Australian Government
Bureau of Meteorology

Tasmanian record major flooding event - June 2016

Submission to Tasmanian Government Flood Review

Document 1 of 3

25 November 2016

Submission Documents

Count	Document Title
1	Tasmanian record major flooding event - June 2016
2	Flood warning products for June 2016 flooding event
3	Major Flooding in Huonville, July 2016

Note:

1. Data used in this report has been subjected to limited quality checking during operations and may have errors
2. This product includes data made available to the Bureau by other agencies. Separate approval may be required to use the data for other purposes.
3. This report is not a complete set of all data that are available. It is a representation of some of the key information.

Report on the Tasmanian major flooding event, June 2016
Published by the Bureau of Meteorology
GPO Box 1289
Melbourne VIC 3001
(03) 9669 4000
floodwarning@bom.gov.au
www.bom.gov.au

Cover image: Kings Bridge and South Esk River at the Cataract Gorge above Launceston at the peak of the flood. Photograph by Rick Eaves (ABC) used with permission.

Table of contents

1 Introduction 1
2 Meteorological summary 2
3 Detailed hydrology 7
3.1 Antecedent conditions 7
3.2 Maps of recorded rainfall 9
3.3 Maps of rainfall annual exceedance probability 11
3.4 Catchment summaries 13
3.5 Peak river heights 34
4 Communication and warnings 37
5 Impacts of floods on flood forecasting and warning services 41
6 Summary 42
7 Appendix 1: Rainfall Tables 43
8 Appendix 2: Rainfall Intensity-Frequency-Duration Analyses 49
9 Appendix 3: Glossary of Terms 58

List of tables

Table 1 Peak river levels observed during 4 - 14 June 2016 and historical comparisons for key forecast locations. Table 1 Continued 36
Table 3 Number of flood products issued during the June 2016 flood 40
Table 4 Flood warnings and alerts by catchment and severity. 40
Table 5 IFD terminology conversion chart 49

List of figures

Figure 1 Synoptic Situation (satellite imagery and mean sea level pressure) for Saturday 4 June 2016, 10 am (left) and 10 pm (right) 2
Figure 2 Synoptic Situation (satellite imagery and mean sea level pressure) for Sunday 5 June 2016, 10 am (left) and 10 pm (right) 3
Figure 3 Synoptic Situation (satellite imagery and mean sea level pressure) for Monday 6 June 2016, 10 am (left) and 10 pm (right) 3
Figure 4 Radar rainfall images for periods of heavy rain (11:36 pm 4 June, 1:24 pm 5 June, 9:00 pm 5 June, 6:24 am 6 June) 5
Figure 5 Monthly time series of June sea surface temperature anomalies. 6
Figure 6 Sea Surface Temperature percentiles for June 2016 for all waters around Australia 6
Figure 7 Mersey River catchment-wide root zone (0-1 metre depth) modelled soil moisture as percentage of the capacity of the soils. 8
Figure 8 Soil dryness index for 3 and 8 of June 2016 (left and right respectively). 8
Figure 9 Three day (72 hour) gridded rainfall totals for Tasmania ending 9 am 7 June 2016. 9
Figure 10 Daily (24 hour) rainfall totals to 9 am from Sunday 5 June 2016 to Friday 10 June 2016. 10
Figure 11 Annual Exceedance Probability of 24 hour rainfall total to 9 am 6 June 2016. 11
Figure 12 Annual Exceedance Probability of 72 hour (3 day) rainfall total to 9 am 7 June 2016. 12
Figure 13 Bureau of Meteorology flood warning catchments for Tasmania 13
Figure 14 Rainfall for Isis River (top) and River level for Forth River below Wilmot (bottom) in the Forth catchment. 15
Figure 15 Rainfall for Fisher River (top) and River level for Mersey River at Liena (bottom) both sites in the Mersey catchment headwaters 17
Figure 16 Transit of the flood down the Mersey River from upstream (top) to downstream (bottom). 18
Figure 17 Rainfall (top) and River level (bottom) for sites in the Meander catchment headwaters. 20
Figure 18 Transit of the flood down the Meander River from upstream (top) to downstream (bottom). 21

Figure 19 Rainfall (top) and River level (bottom) for sites in the Macquarie catchment headwaters. 23
Figure 20 Transit of the flood down the Macquarie River from upstream (top) to downstream (bottom). 24
Figure 21 Rainfall (top) and River level (bottom) for sites in the North Esk catchment. 25
Figure 22 Rainfall (top) and River level (bottom) for sites in the South Esk catchment headwaters. 27
Figure 23 Transit of the flood down the South Esk River from upstream (top) to downstream (bottom). 29
Figure 24 Rainfall (top) and River level (bottom) for sites in the Ouse catchment, a tributary of the River Derwent. 31
Figure 25 Transit of the flood down the lower reaches of the River Derwent below Meadowbank Dam. 32
Figure 26 Rainfall (top) and River level (bottom) for the Jordan River at Mauriceton. 33
Figure 27 Peak flood levels observed between 4 and 14 June 2016. Where June 2016 was a new record, the symbol is surrounded by a circle. Where only the minor flood class level is defined, the symbol is surrounded by a square. 34
Figure 28 Graphical timeline of warnings issued by catchment 39
Figure 29 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Northwest Tasmania. The background shows elevation, rivers, lakes and catchment boundaries. 46
Figure 30 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Northeast Tasmania. The background shows elevation, rivers, lakes and catchment boundaries. 47
Figure 31 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Southern Tasmania. The background shows elevation, rivers, lakes and catchment boundaries. 48
Figure 32 Rainfall Intensity-Frequency-Duration analysis for a site in the Forth headwaters. 50
Figure 33 Rainfall Intensity-Frequency-Duration analysis for a site in the Mersey headwaters. 51
Figure 34 Rainfall Intensity-Frequency-Duration analysis for a site in the Meander headwaters. 52
Figure 35 Rainfall Intensity-Frequency-Duration analysis for a site in the Macquarie headwaters. 53
Figure 36 Rainfall Intensity-Frequency-Duration analysis for a site in the North Esk headwaters. 54
Figure 37 Rainfall Intensity-Frequency-Duration analysis for a site in the South Esk headwaters. 55
Figure 38 Rainfall Intensity-Frequency-Duration analysis for a site in the Derwent headwaters. 56
Figure 39 Rainfall Intensity-Frequency-Duration analysis for a site in the Jordan headwaters. 57

1 Introduction

A strong, moisture-laden weather system brought exceptional flooding to several catchments in Tasmania in early June 2016. There were several hundred millimetres of rain over the 72 hours to 9 am Tuesday 7 June. The rain was particularly heavy in the 24 hours to 9 am Monday 6 June.

During the June 2016 flood event, major flood levels were exceeded at numerous flood forecasting locations and several river level measurement stations experienced the highest water level on record. From 3 to 12 June 2016, the Bureau of Meteorology issued a total of 8 flood watches and 203 flood warnings, as well as 21 severe weather warnings, and gave at least 70 interviews to television, radio and print media.

The purpose of this report is to document the meteorological and hydrological conditions leading up to, and including, the June 2016 flood event. The report also records the Bureau of Meteorology's (Bureau's) associated Flood Forecasting and Warning Service.

Section 2 contains a summary of the climatological and meteorological situation prior to and during the June 2016 flood event.

Section 3 describes the detailed hydrology for the June 2016 flood, beginning with an analysis of the antecedent soil moisture conditions, followed by maps of recorded rainfall and rainfall probability. Catchment-by-catchment descriptions of the characteristics of the rain and recorded flooding are provided in section 3.4, followed by a summary of peak river levels at forecast locations.

Section 4 includes a timeline of significant communications for the June 2016 flood event, followed by a summary of the flood warning products.

Section 5 describes the impacts of the June 2016 flood on the Bureau's Flood Warning Service.

Appendices provide maps and tables of daily rainfall totals during the June 2016 flood event, as well rainfall intensity-frequency-duration (IFD) analyses at key locations and a glossary of terms.

2 Meteorological summary[1]

An upper level trough developed over central and eastern Australia in the first week of June 2016. The upper trough and an accompanying low pressure surface trough intensified on 3 June as the system tracked across southeast Queensland. Moist air drawn into the eastern flank of the trough from the Coral Sea resulted in heavy rainfall in southeast Queensland.

Figures 1, 2 and 3 below show the synoptic situation from 4 to 6 June, with low and high pressure systems identified by "L" and "H" respectively. Isolines of sea level pressure are shown in yellow and the fronts and troughs are shown in red and blue, with the direction of movement of features given by arrows. The satellite images for the respective times are shown in the background, with cloudy areas in white.

The trough system moved off the northeast coast of New South Wales on 4 June (dashed line, Figure 1) and developed into a mainland East Coast Low early on 5 June (Figure 2), producing heavy rainfall, strong winds and a large sea swell along the New South Wales coast. Rainfall totals for the 24 hours to 9 am across the New South Wales northeast coast were well in excess of 200 mm.

A strong and near-stationary high pressure system over New Zealand (lower right corner of Figure 1 to Figure 3), maintained a northeasterly airstream into the trough allowing a continuous feed of moisture into the low pressure system. As the complex low tracked slowly southwards and interacted with multiple centres of low pressure, a very strong, moist northeasterly flow was directed over Tasmania from 5 to 7 June (see Figure 2 and Figure 3).There were damaging northeasterly winds about northern and eastern parts of Tasmania, and damaging surf on the east coast.

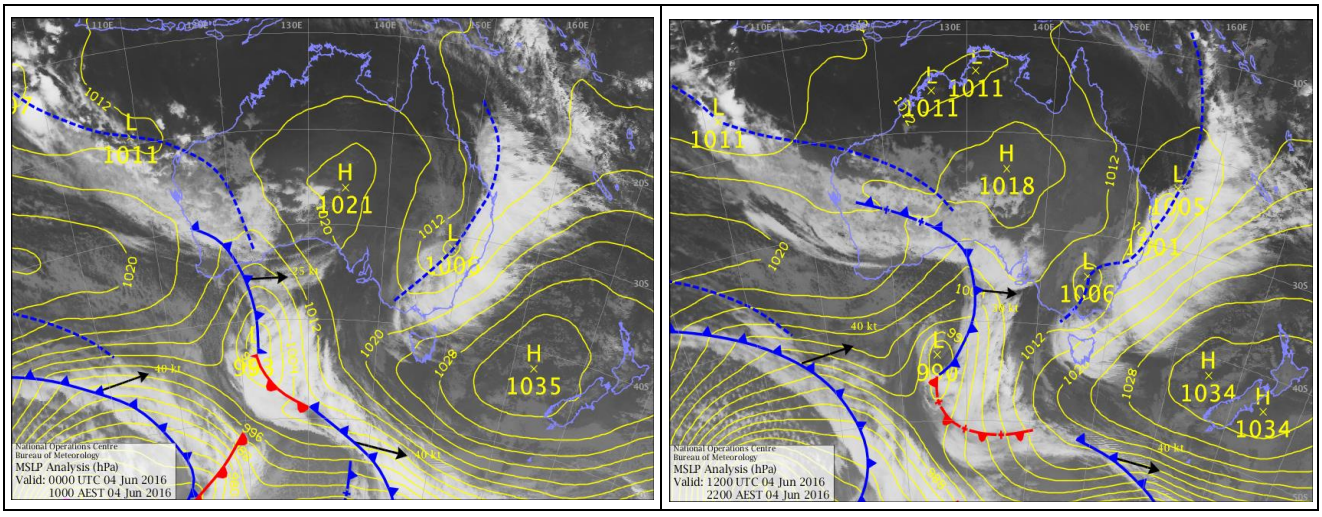


Figure 1 Synoptic Situation (satellite imagery and mean sea level pressure) for Saturday 4 June 2016, 10 am (left) and 10 pm (right)

[1] *This section is based on Special Climate Summary 57 "Extensive Early June Rainfall Affecting Australian East Coast" and more detail can be found at http://www.bom.gov.au/climate/current/statements/scs57.pdf*

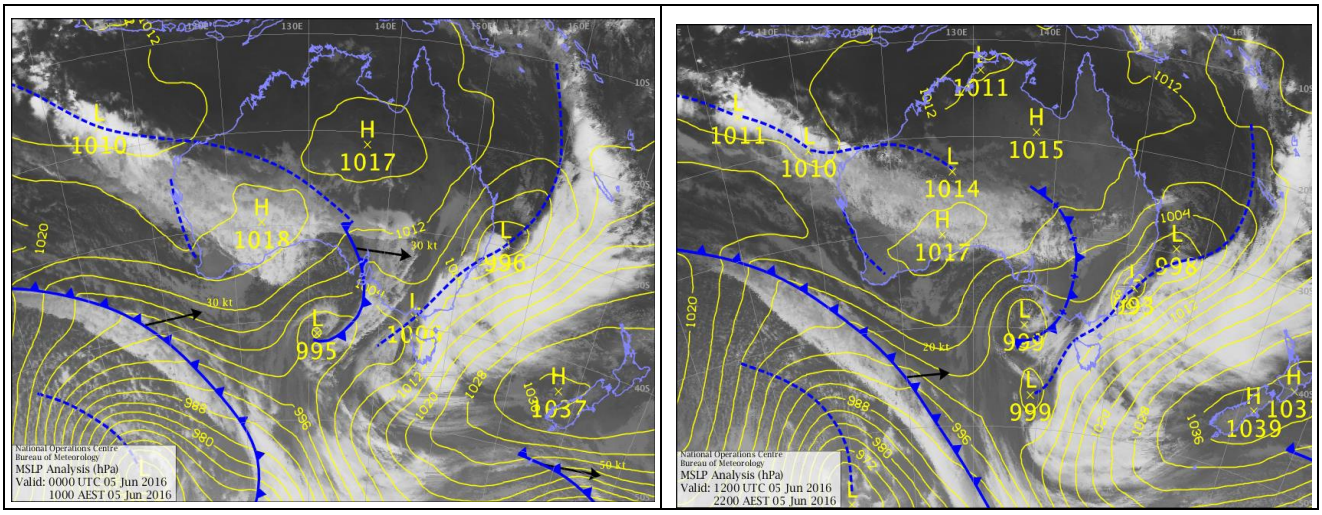


Figure 2 Synoptic Situation (satellite imagery and mean sea level pressure) for Sunday 5 June 2016, 10 am (left) and 10 pm (right)

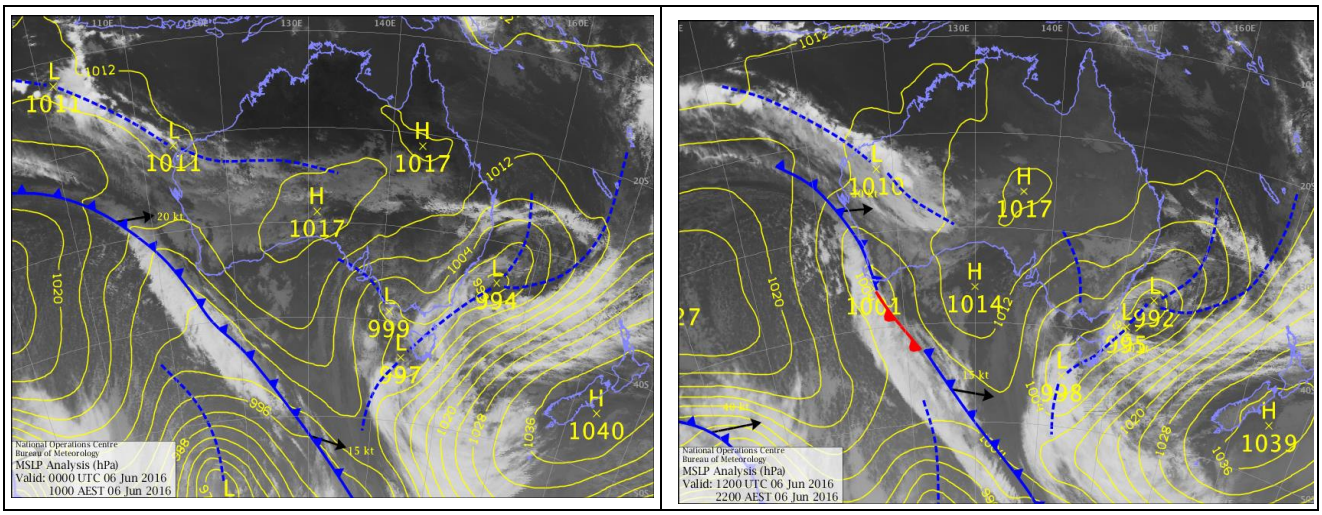


Figure 3 Synoptic Situation (satellite imagery and mean sea level pressure) for Monday 6 June 2016, 10 am (left) and 10 pm (right)

Heavy rainfall on Sunday 5 June and Monday 6 June brought major flooding to Tasmania's northern river basins. The flooding is described further in sections 3.4 and 3.5. The north of the State generally recorded 50 to 100 mm of rainfall in the 24 hours to 9 am on Sunday 5 June, with 129 mm at Pyengana a new June record for that station.

The heaviest rainfall then occurred Sunday 5 June night into Monday 6 June morning as the trough system approached from the west and then slowly moved over the State. Broad areas in the north of the State received well in excess of 150 mm in the 24 hours to 9 am Monday 6 June. Across the State, in the 24 hours to 9 am on Monday 6 June, 33 stations with 40 or more years of data set new June daily rainfall records. In total 59 stations set new June daily rainfall records. Eight long term stations reported their wettest day on record, including both Yolla and Loongana in the State's northwest, both of which recorded 248 mm to 9 am Monday 6 June, exceeding their previous wettest days by over 100 mm. The highest rainfall total recorded in the 24 hours to 9 am Monday 6 June was at Fisher River (above Lake MacKenzie – operated by Hydro Tasmania) which received 278.6 mm. Over the Northern rainfall district (district 91 – see http://www.bom.gov.au/climate/cdo/about/rain-districts.shtml), this was the wettest day on record with a district average of 114.5 mm.

The heavy rainfall shifted to the east and southeast of the State and then eased as the system tracked to Tasmania's southeast on 7 June. Most of northern Tasmania, except for the far northwest and the area around Launceston, had at least 100 mm over the three days from 5 to 7 June, with three-day totals above 200 mm occurring widely on the north side of the Central Plateau, and in the northeast highlands (see section 3.2).

Figure 4 shows the estimated rain rates from the West Takone radar at selected times from the evening of Saturday 4 June to the morning of Monday 6 June. The coloured areas indicate the areas where raindrops were detected in the atmosphere, with heavier falls shown in green and yellow. The ability of the radar to accurately measure rainfall in the eastern part of the State (e.g. east of Launceston) is limited because of the long distance from the radar and the blockage of the view by topography.

The intensity of the rainfall in the north of the State was the result of the combination of three factors. Firstly, the moisture feed into the system extended across the Tasman Sea from as far north as the central Coral Sea. Figure 5 and Figure 6 indicate that the sea surface temperatures over these waters were very much above average for June, continuing the record temperature trend observed over autumn. This increased the amount of moisture available for evaporation into the atmosphere. An estimate of the amount of moisture in the atmosphere, given by precipitable water, was close to the highest on record for June at several measurement locations along the east coast of Australia. A new June record was reported at Hobart Airport on the evening on Monday 6 June.

Secondly, this moisture was driven on to the northern and eastern parts of the State in the strong northeasterly winds that the synoptic situation produced. Finally, the low level winds were lifted by the topography over northern Tasmania to reinforce the upward motion present in the rainband, making a very efficient precipitating synoptic system.

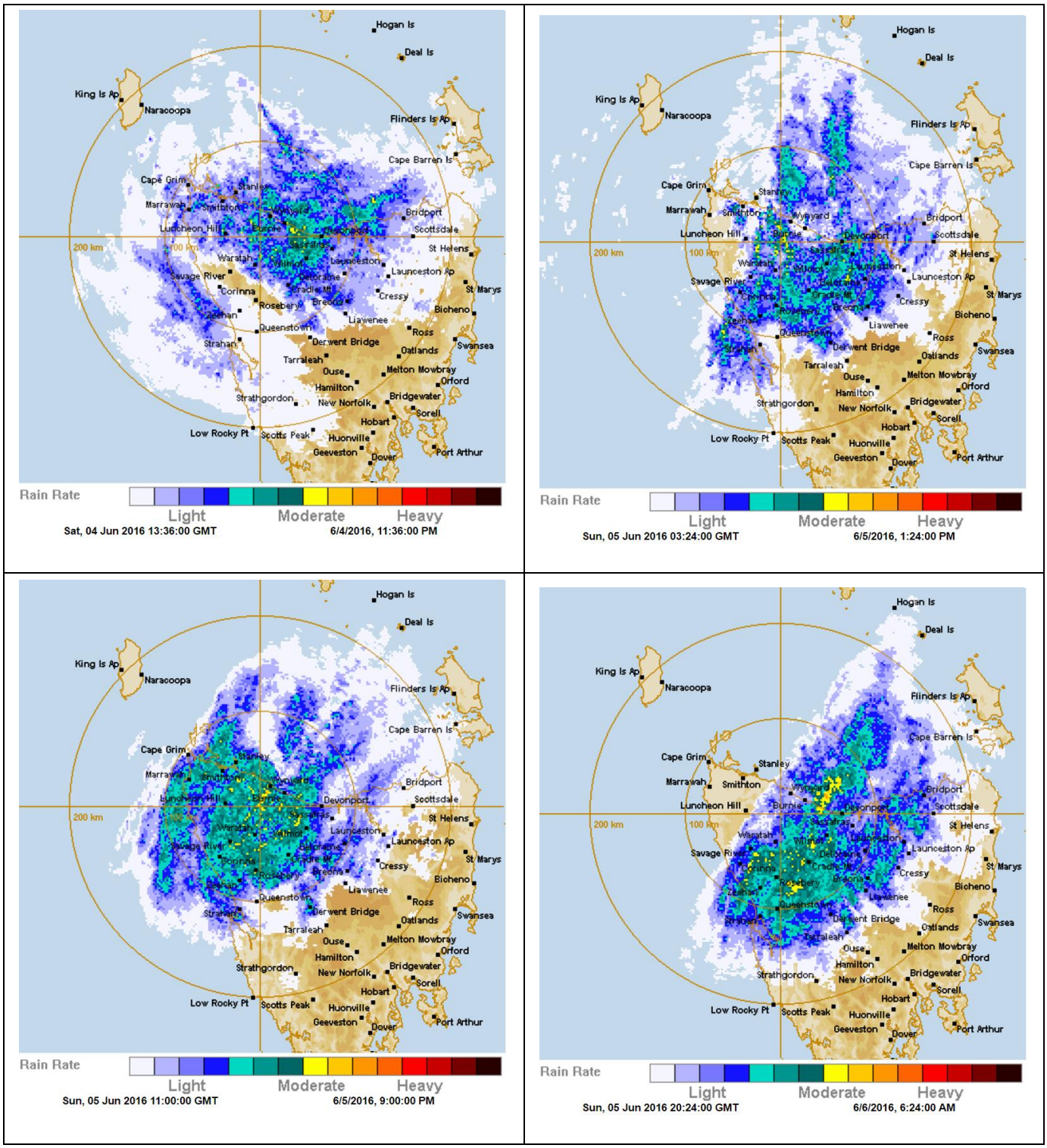


Figure 4 Radar rainfall images for periods of heavy rain (11:36 pm 4 June, 1:24 pm 5 June, 9:00 pm 5 June, 6:24 am 6 June)

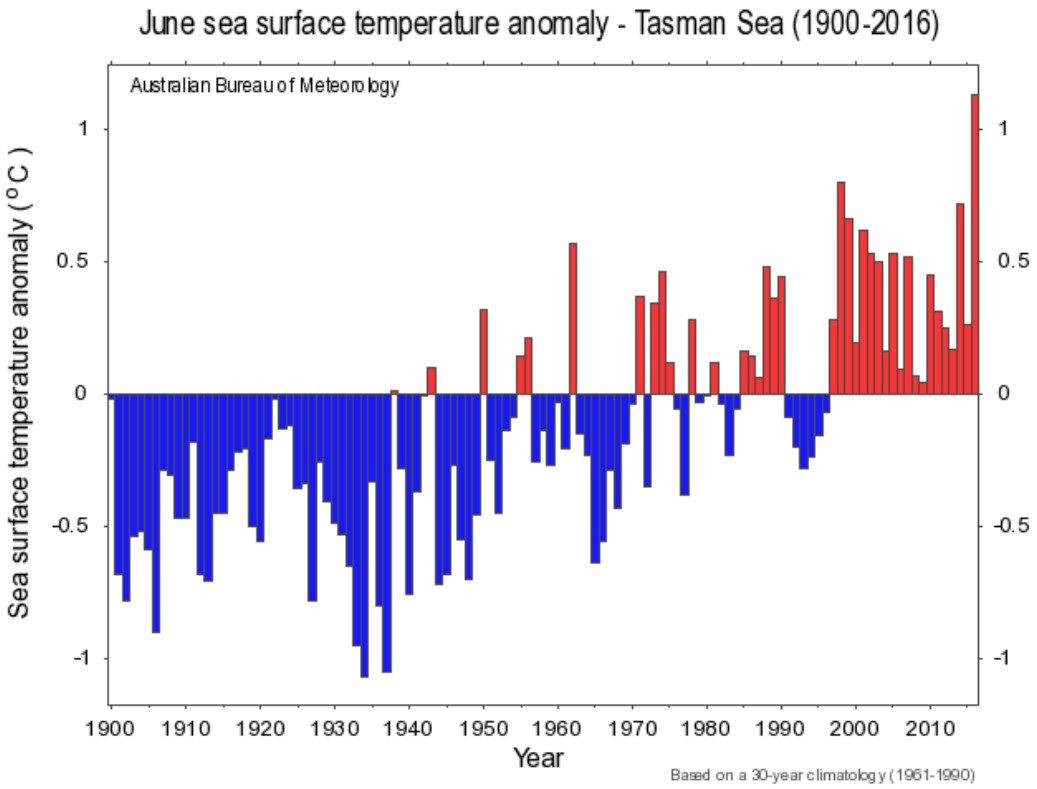


Figure 5 Monthly time series of June sea surface temperature anomalies.
http://www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=sst&area=tas&season=06&ave_yr=0

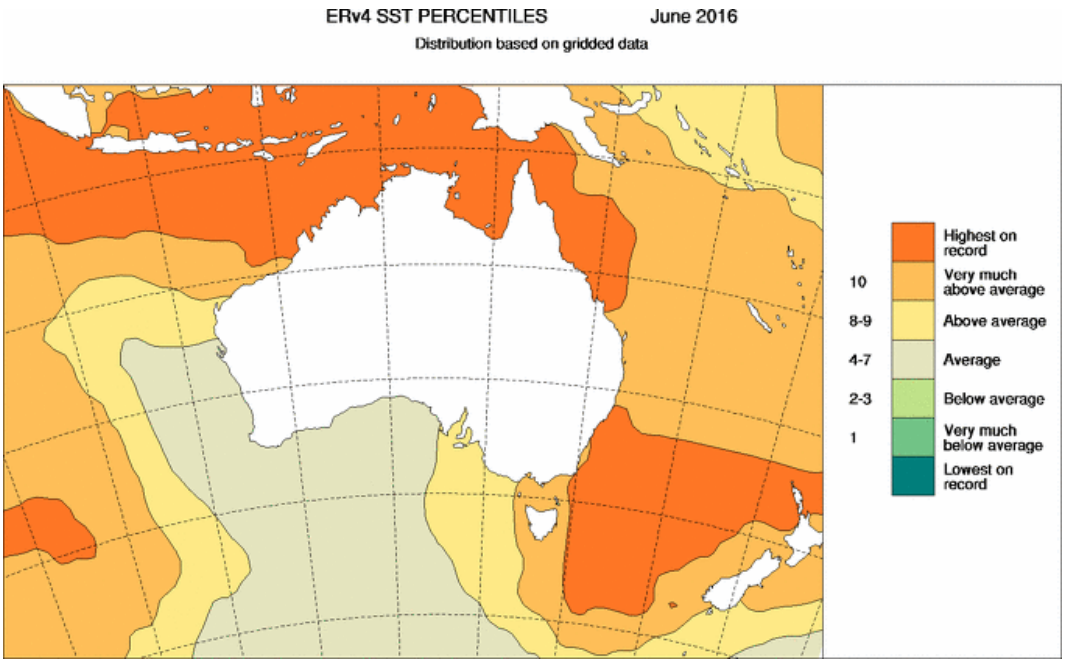


Figure 6 Sea Surface Temperature percentiles for June 2016 for all waters around Australia.

