High level flood modelling for Metz Solar Farm

Prepared for
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1 Introduction

This document provides:

1. Summary of flooding conditions for the EIS addressing the assessment requirements, covering the following (where relevant):

    a. Existing Conditions;
    b. Potential Impacts; and
    c. Mitigation measures (should they be required).

2. Technical detail of modelling undertaken for:

    a. Flow volumes using RORB; and
    b. Water levels using Hec-Ras.

Modelling undertaken has adopted conceptual design features to assess the likely effects on flooding associated with the proposed Metz Solar Farm (the Proposed Development), and the potential impacts of any changes on the downstream environment. Such modelling provides an opportunity to examine likely flood behaviour and to form an opinion as to whether the Proposed Development is likely to have a significant impact on flood behaviour and downstream flood risks.

2 Existing flood conditions

Figure 1 outlines the region where the Proposed Development will be located along with the key catchment and associated flow lines (noting that flow lines do not necessarily translate to defined waterway). For the purposes of identifying the existing flood conditions for the proposed region, only the key catchment that covers the majority of the solar array region was examined. This was undertaken as the regions outside this catchment are very small and are located at the very upstream end of adjacent watershed regions and therefore the flooding impacts would be inconsequential.

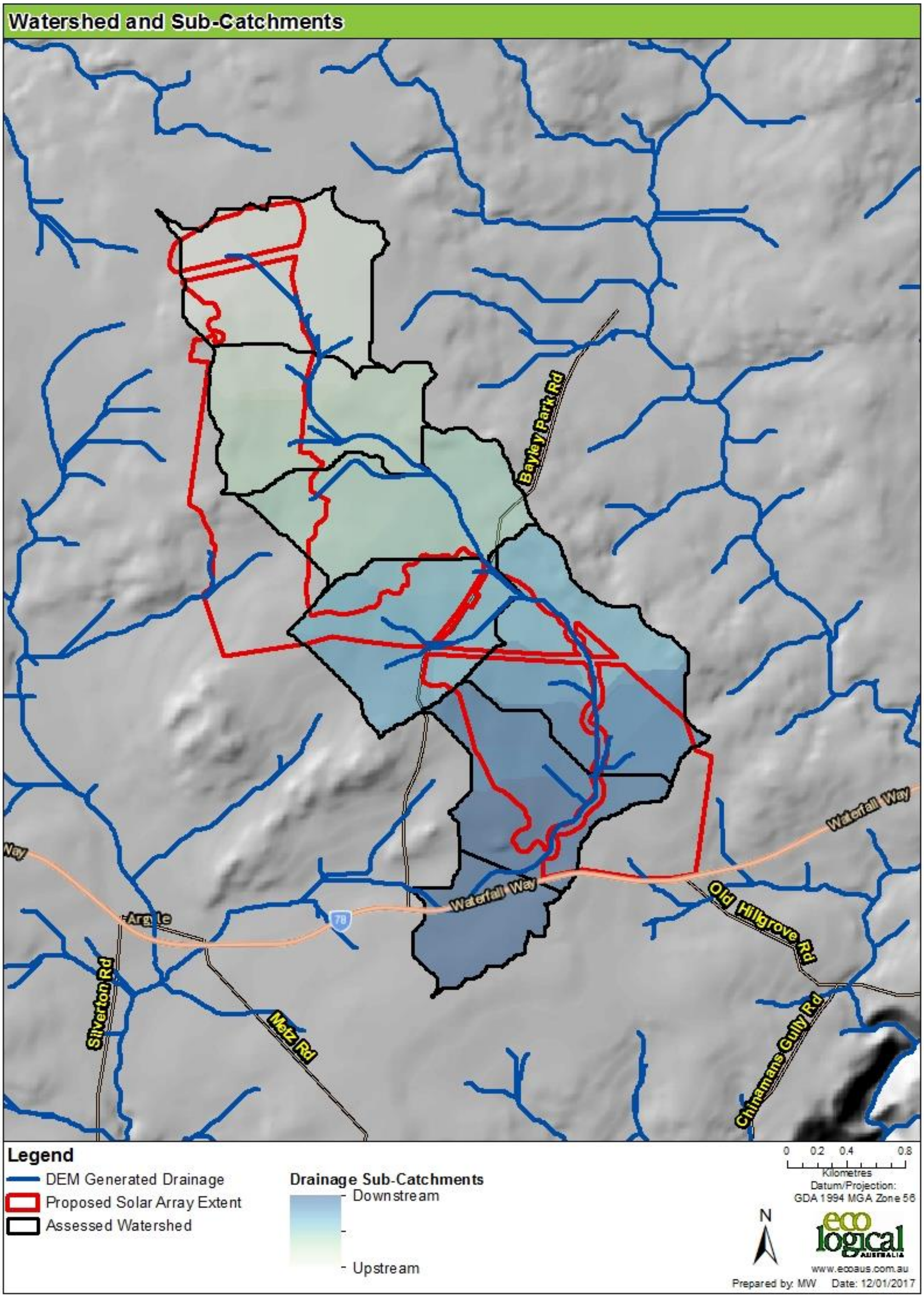

Figure 1: Catchment Layout

To categorise the existing design flood conditions for the area of interest required the use of regionalised flood models as no appropriate rainfall, water level or flow information exists in or near the catchment of interest. The flood volumes and levels were determined by the RFFE model (Western Sydney University), RORB (Monash University and Hydrology and Risk Consulting) and HEC-RAS (U.S. Army Corps of Engineers) programs.

The RFFE model was parameterised using GIS datasets. The model was used to determine a representative runoff to calibrate the RORB model to in the absence of local gauged data. The RORB model was parameterised using GIS datasets, Bureau of Meteorology's Intensity-Frequency-Duration (IFD) information, the Australian Rainfall and Runoff (2016) data hub and the RFFE outputs. The HEC-RAS model was parameterised using GIS datasets, RORB model outputs and local site information (e.g. land cover).

Event durations from 10 minute to 7 days were run through the models to determine the critical flood duration and volume for the 10% Annual Exceedance Probability (AEP), 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and 0.1% AEP events. For this development the probable maximum flood was not examined as it was not deemed appropriate given the site of interest is not flood prone land, the Proposed Development is demonstrated to not increase flood risk (flow rates or levels) and there is negligible downstream development (i.e. only grazing land) that could potentially be impacted.

As the catchment in question is rural without any impervious areas, a large amount of rainfall is required to cause the critical flood (the flood with the highest peak flow). That flood for this region are the 6 or 7 day events and the resultant peak flows are outlined in **Table 1** at the downstream end of the solar array region. Please note that unless a specific catchment (RORB model) or chainage (HEC-RAS model) location is specified, all table results in this document refer to the downstream end of the solar array region.

Table 1: Peak flows for existing conditions

AEP (%)	Peak flow (m^3/s)
10%	770
2%	1,117
1%	1,248
0.5%	1,360
0.2%	1,565
0.1%	1,701

The flows **Table 1** and flows for the other sub catchments were used as inputs to the HEC-RAS model for the catchment. The cross sections for the model are shown in **Figure 2**. The flow depths for the peak flows at the downstream end of the Proposed Development region (3rd cross section upstream from the downstream extent) are shown in **Table 2**. The depths are the depth of water from the surface to the lowest point in the cross section in the Digital Elevation Model (DEM).

