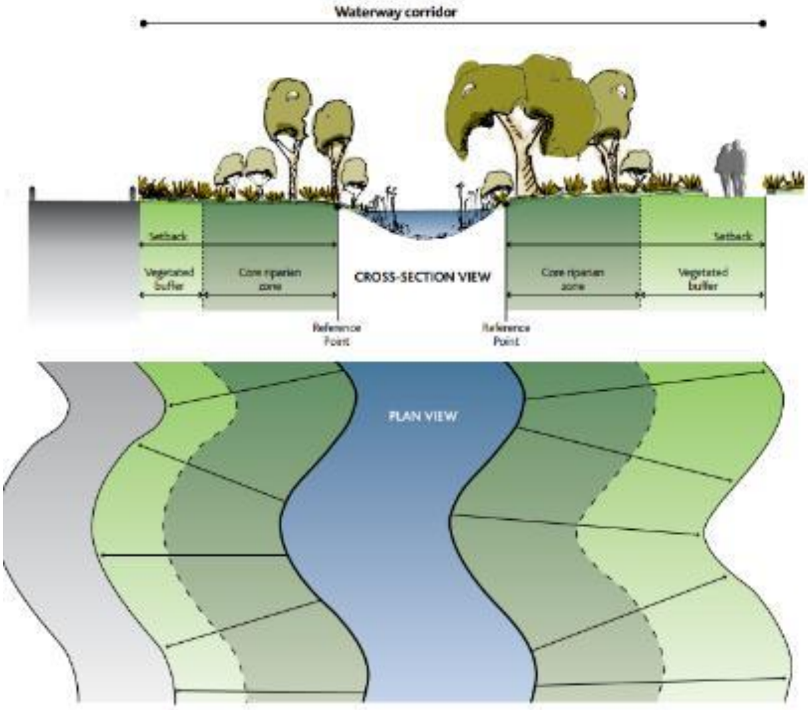

Figure C3- Typical riparian zones

In the absence of any specific requirement, a core riparian buffer distance of 30 metres is typical for larger streams and channels, however this may be reduced for smaller stream associated with upper catchment areas.

Accordingly, identifiable waterways (as obtained from Victorian Government database) have been buffered by a distance of 30 metres and used to identify areas where conflicts may occur.

Outcomes are assessed as follows:

- All wind turbines are located outside of the 30m buffer distance from identifiable waterways.
- The solar farm is located outside the 30 metre buffer distance.
- There are some encroachments with access tracks, and it will be dependent on how these are constructed to ensure good riparian outcomes. It is noted that the Wimmera CMA Works on Waterways permit conditions provide guidance on culvert sizing and design to maintain passage of flows and other ecological functions (such as migration of fish) and are considered an appropriate risk mitigation approach.
- Reticulation being located underground will have minimal riparian interaction during operational phases, although some requirements will be needed depending on the construction method to reinstate works area and protect sensitive ecosystems.
- As an overall assessment riparian risk are considered low and can be mitigated by standard conditions that will be addressed through the permit process.

Based on the expected condition of Seven Mile creek at the locations where the buffer encroachments occur it is considered low risk to the waterway form and function. The watercourse is expected to be ephemeral, relatively steep, and partial connectivity will remain across the entire creek width. As such sensible precautions to minimise erosion and should be sufficient to reduce risks to low.

Risk Assessment outcomes

Table C4 shows the outcomes of the risk assessment and includes recommended mitigation strategies and actions to reduce the raw risk to low. Where the mitigation options identified, these should be included in the Project response.

Table C4- Risk assessment outcomes and mitigations

Risk ID	Hazard	Risk Type	Assessment Standard	Frequency	Severity of Impact	Risk outcome	Assessment/ Mitigation to reduce low
1	Wind turbines (no impact)	operations	Flood depth	-	-	0	Assessed as no risk
2	Wind Turbine T12 (turbine and base)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
3	Wind Turbine T18 (base only)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
4	Wind Turbine T19 (base only)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
5	Wind Turbine T29 (base only)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
6	Wind Turbine T40 (turbine and base)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
7	Wind Turbine T47 (turbine and base)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts
8	Wind turbines (no impact)	floodplain	Afflux	-	-	0	Assessed as no risk
9	Wind Turbine T12, T18, T19, T29, T40, T47	floodplain	Afflux	High	Low	3	Assessed as low risk (i.e. no likely impact)
10	Wind Turbine T12, T18, T19	floodplain	Riparian impact	Medium	Low	2	Precautions to minimise erosion around turbine bases
11	Solar Array (general)	operations	Flood depth	High	Medium	4	Ensure freeboard is sufficient to avoid impacts