3 Detailed hydrology

3.1 Antecedent conditions

From September 2015 to April 2016 Tasmania generally experienced very dry conditions, with a record dry spring. The exception was at the end of January 2016 when a low pressure system brought heavy rainfall to the north of the State and led to widespread flash flooding down the east coast and parts of the central north[2]. The January 2016 event resulted in moderate flooding in the South Esk River and over 100 calls for assistance to the Tasmanian Northern Region State Emergency Service. Even this was not enough to counteract long-term rainfall deficiencies.

By the end of April 2016, water storage levels across the State reached record lows. An extended period of rain started in May 2016, with the south, central, and northeast parts of the State receiving in excess of 200% of their average monthly rainfall. Sites in the Huon catchment in the south of the State experienced minor flooding and sites along the North Esk River approached their minor flood levels on several occasions. Soil moisture levels increased during this time, approaching the normal levels for this time of year in the west and north of the State.

The Bureau operates a continental land surface water balance model (the Australian Water Resources Assessment Landscape Model version 5). Figure 7 shows the Mersey River average catchment-wide soil moisture over a twelve month period from August 2015 to August 2016. The heavy black line shows 2015-2016 and the light grey line shows the seasonal median from 2010-2015, a mix of wet and dry years. This illustrates the dry period preceding January 2016, the steady replenishment of soil moisture throughout May 2016 and then rapid rises in early June 2016.

The Soil Dryness Index (SDI) is another measure of soil moisture deficit. It is commonly used for fire danger assessment and is an estimation of the amount of rainfall necessary to saturate the soil. In this index, the lower values show areas where smaller amounts of rainfall would be required to saturate the soil, indicating wetter catchment conditions. The SDI on 3 June, prior to the start of the June 2016 flood event, and on 8 June, after the main rainfall had occurred, are shown in Figure 8. The values at the start of the June 2016 flood event were fairly typical for June in the west and north and were comparable to the values observed around the same time in 2015. After the main rainfall, most catchments across the State were close to saturation.

[2] *The January event is documented in Special Climate Statement 54 "Extreme Rainfall in Northern and Eastern Tasmania" and more detail can be found at: http://www.bom.gov.au/climate/current/statements/scs54.pdf*

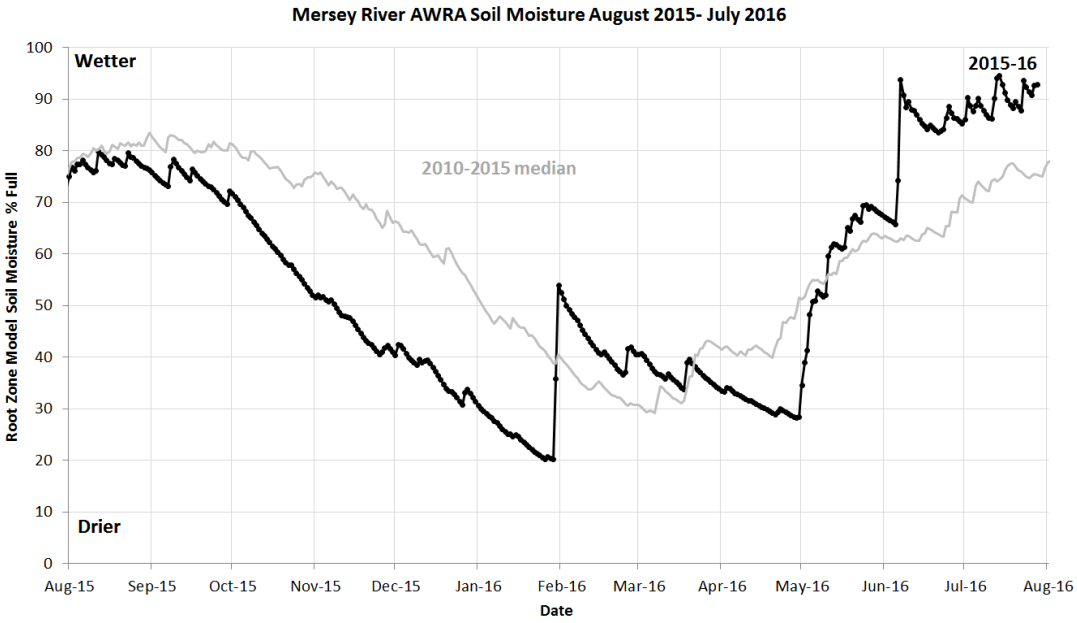


Figure 7 Mersey River catchment-wide root zone (0-1 metre depth) modelled soil moisture as percentage of the capacity of the soils.

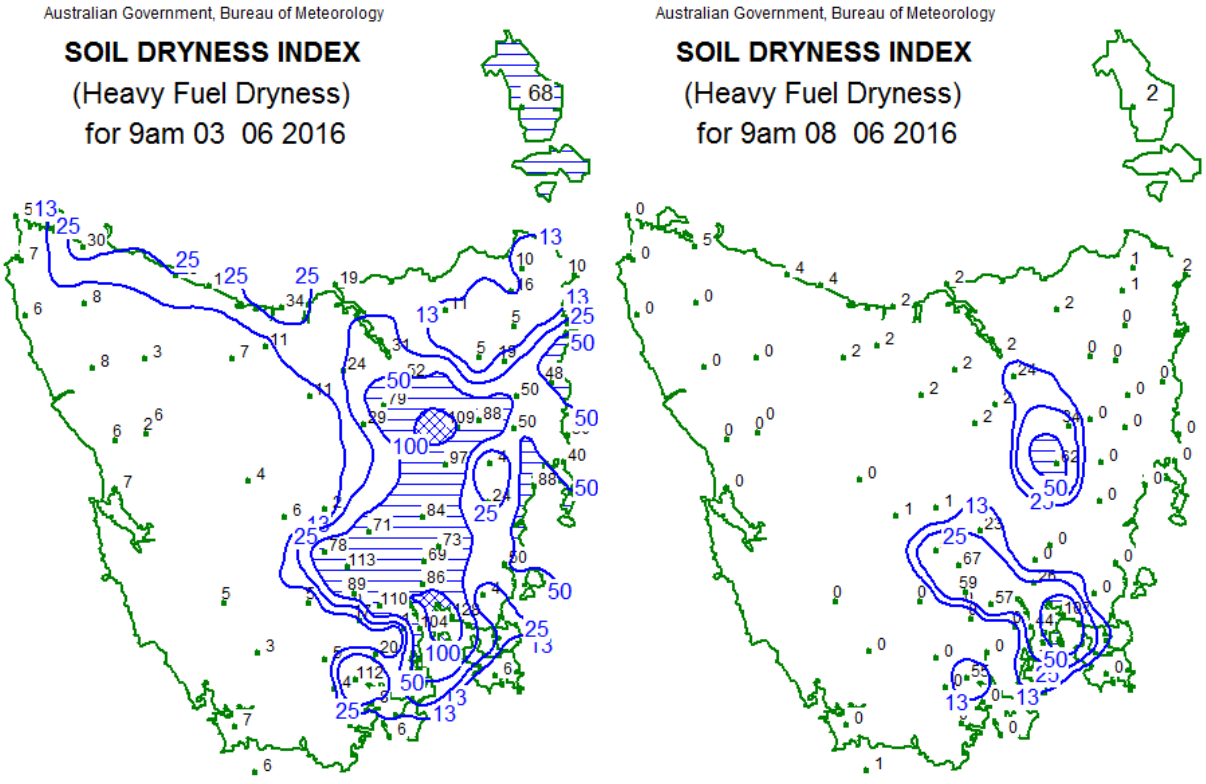


Figure 8 Soil dryness index for 3 and 8 of June 2016 (left and right respectively).

3.2 Maps of recorded rainfall

Figure 9 shows the gridded three day (72 hour) rainfall totals across the State ending 9 am 7 June. The highest rainfall for this period was reported across the north of the State, particularly the North East Highlands and Western Tiers. Figure 10 shows map displays of the daily (24 hour) rainfall totals to 9 am for 5 to 10 June. The highest two day (48 hour) rainfall total recorded for this event was 403 mm at Fisher River (ending 7 pm 6 June 2016). A complete list and higher resolution maps of daily rainfalls is included in Appendix 1: Rainfall tables.

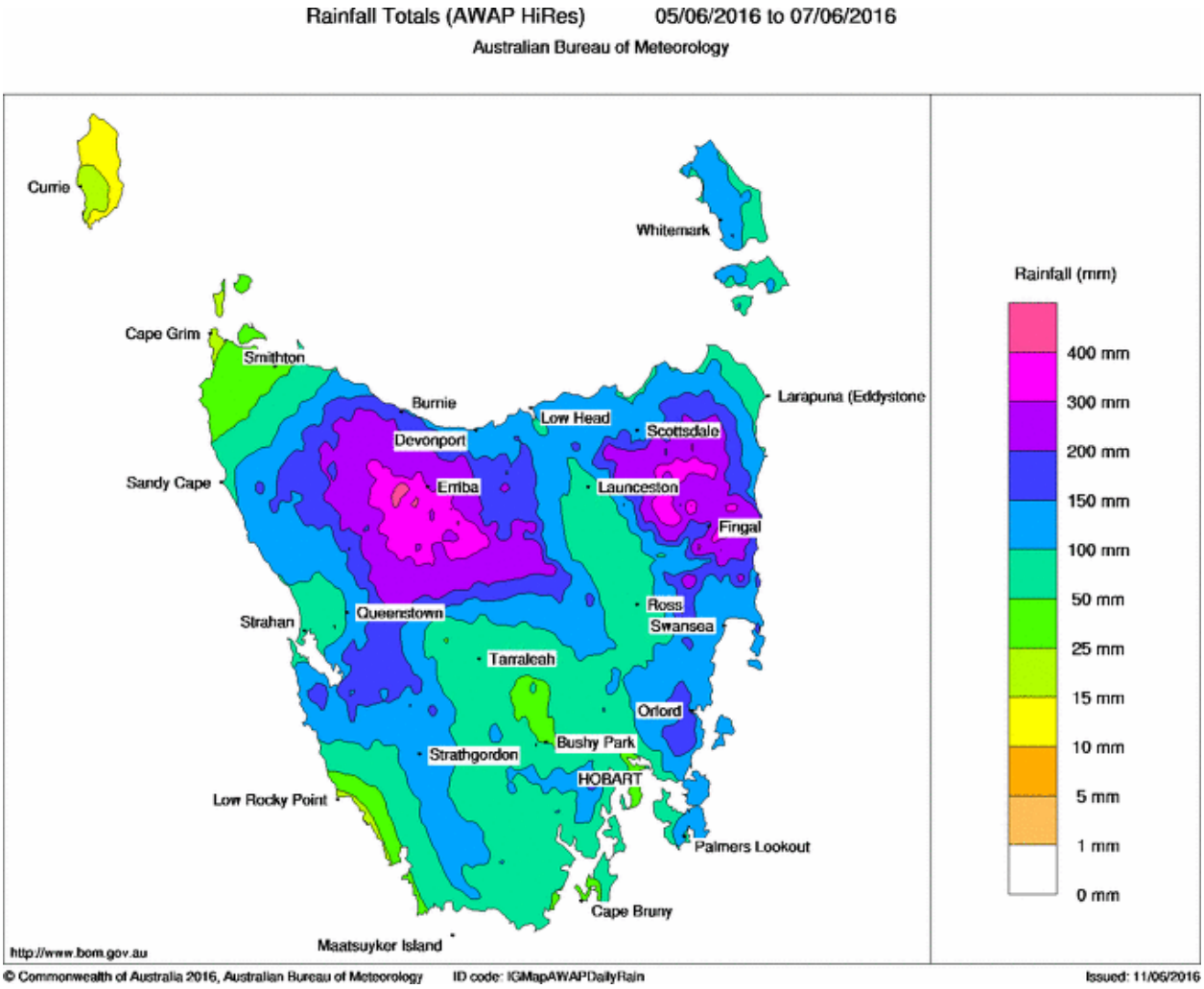


Figure 9 Three day **(**72 hour) gridded rainfall totals for Tasmania ending 9 am 7 June 2016.

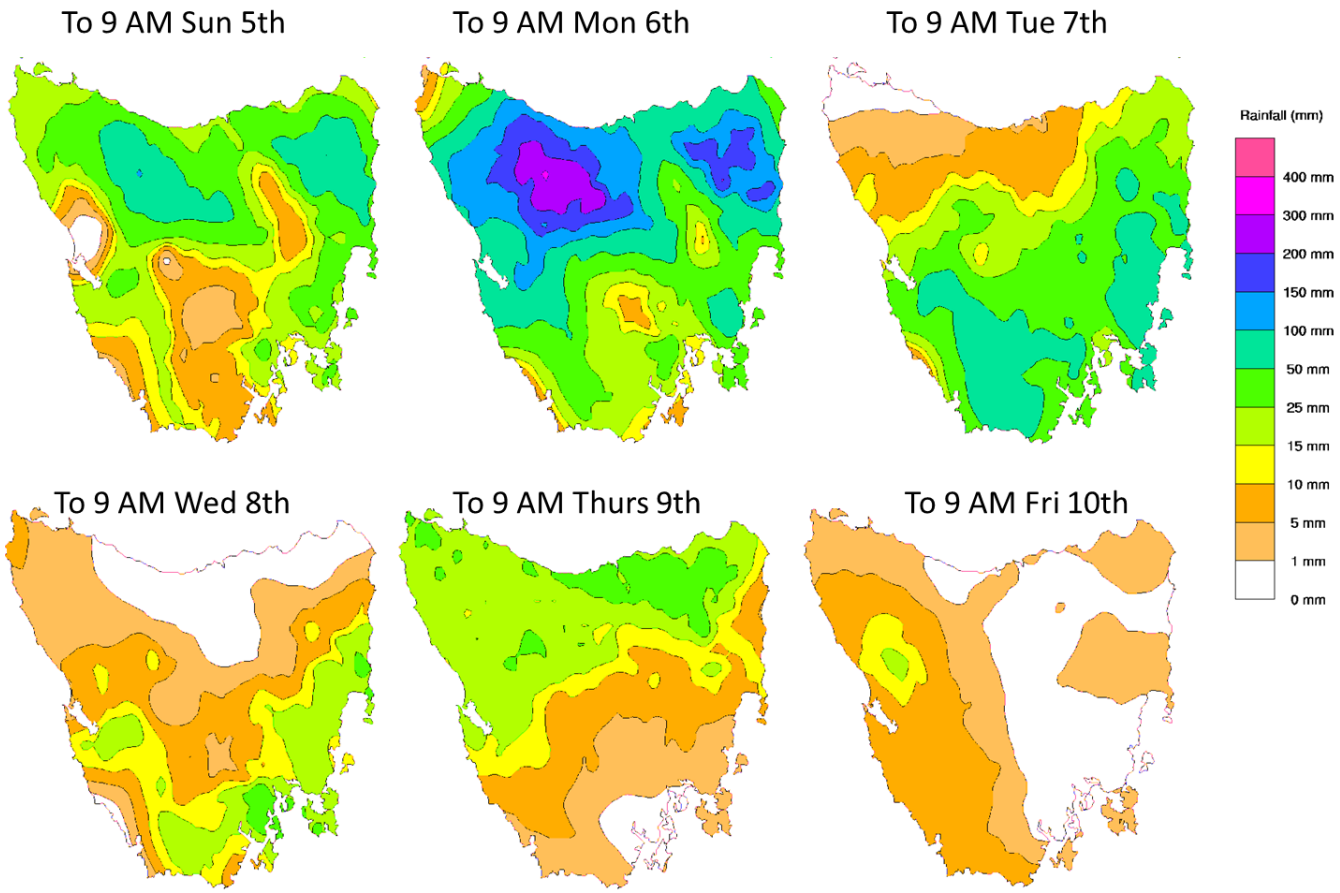


Figure 10 Daily (24 hour) rainfall totals to 9 am from Sunday 5 June 2016 to Friday 10 June 2016.

3.3 Maps of rainfall annual exceedance probability

During the period of rainfall 4 to 10 June 2016, many locations throughout the north of the State recorded rainfall totals that had a less than 1% chance of being exceeded in any given year. Figure 11 and Figure 12 show the Annual Exceedance Probability for the 24 hours and 72 hour durations. Note that these are restricted totals to 9 am to give a broader coverage. Unrestricted totals for some sites may be higher than shown due to the varied timing and intensity of the rainfall. A table for conversion of Annual Exceedance Probability (AEP) to Average Recurrence Interval (ARI) is included in Appendix 2.

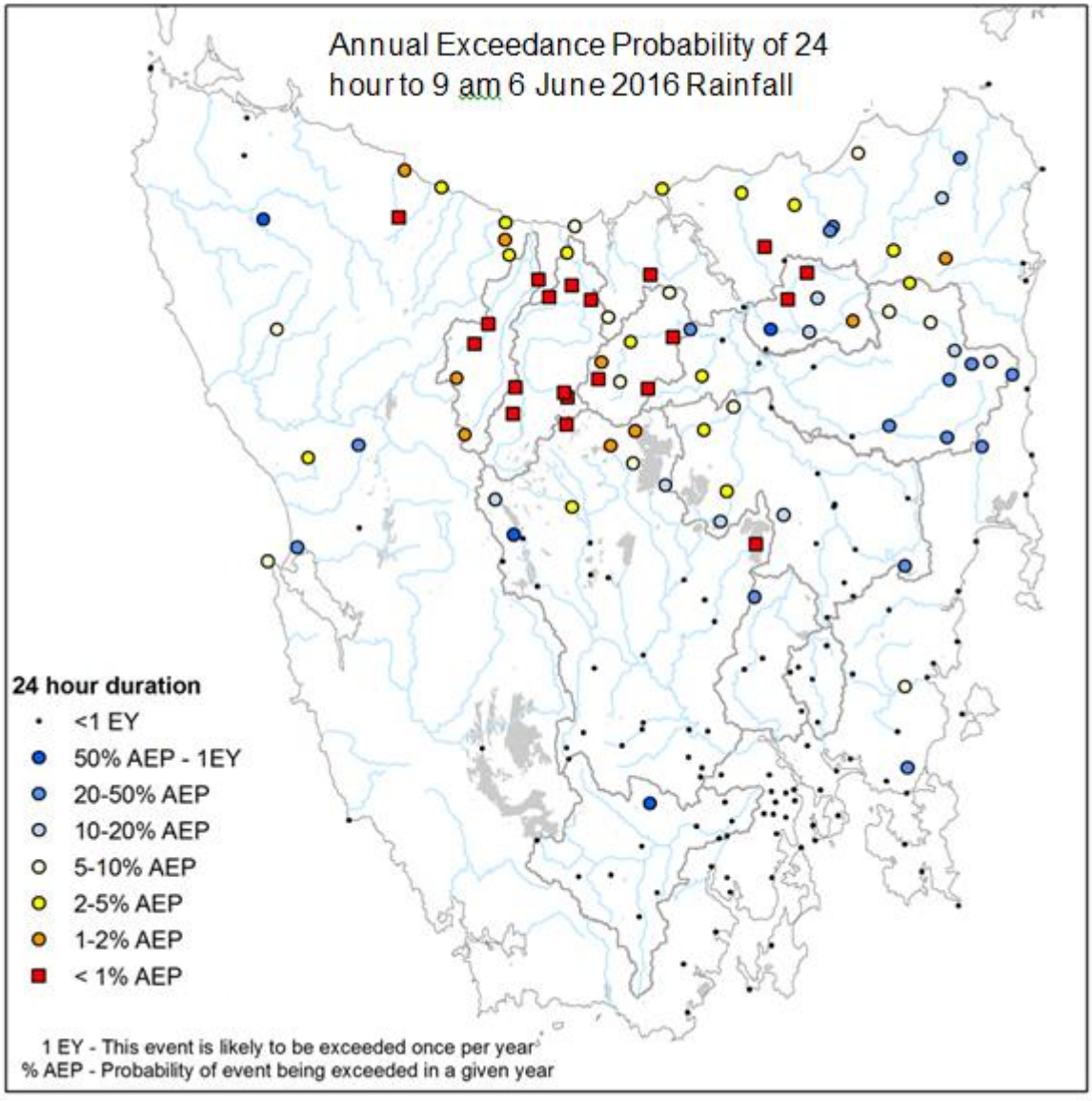


Figure 11 Annual Exceedance Probability of 24 hour rainfall total to 9 am 6 June 2016.

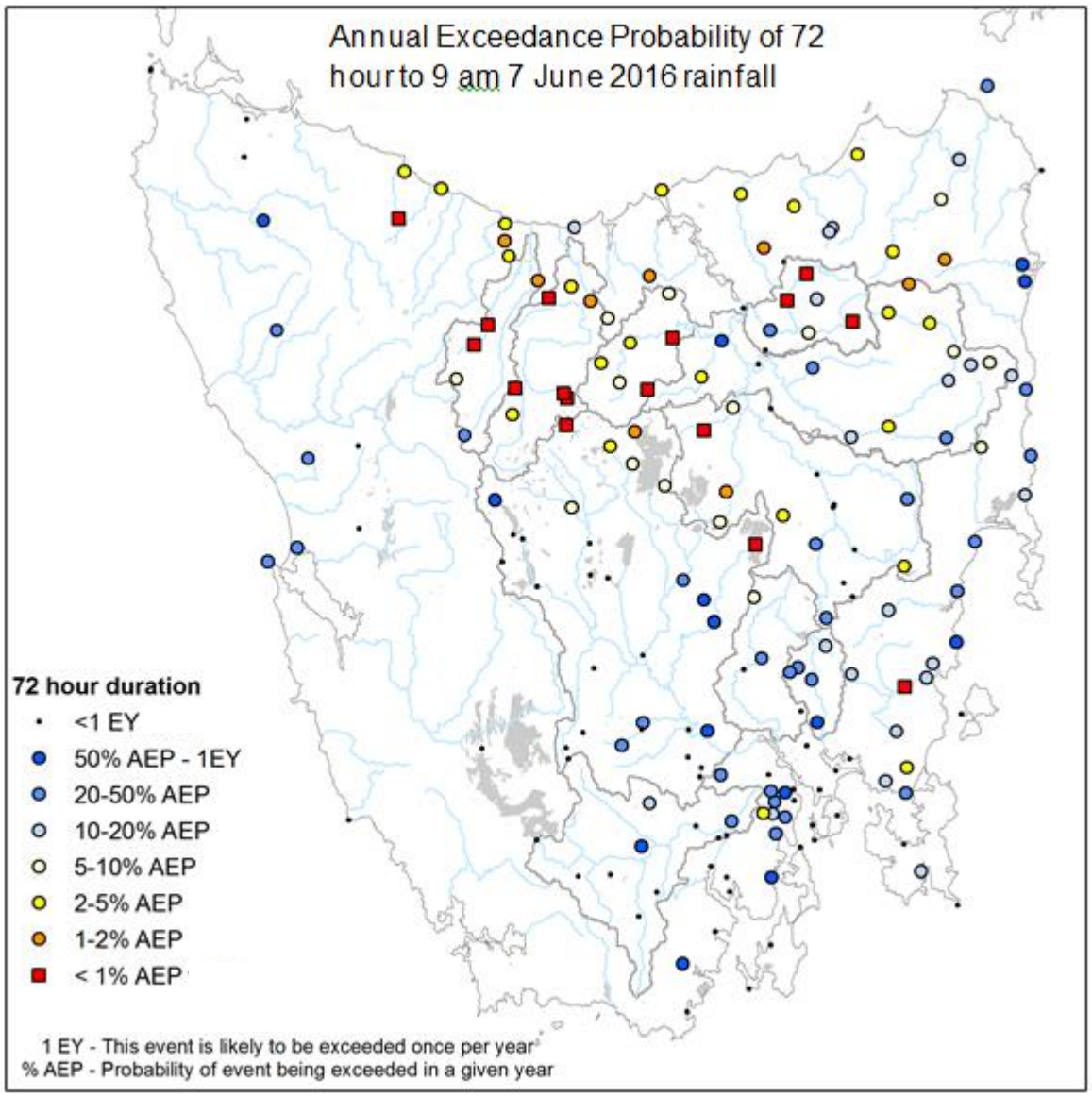


Figure 12 Annual Exceedance Probability of 72 hour (3 day) rainfall total to 9 am 7 June 2016.