Table 2: Peak water levels for existing conditions

AEP (%)	Peak water level depth (m)
10%	2.46
2%	2.86
1%	3.03
0.5%	3.22
0.2%	3.46
0.1%	3.53

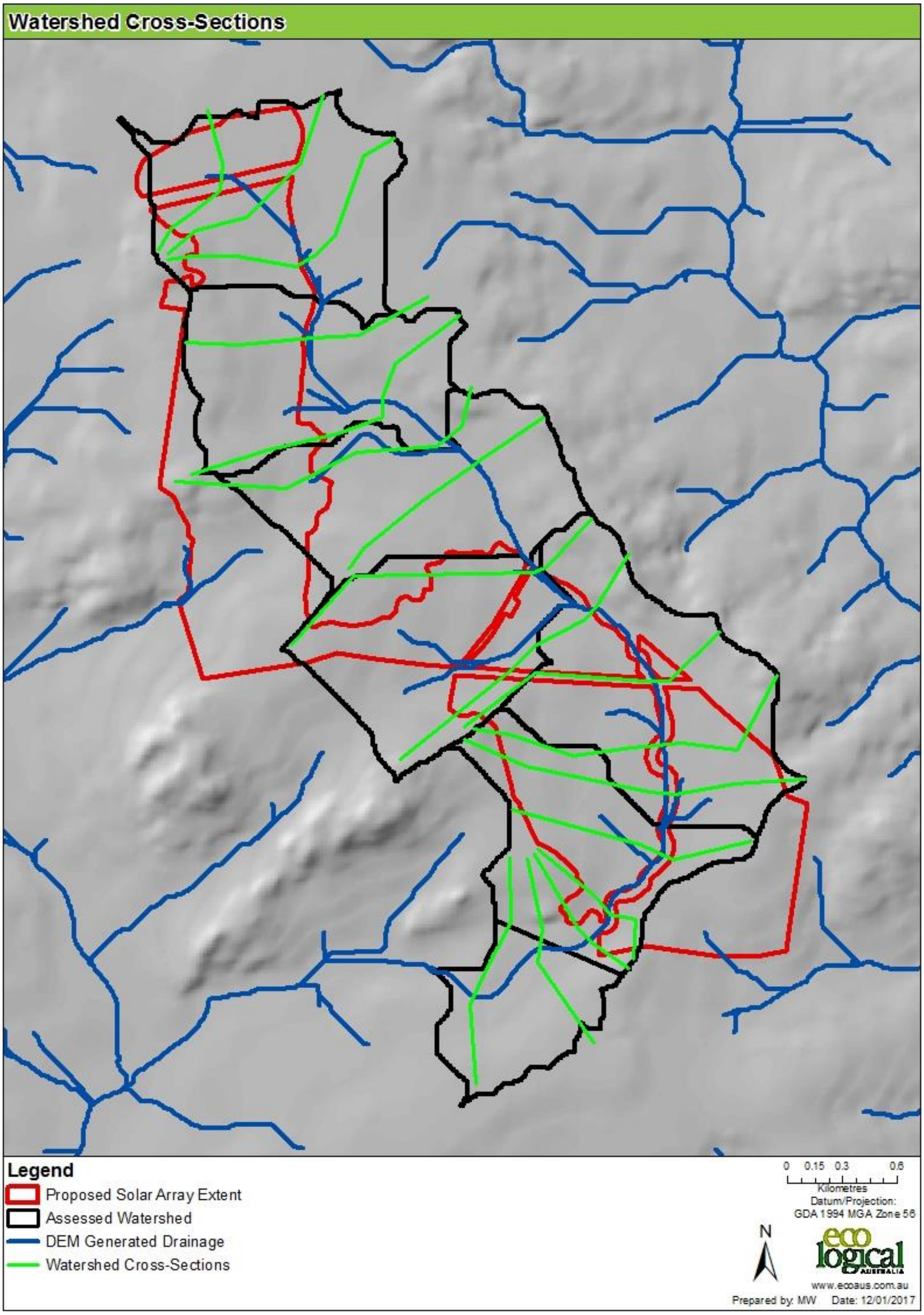

Figure 2: Watershed Cross-sections

The design flows and corresponding water depths from the critical event represent an extreme conceptual event and are considered larger than likely to be experienced, based on expert review of results against the verified landscape and geomorphic characteristics of this catchment and stream, such as:

- The catchment is small;
- The development site is located at the top of the catchment;
- The landform within the catchment is wide and gently sloping;
- There is no indication of flood plain development;
- Limerick Creek exhibits:
  - A low gradient;
  - A chain-of-ponds sequence;
  - No apparent scour or erosion; and
- Flood wrack deposition is low.

The regionalised model results provide a sound basis to compare the flood risk under existing levels of development (current conditions) with those under the Proposed Development.

3 Proposed flood conditions

To determine the impact of the Proposed Development on flooding, the increase in impervious area was applied to the RORB model to represent the solar panels and the associated hard areas (e.g. roadways and sub-station buildings). These impervious areas were determined by averaging the supplied impervious areas across the entire proposed site and then determining the amount of impervious area in each of the RORB sub-areas.

As with the existing (no development) conditions, event durations from 10 minute to 7 days were run through the model to determine the critical flood duration and volume for the 10% Annual Exceedance Probability (AEP), 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and 0.1% AEP events.

For the events modelled in RORB, the critical flood for the catchment was again either the 6 or 7 day event with the peak flows showing either negligible decreases or negligible increases. These changes are due to the increase in impervious area (~1% in each of the catchments is now impervious) resulting in the water running off in a different pattern and changing when peak flows occur compared to the existing conditions (fully pervious). The results are shown in **Table 3.**

Table 3: Peak flows for Proposed Development

AEP (%)	Peak flow (m^3/s)	Difference from existing (%)
10%	804	4.3%
2%	1,108	-0.8%
1%	1,252	0.3%
0.5%	1,369	0.6%
0.2%	1,566	0.1%
0.1%	1,757	3.3%

The flows in **Table 3** and flows for the other sub catchments with the increased impervious area were used as inputs to the HEC-RAS model. No change was made to the HEC-RAS model as the substation buildings will be placed outside the potential flood zone and the solar arrays will be outside of the Limerick Creek riparian zone and are designed and constructed so as to not impede the flow of flood water underneath them. **Table 4** outlines the water level results from the HEC-RAS model.

Table 4: Peak water levels for the Proposed Development

AEP (%)	Peak water level depth (m)	Difference from existing (%)
10%	2.33	1.7%
2%	2.71	0.0%
1%	2.86	0.0%
0.5%	2.99	0.3%
0.2%	3.18	0.0%
0.1%	3.33	1.5%

With the latest release of Australian Rainfall and Runoff providing guidance on incorporating the effects of climate change in design rainfall and flood estimation, the modelling of the 0.5% AEP and 0.2% AEP events, results of which are already shown, in lieu of undertaking an actual climate change assessment was considered not appropriate.

Climate change assessment was undertaken using the Australian Rainfall and Runoff guidelines. The approach recommends applying a 5% change in design rainfall per degree of global warming. Predicted changes in temperature data is provided by the Australian Government through the Climate Change in Australia website (https://www.climatechangeinaustralia.gov.au). The assessment of the RCP 6 climate change scenario (median greenhouse gas emissions) for 2050 projected conditions (representing the design life of the Proposed Development) using the CMIP 5 global climate models (latest global climate models) produced a mean change in temperature of 1.5 degrees Celsius. Therefore the IFD information used as part of the initial assessment was adjusted by 8% and the RORB models re-run. The results are outlined in **Table 5** and show that the peak flows increase by between 6.3% and 10.5% over the flows calculated without climate change impacts.

Table 5: Comparison of climate change flow results for RORB model

AEP (%)	Peak existing conditions climate change flow (m^3/s)	Difference to base design flows (%)	Peak proposed conditions climate change flow (m^3/s)	Difference to base design flows (%)
10%	843	9.4%	867	7.8%
2%	1,188	6.3%	1,203	8.6%
1%	1,337	7.1%	1,372	9.6%
0.5%	1,503	10.5%	1,481	8.2%
0.2%	1,695	8.4%	1,694	8.2%
0.1%	1,875	10.2%	1,908	8.6%

These flows were applied to the HEC-RAS model to determine the effects of climate change on the water levels. The results show that for the critical duration storm event, the water levels will increase due to climate change. At the downstream end of the proposed site the levels are expected to increase by between 3.0% and 4.7% for the existing conditions events and between 3.6% and 4.5% for the proposed conditions events due to climate change (Table 6). Comparing the climate change results within an event (e.g. the 1% AEP) shows that, there is a slight decrease in the water levels for the 0.5% AEP event between the existing and proposed condition models and a slight increase in levels for the other AEP events.

The difference between the existing conditions and the Proposed Development under current and climate change rainfalls show that there will be negligible impact or a slight reduction in the flows and water levels from the critical storm within the catchment.