12	Solar Array (general)	floodplain	Afflux	High	Low	3	Assessed as low risk (i.e. no likely impact)
13	Solar Array (general)	floodplain	Erosion	Medium	Medium	3	Solar tracking of arrays will ensure sunlight is able to reach ground below and support vegetation growth. Experience from other solar facilities indicates that grazing activities should be possible within the farm area.
14	Solar Farm (Buildings and associated Inverter Stations)	operations	Flood depth	High	Medium	4	Raise buildings to achieve floor level with 300mm freeboard
15	Solar Farm (Buildings and associated Inverter Stations)	floodplain	Afflux	High	Low	3	Afflux at boundary is assessed as negligible based on configuration.
16	Solar Farm (Access Tracks)	operations	Hazard Class	High	Low	3	Hazard classification H1- Assessed as low risk
17	Solar Farm (Access Tracks)	floodplain	Afflux	High	Low	3	Dependent on access requirements and road construction. If raised check afflux at boundary is acceptable and enter into landholder agreement as necessary. Works on Waterways permits may be required in consultation with Wimmera CMA
18	Battery Storage	operations	Flood depth	High	Medium	4	Raise battery levels to above flood levels (freeboard 300mm). Make provision for overland flow, whether at surface or intercept drainage and discharge below area of concern.

19	Battery Storage	floodplain	Afflux	High	Low	3	Unlikely to be of concern if passage of water is accommodated or landholder agreement reached
20	Reticulation (no impact)	operations	Flood depth	-	-	0	Assessed as no risk due to undergrounding of cabling
21	Reticulation (impact with flood buffer)	operations	Flood depth	High	Medium	4	Cabling located uderground reduces risk to low. Ensure waterproofing is adequate and penetrations ris above flood level (i.e. freeboard)
22	Reticulation (impact with flood buffer)	floodplain	Afflux	High	-	0	Assessed as low risk (i.e. no likely impact)
23	Reticulation (impact with flood buffer)	floodplain	Erosion/ waterway degradation	High	Medium	4	For crossings inder significant waterways approval will be required from CMA and construction methodology should minimise impact in line with approval conditions
24	Access tracks (H1, H2)	operations	Hazard Class	High	Low	3	Assessed as low risk based on hazard category.
25	Access Tracks (H3 or higher)	operations	Hazard Class	High	Medium	4	Design appropiate crossing or introduce management controls to limit area being accessed during periods of high risk
26	Access tracks (no impact)	floodplain	Afflux	-	-	0	Assessed as no risk
27	Access Tracks (impact with flood buffer)	floodplain	Afflux	Medium	Low	2	For raised roads, ensure adequate design of culverts and conveyance. Check afflux at boundary is acceptable and enter into landholder agreement as necessary

28	All infrastructure (impact with flood buffer)	floodplain	Erosion	High	Low	3	Consider erosion potential in design. Provide treatments as necessary for individual components
29	Ancillary items (impact with flood buffer)	operations	Flood depth	High	Low	3	Locate items away from waterway areas
30	Ancillary items (impact with flood buffer)	floodplain	Afflux	High	Low	3	Temporary storage of large items may need to be considered for impact, but generally assessed as low risk
31	Ancillary items (impact with flood buffer)	operations	Hazard Class	Medium	Low	2	Assessed as low risk based on hazard category.
32	Ancillary items (impact with flood buffer)	floodplain	Erosion	High	Low	3	Include sediment control for areas to reduce risk
33	Ancillary items (impact with flood buffer)	floodplain	Pollution	High	Low	3	Include appropiate materials handling measures to avoid discharge of polltants
34	Site (general)	operational	site safety/ Egress	High	Low	3	Site entrance impacted by medium return storms. Relocate approximately 60m west to avoid impacts and consider warning signs on approach.
35	Site (general)	operational	flood recovery	Low	Low	1	Site entrance impacted by medium return storms. Consider possibility of relocating approximately 60m west to avoid impacts altogether. If not consider warning signs on approach.