Detailed rainfall intensity analyses are included in Appendix 2. The rainfalls were particularly extreme for the 48 hour duration. Short duration rainfall intensities (e.g. 1-3 hour) were not as extreme as the longer duration totals. Few sites, except for the headwaters of the Mersey, had 3 hour intensities more extreme than the 20% chance of being exceeded in any one year.

Note: A flood frequency analysis would be required to assess the probability of flood peaks recorded at each location. The frequency analyses in this report are for rainfall only.

3.4 Catchment summaries

Figure 13 shows the catchments covered by the Bureau's Flood Warning Service that is documented in the Tasmanian Service Level Specification (SLS). This document is available on the website http://www.bom.gov.au/tas/flood/SLS-2014-15-TAS-signed.pdf. Flood watches may cover areas outside of these catchments.

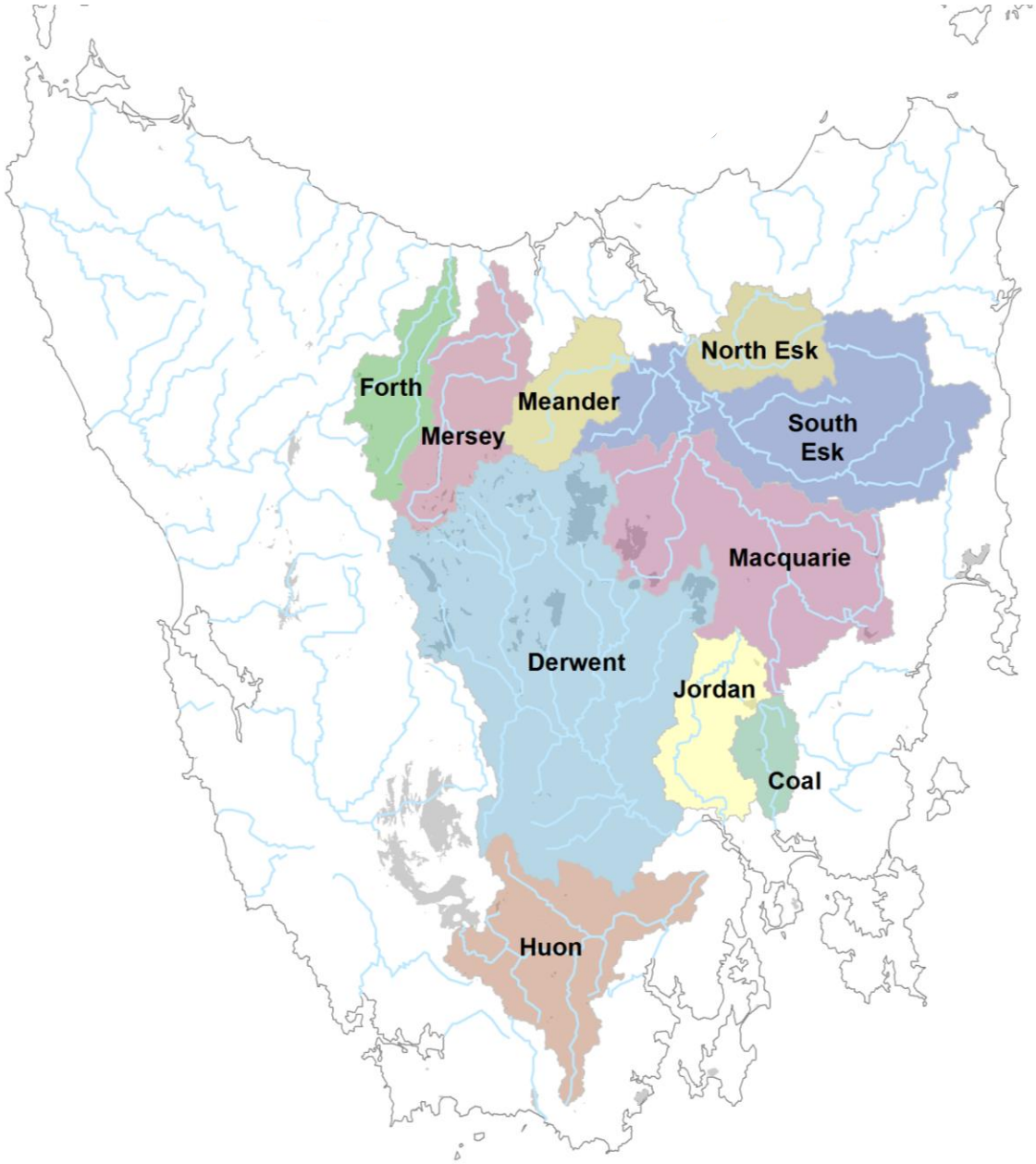


Figure 13 Bureau of Meteorology flood warning catchments for Tasmania

The hydrology presented in this report concentrates on flooding that occurred in Tasmanian river basins covered by flood warning service shown in Figure 13, and includes data from key river level and rainfall data from the real time Flood Warning Network stations only. It does not include an assessment of catchments for which the Bureau does not provide a flood warning service.

Forth River

Rainfall in the Forth catchment commenced around 8 pm Saturday 4 June and had mostly cleared by 10 am Monday 6 June. There was widespread rainfall in excess of 200 mm in three days. The highest total of 318 mm was recorded at Lake Gairdner Dam. River levels began rising in the headwaters at the Lemonthyme power station early Sunday morning. Two peaks occurred in the headwaters at Lemonthyme at 10:45 pm Sunday and 8:15 am Monday and peaked downstream above the major flood level (7.5 metres) at the forecast location on the Forth River below Wilmot Junction at 11:50 am Monday. The flood peak of 7.93 metres at this location was the highest on record, exceeding the height of 7.18 metres during the August 1970 flood. Flood warnings commenced at 4:19 pm Saturday 4 June and were finalised 9:02 am Wednesday 8 June. The first major warning was issued at 8:37 am Monday 6 June.

Figure 14 shows the hourly rainfall for Isis River and the river level for Forth River below Wilmot River. The minor (green), moderate (yellow) and major (red) flood class levels for the Forth River below Wilmot site are shown on the bottom graph. In this and following graphs the label on the horizontal axis (e.g. "6 Jun Mon") and light vertical lines mark the start of that day.

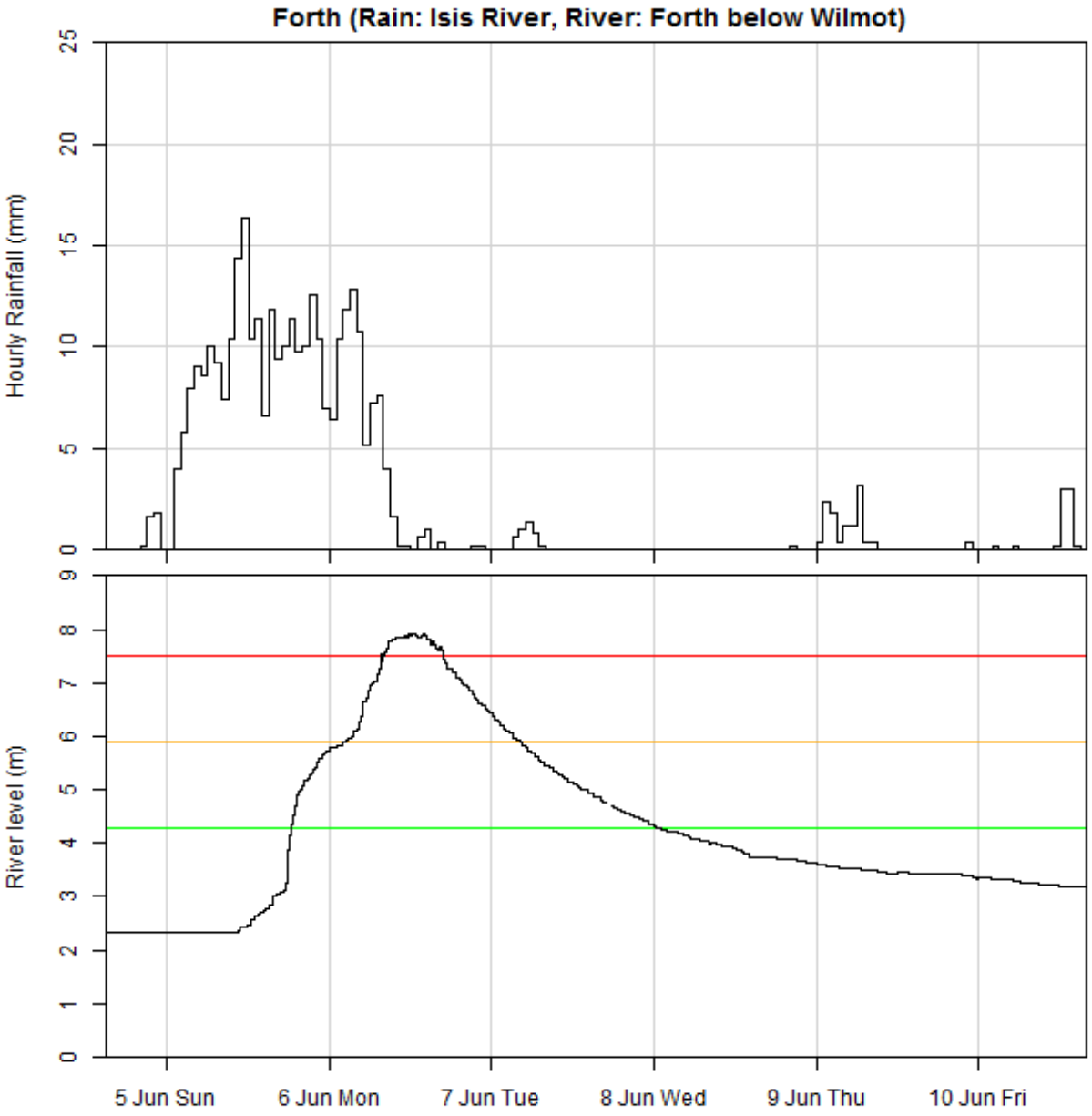


Figure 14 Rainfall for Isis River (top) and River level for Forth River below Wilmot (bottom) in the Forth catchment.

Mersey

Rainfall in the Mersey catchment commenced around 7 pm Saturday 4 June and had mostly cleared by 10 am Monday 6 June. There was widespread rainfall in excess of 240 mm in three days, with the highest total of 409 mm recorded at Fisher River near Lake Mackenzie. River levels began rising in the headwaters at Fisher River around 2 am Sunday 5 June. Two peaks occurred at Liena, below Lake Parangana at 9 pm Sunday and 7 am Monday. The river is estimated to have peaked downstream at Latrobe Bridge during Monday morning. The flood peaks at Liena, Kimberley and Latrobe Bridge were all the highest on record. Flood warnings commenced at 3:17 pm Saturday 4 June and were finalised at 2:56 pm Wednesday 11 June. The first major warning was issued at 4:16 pm Sunday 5 June.

Figure 15 shows the hourly rainfall totals for Fisher River and the river level for Mersey River at Liena, in the headwaters of the Mersey River. Note the sustained high intensity rainfall of over 5 mm/hr for this period. The minor flood class level for Liena is shown in green on the bottom graph. The station does not have moderate and major flood class levels defined. The June 2016 river level was higher than the previous record. Late Monday evening the station stopped reporting data due to an instrumentation failure caused by the flood, but was repaired shortly after.

Figure 16 shows the transit of the flood down the Mersey River from Liena to Kimberley. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS are shown for Kimberley. The river level data was unavailable after 9:20 am on 6 June due to major infrastructure damage caused by the flood. Only manual readings were available at Latrobe Bridge downstream and have not been included here.

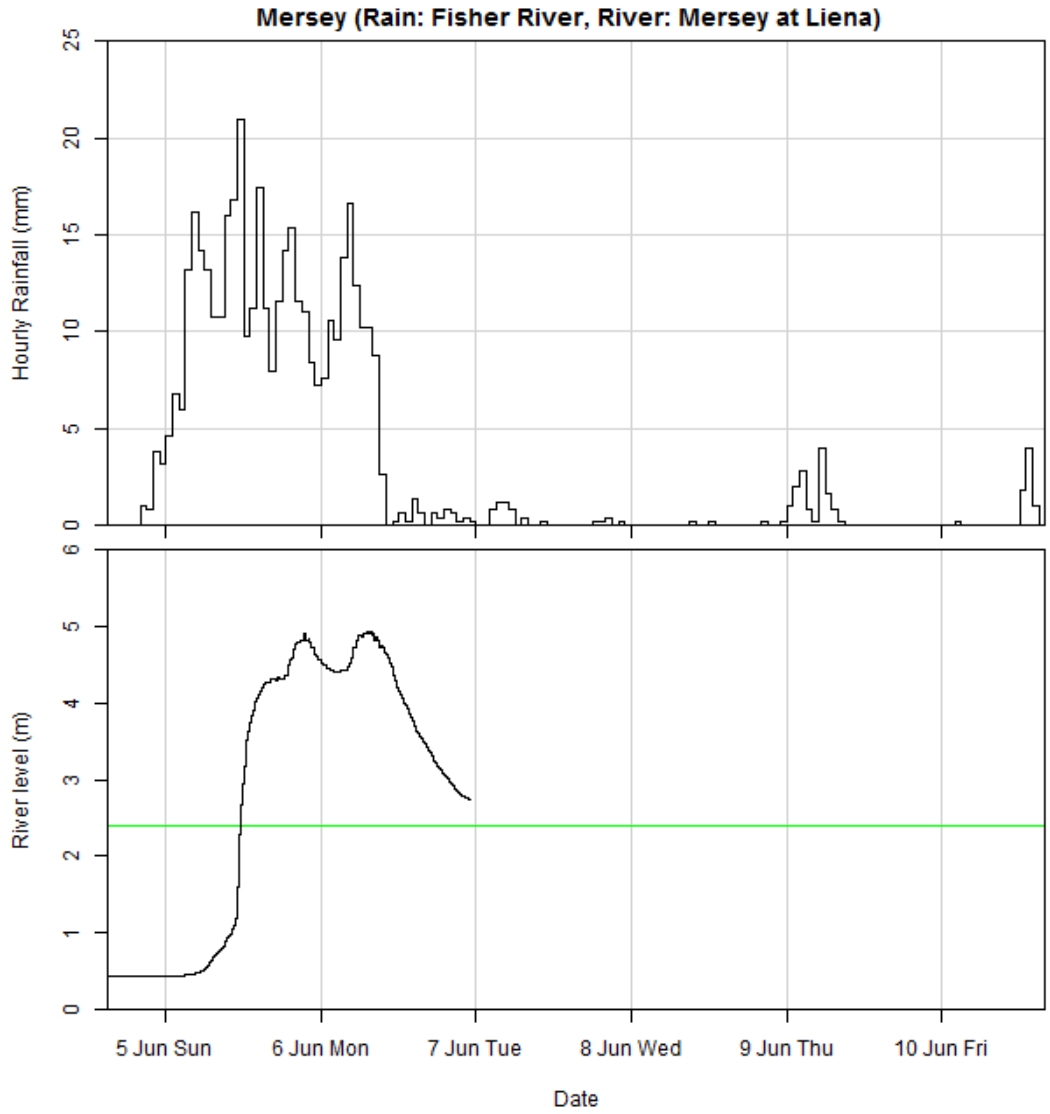


Figure 15 Rainfall for Fisher River (top) and River level for Mersey River at Liena (bottom) both sites in the Mersey catchment headwaters

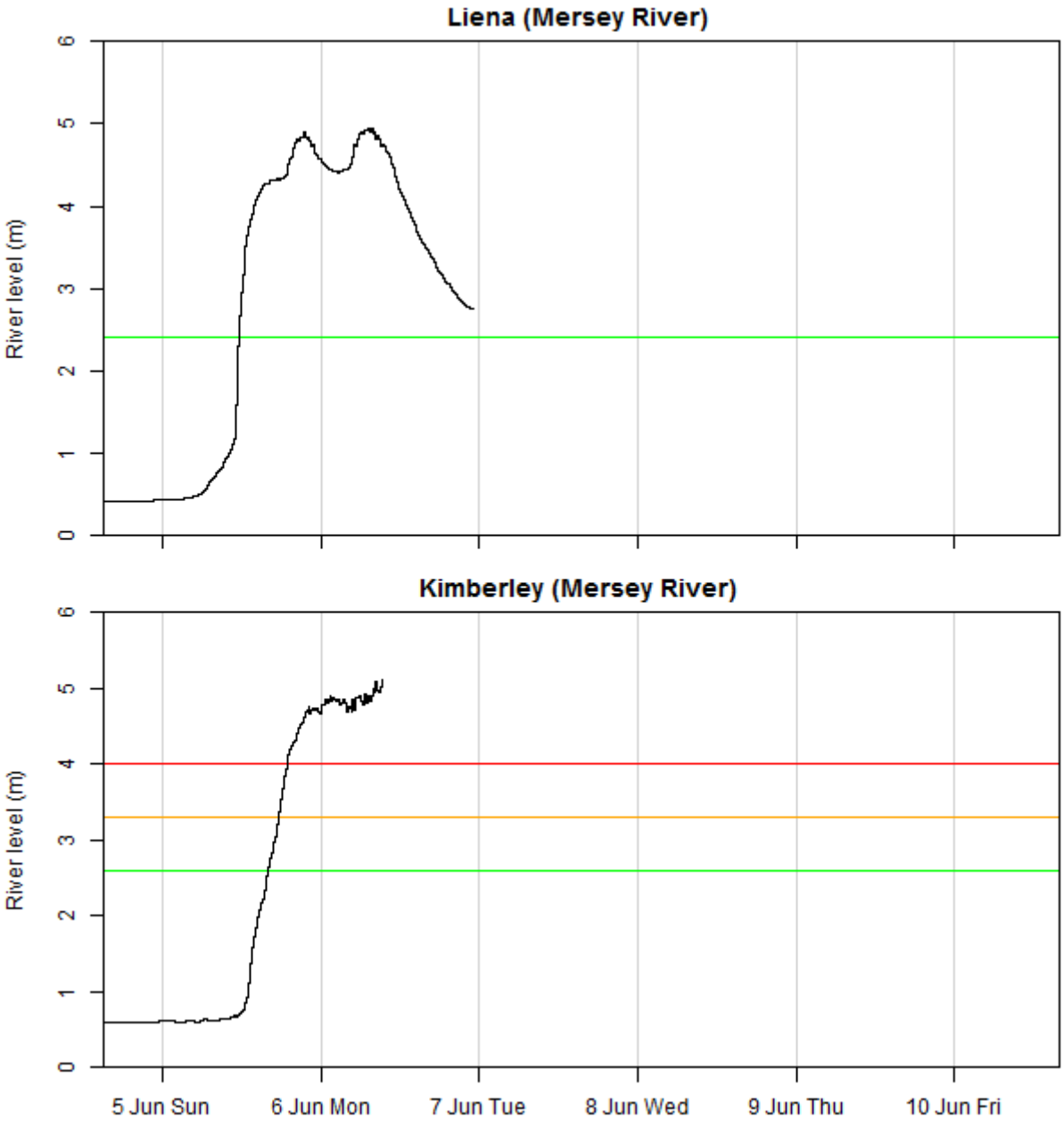


Figure 16 Transit of the flood down the Mersey River from upstream (top) to downstream (bottom).

Meander River

Rainfall in the Meander catchment commenced around 7 pm Saturday 4 June 2016 and had mostly cleared by 10 am Monday 6 June. There was widespread rainfall in excess of 180 mm in three days, with the highest total of 253 mm recorded at Quamby Bluff. River levels began rising at Meander mid-morning on Sunday 5 June. The moderate flood peak at Meander occurred at 9:50 am Monday, with major flooding at Deloraine peaking around 3.8 metres at 4:15 pm on Monday afternoon, the highest level since August 1970. The river level downstream peaked well above the major flood level (7 metres) at Westwood Bridge during Wednesday 8 June morning, with high flows from the South Esk River elevating river levels in the lower reaches of the Meander River. The estimated flood peak at Westwood Bridge was the highest since 1969. Flood warnings commenced at 3:52 pm Saturday 4 June and were finalised at 3:41 pm Saturday 11 June. The first major warning was issued at 9:59 pm Sunday 5 June.

Figure 17 shows the rainfall (top) and river level (bottom) for sites in the Meander catchment headwaters. The rainfall site is at Western Creek owned by the Department of Primary Industries, Parks, Water and Environment (DPIPWE) and the river level site is Meander River at Meander. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for Meander are shown on the bottom graph.

Figure 18 shows the transit of the flood down the Meander River from upstream at Meander (top), through Deloraine (middle) and downstream to Westwood Bridge(bottom). The minor (green), moderate (yellow) and major (red) flood class levels are shown for each site, as defined in the SLS. There was a brief outage at Deloraine on Monday 6 June due to instrumentation failure. The station was repaired by Hydro Tasmania that afternoon and data was retrieved from the logger to complete the hydrograph. River levels were well above major flood when the gauges at Strathbridge and Westwood bridge downstream ceased reporting due to major infrastructure damage and sensor failure caused by the flood.

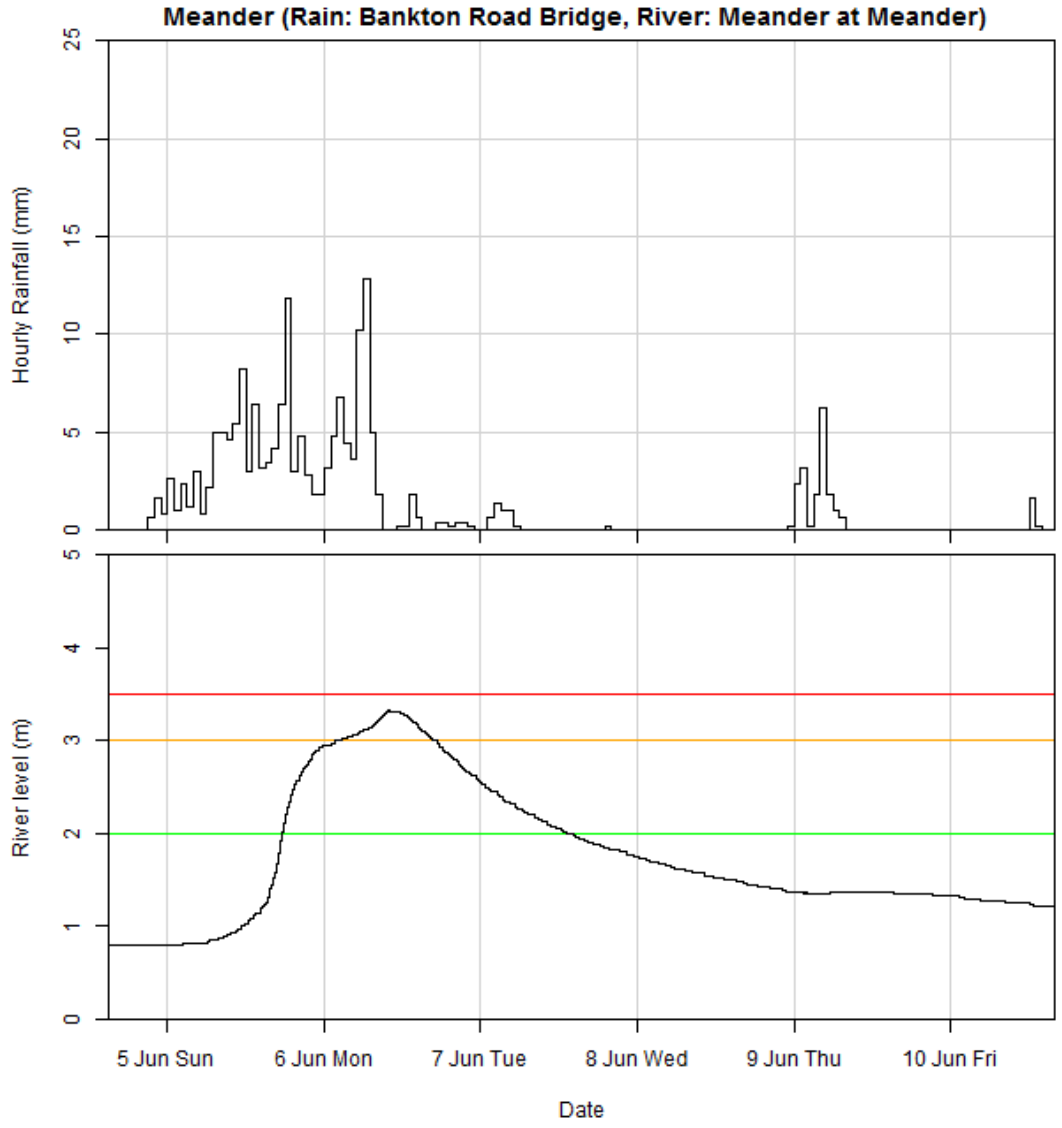


Figure 17 Rainfall (top) and River level (bottom) for sites in the Meander catchment headwaters.