Table 6: Comparison of climate change water level results for the HEC-RAS model

AEP (%)	Peak existing conditions climate change water level (m)	Difference to base design water level (%)	Peak proposed conditions climate change water level (m)	Difference to base design water level (%)
10%	2.39	4.0%	2.42	3.9%
2%	2.79	3.0%	2.81	3.7%
1%	2.95	3.1%	2.99	4.5%
0.5%	3.12	4.7%	3.1	3.7%
0.2%	3.31	4.1%	3.31	4.1%
0.1%	3.43	4.5%	3.45	3.6%

4 Implications of results for the Proposed Development

The modelling undertaken as part of the EIS has been to clarify whether the Proposed Development would have any significant impact on the flooding within and downstream of the development. Given the nature of a solar farm development, being the installation of solar panels which will be raised above the ground (and therefore not impeding flow), the flow and water level analysis focused on whether the change in impervious area (hard surfaces) within the catchment would change the critical (peak) design flood flows.

As there was no historic flow or water level information for the catchment, the RORB (flow modelling) and HEC-RAS (water level modelling) were parameterised based on regionalised information (including regionalised flood frequency estimates) and used to compare the differences between pre and post development conditions. This means that the flow volumes and water depths determined by the models should be examined with more reliance on the comparison of results rather than in absolute terms.

The overall outcome of analysing the effect of the development on flows and water levels shows that the development should have minimal impact on flooding associated with the critical storm for the catchment. The results show either minor increases or decreases in flow and level depending on which annual exceedance probability event is being examined.

The events that show an increase in these levels would have negligible impact downstream of the site and those that show a decrease will reduce the flooding impact downstream for the critical storm duration (6 or 7 days).

5 Technical Detail of Water Volume Modelling

This section outlines the flow volume modelling that was undertaken to determine flows through the site. These flows were used as inputs to determine the water levels through the site.

5.1 Regional Analysis

To provide an estimate of the likely design flow volumes from the catchment the Regional Flood Frequency Estimation (RFFE) model (http://rffe.arr-software.org/) was used. It uses information from nearby similar catchments to provide an estimation of their 6 hour peak durations. The details required for this are:

- Catchment outlet location (latitude and longitude);
- Catchment centroid location (latitude and longitude); and
- Catchment area.

The results of this are shown in **Figure 3**.

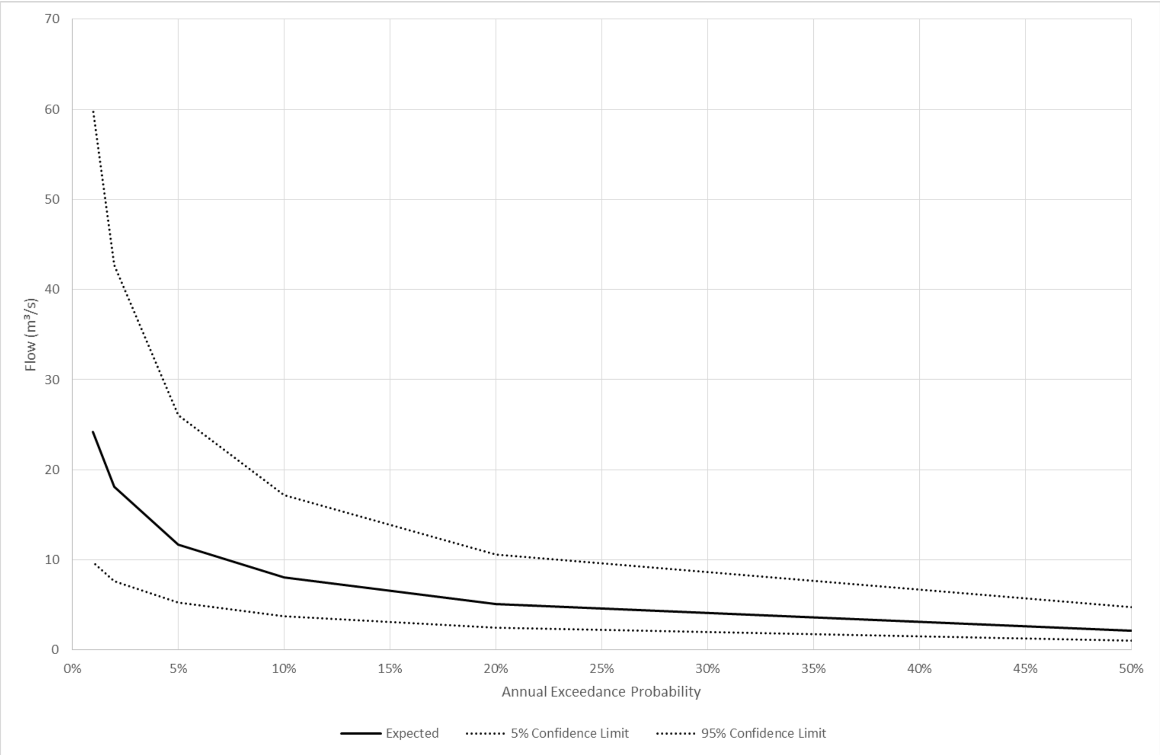

Figure 3: RFFE 6 hour estimates

5.2 Catchments

Figure 1 shows the proposed site and the catchments determined based on the available DEM. The analysis of the proposed site and the DEM determined that most of the site fell within one watershed region. The components that fell within other watersheds were deemed to have negligible impact on flood volumes as:

- There would be minimal runoff generated from rainfall from such small areas;
- The regions are at the very top of the watershed; and

- The solar arrays are mounted on steel piles above the ground and are not sensitive to flooding, as:
  - The PV panel is located approximately 1 m above ground level, and hence out of flood;
  - The piles are water resistant and do not impede the movement of floodwaters; and
  - Cabling and electrical equipment is water resistant and can be located in areas outside of flood risk.

For the purposes of RORB modelling the catchment was divided up into seven sub-catchments for inclusion in the model. The catchment and link details for the existing and post solar farm conditions that are applied to the RORB catchment file, shown in Figure 4, are outlined in **Table 7** and **Table 8**. These characteristics were determined using GIS analysis in ArcMap. The percent impervious for the proposed conditions was determined by averaging the impervious area of the Proposed Development across the Site and then determining the areas of which fall within each of the RORB sub-areas.

Table 7: Catchment characteristics

Sub Area	Area (ha)	Percent impervious (%)	
		Existing conditions	Proposed conditions
A	127.2	0.0%	7.4%
B	116.1	0.0%	8.2%
C	123.0	0.0%	2.4%
D	115.8	0.0%	8.5%
E	152.3	0.0%	9.4%
F	107.2	0.0%	10.1%
G	57.3	0.0%	0.0%

Table 8: Link parameters

Link Name	Reach Length (km)	Reach Type
A to B	0.952	Natural
B to C	0.880	
C to Mid	0.715	
D to Mid	0.717	
Mid to E	0.996	
E to F	0.923	
F to G	0.967	
G to End	0.516	