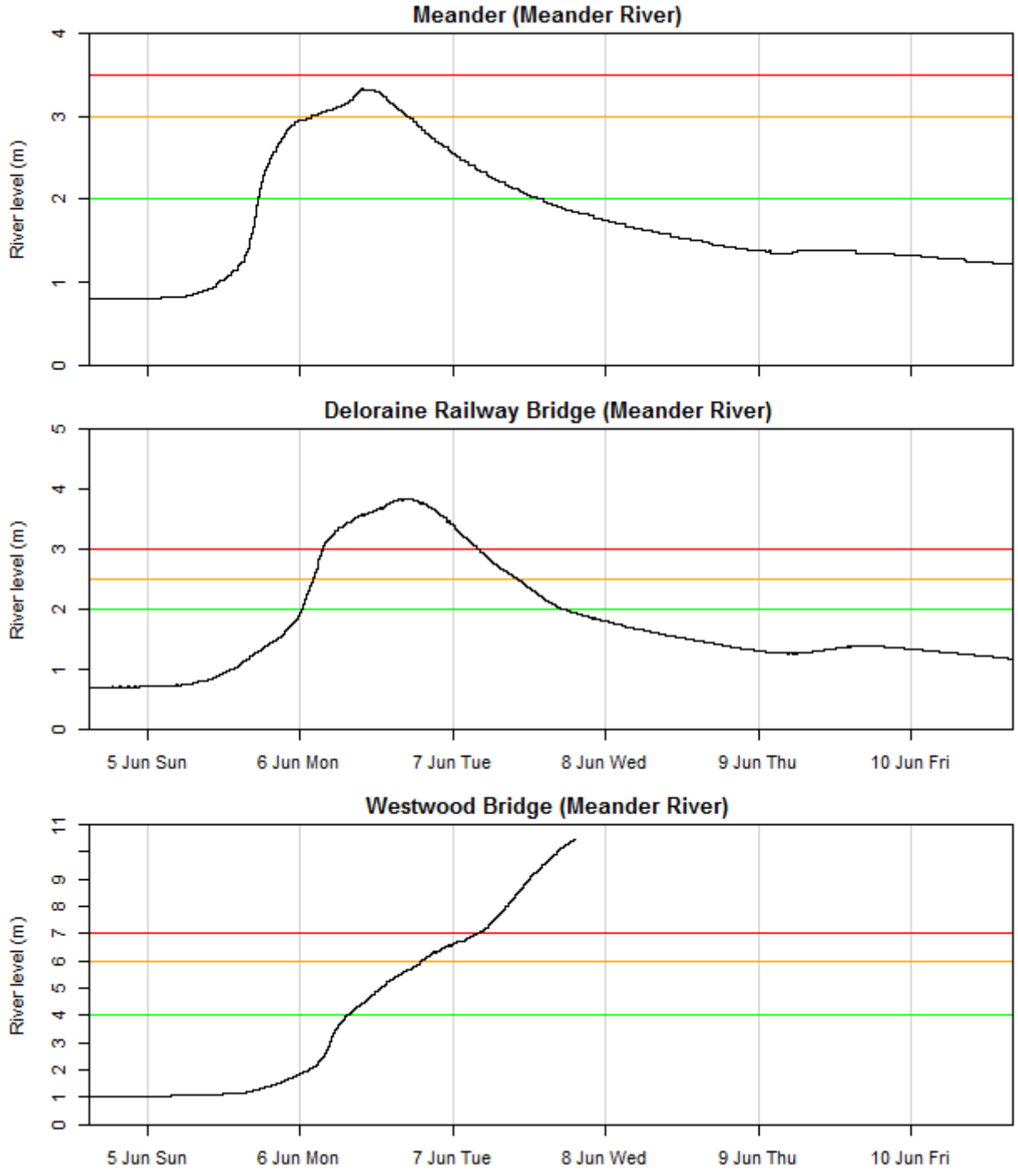


Figure 18 Transit of the flood down the Meander River from upstream (top) to downstream (bottom).

Macquarie River

Rainfall in the Macquarie catchment commenced around 4 pm Saturday 4 June 2016 and had mostly cleared by 4 pm Tuesday 7 June. There was widespread rainfall in excess of 40 mm in three days across the Midlands and more than 150 mm in three days at higher elevations in the east and west, with the highest total of 188 mm recorded at Tooms Lake. The western tributaries including Brumbys Creek, Lake River and Isis River began rising mid to late Sunday morning while the southern end of the catchment (Macquarie at Mt Morriston) began rising late on Sunday evening. Mt Morriston experienced multiple progressively rising peaks throughout Monday until the highest peak at 0:30 am Tuesday 7 June, above the moderate flood level. The catchment outlet at Cressy Pumps exceeded the major flood level (5 metres), peaking at 5.42 metres around 9:45 pm Monday 6 June from the runoff from the Western Tiers. There was a second lower peak 4 pm Wednesday 8 June as the main flood peak from the upper Macquarie River reached Cressy. Flood warnings commenced at 4:19 pm Saturday 4 June and were finalised at 10:02 am Sunday 12 June. The first major warning was issued at 2:37 pm Monday 6 June.

Figure 19 shows the rainfall (top) and river level (bottom) for sites in the Macquarie catchment headwaters. The rainfall site is at Tooms Lake towards the southern end of the catchment and the river level site is Macquarie River at Mt Morriston. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for Mt Morriston are shown on the bottom graph.

Figure 20 shows the transit of the flood down the Macquarie River from upstream at Mt Morriston (top) to downstream at Cressy (bottom), through Ross, Morningside and Westmoor. The minor (green), moderate (yellow) and major (red) flood class levels are shown for each site as defined in the SLS. Moderate and major flood levels have not been defined for Macquarie River above Westmoor. The initial peak downstream at Westmoor and Cressy came from runoff from the western headwaters, which was followed by a second peak Wednesday from the main Macquarie catchment.

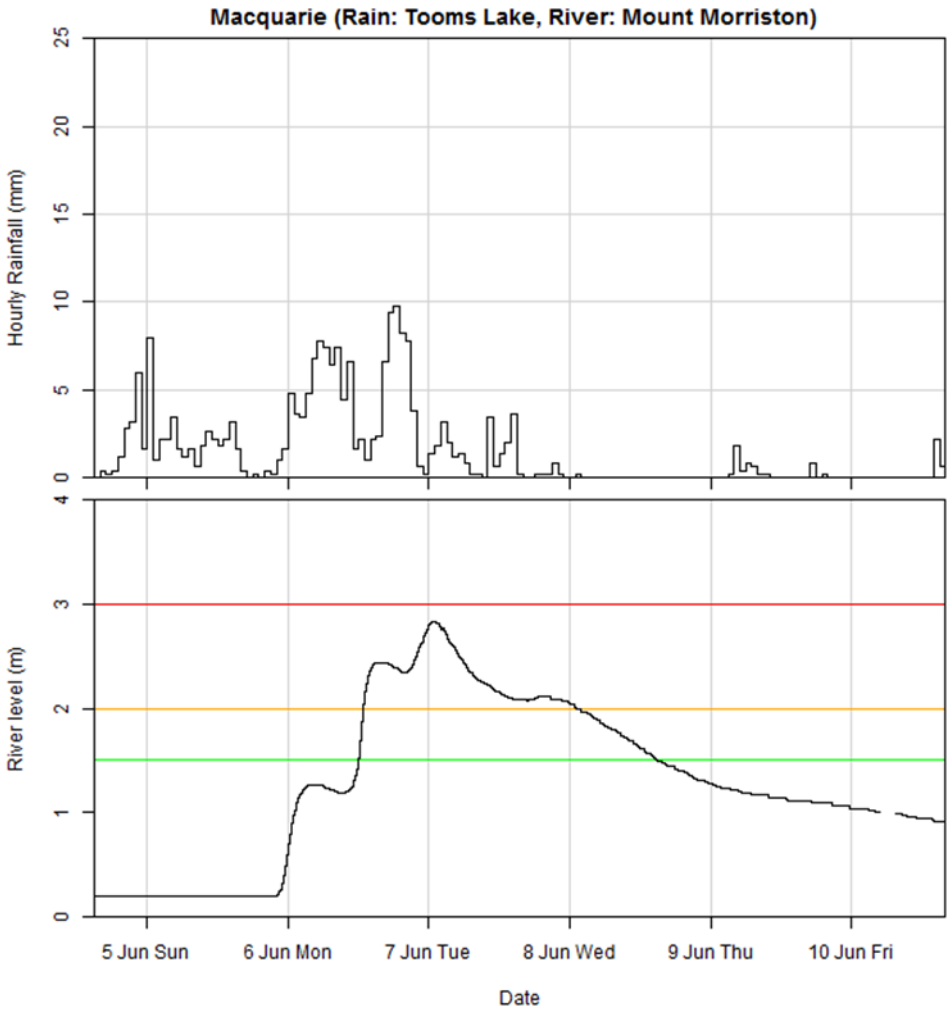


Figure 19 Rainfall (top) and River level (bottom) for sites in the Macquarie catchment headwaters.

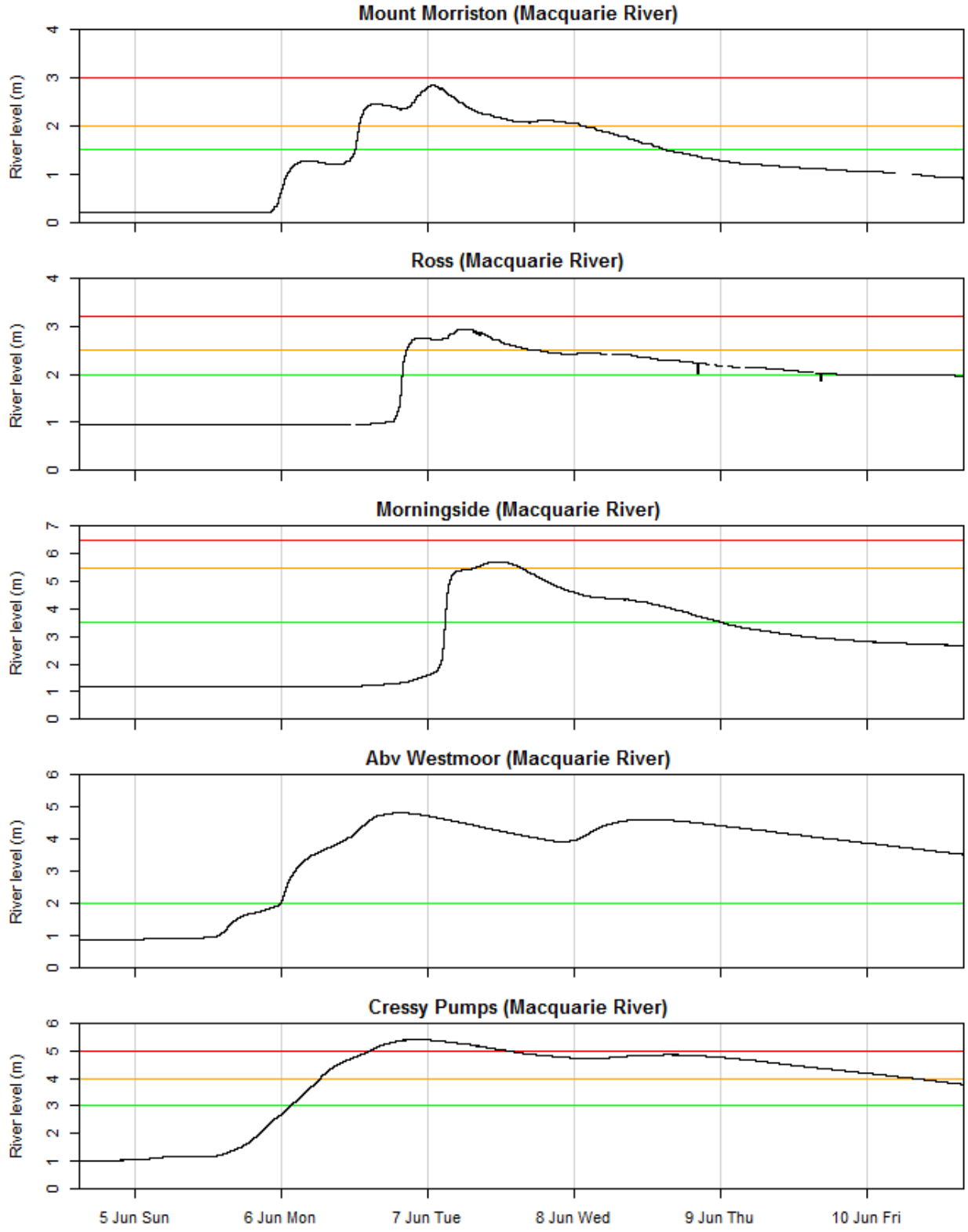


Figure 20 Transit of the flood down the Macquarie River from upstream (top) to downstream (bottom).

North Esk River

Rainfall in the North Esk catchment commenced around 4 pm Saturday 4 June 2016 and had mostly cleared by 6 pm Monday 6 June. This was followed by a second lesser burst of rain after midnight on Thursday 9 June. There was widespread rainfall in excess of 200 mm in three days, with the highest total of 252 mm recorded at Nunamara. River levels began rising in the St Patricks River at Nunamara early on Sunday morning. A moderate flood peak of 3.4 metres at Nunamara occurred at 9:50 am Monday 6 June and the river level peaked downstream at Corra Linn at 6.44 metres, well above the major flood level (4.9 metres) metres around two hours later. The flood peaks at Corra Linn and Ballroom were the highest on record, exceeding the levels reached in 1929. Flood warnings commenced at 3:27 pm Saturday 4 June and were finalised at 9:53 am Saturday 11 June. The first major warning was issued at 6:26 am Monday 6 June.

Figure 21 shows the rainfall for Mt Barrow (top) and river level for North Esk River at Corra Linn (bottom). Mt Barrow is located near the centre of the North Esk catchment. Corra Linn is the key forecast location for the North Esk catchment, providing an indication of the flow through to Launceston. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for Corra Linn are shown on the bottom graph.

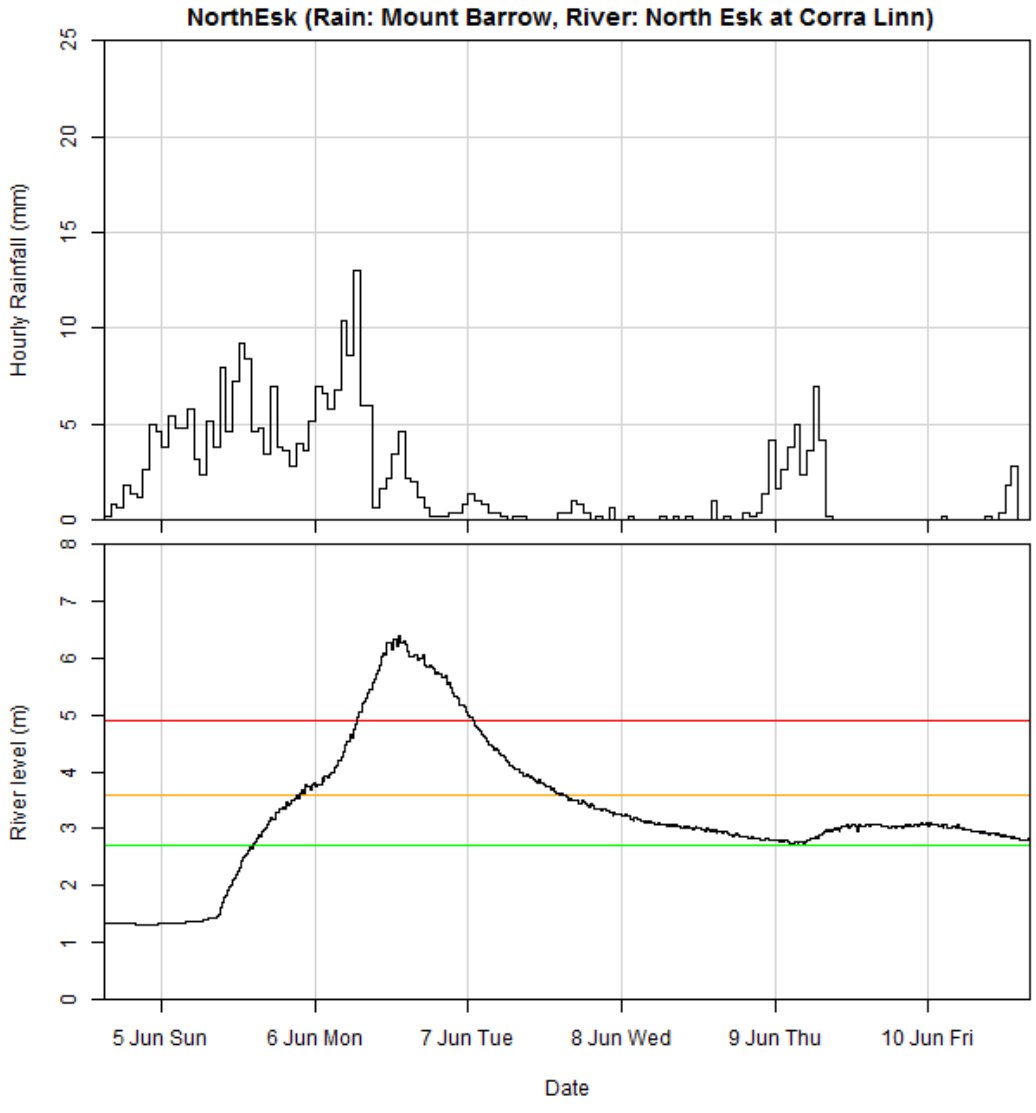


Figure 21 Rainfall (top) and River level (bottom) for sites in the North Esk catchment.

South Esk River

Rainfall in the South Esk catchment commenced around 1 pm Saturday 4 June and had mostly cleared by 2 pm Monday 7 June. This was followed by a second lesser burst of rain after midnight on Thursday 9 June. There was widespread rainfall in excess of 200 mm in three days around the northeast highlands, with the highest total of 329 mm recorded at Mount Victoria in the northeast, and closer to 50 mm in three days recorded at lower elevations below Avoca. River levels began rising at the Upper Esk Road Bridge and the Nile River at Deddington around 9 pm Saturday 4 June. Major flooding was observed at five river sites within the catchment, including the towns of Fingal, Perth and Longford. Trevallyn Dam above Launceston peaked above the major flood level at 5 am Wednesday, with a flow of around 2 250 cubic metres per second (cumecs), similar to the 1969 flood of 2 400 cumecs. Flood warnings commenced at 3:50 pm Saturday 4 June and were finalised at 9:38 am Sunday 12 June. The first major warning was issued at 7:21 am Monday 6 June.

Figure 22 shows the rainfall (top) and river level (bottom) for sites in the South Esk catchment headwaters. The rainfall site is at Mt Victoria, part of the North East Highlands and the river level site is the South Esk River at Fingal. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for Fingal are shown on the bottom graph.

Figure 23 shows the transit of the flood down the South Esk headwaters from upstream (top) to downstream (bottom). The sites shown include the key forecast locations along the main channel, Fingal, Llewellyn, Perth, Longford and Trevallyn Dam, along with Lewis Hill on the St Pauls River. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for each site are shown. The South Esk at Llewellyn had an instrumentation failure during the June 2016 flood event resulting in missing data around the peak of the flood. The river level is estimated to have peaked at 10.85 metres based on a post flood survey. All other sites reported throughout the flooding.

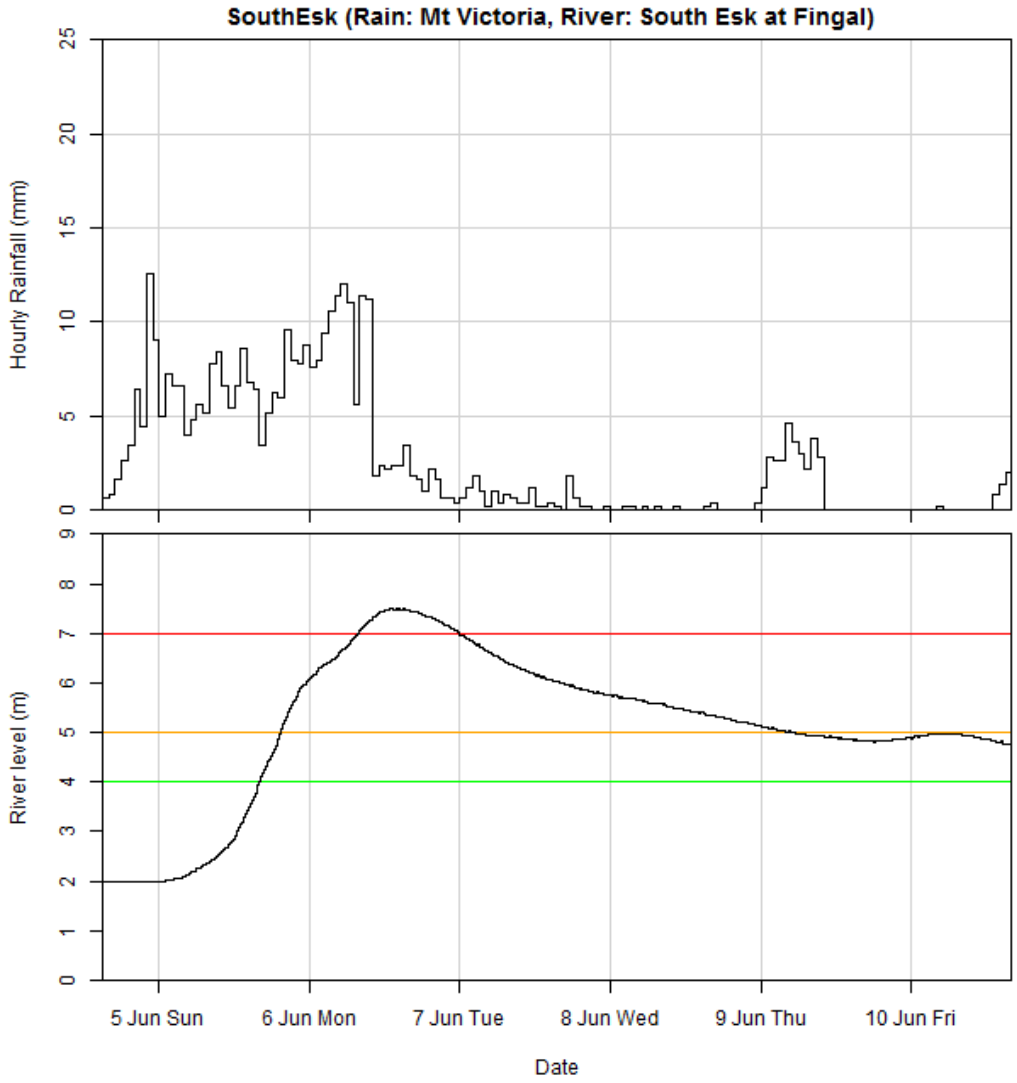
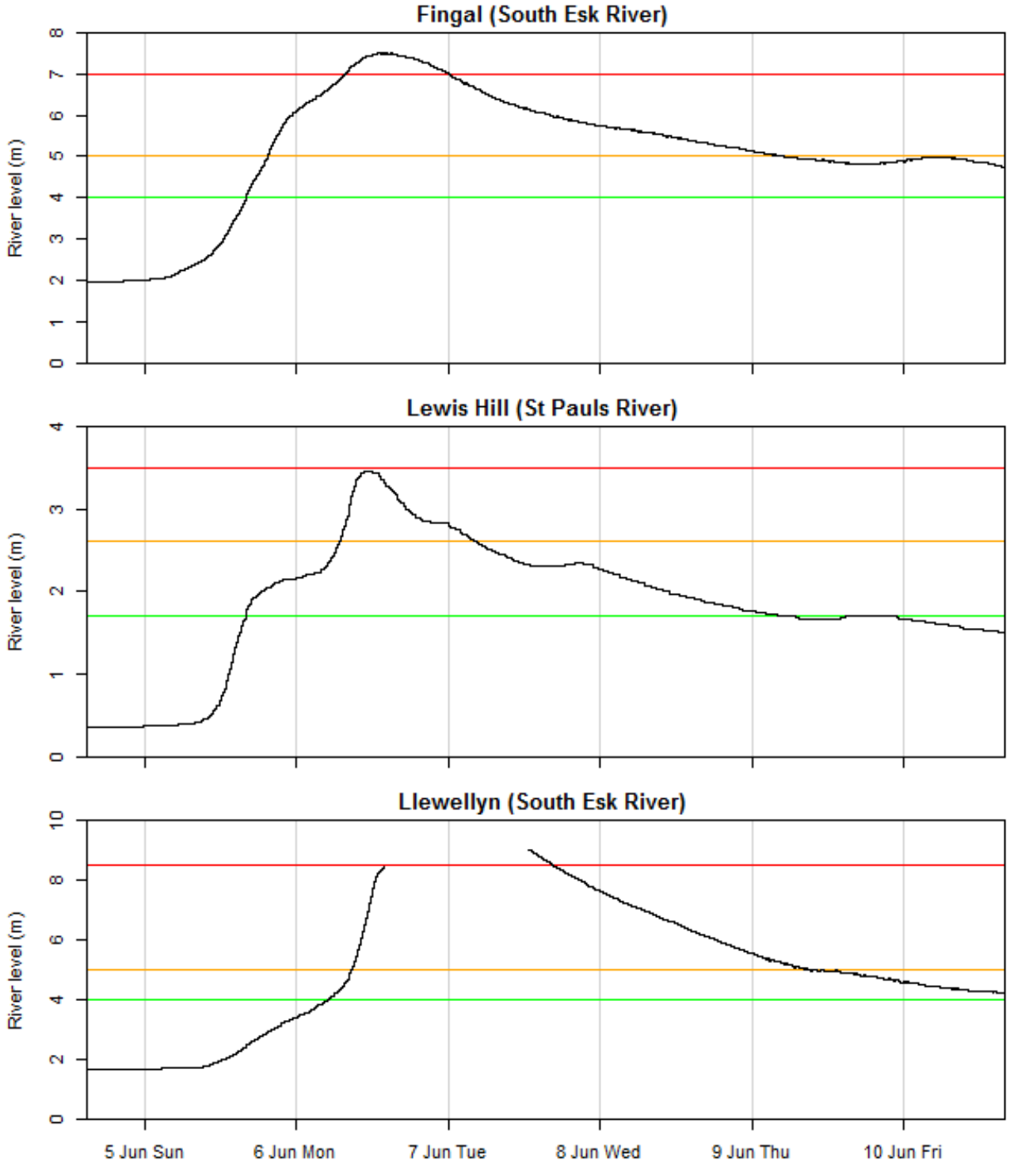


Figure 22 Rainfall (top) and River level (bottom) for sites in the South Esk catchment headwaters.


Fingal (South Esk River)
River level (m)
0
1
2
3
4
5
6
7
8
Lewis Hill (St Pauls River)
River level (m)
0
1
2
3
4
Llewellyn (South Esk River)
River level (m)
0
2
4
6
8
10
5 Jun Sun
6 Jun Mon
7 Jun Tue
8 Jun Wed
9 Jun Thu
10 Jun Fri

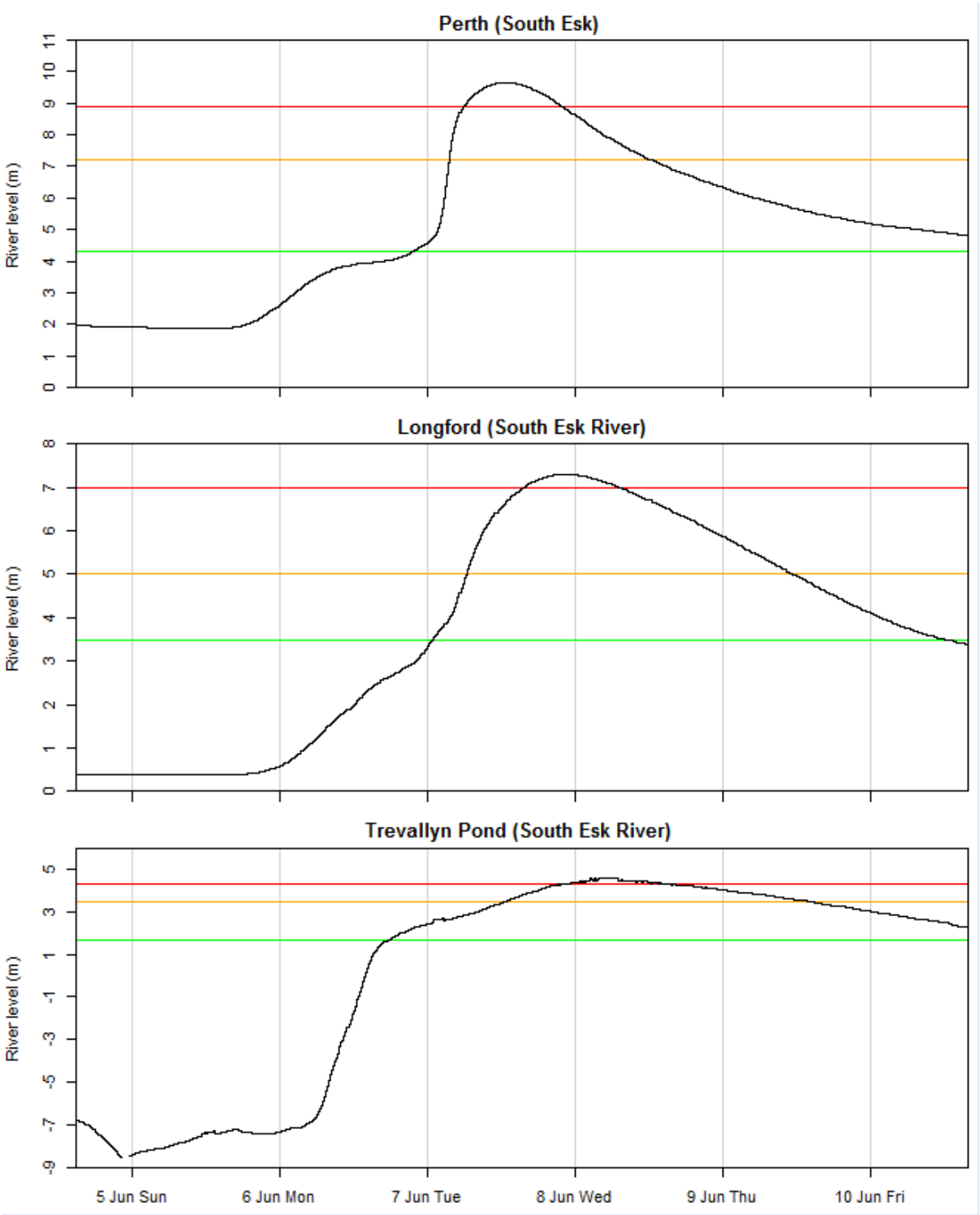


Figure 23 Transit of the flood down the South Esk River from upstream (top) to downstream (bottom).

Derwent River

Rainfall around the upper reaches of the Derwent catchment commenced around 6 pm Saturday 4 June and had cleared by 8 pm Tuesday 7 June. There was widespread rainfall in excess of 100 mm in three days in the headwaters, with the highest total of 334 mm recorded at Lake Gwendy, and 50 mm in three days downstream. River levels in the Ouse headwaters began rising mid-morning Sunday 5 June and the flood peak progressed rapidly downstream, with major flooding developing at Ashton and Ouse during Monday 6 June. The Derwent below Meadowbank Dam peaked above the major flood level (7.3 metres) at 3:15 pm Monday 6 June due to these strong inflows from the Ouse and Clyde rivers. Minor flooding peaked at New Norfolk at 0:30 am Tuesday morning. Flood warnings commenced at 10:37 pm Sunday 5 June and were finalised at 9:54 am Thursday 9 June. The first major warning was issued at 12:10 pm Monday 6 June.

Figure 24 shows rainfall (top) and River level (bottom) for sites in the Ouse catchment, a tributary of the River Derwent. The rainfall is for the site at Lake Gwendy, at the northern end of the River Ouse. The river level is for the station at Ashton, partway down the river. The minor (green) flood class level defined in the SLS for Ashton is shown on the bottom graph. Moderate and major flood levels have not been defined for this forecast location. The river level data is unavailable for the around the peak of the June 2016 flood event due to an instrumentation failure.

Figure 25 shows the transit of the flood down the lower reaches of the River Derwent below Meadowbank Dam, through Macquarie Plains to New Norfolk. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for each site are shown. The impact of the tide is evident in the hydrograph for New Norfolk.

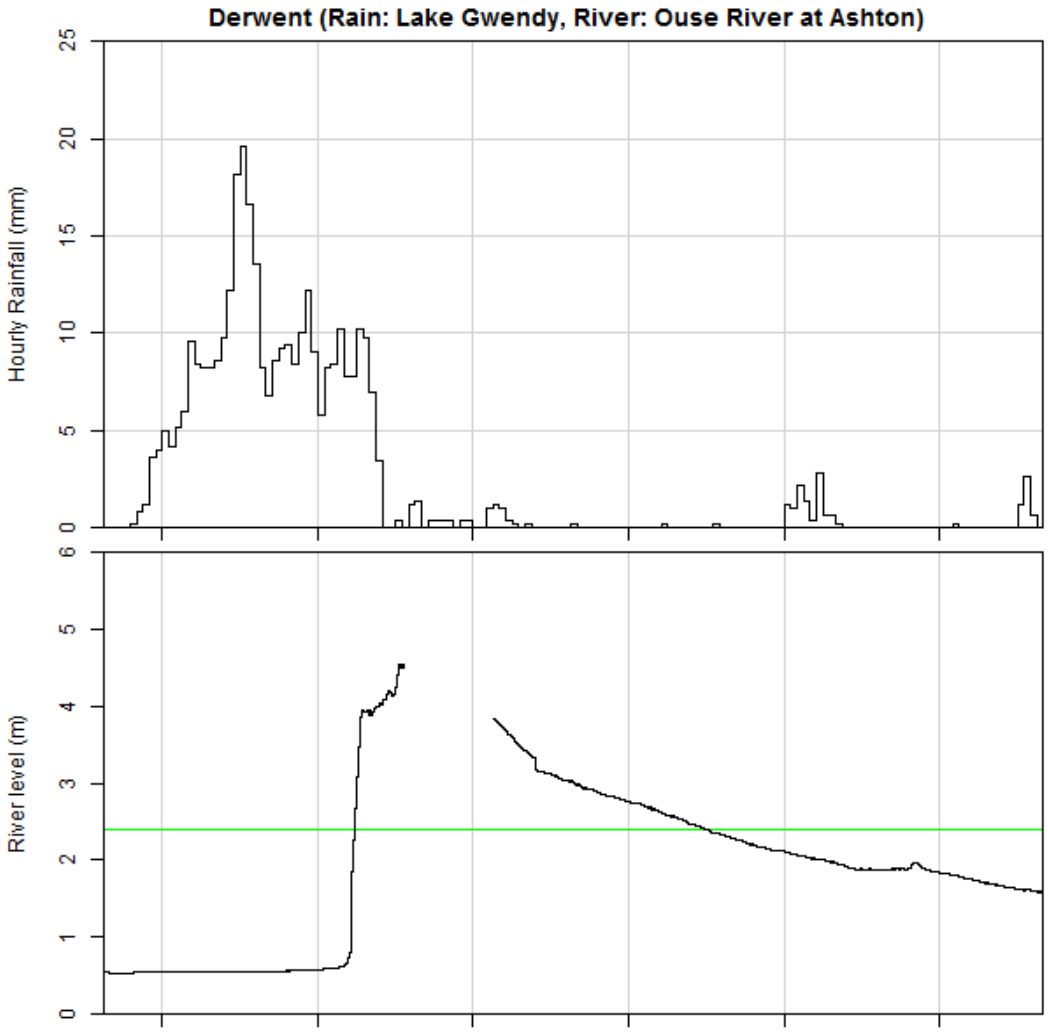


Figure 24 Rainfall (top) and River level (bottom) for sites in the Ouse catchment, a tributary of the River Derwent.

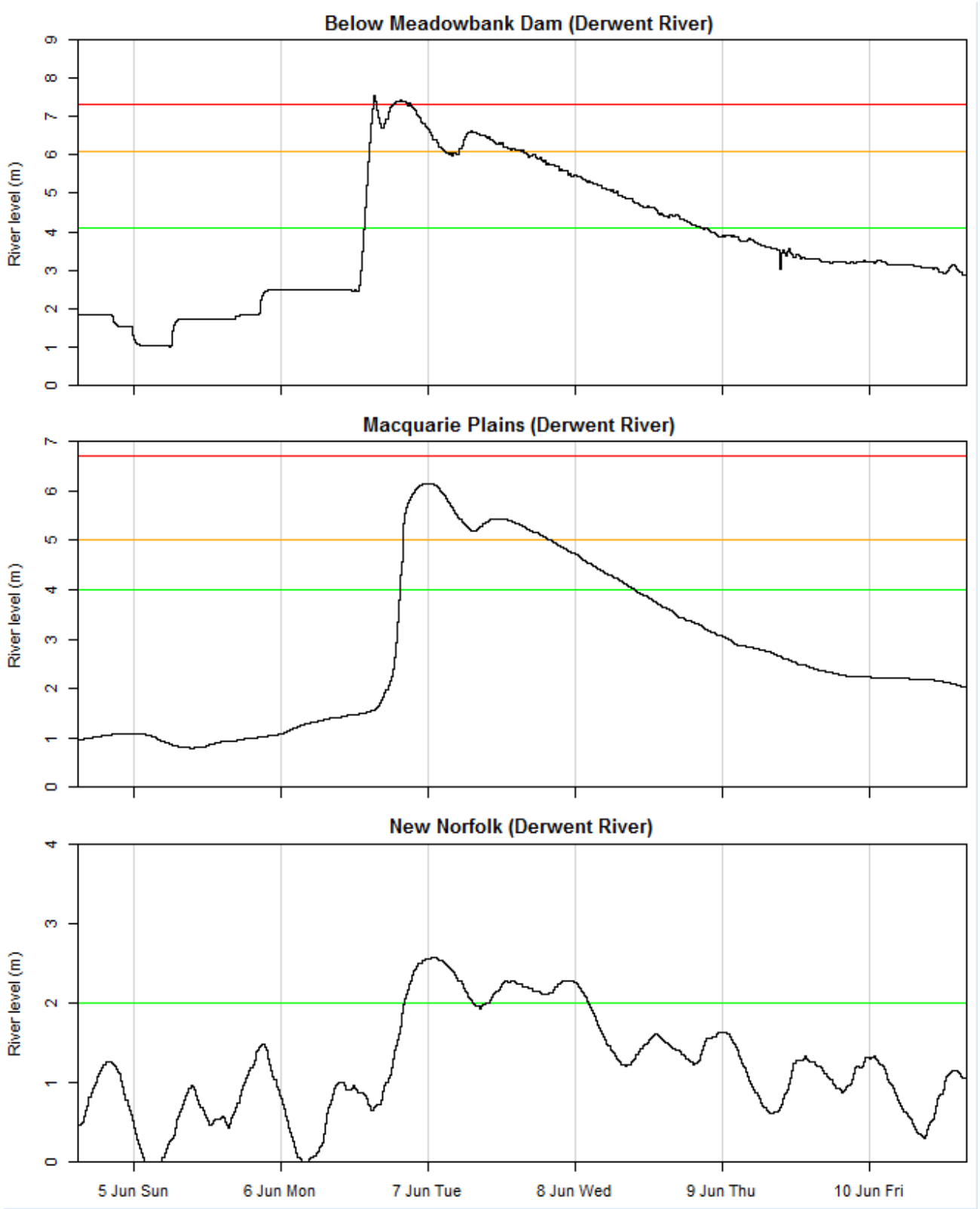


Figure 25 Transit of the flood down the lower reaches of the River Derwent below Meadowbank Dam.

Jordan River

Rainfall in the Jordan catchment commenced around 6 pm Saturday 4 June and had cleared by 8 pm Tuesday 7 June. There was widespread rainfall in excess of 70 mm in three days, with the highest total of 113 mm recorded at Rotherwood. Figure 26 shows the rainfall (top) and river level (bottom) for the Jordan River at Mauriceton. The minor (green), moderate (yellow) and major (red) flood class levels defined in the SLS for Mauriceton are also shown. River levels at Mauriceton rose rapidly from below minor to 1.99 metres, near the moderate flood level of 2.0 metres between 2:00 am and 3:30 am Tuesday 7 June. Flood warnings commenced at 5:25 am Tuesday 7 June and were finalised at 9:55 am Friday 10 June. No major flood warnings were required for this event.

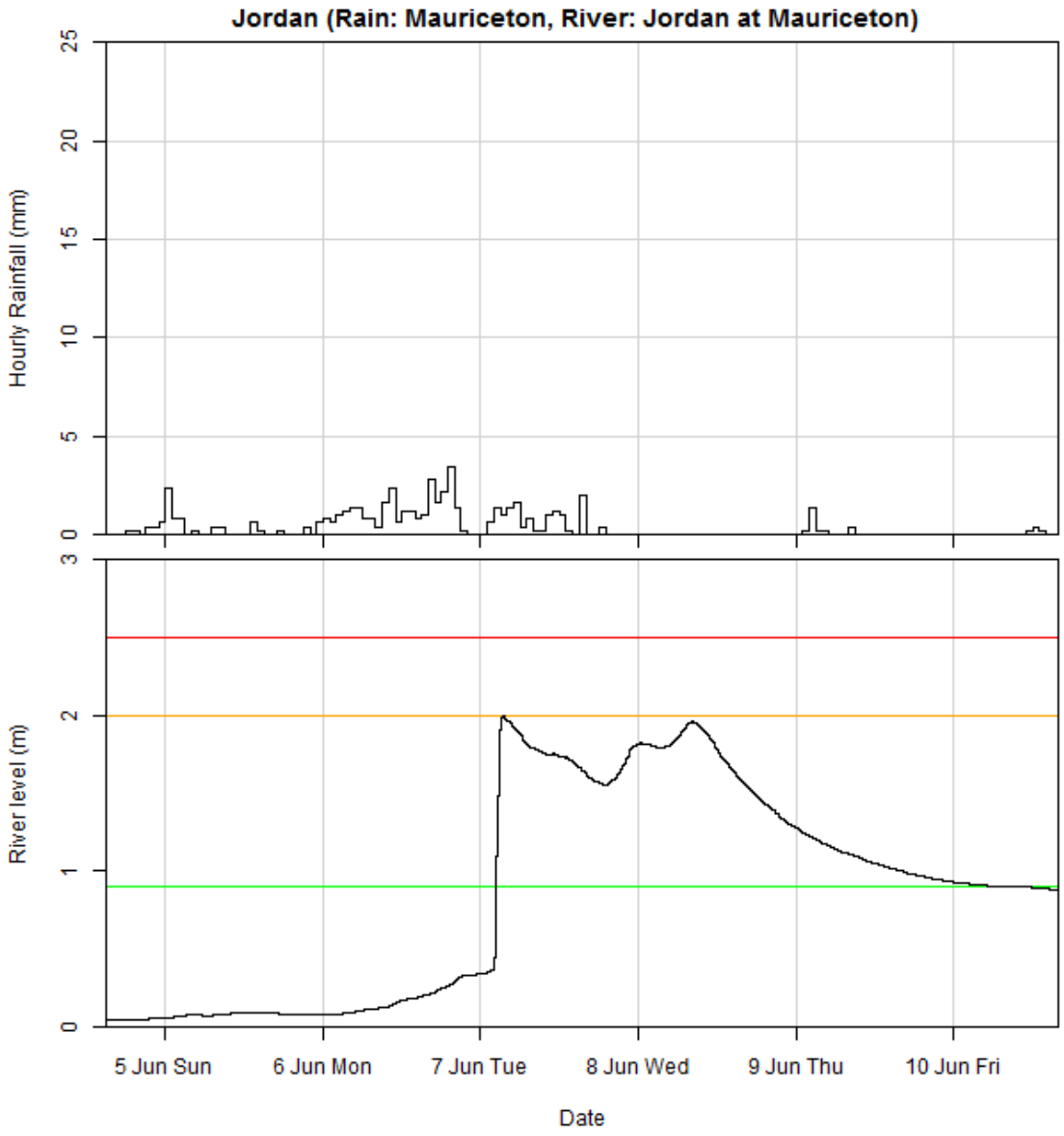


Figure 26 Rainfall (top) and River level (bottom) for the Jordan River at Mauriceton.

3.5 Peak river heights

A map displaying the Peak Flood Class during the period 4 June to 14 June 2016 is shown in Figure 27. The classification at each location is based on the observed peak river level and the flood class definitions. As is evident, major flood levels were recorded at many locations across the State. Some of the locations on this map (indicated by squares), such as those in the Mersey catchment in the central north, are classified as minor flooding even though exceptional floods occurred. This is because these sites do not have moderate or major flood class levels defined. The map also shows locations where the June 2016 observed peak river height set a new record (indicated by circles). Table 1 provides detailed peak river height information by station.

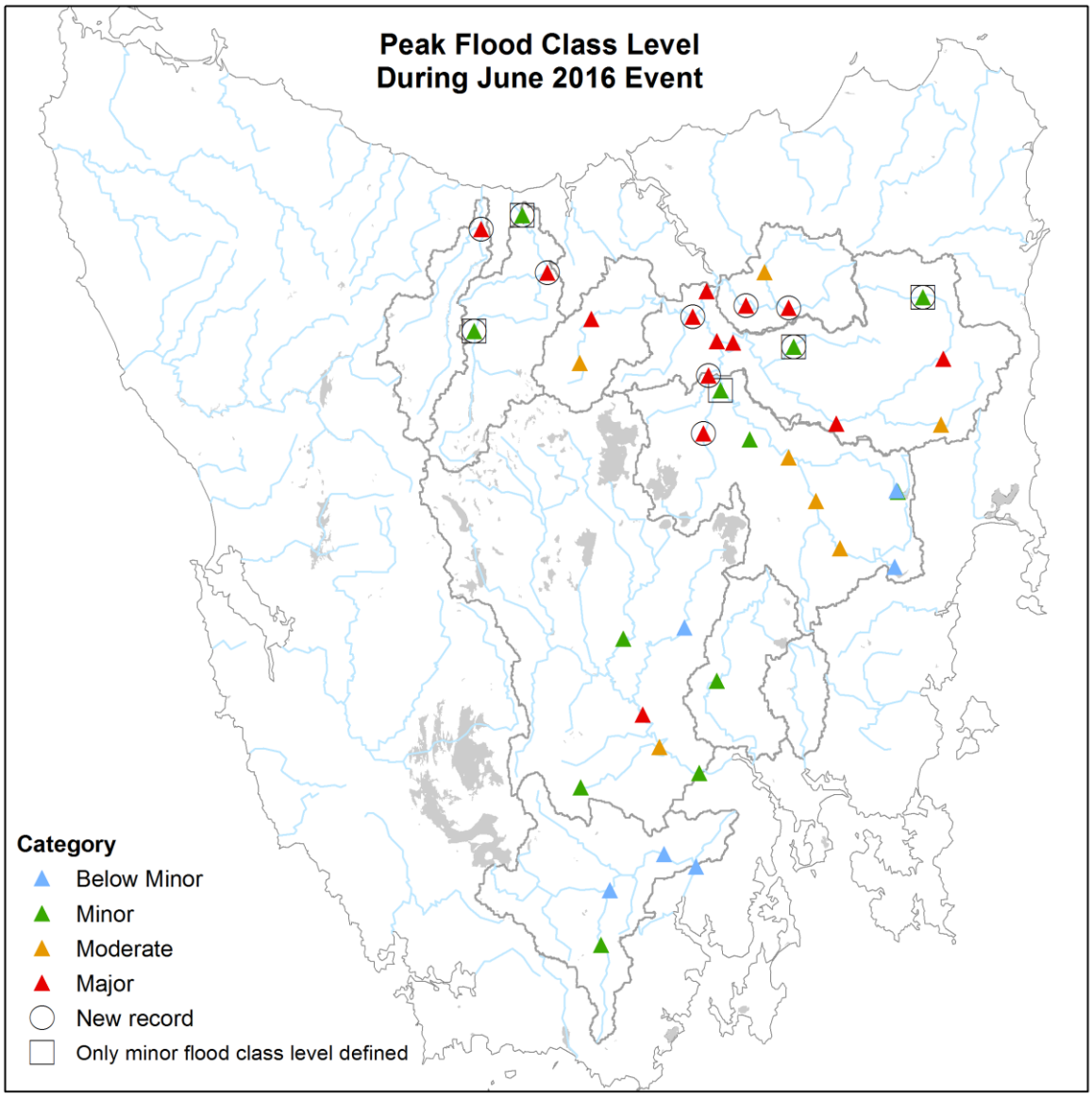


Figure 27 Peak flood levels observed between 4 and 14 June 2016. Where June 2016 was a new record, the symbol is surrounded by a circle. Where only the minor flood class level is defined, the symbol is surrounded by a square.

Table 1 Peak river levels observed during 4 - 14 June 2016 and historical comparisons for key forecast locations.