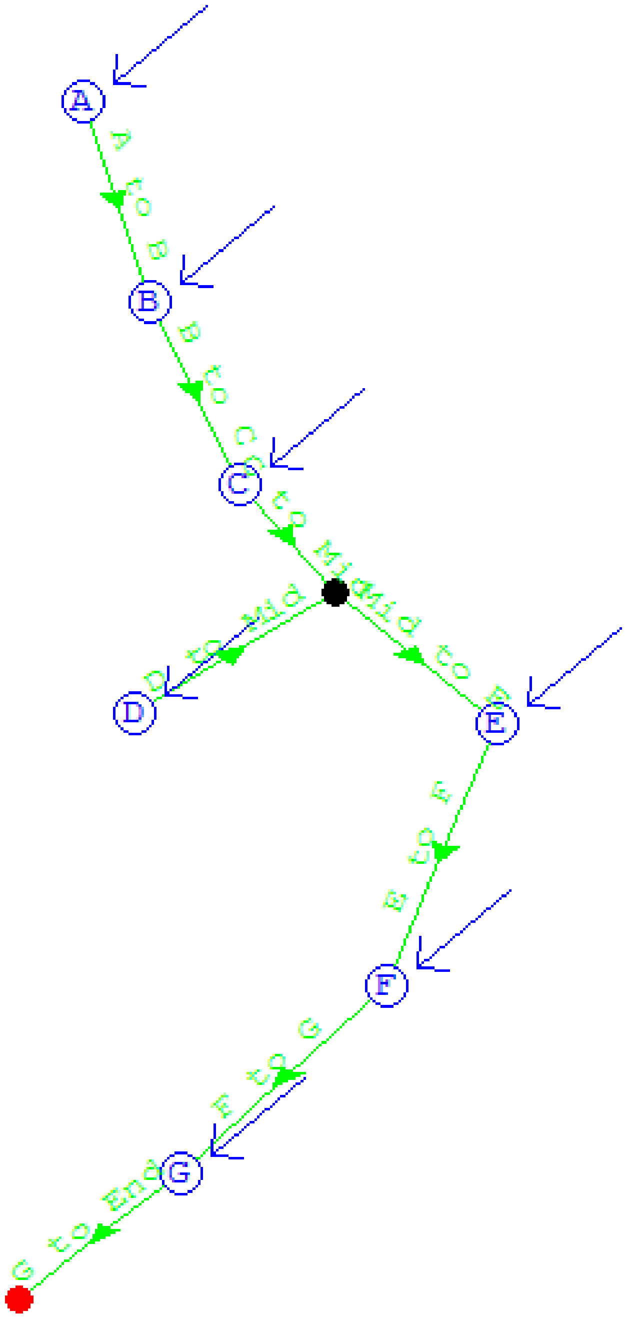

Figure 4: RORB catchment file

5.3 IFD Information

The IFD information was sourced for the Site from the 2016 Bureau of Meteorology IFD curves on February 17th 2017 for coordinate 30.5125°S and 151.8625°E and is outlined in **Table 9**. It should be noted that the durations between 1 and 5 minutes inclusive were not used as the temporal patterns available from Australian Rainfall and Runoff do not include these durations. Exceedances rarer than the 1% AEP less than 24 hours in duration were not available on the BoM website and were infilled based on a logarithmic regression.

The temporal pattern used for this was sourced from Australian Rainfall and Runoff 2016 and is discussed in the Australian Rainfall and Runoff Section.

Table 9: IFD information for Metz site (greyed out rows were not used as corresponding temporal patterns were unavailable)

Duration	Annual Exceedance Probability Rainfall Depths (mm)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
1 min	1.91	2.20	3.13	3.77	4.42	5.30	6.00	6.67	7.56	8.24	8.91
2 min	3.19	3.65	5.17	6.24	7.28	8.66	9.73	10.86	12.29	13.38	14.46
3 min	4.45	5.10	7.20	8.69	10.10	12.10	13.60	15.15	17.15	18.67	20.18
4 min	5.60	6.43	9.09	11.00	12.80	15.30	17.20	19.18	21.72	23.64	25.56
5 min	6.65	7.64	10.80	13.00	15.20	18.20	20.50	22.83	25.85	28.15	30.44
10 min	10.6	12.3	17.4	21.0	24.7	29.6	33.5	37.3	42.3	46.0	49.8
15 min	13.3	15.4	21.9	26.5	31.1	37.3	42.3	47.0	53.4	58.1	62.9
30 min	18.0	20.8	29.6	35.8	42.1	50.6	57.4	63.8	72.4	78.9	85.4
1 hour	22.6	25.9	36.7	44.3	52.0	62.6	70.9	78.7	89.3	97.3	105.3
2 hour	27.2	31.0	43.2	52.0	60.9	73.2	83.1	91.9	104.1	113.3	122.6
3 hour	30.2	34.2	47.2	56.6	66.2	79.6	90.5	99.8	112.9	122.9	132.8
6 hour	36.5	40.9	55.6	66.2	77.3	93.1	106.0	116.3	131.5	142.9	154.4
12 hour	45.1	50.3	67.7	80.4	93.7	113.0	128.0	140.5	158.6	172.3	186.0
24 hour	57.0	63.5	85.4	101.0	118.0	142.0	161.0	179.0	206.0	228.0	251.0
48 hour	71.9	80.5	109.0	130.0	151.0	180.0	203.0	230.0	265.0	292.0	320.0
72 hour	81.4	91.2	124.0	148.0	172.0	204.0	228.0	255.0	291.0	319.0	348.0
96 hour	87.8	98.5	134.0	159.0	184.0	218.0	243.0	269.0	304.0	333.0	362.0
120 hour	92.4	104.0	140.0	165.0	191.0	225.0	252.0	275.0	311.0	340.0	370.0
144 hour	95.7	107.0	143.0	168.0	195.0	229.0	255.0	278.0	314.0	344.0	374.0

Duration	Annual Exceedance Probability Rainfall Depths (mm)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
168 hour	98.1	109.0	145.0	169.0	195.0	229.0	256.0	278.0	314.0	346.0	377.0

5.4 Australian Rainfall and Runoff Information

The other information required for setting up the RORB model was sourced from the Australian Rainfall and Runoff (2016) data hub (http://data.arr-software.org) for the same location as the IFD information. The key information obtained were the temporal patterns and the losses. The region that these parameters are sourced from is the Macleay River with the particular region being East Coast South.

For this region the initial loss is 9.0mm and the continuing loss is 5.3 mm/hr. For each temporal pattern duration, 30 patterns were available to be used by RORB. The number of increments in each of these patterns varied between 2 and 56. RORB has a limit of 50 increments in its input so the pattern with 56 increments (168 hour duration) was aggregated to 28 increments. Patterns were available for the durations outlined in **Table 10**, the shaded durations are durations were IFD information is not available (and therefore were not used).

Table 10: Temporal Pattern Durations from Australian Rainfall and Runoff

Durations			
10 minute	1 hour	9 hour	48 hour
15 minute	1.5 minute	12 hour	72 hour
20 minute	2 hour	18 hour	96 hour
25 minute	3 hour	24 hour	120 hour
30 minute	4.5 hour	30 hour	144 hour
45 minute	6 hour	36 hour	168 hour

The temporal pattern information was used to provide inputs to the Monte Carlo model run in RORB. A base set of patterns were used as part of defining the IFD information in RORB. As a Monto Carlo run was being undertaken, the first pattern for each of the durations was used to complete the IFD specification.

5.5 Parameter File

As there is no observed flow data for this catchment, the RORB parameter file was setup using the “Separate catchment and generated design storm(s)” option. The model operates using a single set of routing parameters for the whole model and an initial loss / continuing loss model. The design rainfall specification used is:

- A user defined IFD (detailed above);
- Monte Carlo simulation from 10 minute to 168 hour durations;
- Default time increments of 70;
- Uniform areal pattern; and
- Constant losses.

The parameter specification is:

- Kc of 57.0 to calibrate to RFFE analysis (results shown below);
- M of 0.8; and
- Initial loss and continuing loss based on the Australian Rainfall and Runoff values discussed above.

The Monte Carlo simulation details are:

- Number of rainfall divisions: 50 (default);
- Number of samples per division: 20 (default);
- Temporal patterns as described above;
- No pattern censoring; and
- Fixed initial loss.

5.6 Results

The RORB model was calibrated to the RFFE analysis to fit within the confidence limits of the results. This calibration targeted obtaining the best possible fit to the 1% AEP result (closet to best estimate). The outcome of this is shown in (**Figure 5**) and shows that the 1%, 2%, 5% and 20% AEP results fall within the confidence limits of the RFFE analysis with the 50% AEP results just too high. As the purpose of the modelling was to examine the rarer frequency events (e.g. 1% AEP) this slight difference in the 50% AEP was deemed acceptable.

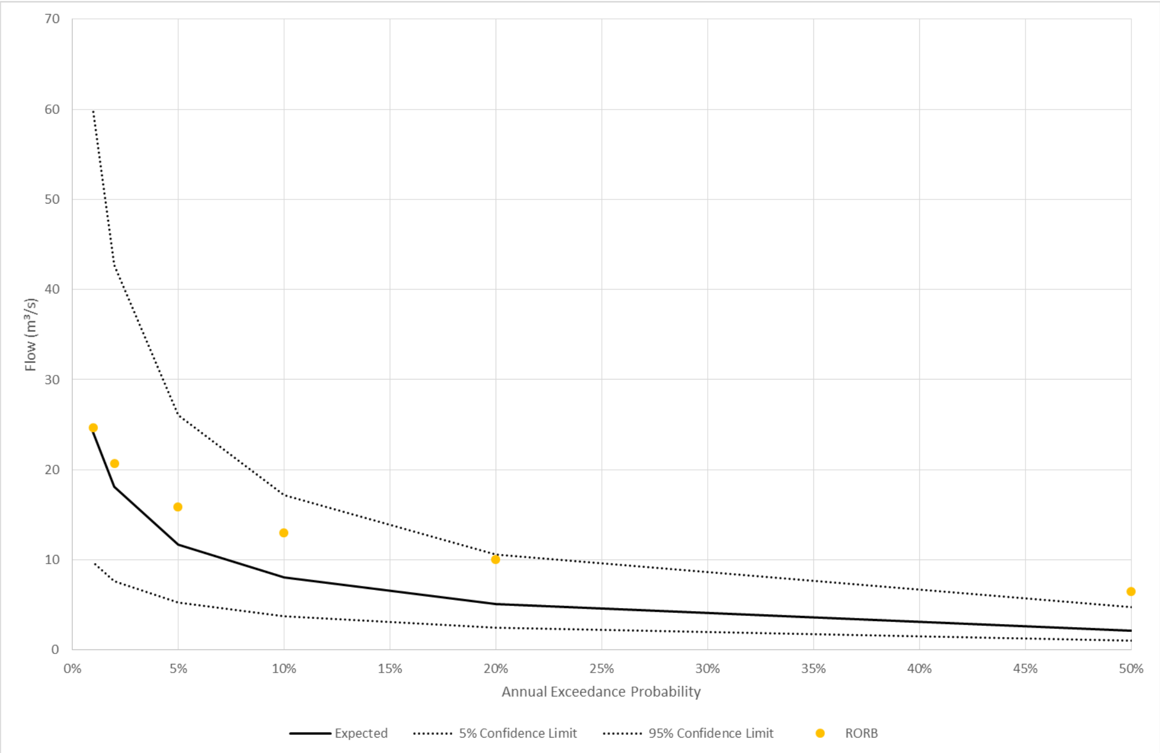

Figure 5: RFFE – RORB calibration

The model was run and produced the results outlined in **Figure 6** and **Figure 7**.

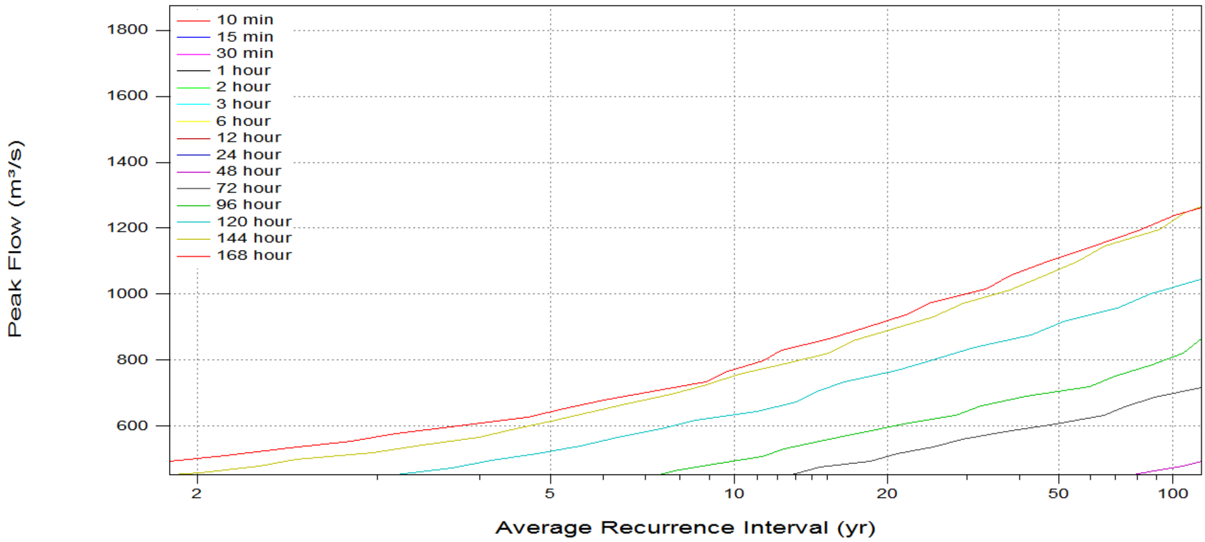

Figure 6: RORB model results for existing conditions

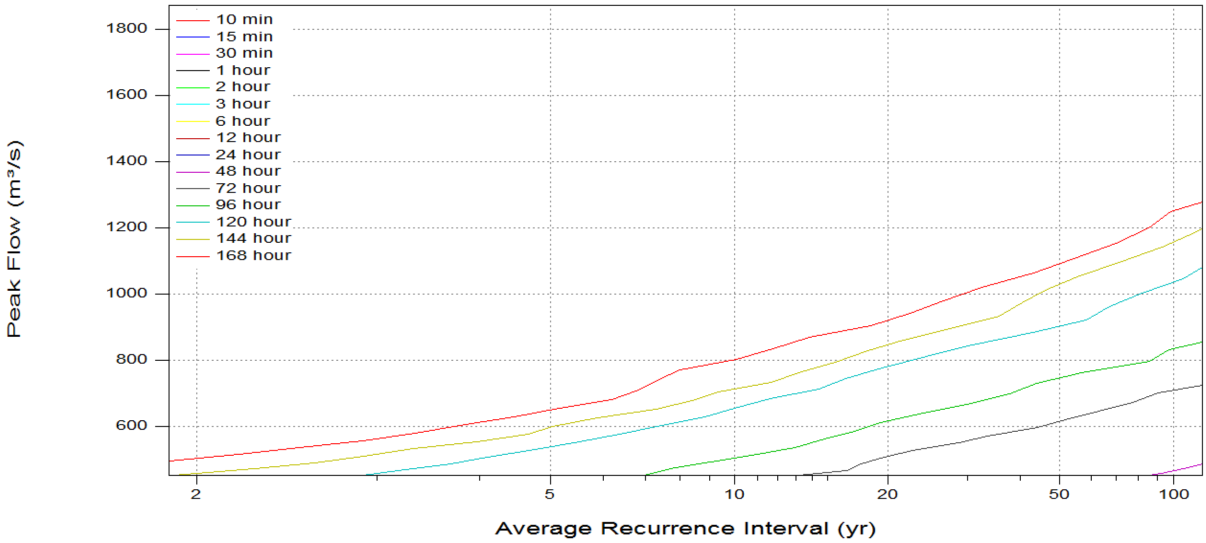

Figure 7: RORB model results for proposed conditions

5.7 Climate Change Impacts

With the latest release of Australian Rainfall and Runoff providing guidance on incorporating the effects of climate change in design rainfall and flood estimation, the modelling of the 0.5% AEP and 0.2% AEP events in lieu of undertaking an actual climate change assessment was not appropriate. Therefore a climate change assessment was undertaken using the Australian Rainfall and Runoff guidelines. The approach recommends applying a 5% change in design rainfall per degree of global warming. To obtain the change in temperature data provided by the Australian Government through the Climate Change in Australia website (https://www.climatechangeinaustralia.gov.au) was used. The assessment of the RCP 6 climate change scenario for 2050 projected conditions (representing the design life of the Proposed Development) using the CMIP 5 global climate models produced a mean change in temperature of 1.5 degrees Celsius for the Central Slopes climate region. Therefore the IFD information used as part of the initial assessment (**Table 9**) was adjusted by 8% and the RORB models re-run (**Table 11**).