Bureau ID	River	Location	Peak Level June 2016 (m)	Time	Flood Class	June 2016 Rank	Start of Data	Highest since	Record Peak Level (m)	Record Date (month/ year)
Forth										
591036	Forth	Below Wilmot	7.93	6-Jun 11:50	Major	Record	1970		7.18	8/1970
Mersey										
591034	Mersey	Liena	4.94	6-Jun 07:00	Minor+	Record	1932		4.78	8/1970
091266	Mersey	Kimberley	~5.4	6-Jun Morning	Major	Record	1921		5.18	8/1970
091279	Mersey	Latrobe Bridge	~4.6	6-Jun Morning	Minor+	Record	1994		4.10	9/1998
Meander										
091267	Meander	Meander	3.33	6-Jun 09:50	Moderate	4	1960	7/2013	3.40	5/1997
091227	Meander	Deloraine Railway Bridge	3.83	6-Jun 16:15	Major	3	1929	8/1970	4.15	4/1929
091303	Meander	Westwood Bridge	~11.5	8-Jun Morning	Major	Record	2002		10	3/2011
Macquarie										
093052	Macquarie	Mt Morriston	2.84	7-Jun 00:29	Moderate	11	1960	8/2011	3.58	4/1960
093051	Macquarie	Ross	2.95	7-Jun 06:20	Moderate	11	1921	8/2011	4.11	4/1929
093026	Macquarie	Morningside	5.71	7-Jun 11:30	Moderate	3	1921	8/2011	6.56	8/2011
593000	Lake	Parknook	4.58	6-Jun 12:45	Major	Record	1956		4.35	4/1960
591013	Macquarie	Abv Westmoor	4.81	6-Jun 20:00	Minor+	4	2001	8/2011	5.35	8/2011
591049	Macquarie	Cressy Pumps	5.42	6-Jun 21:55	Major	Record	1985		5.19	8/2011

No moderate or major flood level defined ~ Estimated based on post-flood inspection

In the case of multiple peaks, only the highest is reported. Based on operational data collected during and shortly after the flood

Table 1 Continued

Bureau ID	River	Location	Peak Level June 2016 (m)	Time	Flood Class	June 2016 Rank	Start of Data	Highest since	Record Peak Level (m)	Record Date (month /year)
North Esk										
091271	St Patricks	Nunamara Offtake	3.40	6-Jun 09:49	Moderate	3	1958	7/1988	4.80	7/1988
591033	North Esk	Ballroom	4.38	6-Jun 15:30	Major	Record	1923		3.90	8/2005
091263	North Esk	Corra Linn	6.44	6-Jun 12:09	Major	Record	1929		5.15	4/1929
South Esk										
092106	South Esk	Mathinna	4.55*	6-Jun 10:27	Minor+	Record	1991		4.41	3/2011
592002	Break O'Day	Killymoon	3.97	6-Jun 10:00	N/A	4	1952	1/1995	4.52	3/1974
092091	South Esk	Fingal	7.50	6-Jun 13:00	Major	=4	1921	3/2011	9.52	4/1929
092020	St Pauls	Lewis Hill	3.45	6-Jun 10:47	Moderate	=6	1960	1/2016	3.89	5/1969
093044	South Esk	Llewellyn	~10.85	6-Jun Evening	Major	2	1953	3/2011	11.02	3/2011
091326	Nile	Deddington	3.35	6-Jun 09:23	Minor+	Record	1983		3.13	8/2011
591031	South Esk	Perth	9.63	7-Jun 13:15	Major	3	1957	3/2011	10.25	5/1969
091207	South Esk	Longford	7.30	7-Jun 21:12	Major	3	1929	6/1969	9.33	4/1929
591037	South Esk	Trevallyn Pond (height and flow)	130.91 m 2250 cms	8-Jun 05:00	Major	3	1929	6/1969	132.75 m 3,964 cms	4/1929
Derwent										
096070	Shannon	Hermitage	3.24	6-Jun 14:00	N/A	Record	1965		2.91	4/1996
095046	Clyde	Bothwell	1.99	6-Jun 18:45	< Minor	5	1960	8/2011	2.89	4/1960
595012	Derwent	Blw Meadowbank	7.54	6-Jun 15:15	Major	3	1974	8/2007	7.60	9/1980
095042	Derwent	Macquarie Plains	6.15	6-Jun 23:28	Moderate	8	1922	8/2007	10.15	4/1960
095066	Derwent	New Norfolk	2.58	7-Jun 00:24	Minor	6	1952	8/2011	7.2	4/1960
Jordan										
094143	Jordan	Mauriceton	1.99	7-Jun 03:30	Minor	11	1966	8/2011	3.81	11/1975

* Noisy data values near peak + No major or moderate flood level defined ~ Estimated based on post flood inspection

In the case of multiple peaks, only the highest is reported. Based on operational data collected during and shortly after the flood.

4 Communication and warnings

The Service Level Specification (SLS) documents and describes the flood forecasting and warning services provided by the Bureau in Tasmania, including the Bureau's role in the Total Flood Warning System and its interaction with other stakeholders. The Bureau issues flood watches and warnings, and provides a threshold-based rainfall and river alerting service for specific sites.

Flood watches and warnings are issued directly to a list of stakeholders with emergency management responsibilities. The direct dissemination methods supported include email, fax and internet protocols. The format of messaging in flood related products conforms to a nationally consistent standard. Flood watches and warnings are also communicated by the Bureau via:

- **Radio:** Radio stations, particularly the ABC, broadcast flood warning information as part of their news bulletins, or whenever practicable. This form of broadcast may be covered in separate agreements between the Bureau and broadcasters.
- **Weather warning service:** Flood warning information is recorded on a contracted telephone information service. Calls to this service incur a fee-for-service charge.
- **Internet:** Flood watches and warnings are published on the Bureau's public web site and available by internet protocols, along with related rainfall and river level information.

Emergency management partners and media can also access flood level and warning information directly from the Bureau Flood Warning Centre and Bureau National Operations Centre, subject to operational constraints. The Bureau does not publish to the public the contact details for the Flood Warning Centres and Bureau National Operations Centre.

The location of the trough system near Tasmania on the 5 and 6 of June was a critical factor in determining the severity of this rainfall event and the location of the heaviest falls. Computer model information on Thursday 2 June predicted that the position of the trough system was such that a heavy rainfall event was possible for northern Tasmania.

Bureau forecasters first alerted the Tasmanian State Emergency Service (SES) on Thursday 2 June, and first mentioned the possibility of heavy rain for Sunday 5 June in weather forecasts and on Twitter. On Thursday 2 June 2016, several days before the start of the June 2016 flood event, the Bureau's Tasmanian Flood Warning Centre issued tweets on Twitter for heavy rain and damaging surf, followed by a media release and more tweets on Friday 3 June. Additionally, throughout the period from Friday 3 June to Wednesday 8 June, the Bureau gave at least 70 interviews to television, radio and print media concerning the weather and flooding about various parts of the State.

The primary purpose of a flood watch is to provide early advice to communities and the relevant emergency service organisations of the potential threat from a developing weather situation. The first flood watch was issued at 11:58 am Friday 3 June for minor to moderate flooding across all Northern and Eastern Basins from Sunday onwards. The flood watch was later expanded to include all Tasmanian river basins at 4:15 pm Sunday 5 June. The Flood Watch also indicated that flash flooding of small creeks and low lying areas could occur. This was followed by a Severe Weather Warning for Heavy Rain for the northern half of Tasmania (from Swansea to Strahan) at 1:53 pm Saturday 4 June. This too indicated that heavy rain on Sunday could lead to possible flash flooding. The flood watch was finalised at 9:54 am Tuesday 7 June when the rainfall had generally eased.

Before the rain began Sunday 5 June and as much as three days in advance of flooding, five flood-related tweets warned of possible flooding. For the period 30 May to 5 June 2016 the Bureau issued 26 tweets using @BOM_Tas. These tweets went to nearly 6000 followers and made over 112,714 total impressions.

The Bureau's Tasmanian Flood Warning Centre was activated on Friday 3 June and provided continuous 24-hour service during the heaviest part of the June 2016 flood event (from 5 am Sunday 5 June to 11 pm Wednesday 8 June). The first flood warnings were issued around 3 pm Saturday 4 June. River level predictions in Major and Moderate Flood Warnings were updated about every 3 hours. In addition, the Tasmanian SES received regular updates by phone throughout the June 2016 flood event from operational forecasters in the Bureau.

During the June 2016 flood, a total of 8 flood watches and 203 flood warnings were issued during 3-12 June. The severity of warnings over time and by catchment is shown graphically in Figure 29. Each product is shown as a row and time is shown on the horizontal axis. The label on the horizontal axis (e.g. "Sun 5/6") and light vertical lines mark the start of that day, heavy vertical lines indicate noon of each day. The severity of the warning is given by the height of the line and the colour (green/lowest is minor, orange/middle is moderate and red/highest is major). Flood watches are shown in the top row.

The number of products issued for each river basin or region and the date for the first and final product are outlined in **Table 2**.

Table 3 includes a count of flood warnings by catchment and severity. It is common for minor and moderate warnings to outnumber major warnings but the abundance of major warnings is an indication of the extreme nature of the June 2016 flood.

An automatic River and Rainfall Alert service is also provided by the Bureau through an agreement with the State Emergency Service, as outlined in the Service Level Specification. Once the trigger river level or rainfall accumulation threshold is reached, an alert is issued. For river alerts, the alert is re-issued after 24 hours if the river level remains above the alert level. Rainfall alerts are re-issued if total rainfall accumulated in the previous 24-hours is still exceeding alert level.

During the June flood event, 132 river alerts were issued. Many of these river alerts were activated for several days. A summary of the river alerts issued by catchment has been included in

Table 3. There were also 30 rainfall alerts issued during this time.

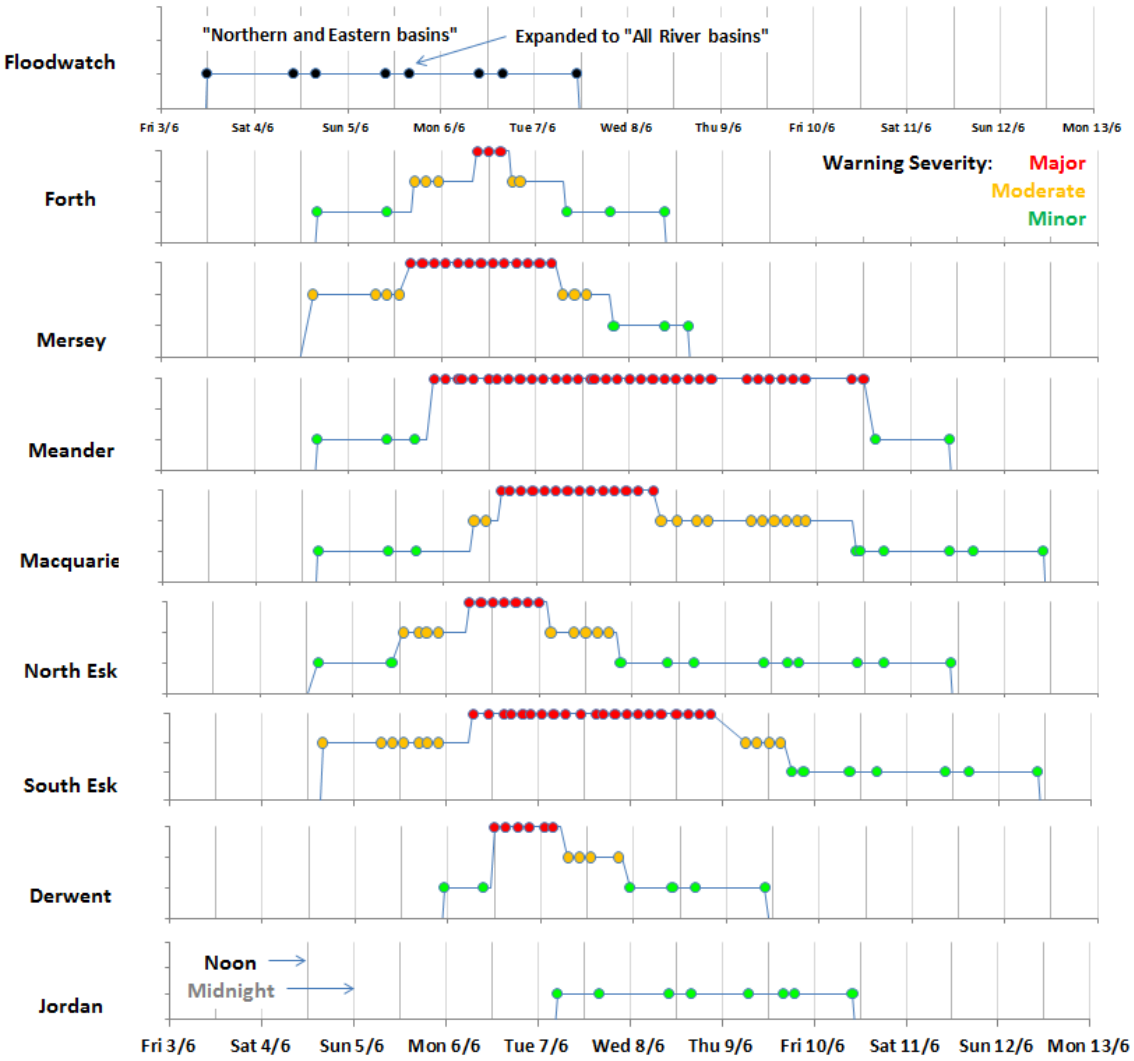


Figure 28 Graphical timeline of warnings issued by catchment

Table 2 Number of flood products issued during the June 2016 flood

Flood Watches	First issue	Last issue	Number of products
All northern and eastern basins	11:57 am Fri 3 June	Expanded	4
All Tasmanian river basins	4:14 pm Sun 5 June	9:53 am Tue 7 June	4

Flood Warnings	First issue	Last issue	Number of products
Mersey River	3:17 pm Sat 4 June	2:56 pm Wed 8 June	23
North Esk River	3:27 pm Sat 4 June	9:53 am Sat 11 June	27
South Esk River	3:49 pm Sat 4 June	9:38 am Sun 12 June	40
Meander River	3:52 pm Sat 4 June	3:41 pm Sat 11 June	41
Macquarie River	4:19 pm Sat 4 June	10:02 am Sun 12 June	35
Forth River	4:19 pm Sat 4 June	9:02 am Wed 8 June	13
River Derwent	10:36 pm Sun 5 June	9:54 am Thu 9 June	16
Jordan River	5:25 am Tue 7 June	9:55 am Fri 10 June	8

Table 3 Flood warnings and alerts by catchment and severity**.**

Catchment	River Alert	Minor	Moderate	Major	Final
Mersey River	0	2	7	13	1
North Esk River	6	10	9	7	1
South Esk River	76	6	12	21	1
Meander River	3	5	0	35	1
Macquarie River	25	8	12	14	1
Forth River	0	4	5	3	1
River Derwent	15	5	4	6	1
Jordan River	4	7	0	0	1
Huon River	3	0	0	0	0
Total	**132**	**47**	**49**	**99**	**8**

Note: a separate submission document provides copies of all flood watches and warnings for the June 2016 flood event.

5 Impacts of floods on flood forecasting and warning services

The June 2016 flood affected the Bureau's Flood Forecasting and Warning Services in a number of ways. The Flood Forecasting and Warning service is dependent on quality rainfall and river level data from both third party and internal sources. Many river gauges throughout the State sustained damage during the floods. This included stations owned by the Bureau, Hydro Tasmania and DPIPWE. The damage ranged from temporary data outages lasting a few hours to complete destruction of sites.

After the floods, an inventory identified 16 flood affected gauges with some form of data outage during the June 2016 flood. By 15 June 2016, 6 of these sites were already restored to service. The lack of accurate river level data due to gauge outages resulted in a reduction in the Bureau service level in three catchments: the Mersey River, lower Meander River and River Ouse. In accordance with the SLS, a notice was sent to the SES on the 16 June 2016 notifying them of the temporary downgrading of flood warning service in these catchments to a generalised warning. Notices were also added to warning text for the affected forecast locations.

As of October 2016, only two sites remained out of service; River Ouse below Staff House Creek (Hydro Tasmania) and Mersey River at Kimberley Railway Bridge (Bureau). The Bureau is coordinating the Mersey River station repairs with Tas Rail and the Meander Valley Council who are performing bridge rebuilding and remediation works at the site. The Flood Recovery Taskforce was notified of this progress on 14 October 2016.

The Bureau, Hydro Tasmania and DPIPWE are in agreement that there will likely be long-term impacts of the June flood on overall data quality. River monitoring stations only measure river height while hydrological models used for flood forecasting are generally calibrated on river flows. There are relationships between river height and flow called rating curves that allow hydrologists to convert between the two. These rating curves are established over many years of manual measurements of floods of various magnitudes and depend on the shape of the river bed. During the June 2016 floods, the shape of many rivers was changed, even in catchments where the gauges remained operational. It will take time to re-establish reliable rating curve relationships for modelling purposes and to fully recalibrate the hydrologic models. Flood level classifications may also require review at some locations.

The role of the Tasmanian Flood Warning Consultative Committee (FWCC) is to coordinate the development and operations of the State's flood forecasting and warning services. This includes identifying requirements and establishing priorities.

6 Summary

This report documents the meteorological and hydrological conditions that contributed to major flooding in Tasmania in early June 2016. This was an extreme event by many measures with record rainfall leading to record flooding at numerous locations.

In the months prior to the June 2016 flood, with the exception of a heavy rain event at the end of January 2016, the period from August 2015 to April 2016 was extremely dry. The widespread rainfall in May 2016 helped return soil moisture conditions to what was typical at that time of year.

A system originated as an East Coast Low off the coast of New South Wales on 5 June. It developed over an area of record-warm sea surface temperatures in the Tasman Sea. This system, along with a strong high pressure system over New Zealand, caused a very strong, moist northeasterly flow to be directed over Tasmania from 5 to 7 June. This resulted in exceptional rainfall, particularly Sunday night into Monday morning 5 - 6 June.

The recorded rainfall rates for durations less than 6 hours were not particularly intense and generally less than the 5% Annual Exceedance Probability (AEP) intensities, or 20 year Average Recurrence Interval (ARI) in the old terminology. For durations greater than 12 hours, and out to 24 hours and 48 hours, many locations throughout the northern half of the state, particularly at higher elevations, recorded rainfall totals much greater than the 1% AEP (100 year ARI) design rainfall intensities. This led to record flood levels, in some cases exceeding previous records by a substantial margin. For example, the North Esk at Corra Linn experienced the worst floods since at least 1929, exceeding the previous record by nearly 1.3 metres. The flooding peaked on most rivers on 6 June although the most downstream locations peaked as late as 8 June, with river levels remaining high for many hours.

Throughout the June 2016 flood, commencing on Thursday June 2, the Bureau issued 21 severe weather warnings, 8 flood watches, 203 flood warnings, 162 river and rainfall alerts and 27 tweets, as well as issuing 4 media alerts/updates and giving at least 70 interviews with television, radio and print media. The Bureau maintained close communications with key partners, such as the State Emergency Service, throughout the June 2016 flood.

7 Appendix 1: Rainfall Tables

Rainfall data are organised by region and catchment and are sorted by the 3-day total. Only stations reporting more than 150 mm in the three days are shown. These sites are a mix of real time and manual reporting sites, including some third party sites. Maps of 3-day totals are shown after the tables in Figure 30, Figure 31 and Figure 32

Note: Data used in this report has been subjected to limited quality checking during operations and may have errors.

"x" means data are missing. "XXX/Y" means XXX mm accumulated over Y days, e.g. 321.4/3 means 321.4 mm accumulated over 3 days.

Smithton-Burnie Coast		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
091321	LOONGANA (SERENDIPITY)	88.0	248.0	4.4	340.4
091109	YOLLA (SEA VIEW)	60.2	248.0	2.4	310.6
091365	SPRENT	35.2	140.4	5.6	181.2
091107	WYNYARD AIRPORT	29.2	127.6	0.4	157.2

Forth River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
591046	LAKE GAIRDNER DAM	99.4	218.8	x	318.2
591004	IRIS RIVER	76.0	230.4	6.8	313.2
091055	LORINNA	63.8	243.4	x	307.2
091322	GOWRIE PARK (O'NEILLS ROAD)	69.0	225.0	7.2	301.2
591000	BORRADAILE PLAINS	52.4	198.8	8.2	259.4
091153	BARRINGTON POST OFFICE	46.4	164.6	5.2	216.2
592004	CRADLE VALLEY (WALDHEIM)	60.0	146.4	4.2	210.6
596071	PINE FOREST MOOR	21.8	131.6	11.4	164.8

Mersey River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
596070	FISHER RIVER ABOVE LAKE MACKENZIE	120.6	278.6	10.6	409.8
596006	LAKE MACKENZIE	106.2	239.8	7.8	353.8
091291	SHEFFIELD SCHOOL FARM	57.8	215.8	4.4	278.0
091266	KIMBERLEY (MERSEY RIVER)	21.6	146.0	x	167.6
091332	RAILTON (DOWBIGGIN STREET)	17.0	144.0	6.4	167.4
596069	MAGGS MOUNTAIN	27.0	120.6	10.4	158.0

Meander River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
091288 ME	QUAMBY BLUFF	62.8	181.0	9.0	252.8
091366 ME	JACKEYS MARSH	55.6	173.0	9.0	237.6
091290 ME	GOLDEN VALLEY (BRODIES ROAD)		170.4/2	11.8	182.2
091236 ME	WESTBURY (BIRRALEE ROAD)	34.8	128.2	7.0	170.0
591067 ME	WESTERN CREEK AT BANKTON ROAD BRIDGE	26.4	123.4	9.0	158.8
091307 ME	LEMANA (WOODLANDS)		149.0/2	8.4	157.4
091227 ME	DELORAINE RAILWAY BRIDGE (MEANDER RIVER)	39.0	107.6	7.0	153.6

South Esk		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
091194	MOUNT VICTORIA (UNA PLAIN)	102.6	193.4	32.8	328.8
092064	CORNWALL	75.0	208.0	36.6	319.6
092141	GRAY (DALMAYNE RD)	64.6	175.0	51.2	290.8
092009	ST MARYS (CULLENSWOOD)	54.0	167.2	33.6	254.8
092106	MATHINNA (SOUTH ESK RIVER)	66.2	121.0	23.6	210.8
092144	MONAMETA (MATHINNA RD)	60.6	120.8	25.8	207.2
092111	UPPER ESK (SOUTH ESK RIVER)	47.8	110.6	31.0	189.4
592002	KILLYMOON (BREAK O'DAY RIVER)	51.4	104.6	27.6	183.6
092012	FINGAL (LEGGE STREET)	39.4	90.0	29.4	158.8

North Esk River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
091271	NUNAMARA OFFTAKE (ST PATRICKS R)	36.4	151.2	64.2	251.8
091305	TARGA (MOUNTAIN VIEWS)	66.6	161.0	19.6	247.2
091198	MOUNT BARROW (SOUTH BARROW)	57.0	149.8	26.6	233.4
092109	UPPER BLESSINGTON	56.6	123.6	36.8	217.0

Macquarie River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
092079	TOOMS LAKE (TOOMS RIVER)	39.6	74.2	75.0	188.8
096049	TODS CORNER	50.0	107.0	21.4	178.4
096081	POATINA	47.6	107.2	18.8	173.6
096083	THE DEN	41.8	100.6	26.2	168.6

Piper-Ringarooma Rivers		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
091086	RINGAROOMA (MAIN STREET)	49.2	118.0	25.0	192.2
092030	PIONEER (MAIN ROAD)	50.2	104.4	21.4	176.0
091053	LILYDALE POST OFFICE		151.5/3	9.6	161.1
091346	LILYDALE (TORWOOD)	35.0	111.4	7.4	153.8

East Coast		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
092051	PYENGANA (FOREST LODGE ROAD)	129.4	211.0	27.0	367.4
092155	BUCKLAND (BROCKLEY ROAD)	26.2	112.0	99.0	237.2
592022	MOUNT ST JOHN	67.0	118.6	45.2	230.8
092158	NUGENT (TWILIGHT VALLEY TBRG)	22.2	70.4	94.2	186.8
092153	COPPING (YAXLEY ESTATE)	26.8	64.0	88.8	179.6
092099	NUGENT (TWILIGHT VALLEY)	20.8	57.8	86.0	164.6

Derwent River		Rainfall to 9 AM			
Bureau ID	Name	05-Jun-16	06-Jun-16	07-Jun-16	3 day totals
596065	LAKE GWENDY	83.0	241.4	9.4	333.8
596049	INTERLAKEN	52.2	142.8	46.6	241.6
596012	PINE TREE RIVULET (LAKE HIGHWAY)	60.4	149.8	10.8	221.0
596028	LAKE AUGUSTA EAST	33.0	145.6	11.4	190.0
094087	KUNANYI (MOUNT WELLINGTON PINNACLE)	28.8	55.0	86.8	170.6

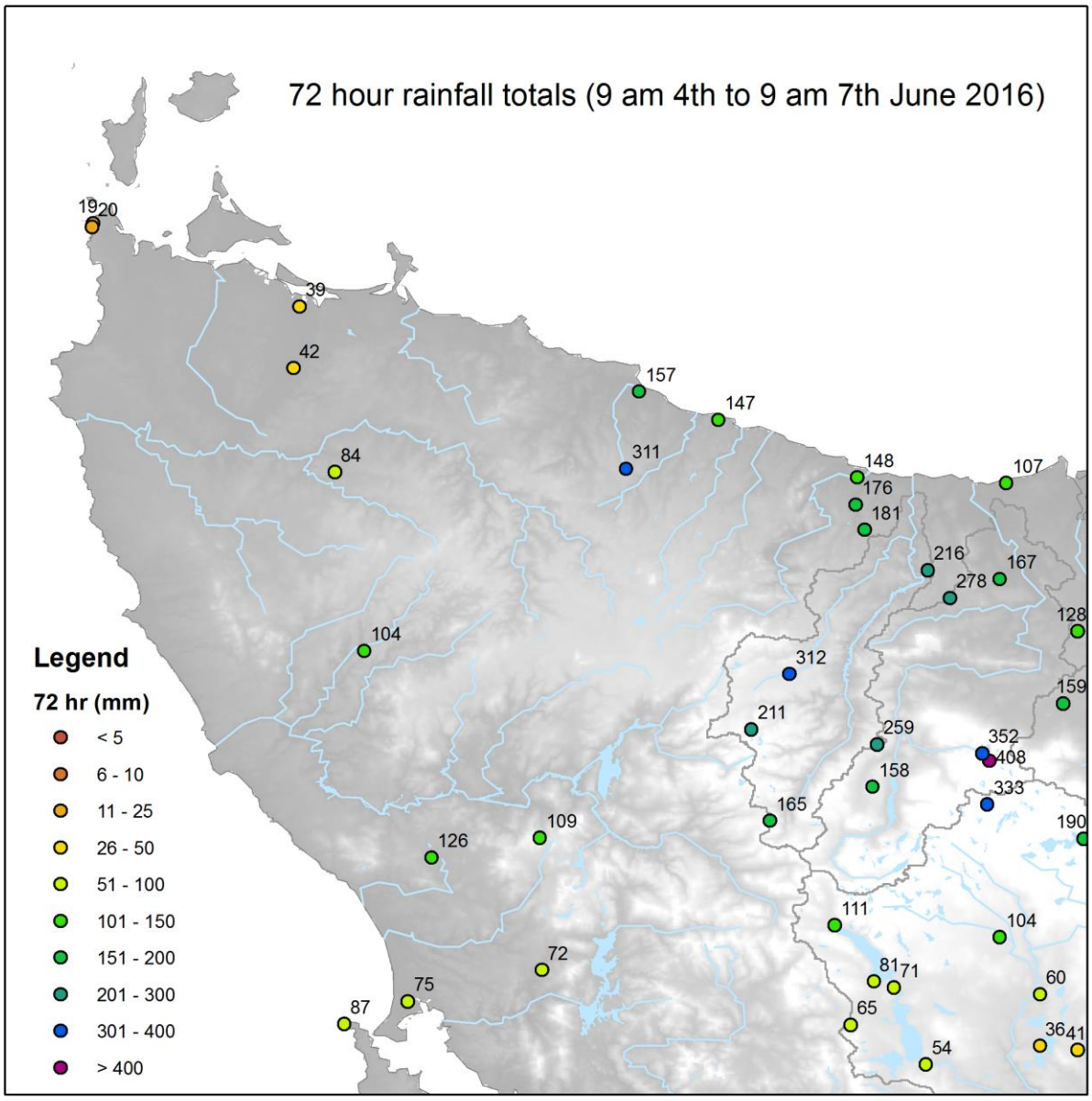


Figure 30 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Northwest Tasmania. The background shows elevation, rivers, lakes and catchment boundaries.