Table 11: Climate change IFD information for the Metz Site (greyed out rows were not used as corresponding temporal patterns were unavailable)

Duration	Annual Exceedance Probability Rainfall Depths (mm)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
1 min	2.05	2.37	3.36	4.05	4.75	5.70	6.45	7.17	8.13	8.86	9.58
2 min	3.43	3.92	5.56	6.71	7.83	9.31	10.46	11.67	13.21	14.38	15.54
3 min	4.78	5.48	7.74	9.34	10.86	13.01	14.62	16.29	18.44	20.07	21.70
4 min	6.02	6.91	9.77	11.83	13.76	16.45	18.49	20.62	23.35	25.41	27.48
5 min	7.15	8.21	11.61	13.98	16.34	19.57	22.04	24.54	27.79	30.26	32.72
10 min	11.4	13.2	18.7	22.6	26.6	31.8	36.0	40.1	45.4	49.5	53.6
15 min	14.3	16.6	23.5	28.5	33.4	40.1	45.5	50.6	57.4	62.5	67.6
30 min	19.4	22.4	31.8	38.5	45.3	54.4	61.7	68.6	77.8	84.8	91.8
1 hour	24.3	27.8	39.5	47.6	55.9	67.3	76.2	84.7	96.0	104.6	113.2
2 hour	29.2	33.3	46.4	55.9	65.5	78.7	89.3	98.8	111.9	121.8	131.8
3 hour	32.5	36.8	50.7	60.8	71.2	85.6	97.3	107.3	121.4	132.1	142.8
6 hour	39.2	44.0	59.8	71.2	83.1	100.1	114.0	125.1	141.3	153.6	165.9
12 hour	48.5	54.1	72.8	86.4	100.7	121.5	137.6	151.0	170.5	185.2	199.9
24 hour	61.3	68.3	91.8	108.6	126.9	152.7	173.1	192.4	221.5	245.1	269.8
48 hour	77.3	86.5	117.2	139.8	162.3	193.5	218.2	247.3	284.9	313.9	344.0
72 hour	87.5	98.0	133.3	159.1	184.9	219.3	245.1	274.1	312.8	342.9	374.1
96 hour	94.4	105.9	144.1	170.9	197.8	234.4	261.2	289.2	326.8	358.0	389.2
120 hour	99.3	111.8	150.5	177.4	205.3	241.9	270.9	295.6	334.3	365.5	397.8
144 hour	102.9	115.0	153.7	180.6	209.6	246.2	274.1	298.9	337.6	369.8	402.1

Duration	Annual Exceedance Probability Rainfall Depths (mm)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
168 hour	105.5	117.2	155.9	181.7	209.6	246.2	275.2	298.9	337.6	372.0	405.3

The results from the RORB model run showed an increase in the flows for each of the design probabilities and durations. The critical storm duration for the site remains 6 or 7 days as per the pre climate change model results. The differences between the pre and post climate change conditions for the existing and post solar farm models are outlined in **Table 12** and show that the peak flows increase by between 6.3% and 10.5% over the flows calculated without climate change impacts.

Table 12: Comparison of climate change flow results for RORB model

AEP (%)	Peak existing conditions climate change flow (m^3/s)	Difference to base design flows (%)	Peak proposed conditions climate change flow (m^3/s)	Difference to base design flows (%)
10%	843	9.4%	867	7.8%
2%	1,188	6.3%	1,203	8.6%
1%	1,337	7.1%	1,372	9.6%
0.5%	1,503	10.5%	1,481	8.2%
0.2%	1,695	8.4%	1,694	8.2%
0.1%	1,875	10.2%	1,908	8.6%

6 Technical Detail of Water Level Modelling

To model the water levels that correspond to the design flows produced by the RORB modelling a HEC-RAS model was developed to investigate the potential water levels within the Proposed Development region. As with the RORB model, the region modelled is the key watershed that drains most of the Proposed Development.

6.1 Model Geometry

To set up the model required a number of GIS based input sets and were produced using the HEC-GeoRAS add in to ArcMap. The key spatial datasets required were:

- The drainage centre line; and
- The drainage cross sections.

The cross sections produced are shown in **Figure 2** This information was turned into a HEC-RAS specific geometry input file using HEC-GeoRAS. Once imported into HEC-RAS the following were defined for each cross section:

- left and right overbank stations (i.e. point where main channel ends on left and right side) were defined for each of the cross sections based on the cross section elevations;
- distance downstream to the next cross section for the left and right overbank regions were set equal to the distance downstream of the channel that was set based on the drainage centre line; and
- Manning's n (roughness) values for the left, right and channel regions of the cross section. These were set to 0.04 based on the characteristics of the site. The value was sourced from guidelines produced by the Brisbane City Council.

(https://www.brisbane.qld.gov.au/sites/default/files/ncd_appendixc_part3.pdf).

The cross sections were then interpolated to create additional cross sections between those initially detailed. This allows allow smoother transitions between each cross section calculation within HEC-RAS. The distance between the cross sections after interpolation was approximate 90 metres. The final model layout is shown in **Figure 8.**

No changes were made to the geometry of the HEC-RAS model between the existing conditions and the proposed conditions as it has been assumed that buildings (e.g. power sub-stations) will be situated out of the flow paths and the solar panels will be designed to be above the relevant design flood level.

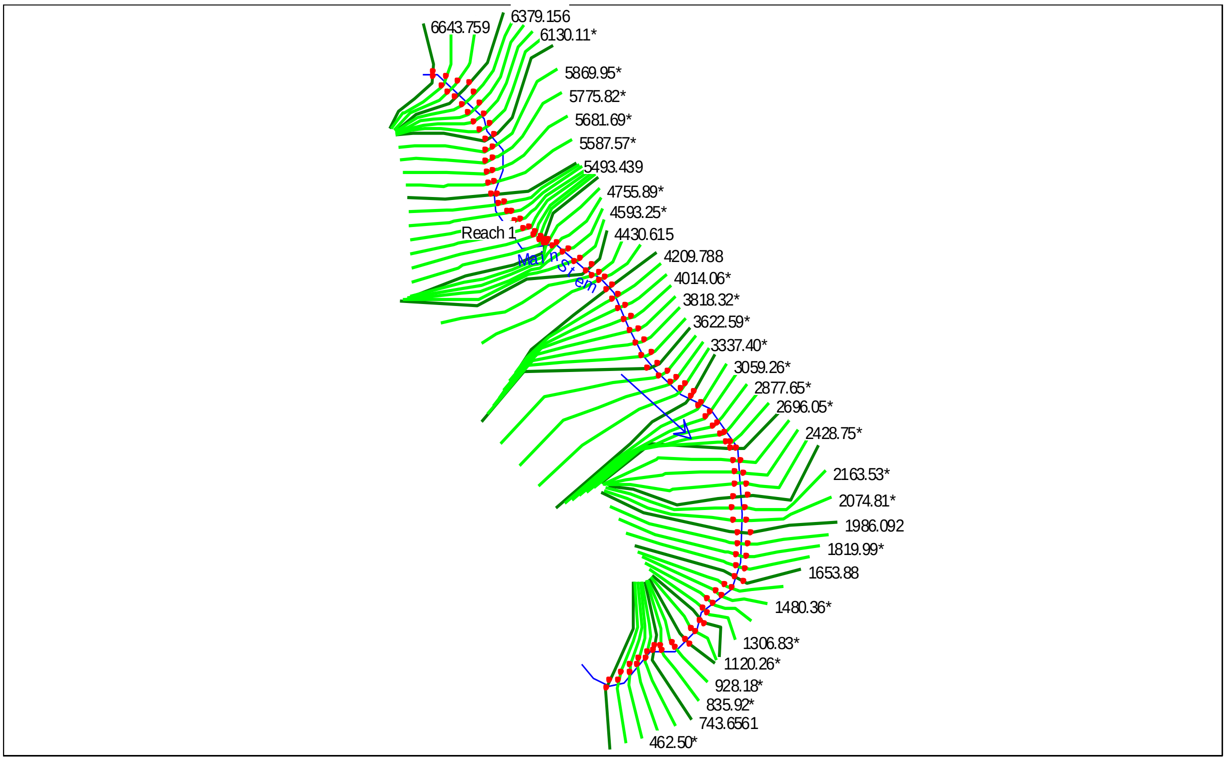

Figure 8: HEC-RAS model geometry

6.2 Model Flows

The model requires flow conditions to be specified to allow the HEC-RAS calculations to determine their corresponding water levels. These flows can be specified for a number of profiles and at cross sections in the model. Flows were specified at cross sections that corresponded to the catchments from the RORB model for the 10%, 2%, 1%, 0.5%, 0.2% and 0.1% AEP. **Table 13** and shows the flows for the existing and proposed conditions HEC-RAS models. To complete the flow setup a boundary conditions needs to be setup. For each of these conditions a critical depth downstream condition was implemented.