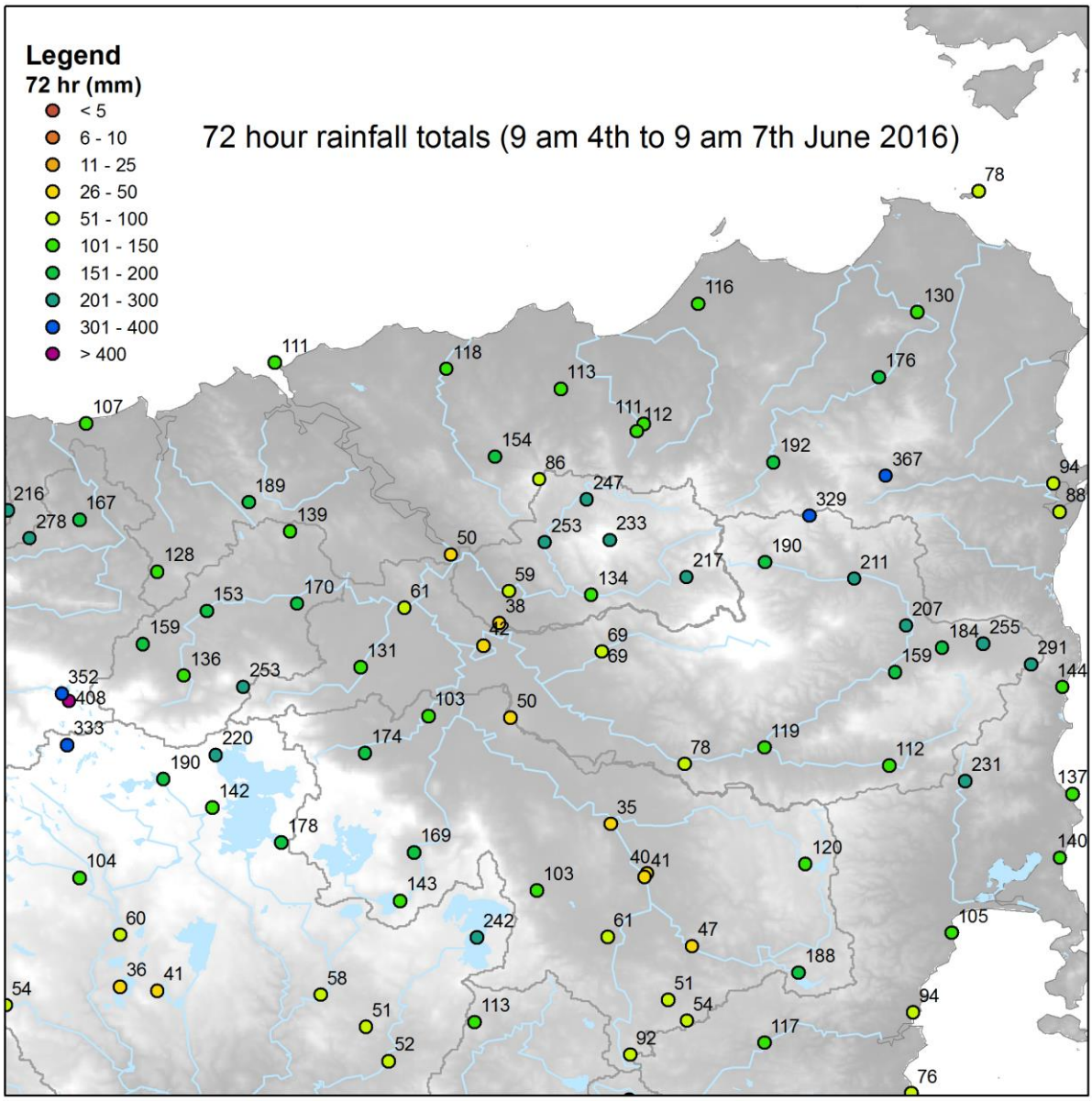


Figure 31 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Northeast Tasmania. The background shows elevation, rivers, lakes and catchment boundaries.

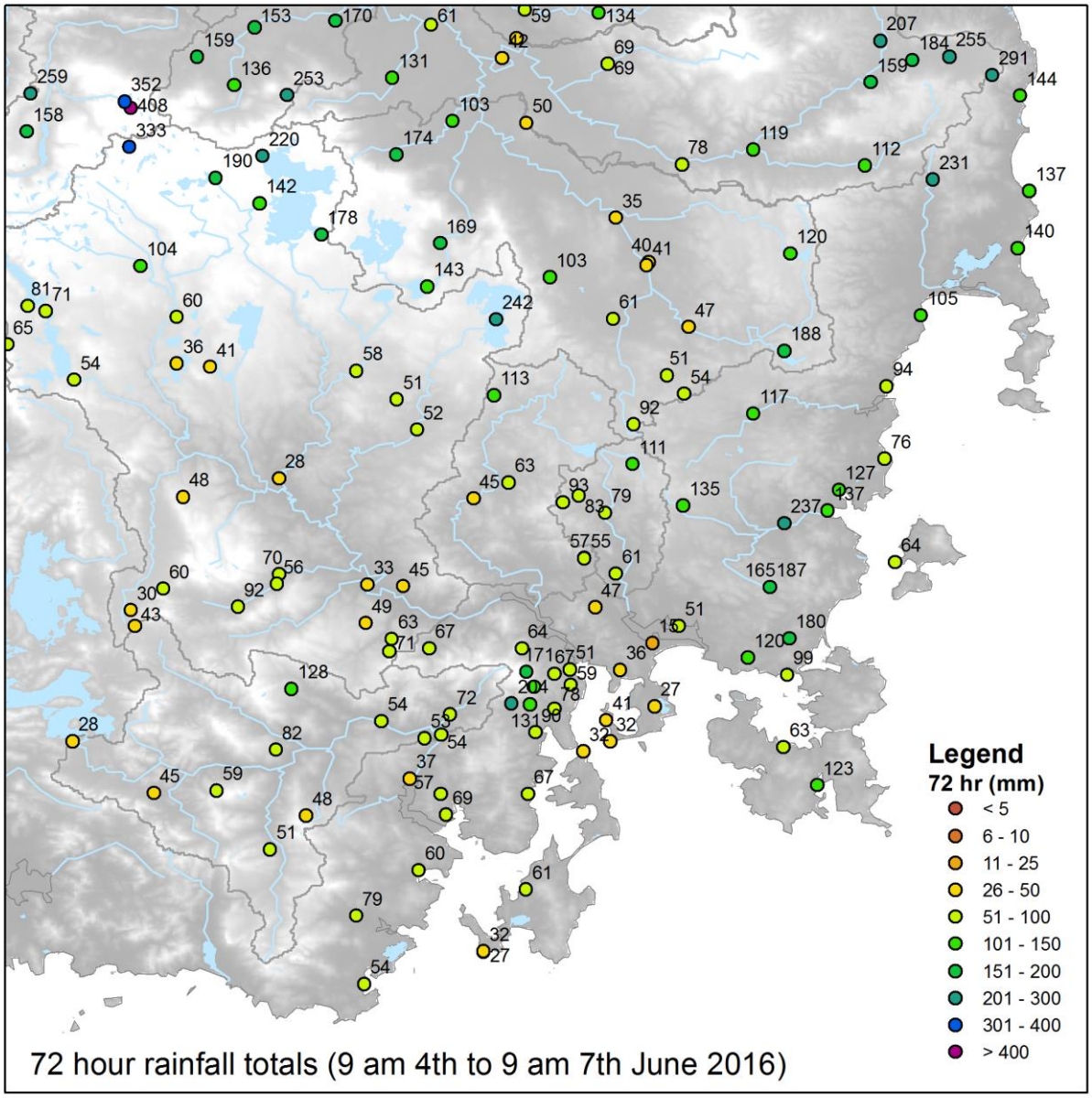


Figure 32 72 hour (3 day) precipitation total to 9 am 7 June 2016 for Southern Tasmania. The background shows elevation, rivers, lakes and catchment boundaries.

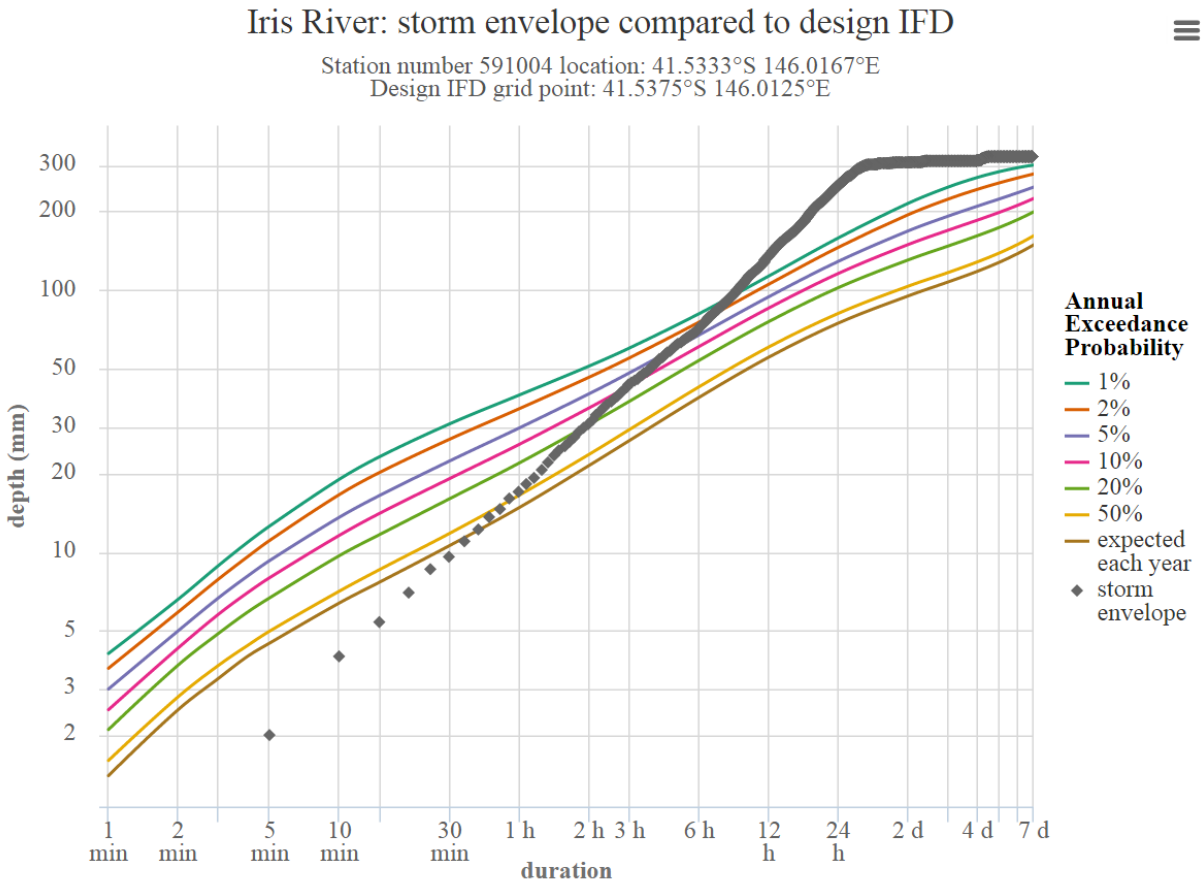
8 Appendix 2: Rainfall Intensity-Frequency-Duration Analyses

The figures on the following pages display Rainfall Intensity-Frequency-Duration (IFD) analyses for a key rain gauge in each catchment that experienced flooding. The horizontal axis is the duration of the rainfall and the vertical axis is the depth. The coloured lines indicate the Annual Exceedance Probability (AEP) from the 2013 IFDs. These give the probability of experiencing a combination of rainfall depth and duration (e.g. the Iris River gauge has a 1% chance (green line) of exceeding 30 mm of rain (vertical axis) in 30 minutes (horizontal axis). The dark line/dots are the maximum rainfall intensities for all durations during the June 2016 flood. In several cases, the 24-48 hour duration rainfall amounts exceeded the 1% AEP (100 year ARI) design rainfall intensities (based on the 2013 IFD).

indicates the conversion between the old ARI terminology and the new AEP probability terminology now used for IFDs.

Table 4 IFD terminology conversion chart

New Terminology				Old Terminology
EY	AEP (%)	AEP (1 in x)		ARI (1 in x)
0.69	50.00	2.00		1.44
0.50	39.35	2.54		2.00
0.22	20.00	5.00		4.48
0.20	18.13	5.52		5.00
0.11	10.00	10		9.49
0.05	5.00	20		19.5
0.02	2.00	50		49.5
0.01	1.00	100		100

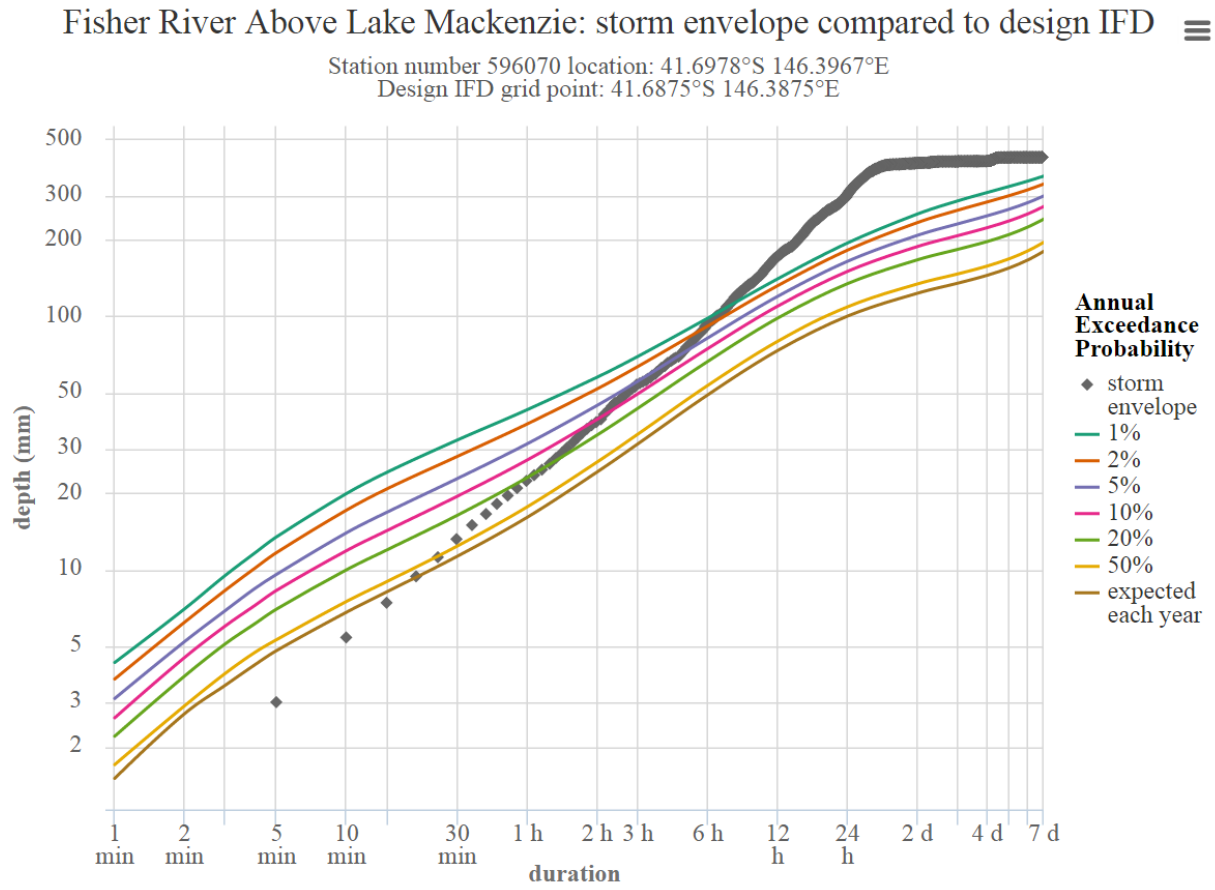


Location: Iris River - H591004

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
16.4	1 hour ending at 11:00 05/06/2016	50%-1EY
41.2	3 hours ending at 11:00 05/06/2016	10-20%
71.0	6 hours ending at 15:00 05/06/2016	2-5%
134.2	12 hours ending at 21:00 05/06/2016	<1%
249.4	24 hours ending at 04:00 06/06/2016	<1%
307.8	48 hours ending at 16:00 06/06/2016	<1%
312.2	72 hours ending at 07:00 07/06/2016	<1%

Figure 33 Rainfall Intensity-Frequency-Duration analysis for a site in the Forth headwaters.

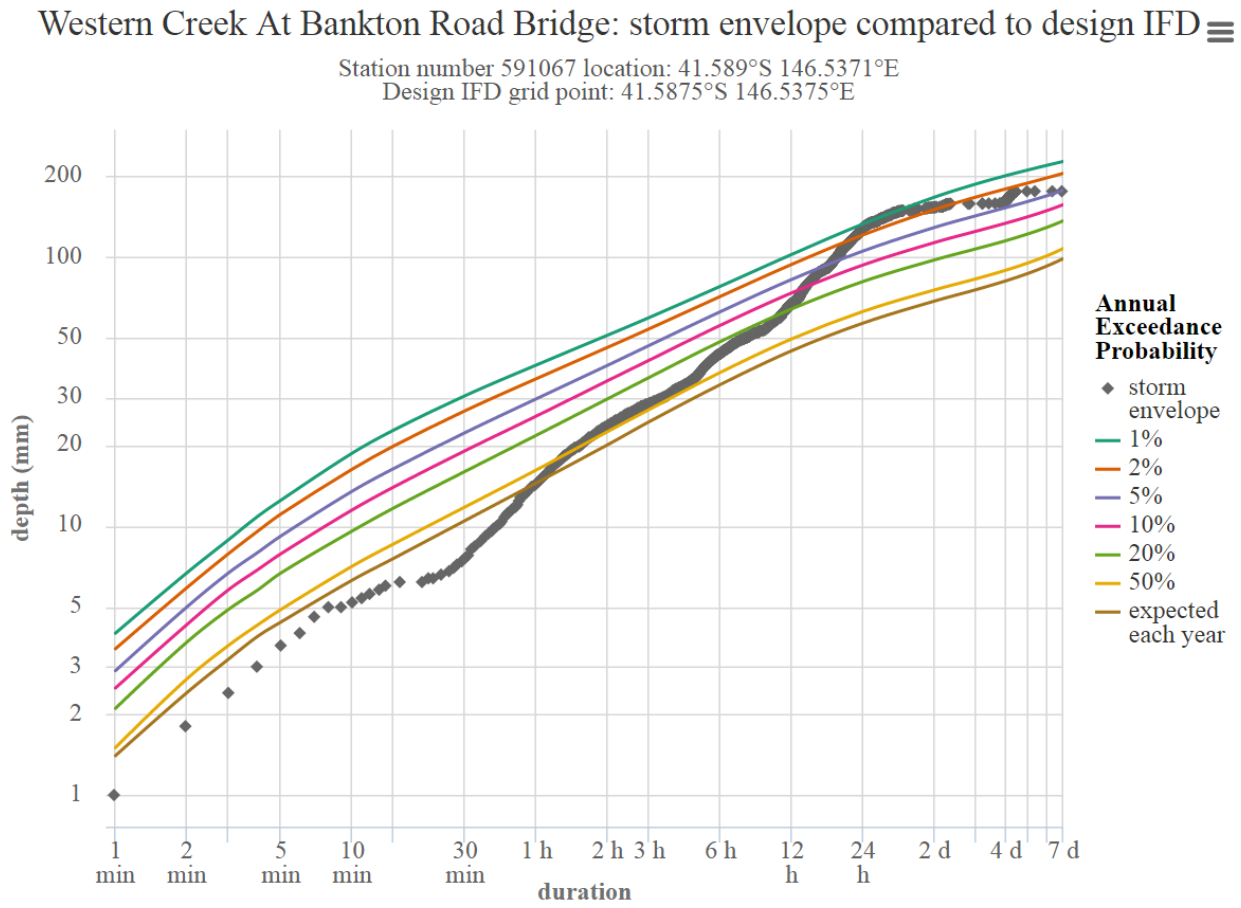


Location: Fisher River above Lake Mackenzie - H596070

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
21.0	1 hour ending at 11:00 05/06/2016	20-50%
53.8	3 hours ending at 11:00 05/06/2016	5-10%
92.2	6 hours ending at 14:00 05/06/2016	2-5%
170.6	12 hours ending at 14:00 05/06/2016	<1%
298.0	24 hours ending at 04:00 06/06/2016	<1%
402.6	48 hours ending at 19:00 06/06/2016	<1%
409.0	72 hours ending at 19:00 07/06/2016	<1%

Figure 34 Rainfall Intensity-Frequency-Duration analysis for a site in the Mersey headwaters.

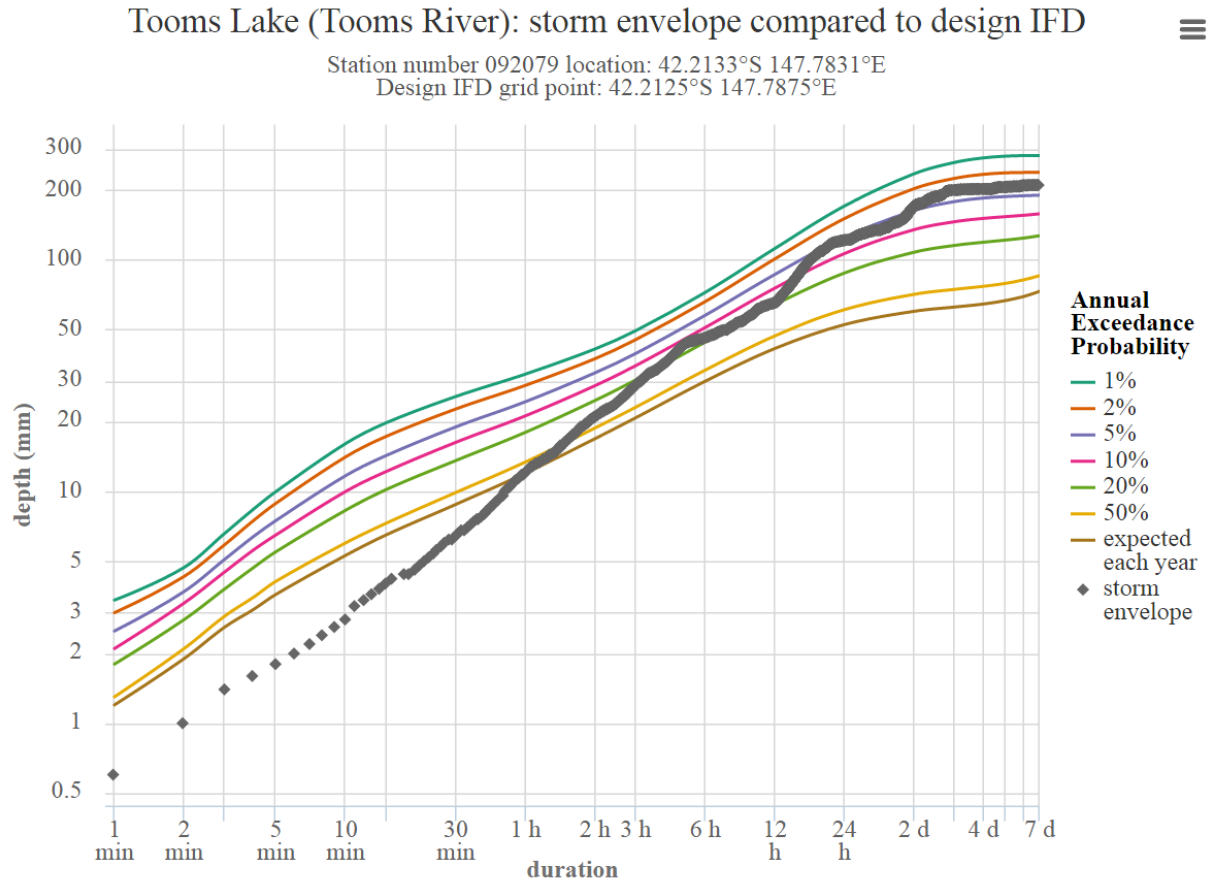


Location: Western Creek at Bankton Road Bridge - H591067

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
12.8	1 hour ending at 07:00 06/06/2016	1EY
28.0	3 hours ending at 08:00 06/06/2016	20-50%
42.8	6 hours ending at 08:00 06/06/2016	20-50%
66.6	12 hours ending at 19:00 05/06/2016	10-20%
126.6	24 hours ending at 07:00 06/06/2016	1-2%
153.8	48 hours ending at 21:00 06/06/2016	1-2%
158.8	72 hours ending at 06:00 07/06/2016	2-5%

Figure 35 Rainfall Intensity-Frequency-Duration analysis for a site in the Meander headwaters.

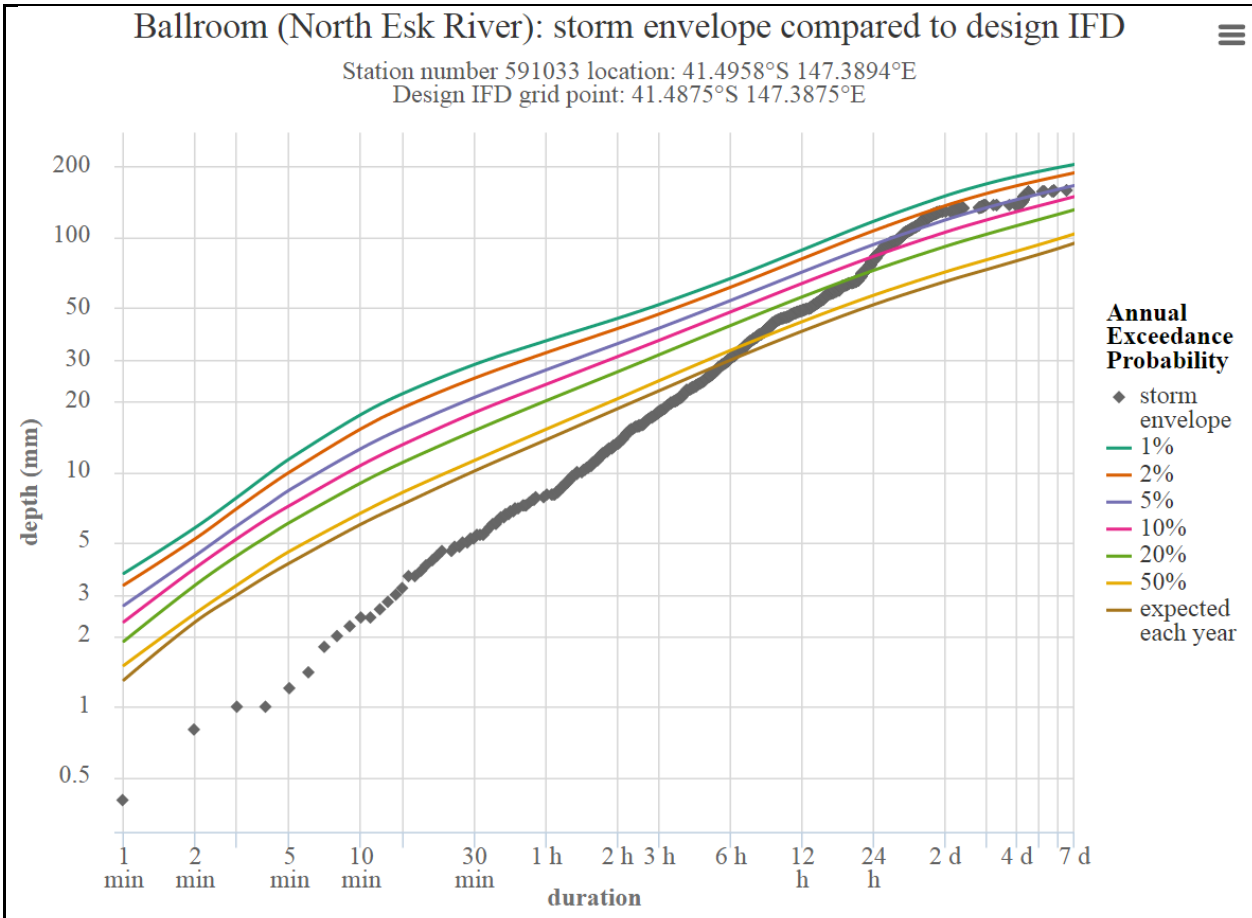


Location: Tooms Lake (Tooms River) - H092079

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
9.8	1 hour ending at 18:00 06/06/2016	<1EY
27.4	3 hours ending at 19:00 06/06/2016	20-50%
45.6	6 hours ending at 21:00 06/06/2016	10-20%
65.0	12 hours ending at 11:00 06/06/2016	10-20%
121.0	24 hours ending at 21:00 06/06/2016	5-10%
167.0	48 hours ending at 21:00 06/06/2016	2-5%
199.4	72 hours ending at 15:00 07/06/2016	2-5%

Figure 36 Rainfall Intensity-Frequency-Duration analysis for a site in the Macquarie headwaters.

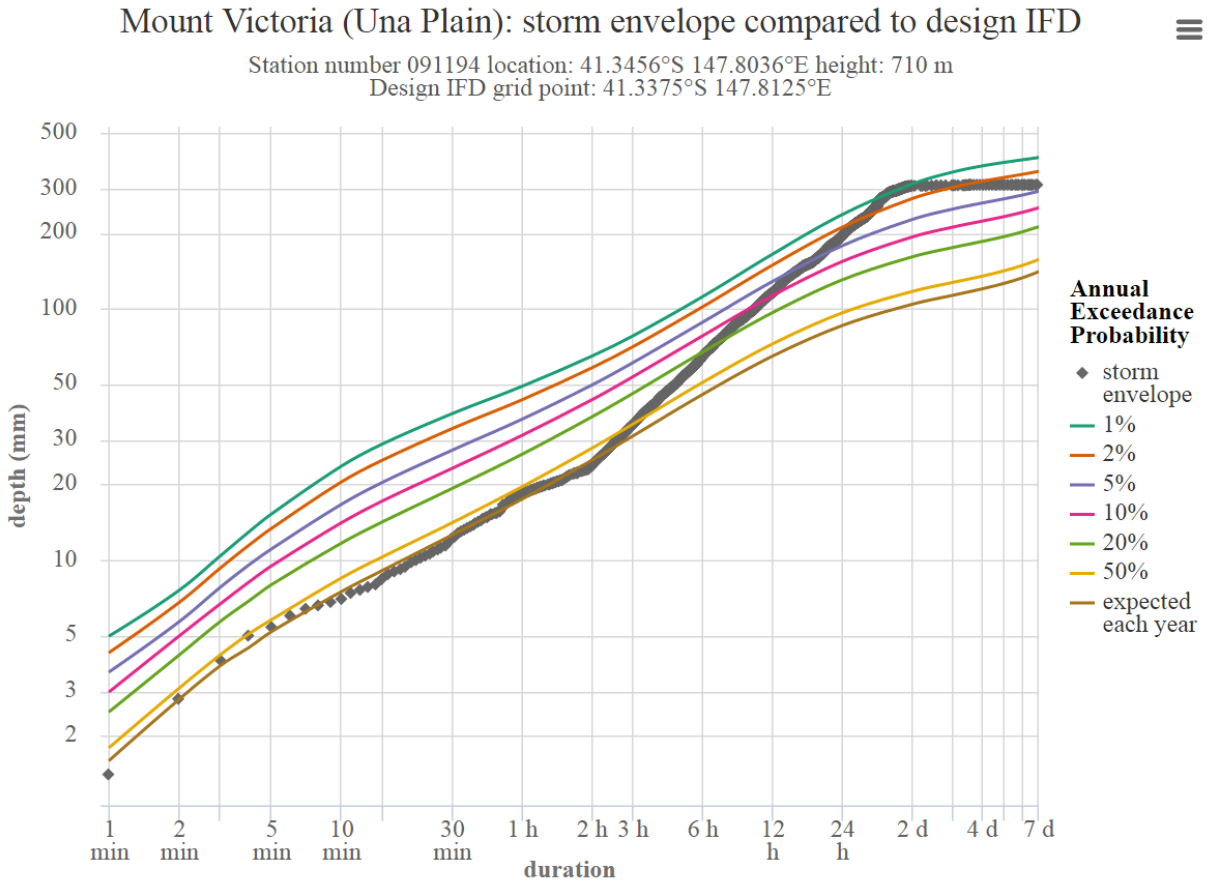


Location: Ballroom (North Esk River) - H591033

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
8.0	1 hour ending at 12:00 05/06/2016	< 1EY
18.0	3 hours ending at 14:00 05/06/2016	< 1EY
30.6	6 hours ending at 15:00 05/06/2016	50%-1EY
48.6	12 hours ending at 16:00 05/06/2016	20-50%
79.2	24 hours ending at 09:00 06/06/2016	10-20%
128.8	48 hours ending at 19:00 06/06/2016	2-5%
137.2	72 hours ending at 19:00 07/06/2016	2-5%

Figure 37 Rainfall Intensity-Frequency-Duration analysis for a site in the North Esk headwaters.

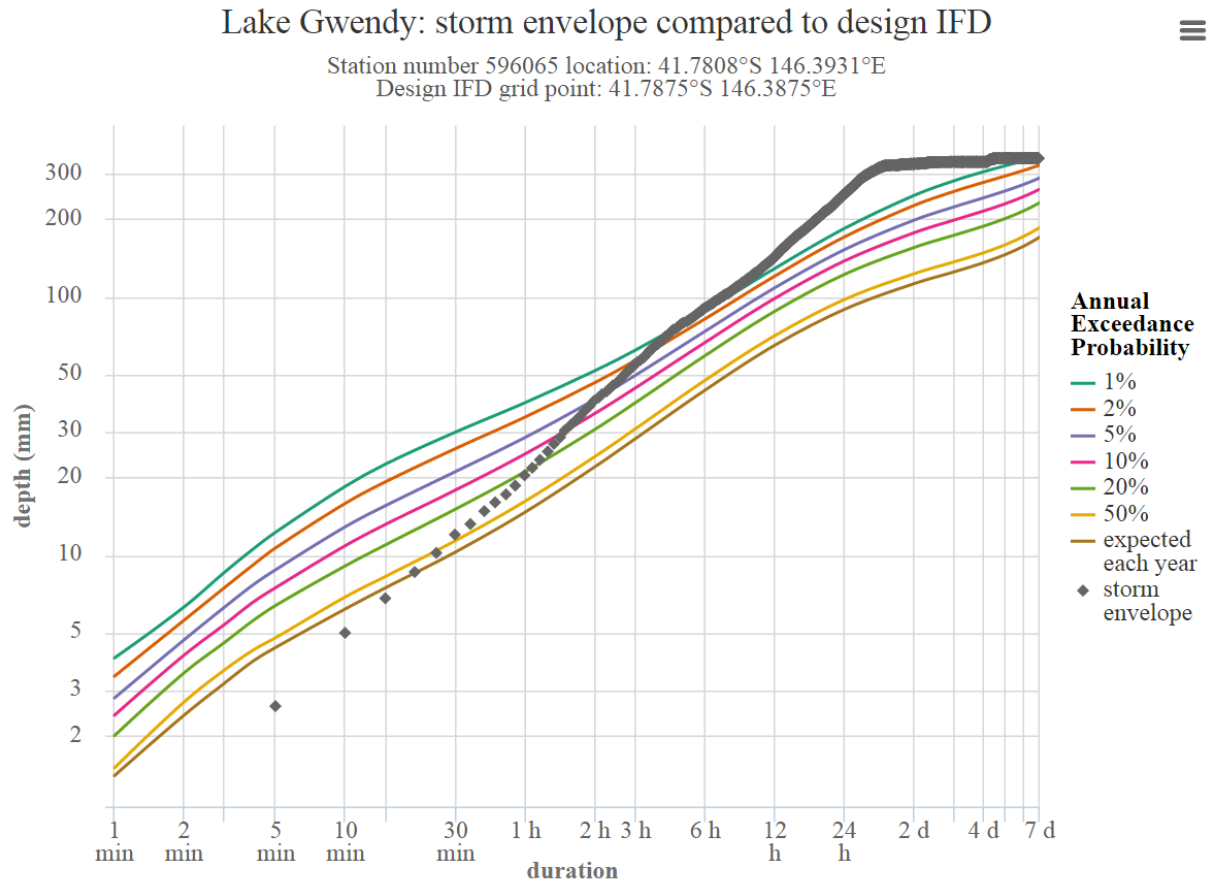


Location: Mount Victoria (Una Plain) - H091194

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
12.6	1 hour ending at 22:00 04/06/2016	<1EY
34.4	3 hours ending at 06:00 06/06/2016	50%-1EY
62.6	6 hours ending at 09:00 06/06/2016	20-50%
114.8	12 hours ending at 09:00 06/06/2016	5-10%
193.6	24 hours ending at 09:00 06/06/2016	2-5%
311.2	48 hours ending at 16:00 06/06/2016	1-2%
331.0	72 hours ending at 14:00 07/06/2016	1-2%

Figure 38 Rainfall Intensity-Frequency-Duration analysis for a site in the South Esk headwaters.

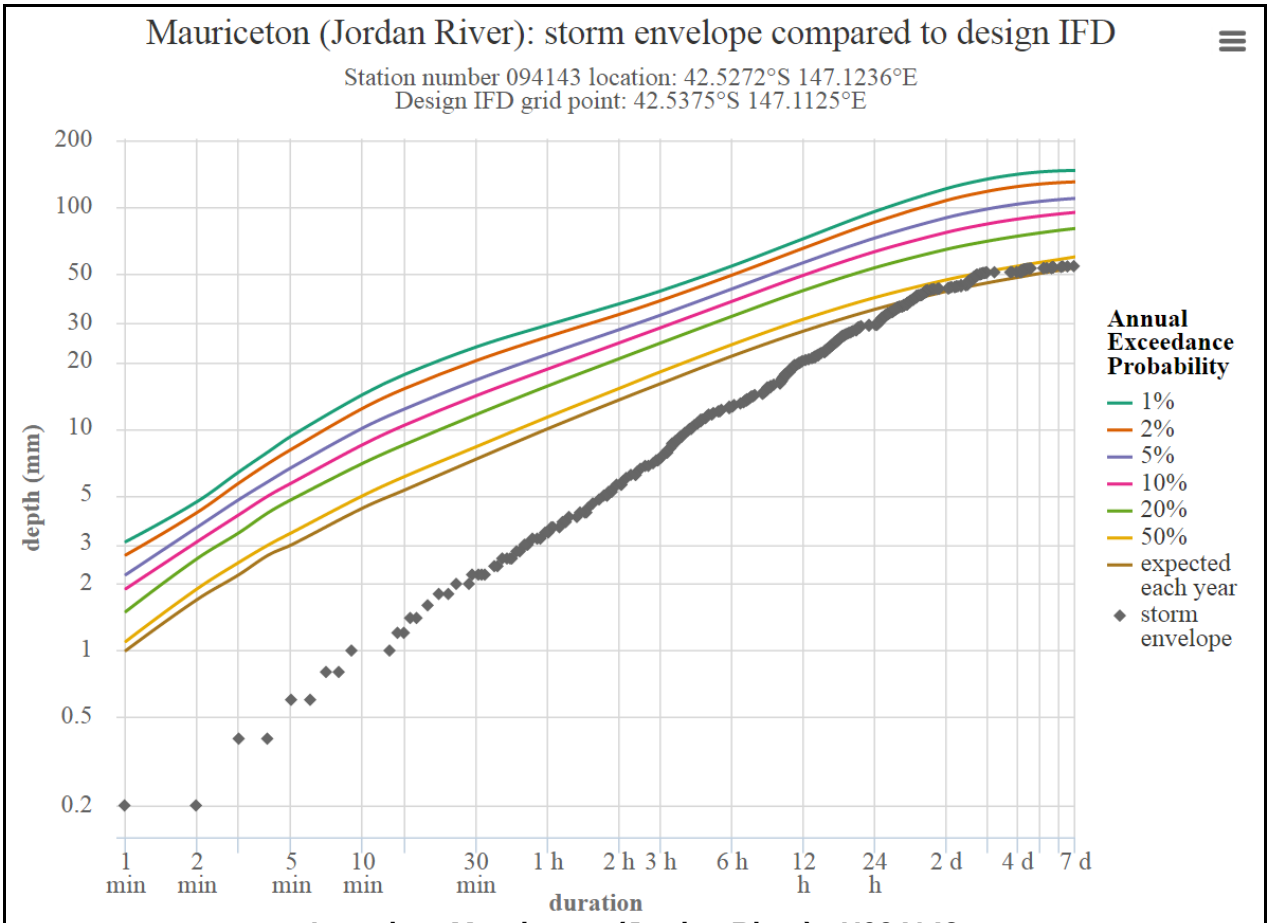


Location: Lake Gwendy - H596065

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
19.6	1 hour ending at 12:00 05/06/2016	20-50%
54.4	3 hours ending at 13:00 05/06/2016	2-5%
90.0	6 hours ending at 14:00 05/06/2016	1-2%
141.2	12 hours ending at 15:00 05/06/2016	<1%
248.6	24 hours ending at 07:00 06/06/2016	<1%
327.6	48 hours ending at 19:00 06/06/2016	<1%
333.2	72 hours ending at 15:00 07/06/2016	<1%

Figure 39 Rainfall Intensity-Frequency-Duration analysis for a site in the Derwent headwaters.



Location: Mauriceton (Jordan River) - H094143

Analysis of the rainfall for the 4-14 June 2016

Rainfall (mm)	Period Ending	AEP (%)
3.4	1 hour ending at 20:00 06/06/2016	< 1EY
7.2	3 hours ending at 20:00 06/06/2016	< 1EY
12.4	6 hours ending at 21:00 06/06/2016	< 1EY
20.2	12 hours ending at 21:00 06/06/2016	< 1EY
29.6	24 hours ending at 21:00 06/06/2016	< 1EY
43.2	48 hours ending at 19:00 07/06/2016	50%-1EY
50.8	72 hours ending at 19:00 07/06/2016	50%-1EY

Figure 40 Rainfall Intensity-Frequency-Duration analysis for a site in the Jordan headwaters.

9 Appendix 3: Glossary of Terms

A3.1 General

Annual Exceedance Probability (AEP): the probability of an event occurring or being exceeded within a given year based on long term averages, usually expressed as a percentage.

Annual Recurrence Interval: the average period between occurrences equalling or exceeding a given event. Also referred to as the *Return Period*.

Australian Government Crisis Coordination Centre: an all-hazards, 24/7 facility that provides whole-of-government situational awareness to inform national decision-making during a crisis. The Centre also coordinates physical Australian Government assistance during disasters and emergencies and manages the National Security Hotline, a vital component of Australia's national counter-terrorism efforts.

Bureau Flood Warning Centre: an operational area set aside in each capital city to fulfil the Bureau's role in the Total Flood Warning System specifically flood forecasting and warning.

Bureau National Operations Centre: The principal role of the National Operations Centre is to augment regional flood forecasting teams during major floods and to provide operational system support. The National Operations Centre is also responsible for leading new initiatives to enhance the quality of operations and services.

Catchment Directive: A catchment directive provides guidance specific to a catchment to help develop forecasting and warning products.

Department of Primary Industries, Parks, Water and Environment (DPIPWE): responsible for the sustainable management and protection of Tasmania's natural and cultural assets for the benefit of Tasmanian communities and the economy.

Exceedances per Year (EY): number of times that an event is likely to occur or be exceeded within a year.

Flood warning: A written product to provide advice on impending flooding so people can take action to minimise its negative impact. This will involve some people taking action on their own behalf and others doing so as part of agency responsibilities.

Flood Warning Consultative Committee (FWCC): The Tasmanian Flood Warning Consultative Committee was formed in 1988. The Committee's role is to coordinate the development and operations of the State's flood forecasting and warning services. It is an advisory body and reports to the Bureau and participating State and local government agencies twice each year. The membership includes:

- Bureau of Meteorology (Chair/Secretariat)
- State Emergency Services
- Tasmanian Farmers and Graziers Association
- Hydro Tasmania
- Department of Primary Industries, Parks, Water and Environment (DPIPWE)
- Launceston City Council
- Northern Midlands Council
- Huon Valley Council
- Central Coast Council
- Kentish Council

- Local Government Association of Tasmania

Flood Warning Network: rainfall and river height stations which are used for flood warning and forecasting operations. The stations are owned and operated by various agencies.

Flood watch: A written product that alerts when the combination of forecast rainfall and catchment conditions indicates the flooding is likely.

National Crisis Coordination Centre: The Australian Government Crisis Coordination Centre has been designed to connect relevant Australian Government, State and Territory agencies to centralise Australian Government actions during complex national crises, to develop a single, timely and consistent picture or understanding of a crisis, its implications and the national capacity to respond.

National Flood Warning Arrangements: The National Arrangements outline the general roles and responsibilities of each level of Government in providing and supporting an effective flood warning service and includes separate chapters describing the specific arrangements and agency roles that apply in each jurisdiction.

Probability: The chance of an event occurring based on statistical analysis of historical records, usually expressed as a percentage.

Protective behaviour: generating appropriate and timely actions and behaviours from the agencies involved and from the threatened community.

Rainfall Intensity: The rainfall rate, typically measured in millimetres per hour (mm/hr). For the Intensity-Frequency-Durations (IFDs) this is now expressed in terms of depth in millimetres for a specified duration. This varies spatially and temporally throughout a storm event.

Rainfall or River Alert: An automatic River and Rainfall Alert service is provided by the Bureau through an agreement with the State Emergency Service, as outlined in the Service Level Specification. Once the trigger river level or rainfall accumulation threshold is reached, an alert is issued. For river alerts, the alert is re-issued after 24 hours if the river level remains above the alert level. Rainfall alerts are re-issued if total rainfall accumulated in the previous 24-hours is still exceeding alert level.

Service Level Specification (SLS): A document that outlines the Service Level Specification for Flood Forecasting and Warning Services provided by the Commonwealth of Australia through the Bureau of Meteorology for the State of Tasmania in consultation with the Tasmanian Flood Warning Consultative Committee.

Severe Thunderstorm: A thunderstorm is characterised by sudden electrical discharges, each manifested by a flash of light (lightning) and a sharp rumbling sound. Thunderstorms are associated with convective clouds (cumulonimbus) and are usually accompanied by precipitation. Thunderstorms are often short-lived and impact on only a small area. Severe thunderstorms may last for an hour or more and can have a more widespread impact.

A severe thunderstorm will also have one or more of the following phenomena:
- Tornado
- Wind gust of 90 km/h (49 knots) or more
- Hailstones with diameter of 2 cm or larger
- Very heavy rain sufficient to cause flash flooding

Weather warnings: Weather warnings are messages sent out by the Bureau to warn the community of potentially hazardous or dangerous weather conditions. Such warnings include but are not limited to: road weather alerts, severe thunderstorm warnings, severe weather warnings for heavy rain, strong or gale force winds, marine wind warnings, warnings for sheep graziers and frost warnings. More information on weather terms is given in the Bureau's glossary.

A3.2 The components of the Total Flood Warning System

Based on the Manual 21 Australian Emergency Manual Series, Australian Government 2009 (see the Manual for more details).

Communication: disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood (see Chapter 6).

Interpretation: identifying in advance the impacts of the predicted flood levels on communities at risk (see Chapter 4).

Message construction: devising the content of the message which will warn people of impending flooding (see Chapter 5).

Monitoring and prediction: detecting environmental conditions that lead to flooding, and predicting river levels during the flood (see Chapter 3),

Review: examining the various aspects of the system with a view to improving its performance (see Chapter 7).

A3.3 Flood classifications

The classification of minor, moderate and major flood levels at key river height stations is based upon the effect of flooding for some distance upstream and downstream of that station. These levels are determined using the following descriptive categories of flooding, historical data or relevant local information.

The process for establishing flood class levels involves determining local flood effects, review and endorsement by relevant stakeholders and passing recommendations to the Bureau for inclusion in forecast and warning procedures. The process for establishment of flood class levels specific to each State and Territory is documented in the National Arrangements.

- Minor flooding - Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

- Moderate flooding - In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.

- Major flooding - In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.