Table 13: Existing conditions design flow inputs from RORB, * represents interpolated cross section

RORB Location	HEC-RAS cross section river station (m)	10% AEP flow (m³/s)	2% AEP flow (m³/s)	1% AEP flow (m³/s)	0.5% AEP flow (m³/s)	0.2% AEP flow (m³/s)	0.1% AEP flow (m³/s)
Sub Area A	6643.759	0.149	0.149	0.149	0.149	0.149	0.149
Downstream Sub Area A	5775.82*	190.405	267.9	308.593	353.579	394.577	430.798
Downstream Sub Area B	4430.615	328.008	469.637	536.373	615.893	694.84	749.12
Downstream of Sub Areas C and D	3524.725	583.993	808.02	913.457	1037.955	1163.143	1271.443
Downstream Sub Area E	1819.99*	694.27	988.864	1102.64	1222.962	1384.434	1520.553
Downstream Sub Area F	835.92*	770.813	1117.317	1248.333	1360.219	1564.677	1700.842
Downstream Sub Area G	275.0615	818.493	1185.753	1314.346	1451.819	1668.57	1805.058

Table 14: Proposed conditions design flow inputs from RORB, * represents interpolated cross section

RORB Location	HEC-RAS cross section river station (m)	10% AEP flow (m³/s)	2% AEP flow (m³/s)	1% AEP flow (m³/s)	0.5% AEP flow (m³/s)	0.2% AEP flow (m³/s)	0.1% AEP flow (m³/s)
Sub Area A	6643.759	0.149	0.149	0.149	0.149	0.149	0.149
Downstream Sub Area A	5775.82*	185.967	271.913	309.785	343.368	386.414	421.673
Downstream Sub Area B	4430.615	323.376	469.231	541.461	587.36	671.051	747.378
Downstream of Sub Areas C and D	3524.725	566.966	827.282	912.085	1017.75	1166.164	1323.928
Downstream Sub Area E	1819.99*	710.698	995.703	1115.01	1223.334	1409.632	1578.964
Downstream Sub Area F	835.92*	804.101	1108.35	1251.772	1368.768	1565.768	1757.273
Downstream Sub Area G	275.0615	848.278	1167.485	1326.507	1443.527	1661.819	1828.774

6.3 Results

The results from the model runs are shown in **Table 15**, **Table 16**, Table 17, Table 18, Table 19 and Table 20 for the 10%, 2%, 1%, 0.5%, 0.2% and 0.1% AEP flow events respectively at each of cross sections shown in **Figure 2**.

The results show that for the critical duration storm event the water levels will, in general, reduce between the existing and proposed condition models. This result is due to the impervious area characteristics changing from none in the existing model to a proportion of each of the catchments in the proposed model. This reduces the flows, as discussed in the RORB model section. This reduction in flows results in the decrease in water levels.

Therefore it is considered that the Proposed Development will not have a significant impact on flood levels, and may in fact reduce the water levels within the catchment at the critical flood.

Table 15: 10% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0
2	6379.156	0.02	0.02	0
3	5964.076	0.55	0.54	-0.01
4	5493.439	0.8	0.79	-0.01
5	4837.21	1.04	1.03	-0.01
6	4430.615	1.35	1.35	0
7	4209.788	1.34	1.33	-0.01
8	3524.725	1.6	1.57	-0.03
9	3150.067	2.63	2.59	-0.04
10	2605.241	1.94	1.92	-0.02
11	2252.25	1.22	1.2	-0.02
12	1986.092	1.37	1.34	-0.03
13	1653.88	2.48	2.51	0.03
14	1220.073	2.46	2.49	0.03
15	1020.439	2.29	2.33	0.04
16	743.6561	2.6	2.64	0.04
17	275.0615	2.28	2.31	0.03

Table 16: 2% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
2	6379.156	0.02	0.02	0
3	5964.076	0.73	0.74	0.01
4	5493.439	0.94	0.95	0.01
5	4837.21	1.2	1.21	0.01
6	4430.615	1.59	1.59	0
7	4209.788	1.58	1.58	0
8	3524.725	1.88	1.9	0.02
9	3150.067	3.03	3.06	0.03
10	2605.241	2.18	2.2	0.02
11	2252.25	1.42	1.44	0.02
12	1986.092	1.6	1.63	0.03
13	1653.88	2.94	2.94	0
14	1220.073	2.9	2.9	0
15	1020.439	2.71	2.71	0
16	743.6561	3.05	3.04	-0.01
17	275.0615	2.7	2.68	-0.02

Table 17: 1% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0
2	6379.156	0.02	0.02	0
3	5964.076	0.81	0.82	0.01
4	5493.439	1	1	0
5	4837.21	1.27	1.27	0
6	4430.615	1.69	1.7	0.01
7	4209.788	1.68	1.68	0
8	3524.725	2	2	0
9	3150.067	3.2	3.2	0
10	2605.241	2.28	2.28	0
11	2252.25	1.5	1.5	0
12	1986.092	1.71	1.7	-0.01

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
13	1653.88	3.09	3.11	0.02
14	1220.073	3.05	3.06	0.01
15	1020.439	2.86	2.86	0
16	743.6561	3.2	3.2	0
17	275.0615	2.81	2.98	0.17

Table 18: 0.5% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0
2	6379.156	0.02	0.02	0
3	5964.076	0.9	0.88	-0.02
4	5493.439	1.06	1.04	-0.02
5	4837.21	1.34	1.33	-0.01
6	4430.615	1.8	1.76	-0.04
7	4209.788	1.78	1.75	-0.03
8	3524.725	2.13	2.11	-0.02
9	3150.067	3.38	3.35	-0.03
10	2605.241	2.38	2.37	-0.01
11	2252.25	1.59	1.57	-0.02
12	1986.092	1.82	1.8	-0.02
13	1653.88	3.25	3.25	0
14	1220.073	3.2	3.2	0
15	1020.439	2.98	2.99	0.01
16	743.6561	3.32	3.33	0.01
17	275.0615	3.41	3.4	-0.01

Table 19: 0.2% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0
2	6379.156	0.02	0.02	0
3	5964.076	0.98	0.96	-0.02

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
4	5493.439	1.11	1.1	-0.01
5	4837.21	1.4	1.39	-0.01
6	4430.615	1.91	1.88	-0.03
7	4209.788	1.89	1.86	-0.03
8	3524.725	2.26	2.26	0
9	3150.067	3.55	3.56	0.01
10	2605.241	2.48	2.48	0
11	2252.25	1.68	1.68	0
12	1986.092	1.92	1.92	0
13	1653.88	3.45	3.48	0.03
14	1220.073	3.4	3.42	0.02
15	1020.439	3.18	3.18	0
16	743.6561	3.53	3.53	0
17	275.0615	3.18	3.18	0

Table 20: 0.1% AEP HEC-RAS modelled water levels (upstream to downstream)

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0
2	6379.156	0.02	0.02	0
3	5964.076	1.04	1.03	-0.01
4	5493.439	1.16	1.15	-0.01
5	4837.21	1.45	1.44	-0.01
6	4430.615	1.97	1.97	0
7	4209.788	1.95	1.95	0
8	3524.725	2.35	2.4	0.05
9	3150.067	3.69	3.76	0.07
10	2605.241	2.56	2.59	0.03
11	2252.25	1.74	1.77	0.03
12	1986.092	1.99	2.03	0.04
13	1653.88	3.61	3.67	0.06
14	1220.073	3.54	3.6	0.06

Cross section	HEC-RAS River station	Existing water depth (m)	Proposed water depth (m)	Difference (m)
15	1020.439	3.28	3.33	0.05
16	743.6561	3.61	3.65	0.04
17	275.0615	3.6	3.61	0.01

6.4 Climate Change Impacts

The climate change flows determined for the site were applied to the HEC-RAS model to determine the effects of climate change on the water levels. The results are shown in **Table 21**, **Table 22**, **Table 23**, Table 24, Table 25 and Table 26 for the 10%, 2%, 1%, 0.5%, 0.2% and 0.1% AEP flow events respectively at each of cross sections shown in **Figure 2**.

The results show that for the critical duration storm event the water levels will increase due to climate change. At the downstream end of the proposed site the levels are expected to increase by between 3.0% and 4.7% for the existing conditions events and between 3.6% and 4.5% for the proposed conditions events due to climate change. Comparing the climate change results within an event (e.g. the 1% AEP) shows that there is a slight increase in water levels between the existing and proposed conditions for all AEP event except the 0.5% AEP event which decreases slightly. This is in line with the changes in flows observed from the RORB model.

Table 21: 10% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	0.55	0.58	0.03	0.54	0.58	0.04
4	5493.439	0.8	0.82	0.02	0.79	0.82	0.03
5	4837.21	1.04	1.07	0.03	1.03	1.07	0.04
6	4430.615	1.35	1.4	0.05	1.35	1.41	0.06
7	4209.788	1.34	1.38	0.04	1.33	1.4	0.07
8	3524.725	1.6	1.65	0.05	1.57	1.68	0.11
9	3150.067	2.63	2.71	0.08	2.59	2.75	0.16
10	2605.241	1.94	1.99	0.05	1.92	2.01	0.09
11	2252.25	1.22	1.26	0.04	1.2	1.28	0.08
12	1986.092	1.37	1.41	0.04	1.34	1.43	0.09
13	1653.88	2.48	2.58	0.1	2.51	2.63	0.12
14	1220.073	2.46	2.56	0.1	2.49	2.6	0.11
15	1020.439	2.29	2.39	0.1	2.33	2.42	0.09
16	743.6561	2.6	2.7	0.1	2.64	2.73	0.09
17	275.0615	2.28	2.36	0.08	2.31	2.38	0.07

Table 22: 2% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	0.73	0.77	0.04	0.74	0.77	0.03
4	5493.439	0.94	0.96	0.02	0.95	0.96	0.01
5	4837.21	1.2	1.24	0.04	1.21	1.23	0.02
6	4430.615	1.59	1.63	0.04	1.59	1.64	0.05
7	4209.788	1.58	1.62	0.04	1.58	1.62	0.04
8	3524.725	1.88	1.96	0.08	1.9	1.97	0.07
9	3150.067	3.03	3.14	0.11	3.06	3.16	0.1
10	2605.241	2.18	2.25	0.07	2.2	2.25	0.05
11	2252.25	1.42	1.47	0.05	1.44	1.48	0.04
12	1986.092	1.6	1.67	0.07	1.63	1.68	0.05
13	1653.88	2.94	3.03	0.09	2.94	3.05	0.11
14	1220.073	2.9	2.99	0.09	2.9	3.01	0.11
15	1020.439	2.71	2.79	0.08	2.71	2.81	0.1
16	743.6561	3.05	3.13	0.08	3.04	3.15	0.11
17	275.0615	2.7	2.76	0.06	2.68	2.79	0.11

Table 23: 1% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	0.81	0.85	0.04	0.82	0.85	0.03
4	5493.439	1	1.02	0.02	1	1.02	0.02
5	4837.21	1.27	1.3	0.03	1.27	1.3	0.03
6	4430.615	1.69	1.72	0.03	1.7	1.74	0.04
7	4209.788	1.68	1.7	0.02	1.68	1.72	0.04
8	3524.725	2	2.09	0.09	2	2.08	0.08
9	3150.067	3.2	3.32	0.12	3.2	3.31	0.11
10	2605.241	2.28	2.35	0.07	2.28	2.34	0.06
11	2252.25	1.5	1.56	0.06	1.5	1.55	0.05
12	1986.092	1.71	1.78	0.07	1.7	1.77	0.07
13	1653.88	3.09	3.21	0.12	3.11	3.25	0.14
14	1220.073	3.05	3.16	0.11	3.06	3.2	0.14
15	1020.439	2.86	2.95	0.09	2.86	2.99	0.13
16	743.6561	3.2	3.29	0.09	3.2	3.33	0.13
17	275.0615	2.81	3	0.19	2.98	2.92	-0.06

Table 24: 0.5% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	0.9	0.93	0.03	0.88	0.94	0.06
4	5493.439	1.06	1.08	0.02	1.04	1.08	0.04
5	4837.21	1.34	1.36	0.02	1.33	1.37	0.04
6	4430.615	1.8	1.84	0.04	1.76	1.85	0.09
7	4209.788	1.78	1.82	0.04	1.75	1.83	0.08
8	3524.725	2.13	2.18	0.05	2.11	2.2	0.09
9	3150.067	3.38	3.45	0.07	3.35	3.48	0.13
10	2605.241	2.38	2.42	0.04	2.37	2.43	0.06
11	2252.25	1.59	1.63	0.04	1.57	1.64	0.07
12	1986.092	1.82	1.85	0.03	1.8	1.87	0.07
13	1653.88	3.25	3.38	0.13	3.25	3.41	0.16
14	1220.073	3.2	3.33	0.13	3.2	3.34	0.14
15	1020.439	2.98	3.12	0.14	2.99	3.1	0.11
16	743.6561	3.32	3.47	0.15	3.33	3.43	0.1
17	275.0615	3.41	3.1	-0.31	3.4	3.47	0.07

Table 25: 0.2% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	0.98	1.03	0.05	0.96	1.03	0.07
4	5493.439	1.11	1.15	0.04	1.1	1.15	0.05
5	4837.21	1.4	1.44	0.04	1.39	1.44	0.05
6	4430.615	1.91	1.96	0.05	1.88	1.97	0.09
7	4209.788	1.89	1.94	0.05	1.86	1.94	0.08
8	3524.725	2.26	2.34	0.08	2.26	2.33	0.07
9	3150.067	3.55	3.67	0.12	3.56	3.66	0.1
10	2605.241	2.48	2.54	0.06	2.48	2.54	0.06
11	2252.25	1.68	1.73	0.05	1.68	1.73	0.05
12	1986.092	1.92	1.98	0.06	1.92	1.98	0.06
13	1653.88	3.45	3.6	0.15	3.48	3.6	0.12
14	1220.073	3.4	3.54	0.14	3.42	3.54	0.12
15	1020.439	3.18	3.31	0.13	3.18	3.31	0.13
16	743.6561	3.53	3.67	0.14	3.53	3.67	0.14
17	275.0615	3.18	3.14	-0.04	3.18	3.14	-0.04

Table 26: 0.1% AEP HEC-RAS modelled water levels (upstream to downstream) climate change comparisons

Cross section	HEC-RAS River station	Existing conditions			Proposed conditions		
		Current climate water depth (m)	Climate change water depth (m)	Difference (m)	Current climate water depth (m)	Climate change water depth (m)	Difference (m)
1	6643.759	0.02	0.02	0	0.02	0.02	0
2	6379.156	0.02	0.02	0	0.02	0.02	0
3	5964.076	1.04	1.1	0.06	1.03	1.11	0.08
4	5493.439	1.16	1.2	0.04	1.15	1.2	0.05
5	4837.21	1.45	1.5	0.05	1.44	1.5	0.06
6	4430.615	1.97	2.06	0.09	1.97	2.05	0.08
7	4209.788	1.95	2.03	0.08	1.95	2.02	0.07
8	3524.725	2.35	2.45	0.1	2.4	2.49	0.09
9	3150.067	3.69	3.83	0.14	3.76	3.87	0.11
10	2605.241	2.56	2.63	0.07	2.59	2.66	0.07
11	2252.25	1.74	1.8	0.06	1.77	1.83	0.06
12	1986.092	1.99	2.06	0.07	2.03	2.09	0.06
13	1653.88	3.61	3.78	0.17	3.67	3.83	0.16
14	1220.073	3.54	3.71	0.17	3.6	3.74	0.14
15	1020.439	3.28	3.43	0.15	3.33	3.45	0.12
16	743.6561	3.61	3.74	0.13	3.65	3.75	0.1
17	275.0615	3.6	3.68	0.08	3.61	3.67	0.06

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